# Integrative processing of invariant aspects of faces: Effect of gender and race processing on identity analysis

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While separation of face identity and expression processing is favored by many face perception models, how the visual system analyzes identity and other face properties remains elusive. Here we investigated whether identity analysis is independent of or influenced by automatic processing of face gender and race. Participants searched for a target face among distractor faces whose gender or race was either the same as or different from the target face. Visual search was faster and more accurate when target and distractor faces differed in gender or race property than when not. The effect persisted for identification of both familiar and novel faces, and cannot be attributed to the low-level physical properties of stimuli or the earlier extraction of face gender/race information before identification. Together with complementary findings showing effects of identity analysis on gender and race categorization, these results indicate that invariant face properties are processed in an integrative way: visual analysis of one property involves, and is therefore affected by, automatic processing of the others. Implications for current theoretical models of face perception are discussed.

Keywords: face perception, face identification, gender categorization, race categorization, invariant face property

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## Introduction

From a glimpse of a person's face, people can quickly extract a wealth of information including the person's identity, gender, race, expression, attractiveness, and so forth. Different face perception models have been proposed to characterize how the visual system recognizes these multiple aspects of a face (Bruce & Young, 1986; Burton, Bruce, & Johnston, 1990; Calder, Burton, Miller, Young, & Akamatsu, 2001; Haxby, Hoffman, & Gobbini, 2000; Martens, Leuthold, & Schweinberger, 2010; Schweinberger, Burton, & Kelly, 1999). The core architecture shared by these models is that different face properties are assumed to be processed via functionally and neurophysiologically separated pathways. That is, the visual system analyzes multiple facial attributes independently of each other.

However, both the theoretical models and their subsequent empirical evaluations are almost exclusively focused on the processing of face identity and expression. An important distinction between these properties is that whereas identity is an invariant property of a face, expression is highly variable, changing from moment to moment (Haxby et al., 2000). While the functional independence between identity and expression analyses is generally favored by various face perception models (Calder & Young, 2005; Haxby et al., 2000; though see Bestelmeyer, Jones, DeBruine, Little, & Welling, 2010, for interactions between processing of expression and race/sex), whether the visual system follows the same principle to process identity and other invariant face properties (e.g., gender and race) has not yet been clearly established. The aims of the present study were to investigate the way that invariant aspects of a face (e.g., identity, gender, and race) are processed, and to differentiate which of the face perception models captures the architecture underlying processing of such properties.

### Perception of face gender, race, and identity: Theoretical models and empirical findings

Gender and race were often categorized as 'semantic information' in earlier face recognition models (Bruce & Young, 1986; Burton et al., 1990). This suggested a parallel architecture in which these attributes were processed independently, and was consistent with findings showing that face familiarity did not affect judgments about face gender (Ellis, Young, & Flude, 1990) and vice versa (Bruce, Ellis, Gibling, & Young, 1987).

Haxby, Hoffman, and Gobbini (2000) built upon these models with a physiological framework for the functional independence between processing of multiple facial attributes. They classified various face properties into *changeable* and *invariant* aspects, and proposed that brain networks underlying these different aspects of face perception are primarily independent. According to their model, an early face representation formed within the inferior occipital area is further processed by two separated neural systems within occipitotemporal cortex. Perception of changeable face aspects (e.g., expression or eye gaze) relies on processing in the superior temporal sulcus, while perception of invariant face aspects (e.g., identity or gender) proceeds within the lateral fusiform gyrus. The dissociable activations within the superior temporal sulcus and fusiform area were observed between judgments of facial expressions and identity (Winston, Henson, Fine-Goulden, & Dolan, 2004), in processing of viewpoint and identity (Andrews & Ewbank, 2004), and for assessments of gaze direction and face gender (Cloutier, Turk, & Macrae, 2008).

Gender and race of a face, according to Haxby et al.'s model, should be analyzed within the same neural system as that supporting identity analysis. Consistent with this prediction, the neural substrates that appear to form the basis for the processing of face gender, race, and identity are largely overlapping (Freeman, Rule, Adams, & Ambady, 2010; Golby, Gabrieli, Chiao, & Eberhardt, 2001; Ng, Ciaramitaro, Anstis, Boynton, & Fine, 2006; Rotshtein, Henson, Treves, Driver, & Dolan, 2005). The fusiform gyrus that underlies identity processing (Rotshtein et al., 2005) is also centrally involved in processing of gender (Freeman et al., 2010) and race (Golby et al., 2001). For instance, Freeman et al. (2010) showed that the magnitudes of brain activity in the lateral fusiform gyrus increased monotonically as the sexually dimorphic face content changed from androgynous to gendered, suggesting that this identity-sensitive area is also modulated by face gender. Processing one invariant face property is therefore unlikely to be immune from the processing of others that recruit the same neural resources. Visual analysis of face gender, race, and identity may show reciprocal influences on each other, rather than running independently.

Schweinberger et al. (Martens et al., 2010; Schweinberger et al., 1999; Schweinberger, & Soukup, 1998) have proposed a parallel-dependent model for perception of identity and expression. They hypothesized that face identity and expression are analyzed in a parallel architecture, in which processing of facial expression relies on information about identity but not vice versa (Martens et al., 2010). The main evidence for this semiparallel model comes from the asymmetric influence between perception of face identity and expression—irrelevant identity variation affects judgments of facial expression but variation of facial expression does not affect identity judgments (Schweinberger & Soukup, 1998). Similar asymmetries have also been shown in face adaptation studies. That is, change of identity between adapting and test faces reduces expression adaptation whereas change of expression does not alter the strength of identity adaptation (Fox & Barton, 2007; Fox, Oruc, & Barton, 2008).

The parallel-dependent model was not proposed to specifically account for face gender and race processing. However, the model may be extended to the processing of invariant face properties, since identity contains gender and race information implicitly (that is, any identity can be characterized as having a gender and race) but gender and race information do not of themselves uniquely specify identity. Moreover, the unidirectional influence from identity to other facial properties is consistent with prior findings on visual analysis of invariant face attributes. While many studies consistently demonstrate that identity analysis (e.g., familiarity judgments) affects processing of gender (Goshen-Gottstein & Ganel, 2000; Rossion, 2002), race (Bruyer, Leclere, & Quinet, 2004), and age (Bruyer, Mejias, & Doublet, 2007), evidence for the reverse direction is somewhat mixed and open to a variety of interpretations (e.g., Bruce et al., 1987; Ganel & Goshen-Gottstein, 2002). For example, Ganel and Goshen-Gottstein (2002) have showed that face familiarity judgments were slower when gender of faces was varied (filter condition) than when not (base condition), suggesting a perceptual interaction between gender and identity analyses. Nevertheless, gender variation in their study was also confounded with the number of face stimuli used in different conditions (two vs. four in base and filter conditions respectively), making it unclear whether slower responses in the filter condition were caused by automatic gender processing or by the larger number of response alternatives.

The effect of race on identity analysis, on the other hand, is mainly manifested in learning and memory of faces (e.g., own-race faces tend to be remembered better than other-race faces, Meissner & Brigham, 2001, or are less well recognized under certain special condition, Ackerman et al., 2006). However, studies of face memory are generally not sensitive enough to tell whether identity and race processing run independently of each other or not. Both an earlier, independent categorization of face race (Levin, 2000) and an interconnected link between race and identity analysis (Bruyer et al., 2007; Golby et al., 2001) could affect the encoding of face identity into memory. Therefore, to determine if the parallel-dependent model can be generalized to processing of invariant face properties, investigations on whether gender or race processing affect identity analysis are essential.

In sum, while previous models of face perception focused specifically on the relationship between processing of identity and facial expressions, theoretical characterization of how they may interact with other facial attributes (e.g., gender or race) and how other face properties interact with each other is lacking. Neither of these models explicitly addressed the nature of the independence or interconnectedness of identity, gender, and race processing. The focus of most previous studies on identity and expressions is very narrow, and does not allow us to understand how the visual system processes the full range of facial attributes. For instance, while most theoretical models agree on the separation of identity and expression processing (Calder & Young, 2005, Haxby et al., 2000), they differ from each other in suggesting how invariant facial attributes are processed. For a more complete evaluation of which model best catches the nature of face processing, investigation on the independence or interconnection among identity, gender, and race processing is crucially needed.

## The present study

The face perception models mentioned above suggest three different characterizations of the relationship between identity, gender, and race processing: independent, partial-independent, and interdependent. The primary goal of the present study was to test which of these models best predicts the relationship between identity analysis and processing of other invariant face properties.

To determine whether invariant face properties are extracted separately from each other or are analyzed in an integrative way, two key issues must be addressed. First, we need to determine whether influences between processing of invariant face properties are asymmetrical or reciprocal. Without evidence that gender or race processing also has an influence on identity analysis, the effect of identity on gender or race processing itself is not sufficient to conclude that these properties are processed in a fully integrated way. A parallel-dependent architecture could also account for the unidirectional influence of identity on gender or race processing, as it does for asymmetrical influences between identity and expression analysis (Schweinberger et al., 1999; Martens et al., 2010). Second, we need to differentiate whether interactions between processing of invariant face properties are driven by their temporal organization or by their perceptual integrity. If gender analysis is finished earlier than identity processing, an influence of gender on identity processing itself is not sufficient to conclude that they are processed in an integrative way, because an earlier process may exert a spontaneous influence on the later one even if they run separately (Baudouin & Tiberghien, 2002; Schweinberger et al., 1999). For example, the influence of an earlier brightness analysis on a later face gender judgment (e.g., Russell, 2009) does not necessarily indicate that brightness and gender of a face are perceptually integrated.

To tackle these questions, the present study used a visual search task to investigate whether identity analysis proceeds independently of processing of face gender and race. Visual search for faces has been shown to be a sensitive tool in investigating the representation of race and identity of a face (Levin, 2000; Tong & Nakayama, 1999). More important, it allowed us to examine effects of face gender or race processing on identity analysis without using familiarity to stand for identity (Bruce et al., 1987; Ganel & Goshen-Gottstein, 2002) and without introducing nonface factors such as semantic name processing (Baudouin & Tiberghien, 2002) or task demands (Ganel & Goshen-Gottstein, 2002).

To see if different invariant face properties affect identity analysis in a similar way, we tested both effects of gender and race on identity analysis using exactly the same paradigm. In Experiment 1, participants were briefly shown a person's face, and then searched for this target face among five faces displayed simultaneously. The key manipulation was that the gender or race of the distractor faces was either the same as or different from that of the target face. If identity analysis runs separately from the processing of gender or race, varying these properties in the distractor faces should not affect target face identification during visual search. In contrast, if the gender or race of a face is automatically involved during identity analysis, participants should find the target face more quickly when these properties of distractor faces are different from the target face than when they are the same. In this case, the dissimilarity of face gender or race during identity processing would facilitate the rejection of distractor faces with different gender or race.

In Experiment 2, the face stimuli used in Experiment 1 were inverted, which is known to affect the processing of invariant aspects of faces but not the low-level physical properties, thereby allowing us to evaluate whether the effects of our gender and race manipulations came from the low-level physical properties of face stimuli. Experiment 3 examined whether the influence of race and gender processing on identification was modulated by face familiarity. Participants searched for both unfamiliar faces as well as their own faces. Finally, Experiment 4 tested the relative speed of making gender, race, and identity judgments when the set of possible responses and the discriminations required were controlled between conditions. This allowed us to check whether, within our paradigm, identity decisions could be generally made more quickly than gender and race judgments.

## Experiment 1

Experiment 1 was conducted to test whether face identification in a visual search task involves concurrent processing of face gender and race. Participants were first shown an unfamiliar person's face, and then searched for this face among a crowd of five faces, with either gender or race of the distractor faces manipulated (hereafter labeled as Gender trials and Race trials respectively). If identity analysis is not affected by the processing of face gender or race, as suggested by the parallel and parallel-dependent models, changing the gender or race of distractor faces should not affect identification of a target face. However, if invariant properties of a face are processed in an interdependent way, we would expect to observe different patterns of visual search performance for conditions with or without gender or race variation.

### Method

#### Participants

Sixteen students (four male) from the University of Hong Kong (HKU) participated in the experiment. Here and elsewhere, all participants were ethnically Chinese. Half of the participants were tested with Gender trials and the other half with Race trials. Signed consent forms were obtained from all participants and they were paid for participating.

#### Materials and design

For Gender trials, photographs of unfamiliar male ($N = 40$) and female Chinese ($N = 40$) students, with a neutral expression, were converted to eight-bit grayscale, and then masked by an oval shape. Hairstyle and skin color were excluded or matched across face stimuli.

For the 40 faces of each gender, 15 were randomly selected as target faces and the rest acted as distractor faces. The size of each face was standardized with an interpupil distance of 40 pixels (1.35 cm). For target faces, a 57-pixel (1.92 cm) larger version was created to be used in the learning stage. For each target face, a test trial was constructed by placing it and four randomly selected distractors on the vertex positions of an invisible pentagon shape (400 × 400 pixels or 13.5 × 13.5 cm), with the constraint that the target face was presented once at all five possible positions, and that distractor faces appeared equally often across all trials. Distractor faces could be of the same or different gender as the target face, forming the same gender condition (Figure 1A) and the different gender condition (Figure 1B), respectively. Five trials were created for each target face in each condition, resulting in 10 target present trials for each target face. Meanwhile, these 10 trials also acted as target absent stimuli for another same-gender target face and vice versa. For each of the eight conditions in a factorial combination of target face (male vs. female), distractor gender (same as vs. different from target), and target presence (present vs. absent), 75 trials were constructed (five for each of 15 target faces), resulting in 600 trials for each participant.

For Race trials, the same race and different race conditions (Figure 1C, D) were similarly created, based on photographs of unfamiliar Caucasian ($N = 40$, all male Australian) and Asian ($N = 40$, all male Chinese) faces.

A 2 × 2 × 2 within-participants design was used for testing Gender or Race trials. These within-participants variables were distractor face (same as or different from target face in terms of gender or race), target presence (present or absent), and target face (male vs. female in Gender trials; Caucasian vs. Asian in Race trials). The primary dependent measure was response time (RT). Response sensitivity, measured as d', was also computed to check for possible speed-accuracy trade-offs (Snodgrass & Corwin, 1988).

#### Procedure

The experiment was conducted on a Macintosh eMac with a 17-inch CRT monitor (1024 × 768 pixels in resolution; Apple, Cupertino, CA), controlled by SuperLab software (Cedrus, CA). Participants were seated about 60 cm from the CRT. Test trials were blocked by gender or race of the target face, with order counterbalanced across participants. Trial orders within each block were randomized. Test trials for each target face proceeded as follows: participants first learned the target face ([with 57-pixel [1.92 cm] interpupil distance) for 3 s; after a 1-s blank screen, 20 test trials for this target face were displayed at the center of the screen in succession; each displayed until a response was made or 3 s elapsed with an intertrial interval of 1 s. This procedure was repeated until 15 target faces of each gender or race were all tested. Participants were instructed to press one key if the target face was present and another key if not, and to respond as accurately and as quickly as possible. Feedback (a gray minus sign) was presented for 150 ms

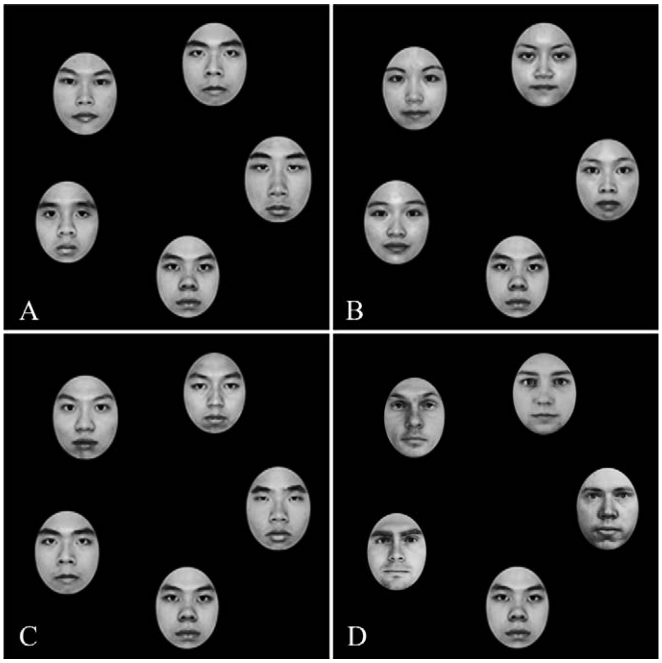


Figure 1. Stimuli from (A) same gender distractor condition, (B) different gender distractor condition, (C) same race distractor condition, and (D) different race distractor condition in searching for a male (top) or an Asian (bottom) target face presented at the lower middle position. Caucasian faces examples are adapted from the Face Database of Max-Planck Institute for Biological Cybernetics (Troje & Bülthoff, 1996).

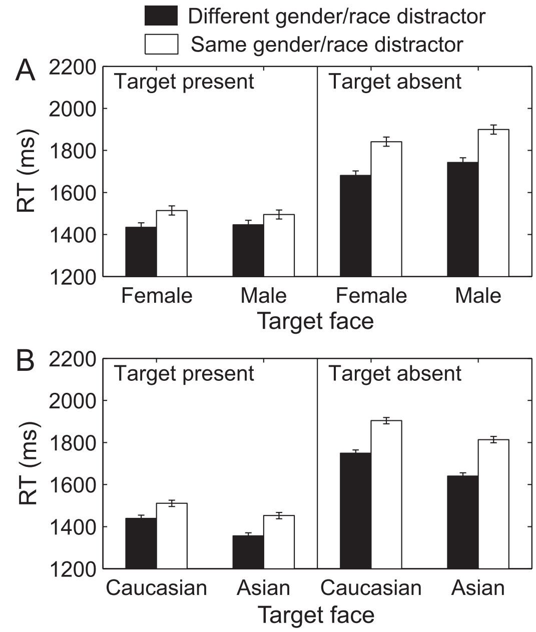


Figure 2. Mean RT in Experiment 1 (upright unfamiliar face) for (A) Gender and (B) Race trials. Error bars are standard errors of the mean.

whenever participants made an incorrect response or did not respond within 3 s.

## Results

### RT

Mean RT for correct responses in Gender and Race trials are plotted in Figure 2 as a function of target presence, target face, and distractor faces. In all experiments reported here, outliers (above 3 *SD* of the mean) and responses faster than 150 ms (indicating a preemptive response) were excluded from data analysis, resulting in <3% of total trials discarded in each experiment.

For Gender trials (Figure 2A), participants were faster to find a face when distractor faces came from the opposing gender than when they came from the same gender, as supported by a main effect of distractor faces in a three-way repeated-measures ANOVA, $F(1,7) = 33.39$, $MSE = 5958$, $p < 0.001$, $\eta_p^2 = 0.83$. Participants' search time was shorter for target present trials than for target absent trials, $F(1,7) = 32.42$, $MSE = 50{,}159$, $p < .001$, $\eta_p^2 = 0.82$. The interaction between these two factors was significant, $F(1,7) = 10.03$, $p < .02$, $\eta_p^2 = 0.59$, showing that the effect of the distractor face was more prominent in the target-absent condition ($t = 6.75$, $p < 0.001$) than in the target-present condition ($t = 2.57$, $p < 0.05$). The target presence effect was also larger in searching for a male face than for a female face, $F(1,7) = 6.14$, $p < 0.05$, $\eta_p^2 = 0.47$. None of the other statistical tests were significant, *F*s < 2.00, *p*s > 0.20.

Race trials showed similar results to Gender trials (Figure 2B). Participants were faster to find a face when other-race faces rather than same-race faces acted as distractors, $F(1,7) = 16.03$, $MSE = 15{,}298$, $p = 0.005$, $\eta_p^2 = 0.70$. Responses for target present trials were again faster than for target absent trials, $F(1,7) = 57.64$, $MSE = 31{,}542$, $p < 0.001$, $\eta_p^2 = 0.89$. The interaction between distractor face and target presence was significant, $F(1,7) = 10.22$, $p < 0.02$, $\eta_p^2 = 0.59$, showing a greater effect of distractor face when the target was absent ($t = 5.28$, $p = 0.001$) than when present ($t = 2.36$, $p = 0.05$). Participants showed a marginally significant advantage in searching for Asian faces than for Caucasian faces, $F(1,7) = 3.94$, $p = 0.09$, $\eta_p^2 = 0.36$. None of the other statistical tests were significant, *F*s < 1.

### Response sensitivity

Mean d' data are plotted in Figure 3 as a function of target face and distractor face, showing a consistent pattern with RT. For Gender trials, participants were more accurate in searching for a face in different-gender than same-gender trials, as a two-way repeated-measures ANOVA revealed a significant main effect of

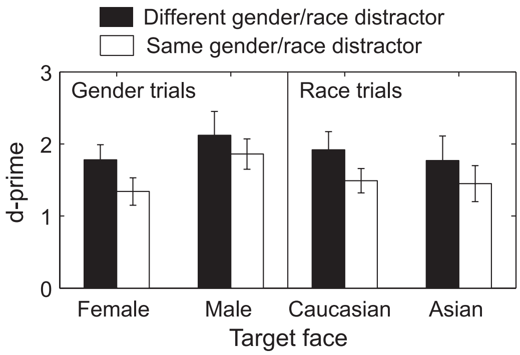


Figure 3. Mean d' in Experiment 1. Error bars are standard errors of the mean.

distractor face, $F(1,7) = 11.98$, $MSE = 0.08$, $p = 0.01$, $\eta_p^2 = 0.63$. Participants were also more sensitive in searching for a male face than for a female face, $F(1,7) = 5.49$, $MSE = 0.28$, $p = 0.05$, $\eta_p^2 = 0.44$. There was no interaction between these factors, $F < 1$.

For Race trials, the ANOVA only revealed a significant main effect of distractor face, $F(1,7) = 14.54$, $MSE = 0.08$, $p < 0.01$, $\eta_p^2 = 0.68$. Whether the target was an Asian or a Caucasian face showed no effect on sensitivity, nor interacted with the effect of distractor face, $F$s $< 1$.

## Discussion

Experiment 1 showed that varying the gender or race of distractors had a clear effect on searching for a target face, suggesting that face identity analysis is not independent from the processing of gender or race. In addition, the two types of distractor variation (gender and race) showed similar effects on face identification. These results are consistent with the hypothesis that invariant facial aspects are processed in an interdependent manner. As face gender or race categorization automatically recruits face identity analysis (Bruyer et al., 2004; Rossion, 2002), face identification during visual search also involves automatic processing of face gender and race. Therefore, the previously observed influence of identity analysis on gender and race processing is not asymmetric. Instead, processing of identity and other invariant properties are interdependent and the influences are bidirectional.

Nonetheless, it is possible that the results of Experiment 1 were caused by the low-level physical properties of test stimuli, rather than influences from the invariant aspects of a face. For example, a male target face might be differentiable from female faces in terms of low-level physical properties such as luminance and contrast. Such differences might make a male target face pop out from the female distractors, thereby leading to a faster and more accurate visual search than for the same face among male distractors. Alternatively, participants may adopt a strategy to first process the race/gender of each face and then only process the identity of faces with the same race/gender of the target face, which would also predict a pattern of response observed in Experiment 1. Experiment 2 used stimulus inversion to address these concerns.

# Experiment 2

Experiment 2 was conducted to test whether the influence of gender or race in visual search for a face was due to differences in low-level physical properties or the categorization-before-identification strategy. In Experiment 2, we inverted the orientation of the stimuli used in Experiment 1. Inversion is known to impair the perception of face-specific properties, such as identity (Rhodes, Hayward, & Winkler, 2006), gender (Zhao & Hayward, 2010), and race (Vizioli, Foreman, Rousselet, & Caldara, 2010), but does not affect the physical properties of face stimuli. If the results of Experiment 1 are completely based on physical stimulus properties rather than processing of invariant face information, face inversion should not affect the pattern of results. Similarly, if participants strategically make gender/race categorization *before* identifying only the faces of the same category, a faster and/or more accurate performance for the different than the same gender/race condition would be expected, although the overall performances for the inverted faces would be lower than that for the upright faces in Experiment 1. For the former, participants only need to make an identity judgment once to decide if a target face is presented (only one of five faces has the same gender/race as the target face), but they need more identity judgments for the latter (i.e., one to five times depends on which of the five same-gender/-race faces is first fixated).

## Method

### *Participants*

Sixteen HKU students (five male) participated in the experiment. Eight of them were tested with Gender trials and the other eight with Race trials.

### *Materials, design, and procedure*

The materials, design, and procedure in Experiment 2 were identical to that of Experiment 1 with the following exceptions. First, all stimuli used in Experiment 1 were inverted. Second, target faces during learning were displayed for 4 s rather than 3 s due to the greater difficulty in encoding inverted faces. For the same reason, test stimuli disappeared after 4 s elapsed or a response was made.

## Results

### RT

For Gender trials (Figure 4A), the consistent effect of the distractor faces observed in Experiment 1 was eliminated. A three-way repeated-measures ANOVA revealed a significant main effect of target presence, $F(1,7) = 38.12$, $MSE = 36{,}601$, $p < 0.001$, $\eta_p^2 = 0.84$; and a significant three-way interaction, $F(1,7) = 6.00$, $p < 0.05$, $\eta_p^2 = 0.46$, due to an unexpected distractor face by target presence interaction in search for a female target face, $F(1,7) = 7.10$, $MSE = 6656$, $p < 0.05$, $\eta_p^2 = 0.50$, but not in search for a male target face, $F < 1$. None of the other statistical tests were significant, $F$s $< 1$.

For Race trials (Figure 4B), there were a main effect of target presence, $F(1,7) = 213.50$, $MSE = 10{,}837$, $p < 0.001$, $\eta_p^2 = 0.97$; a main effect of distractor face, $F(1,7) = 9.07$, $MSE = 13{,}635$, $p = 0.02$, $\eta_p^2 = 0.56$; and a significant interaction between distractor face and target face, $F(1,7) = 17.34$, $p < 0.005$, $\eta_p^2 = 0.71$. None of the other statistical tests were significant, $F$s $< 1.60$, $p$s $> 0.24$. Separate 2 (distractor face) × 2 (target presence) repeated ANOVAs showed that the race of distractor faces affected visual search for inverted Asian faces, $F(1,7) = 14.27$, $p < 0.01$, $\eta_p^2 = 0.67$, but not for inverted Caucasian faces, $F < 1$. It seemed that inversion disproportionately disrupted the processing of own-race faces (i.e., Asian faces, see also Rhodes, Tan, Brake, & Taylor, 1989), which made searching for an inverted Asian face among Asian distractors extremely difficult, and wiped out the advantage in searching for a Caucasian face among Asian distractors.

### Response sensitivity

Mean d' data are shown in Figure 5, which were consistent with RT. For Gender trials, a two-way repeated-measures ANOVA showed that none of the statistical tests were reliable, $F$s $< 2.60$, $p$s $> 0.15$. For Race trials, the same analysis revealed a main effect of distractor face, $F(1,7) = 21.56$, $MSE = 0.03$, $p < 0.005$, $\eta_p^2 = 0.75$, and a significant interaction between distractor face and target face, $F(1,7) = 6.25$, $p < 0.05$, $\eta_p^2 = 0.47$. As with RTs, participants were more sensitive in searching for an inverted Asian face among Caucasian distractor faces than among Asian distractor faces, $t(7) = 6.39$, $p < 0.001$, but showed no effect of distractor race when searching for an inverted Caucasian face, $t(7) = 1.25$, $p = 0.25$.

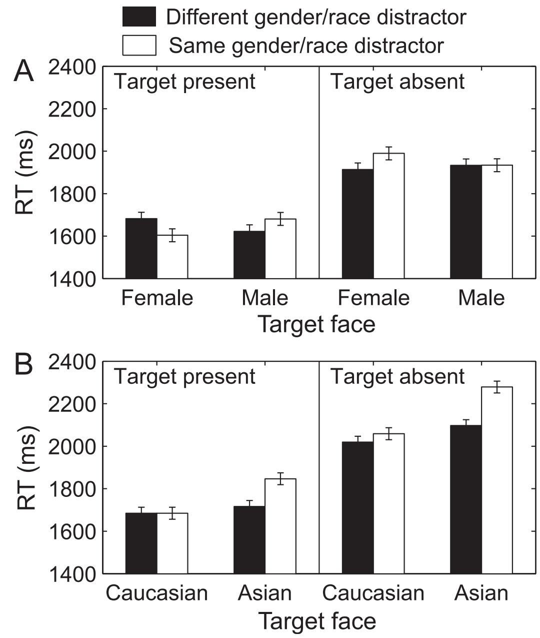


Figure 4. Mean RT in Experiment 2 (inverted unfamiliar faces) for (A) Gender and (B) Race trials.

### Interaction between face orientation and distractor face

Two four-way ANOVAs, one each for gender trials and race trials, with RT data combined from Experiments 1 and 2, revealed significant interactions involving factors of face orientation (upright vs. inverted) and distractor face, confirming that face inversion reduced or eliminated the effects of gender and race variation in distractor faces.

For Gender trials, the ANOVA showed a significant interaction between face orientation and distractor face, $F(1,14) = 12.38$, $MSE = 6108$, $p < 0.005$, $\eta_p^2 = 0.47$. The four-way interaction was also significant, $F(1,14) = 5.05$, $MSE = 5600$, $p < 0.05$, $\eta_p^2 = 0.27$. As shown in Figures 2A and 4A, manipulating the gender of distractor faces showed a consistent effect on identifying an upright face, but not on identifying an inverted face. None of the other interactions of interest were significant, $F$s $< 1.30$, $p$s $> 0.27$. For Race trials, the same analysis revealed a significant three-way interaction among face orientation, distractor face, and target face, $F(1,14) = 8.09$, $MSE = 3209$, $p < 0.02$, $\eta_p^2 = 0.37$. As shown in Figures 2B and 4B, the influence of distractor race in recognizing upright Caucasian and Asian faces disappeared in search for an inverted Caucasian face, but persisted in searching for an inverted Asian face. None of the other interactions of interest were significant, $F$s $< 1$.

Three-way ANOVAs conducted on combined response sensitivity data showed numerically consistent patterns with that of RT, although none of the interactions of interest were significant for either

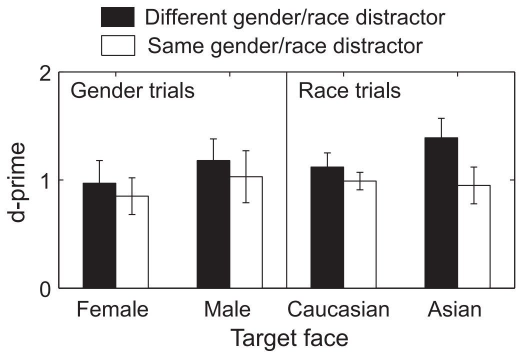


Figure 5. Mean d' in Experiment 2.

Gender trials, $Fs < 2.19$, $ps > 0.16$, or Race trials, $Fs < 2.31$, $ps > 0.15$.

## Discussion

The consistent advantage in searching for a face among distractor faces of a different gender or race was reduced when the same stimuli were inverted in Experiment 2. This result is incompatible with the interpretation of search results for upright faces as being based on image properties of face stimuli. By contrast, it suggests that the effects of distractor faces in Experiment 1 are grounded upon the processing of face gender, race, and identity information in normal upright faces, rather than simply matching the images. Importantly, this result also rules out the possibility that participants took the strategy to categorize face gender/race first and then simply make identity judgment for faces of same gender/race as target face; otherwise we should observe a consistent better performance for trials with distractors from different categories than from the same category. Taken together, the results of Experiments 1 and 2 indicate an integrative processing of invariant face properties. Gender and race processing are automatically involved during identity analysis, rather than occurring separately.

There may be an argument that the involvement of gender and race processing during face identification might be limited to unfamiliar faces, whereas a parallel processing model (Bruce & Young, 1986; Burton et al., 1990) could be proposed for recognition of familiar faces. To look for a newly learned face, the visual system might rely more on identity-independent facial aspects (e.g., gender or race) to individualize different faces. Identifying a familiar face in a crowd, by contrast, might be primarily based on the processing of identity-specific properties without involvement of gender or race analysis. If this is the case, the results of Experiment 1 would be contingent on the familiarity of target faces, rather than a general mechanism in processing invariant facial properties. Experiment 3 addressed this issue.

# Experiment 3

Experiment 3 was conducted to examine whether integrative processing of invariant facial properties is specific to identification of unfamiliar faces or is a general characteristic of face processing. We used each participant's own face as a familiar target, as it has been demonstrated that the self-face is robustly represented and is detected more quickly than an unfamiliar face (Tong & Nakayama, 1999). Participants were paired and searched for both their own face and an unfamiliar participant's face. If the effects of gender and race processing on face identification stemmed from the boosted role of visual cues due to a weak representation of unfamiliar faces, it should disappear when participants search for their own faces. If, however, the effect is rooted in a general mechanism, it would persist in searching for both an unfamiliar face and one's own face. Moreover, the manipulation of face familiarity by pairing participants and their faces, rather than by face images themselves, enabled us to further examine whether participants used image matching or identity judgments during visual search.

## Method

### *Participants*

Sixteen HKU students participated in the experiment. Eight female students were tested with Gender trials and eight male students were tested with Race trials.

### *Materials and design*

Participants' photographs were taken about one week before testing. These eight face photos were edited the same way as that of target faces used in Experiment 1.

For Gender trials, each of these eight target faces was used to create 75 trials for the same gender condition and 75 trials for the different gender condition, with the same distractor faces and the same procedure used in Experiment 1. Participants were paired, and each participant searched for two target faces, one from herself and one from the paired unfamiliar participant. In this way, the two search images were matched for exposure across the experiment. Trials created with faces from another pair of participants functioned as the target absent stimuli in searching for the two target faces. In this way, a group of four participants had exactly the same test trials, and each pair of two participants also had the same two target faces. Thus, face familiarity was manipulated by the relationship between target faces and participants, rather than by target face per se. For Race trials, same race and different race conditions were created in the same way. Photographs of another eight participants and the distractor faces of Race trials in Experiment 1 formed the basis of Race trial stimuli.

A 2× 2 × 2 within participant design was used for both Gender and Race trials. The within-participant variables were target face (self vs. unfamiliar face), face distractors, and target presence. There were 75 trials in each of the eight conditions, resulting in a total of 600 trials for each participant.

### *Procedure*

The procedure was similar to that of Experiment 1 with the following variations due to participants only searching two target faces. The 75 trials in each condition for one target face were pseudo-randomly split into five sets of 15 trials and were tested in five blocks. So participants searched for their own face and an unfamiliar face in 10 alternative blocks (five for each target face), with the order counterbalanced across participants. In each block, participants were first shown the target face (self or unfamiliar face) for 3 s, followed by 60 testing trials, which consisted of one set of 15 trials from each of the four conditions for the target face (2 distractor face types × 2 target presence conditions). The target face appeared equally often in the five possible positions, and all distractor faces appeared equally often within a condition. The order of trials was randomized.

## Results

### *RT*

For Gender trials (Figure 6A), participants were faster to find a face among distractor faces of the opposing gender than among faces of the same gender, $F(1,7) = 57.68$, $MSE = 1940$, $p < 0.001$, $\eta_p^2 = 0.89$; and were faster in searching for their own face than for an unfamiliar person's face, $F(1,7) = 11.42$, $MSE = 25{,}440$, $p = 0.01$, $\eta_p^2 = 0.62$. Participants also responded faster for target present than for target absent conditions, $F(1,7) = 128.95$, $MSE = 21{,}117$, $p < 0.001$, $\eta_p^2 = 0.95$. The interaction between distractor face and target presence was significant, $F(1,7) = 5.50$, $p = 0.05$, $\eta_p^2 = 0.44$, showing a greater effect of distractor face in the target-absent ($t = 7.95$, $p < 0.001$) than in the target-present trials ($t = 4.95$, $p < 0.005$). The three-way interaction was also significant, $F(1,7) = 5.96$, $p < 0.05$, $\eta_p^2 = 0.46$. None of the other statistical tests were significant, $Fs < 1.71$, $ps > 0.23$. Separate 2 (distractor face) × 2 (target presence) repeated ANOVAs revealed that when searching for an unfamiliar face, the effect of distractor face was larger in the target absent condition than in the target present condition, $F(1,7) = 8.62$, $p = 0.02$, $\eta_p^2 = 0.55$; whereas no such interaction was observed when searching for one's own face, $Fs < 1$.

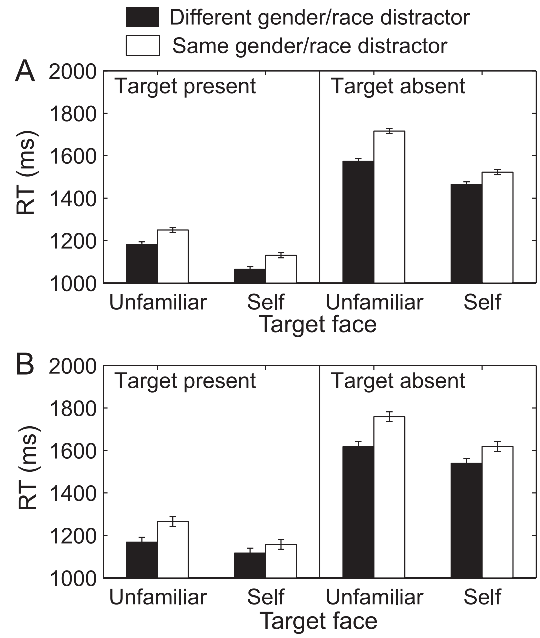


Figure 6. Mean RT in Experiment 3 (upright familiar and unfamiliar faces) for (A) Gender and (B) Race trials.

For Race trials (Figure 6B), the same ANOVA showed that all three main effects were significant. Participants were faster to find a face when the race of distractor faces was different from than the same as that of the target face, $F(1,7) = 8.97$, $MSE = 14{,}293$, $p = 0.02$, $\eta_p^2 = 0.56$. They were faster to search for their own face than for a novel person's face, $F(1,7) = 6.46$, $MSE = 21{,}994$, $p < 0.05$, $\eta_p^2 = 0.48$; and were faster to respond to target present trials than to target absent trials, $F(1,7) = 216.65$, $MSE = 15{,}429$, $p < 0.001$, $\eta_p^2 = 0.97$. None of the interactions were significant, $Fs < 3.26$, $ps > 0.11$.

### *Response sensitivity*

Mean d' data in Experiment 3 are shown in Figure 7. For Gender trials, participants were more sensitive in searching for a face accompanied by distractor faces of the opposing gender than of the same gender, $F(1,7) = 6.40$, $MSE = 0.20$, $p < 0.05$, $\eta_p^2 = 0.48$. They also showed a trend of better performance in search for their own face than for a novel face, $F(1,7) = 3.90$, $MSE = 0.44$, $p = 0.09$, $\eta_p^2 = 0.36$. The interaction between these two variables was not significant, $F < 1$.

For Race trials, there was only a marginally significant main effect of distractor face, $F(1,7) = 4.67$, $MSE = 0.15$, $p = 0.07$, $\eta_p^2 = 0.40$, suggesting that

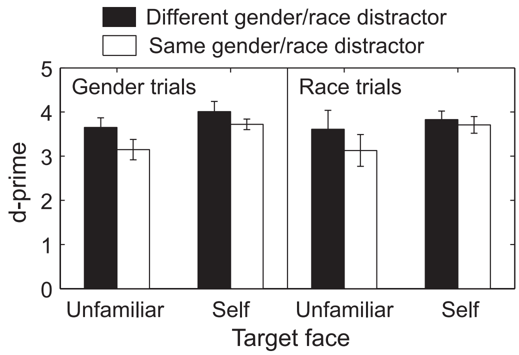


Figure 7. Mean d' in Experiment 3.

participants tended to show higher sensitivity in searching for a face accompanied with distractor faces of a different race than of the same race. The effect of target face and its interaction with distractor face was not significant, $Fs < 3.08$, $ps > 0.12$.

## Discussion

The results of Experiment 3 showed that identifying an unfamiliar face and one's own face both involve automatic processing of face gender and race, ruling out the interpretation that recruitment of identity-independent cues during face identification was due to a weaker representation of target face identity. This result suggests that integrative processing of invariant face properties is a general mechanism in analyzing faces, and is not greatly influenced by variations in familiarity. On the other hand, face familiarity did affect visual search performance. Participants were faster to detect their own face than an unfamiliar face in a crowd, echoing Tong and Nakayama's (1999) proposal that one's own face is robustly represented. More important, this result also favors the idea that participants employed identity analysis, rather than image-matching, to complete the visual search task. An image-matching strategy has difficulty accounting for the face familiarity effect, because the familiarity of the target face was contingent on a specific participant, rather than being defined by particular image properties.

As outlined in the Introduction, before we could draw a conclusion that invariant face properties are processed in a perceptually interdependent way, a direct examination of whether the results observed in Experiments 1-3 are caused by an earlier processing of gender and race than identity is needed. Baudouin and Tiberghien (2002) have proposed that face gender categorization might occur earlier than identification, so that identity analysis might be terminated whenever a nontarget gender is detected. A similar mechanism may also account for the effects of race processing on face identification. This interpretation had an associated prediction that judgments based on gender or race should be faster than those based on identity, and that the effect of gender or race on identity analysis should not happen earlier than the extraction of gender or race properties of a face.

However, the relative speed of gender/race categorization and identification may vary depending upon many methodological factors (Bruce et al., 1987; Goshen-Gottstein & Ganel, 2000; Rossion, 2002). Recent studies have suggested that face identity is processed at an earlier stage than previously thought. Rossion (2002) found that gender judgments about a face are modulated by face identity, indicating that identity information is extracted before the completion of gender categorization. It has also been shown that face identity analysis modulates the earlier psychophysiological correlates of face detection (Harris & Nakayama, 2008; Jacques & Rossion, 2006). Jacques and Rossion (2006) showed that the N170 response—an electrophysiological marker of visual face detection—was decreased when face identity was repeated as compared to when it was changed, indicating that identity is processed during the same time window that a visual stimulus is categorized as a face. These findings suggest that judgments based on identity might occur no later, if not faster, than judgments based on gender or race. To test whether participants in Experiments 1-3 extracted gender and race properties before they knew whether a face displayed the target identity, we examined the temporal organization of gender, race, and identity processing under similar test conditions in Experiment 4.

# Experiment 4

Experiment 4 was designed to test whether explicit face judgments based on gender or race are faster than those based on identity analysis, under the specific conditions employed in Experiments 1-3. Participants were asked to make judgments about faces according to gender, race, or identity, thereby allowing us to directly compare between them. Two identity tasks and two categorization tasks were employed in both Gender trials and Race trials. An identity task consisted of participants judging whether a single face was their own face or the face of another person that they had just been familiarized with. During the categorization task they judged whether a face was male or female (in Gender trials) or whether a face was Asian or Caucasian (in Race trials). The control categorization task was included to match the stimulus structure of the identity task (i.e., only one target face), so the difference between categorization and identification tasks could not be attributed to the mismatched number of target examples. The key manipulation was that *all four tasks were tested with exactly the same distractor faces*. We focused on the performance on these distractor faces, as they provided identical input (i.e., stimuli) and required identical output (i.e., a No response) for both identification and categorization tasks, which allowed us to infer the temporal organization of extracting different face properties. Note that Experiment 4 provided an extreme case of Experiments 1 and 3 by reducing the set size of visual search to one. If the results of Experiments 1 and 3 were due to faster extraction of gender or race information than identity information, the same set of distractor faces should be rejected faster based on their gender or race properties than based on their identity properties.

## Method

### Participants

Sixteen HKU students participated in the experiment. Eight female students were tested with Gender trials and eight male students were tested with Race trials.

### Materials and design

Participants' photographs were taken about one week before testing, and were edited the same way as in Experiment 1. Test stimuli were created by placing each of these faces and all distractor faces used in Experiment 1 on a black color square (180 × 240 pixels, 6.1 by 8.1 cm).

For Gender trials, in the self identity task, participants judged whether a face was their own face, which was displayed 25 times among 25 distractor faces (once all male and once all female). The unfamiliar identity task was identical to self identity task except the target face was changed to an unfamiliar participant's face. In the gender categorization task, participants were asked to judge whether a face was a male (or female) face when all 25 male and 25 female faces were displayed one at a time. In the control categorization task, only one male or female target face was used as target face, which was displayed 25 times as in the identity tasks.

For Race trials, the identity and categorization tasks were similarly constructed, except that photographs of eight new participants and distractor faces used in Race trials of Experiment 1 formed the basis of the stimuli. Participants judged whether a face was Caucasian or Asian in the categorization tasks.

A 4 × 2 within participants design was used for both Gender and Race trials. The independent variables were task and category of distractor face (same as vs. different from target face). Each task had 50 experimental trials preceded by 10 practice trials, which was included to help avoid the possible confusion of successive tasks (e.g., from searching for female faces to male faces).

### Procedure

For identity tasks, participants were first shown a target face for 3 s (depicting either themselves or an unfamiliar participant), and then were presented sequentially with 10 practice test faces followed by 50 experimental test faces (25 target faces, 25 distractor faces). Participants were asked to judge whether the face shown to them was the target face. For categorization tasks, 10 practice and 50 experimental test faces were displayed one by one, and participants were asked to judge whether the face shown to them belonged to a specific face category (i.e., male or female in Gender trials, or Asian or Caucasian in Race trials). Test faces were presented at the center of the screen until a response was made, with an inter-trial interval of 1 s. Test trials were blocked by distractor face (i.e., male or female distractors, or Caucasian or Asian distractors), with the order of block and the order of tasks in each block counterbalanced across participants. The order of test faces in each task was randomized.

## Results

### RT

Mean RT data for correct rejections of distractor faces are plotted in Figure 8 as a function of task and distractor faces. It is worth noting that we were interested in the following three comparisons: (A) whether responses in the categorization task were faster than in the identification task; (B) whether there was an effect of variation in gender or race in the identification task; and (C) whether there was any difference between the two categorization tasks and between the two identity tasks.

For Gender trials (Figure 8A), a repeated-measures ANOVA revealed a significant main effect of condition, $F(3, 21) = 7.49$, $MSE = 10{,}962$, $p = 0.001$, $\eta_p^2 = 0.52$. No other statistical tests were significant, $Fs < 1.16$, $ps > 0.34$. The planned comparisons revealed that (A) participants' responses in the gender categorization task were slower than either the unfamiliar or self identity tasks, $ts(7) = 3.92$, $ps < 0.01$; (B) participants showed a trend of slower responses in identity tasks when the gender of distractor faces was the same as the target face compared to when they were different, $t(7) = 2.25$, $p = 0.06$; and (C) neither the two categorization tasks nor the two identity tasks showed significant differences, $ts < 1$. Therefore, the slower response for the gender categorization task was not because of the difference in the number of target examples between identity and categorization tasks.

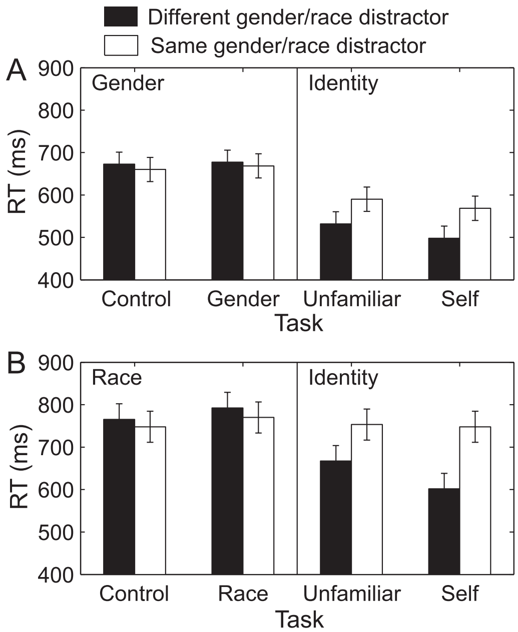


Figure 8. Mean RT for correct rejections in Experiment 4 for (A) Gender and (B) Race trials.

For Race trials (Figure 8B), there was a marginally significant interaction between tasks and the race of distractor faces, $F(3, 21) = 2.53$, $p = 0.08$, $\eta_p^2 = 0.27$. None of the other statistical tests were significant, $F$s $< 1.52$, $ps > 0.25$. The planned comparison revealed that (A) responses in the race categorization task were slower than in the self identity task, $t(7) = 2.90$, $p < 0.05$, and the same trend was also shown for the unfamiliar identity task, $t(7) = 1.94$, $p = 0.09$; (B) participants were slower to reject distractor faces in identity tasks when they shared the same race category with a target face than when they did not, $t(7) = 3.17$, $p = 0.02$; and (C) no difference was observed between either the categorization tasks or the identity tasks, $ts < 1$.

### Response accuracy

Mean accuracy data for rejection of distractors are summarized in Figure 9 as a function of task and category of the distractor face. For Gender trials (Figure 9A), a repeated-measures ANOVA revealed a significant main effect of task, $F(3, 21) = 5.55$, $MSE = 0.004$, $p < 0.01$, $\eta_p^2 = 0.44$. No other statistical tests were significant, $F$s $< 1.04$, $ps > 0.34$. The planned comparisons only showed a marginally higher accuracy for the self identity task than for the gender categorization task, $t(7) = 2.07$, $p = 0.08$. For Race trials (Figure 9B), the ANOVA showed that none of the statistical tests were significant, all $F$s $< 1$, nor were the planned comparisons, $ts < 1.63$, $ps > 0.15$.

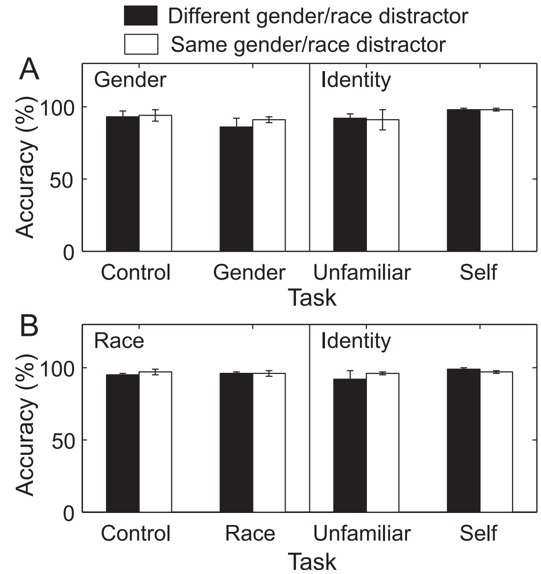


Figure 9. Mean accuracy in Experiment 4 for (A) Gender and (B) Race trials.

### Distribution of response time

The distribution of RT data (on the fastest tail) was analyzed to seek convergent evidence that identity analysis was no slower than gender or race categorization in our specific test conditions. The rationale was that if face gender and race is explicitly extracted earlier than face identity, the onset of responses (i.e., the fastest RTs) to gender or race should be clearly faster than, and therefore separated from, the onset of responses to face identity (Mack, Wong, Gauthier, Tanaka, & Palmeri, 2009).

We ranked each participant's correct rejection responses from the fastest to the slowest for categorization, self-identification and unfamiliar person identification tasks, and then extracted the fastest half responses (12 of 25 possible responses). Mean RT for each rank in each task are plotted in Figure 10. A separation of responses between gender or race categorization tasks (triangles) and identity tasks (circles and diamonds) was found as early as participants could make a correct judgment, with patterns showing that gender and race were not explicitly extracted before identity.

Planned comparisons conducted on each rank supported this observation. For Gender trials, responses for gender categorization were slower than those for unfamiliar face identification, $ts(7) > 3.83$, $ps < 0.01$, and slower than those for self face identification, $ts(7) > 4.00$, $ps < 0.01$, for all twelve ranks. For Race trials, responses for race categorization were slower than those for unfamiliar face identification for ranks 1 to 6, $ts(7) > 2.43$, $ps < 0.05$. Ranks 7 to 12 showed similar trend, $ts(7) > 1.87$, $ps \leq 0.10$. Race categorization was also slower than self face identification for ranks 1 to 4,

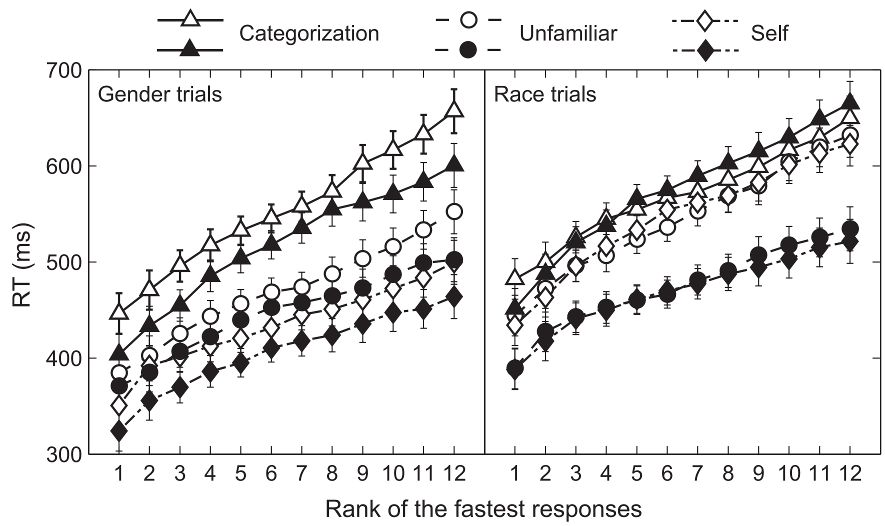


Figure 10. Mean RT for the fastest twelve responses as a function of task and distractor face in Experiment 4. Empty markers indicate same gender/race distractor conditions; filled markers indicate different gender/race distractor conditions. Error bars are standard errors of the mean.

$ts(7) > 2.41$, $ps < 0.05$, but not for the remaining ranks, $ts(7) < 2.21$, $ps > 0.06$. Therefore, even for the fastest responses possible, judgments based on face identification were not slower than those based on gender or race.

## Discussion

In Experiment 4, participants' responses to a distractor face based on identification were generally faster than responses to the same face based on gender or race, suggesting that participants in Experiments 1-3 did not process identity after an earlier extraction of gender and race. This result echoes recent proposals that face individualization occurs at a relative early processing stage (Harris & Nakayama, 2008; Jacques & Rossion, 2006). Consistent with Experiment 2, this finding indicates that an identification-after-categorization strategy (c.f., Baudouin & Tiberghien, 2002) seems to be less likely in our experiments. Therefore, while the present results extend Baudouin and Tiberghien's (2002) finding to different facial attributes (i.e., race) and to familiar faces, they raise questions as to how one invariant aspect of a face could affect the processing of another before being explicitly extracted. We will come back to this issue in the General discussion.

Relative speed in extracting gender, race, and identity of a face may vary depending upon many factors including stimuli (with vs. without cues from hairstyle and skin color) and tasks (e.g., familiarity and gender judgments vs. identity and gender judgments). Gender or race judgments tend to be faster than familiarity judgments about faces when hairstyle or skin color are included in face stimuli (Bar-Haim, Saidel, & Yovel, 2009; Bruce et al., 1987; Ellis et al., 1990), but not so when these prominent cues were removed (Ganel & Goshen-Gottstein, 2002; Goshen-Gottstein & Ganel, 2000; Rossion, 2002). Therefore, one should be cautious in generalizing our findings here to these different conditions. Note that we are not claiming here that face identity is always processed earlier than face gender and race, but rather that extraction of face identity is no slower than extraction of gender and race, at least under tasks employed in our study.

# General discussion

In the present study, we demonstrated the influence of gender and race processing on identity analysis with a visual search task, providing convergent evidence for the hypothesis that invariant face properties are processed in a perceptually interdependent way. First, irrelevant variation of the gender and race of distractor faces consistently affected identification of a target face, indicating that identity analysis is not separated from the processing of other invariant aspects of a face (Experiments 1 and 2). Second, the influence of gender and race processing on identity analysis occurred across faces of varying familiarity (Experiment 3). Identifying an extremely familiar and robustly represented face (i.e., a participant's own face) was not immune to the influence of other invariant face properties. Finally, the results of these experiments were not based upon the relative temporal organization of identity, race, and gender judgments (Experiment 4). Together with established findings showing the involvement of identity analysis during gender and race categorization and the involvement of gender processing in race categorization and vice versa, the present study indicates an integrated and interdependent processing of invariant aspects of a face. Analyzing one invariant face property automatically involves, and is therefore affected by, processing of the others.

## Evaluation of theoretical models on processing of invariant face properties

As mentioned in the Introduction, empirical evidence on whether gender and race affect identity analysis is essential to differentiate competing theoretical models of face processing. Bruce and Young's influential face recognition model (Bruce & Young, 1986; Bruce et al., 1987; Burton et al., 1990) predicts that identity analysis and processing of face gender or race should occur in an independent, parallel way. This hypothesis is inconsistent with our findings that gender and race processing are automatically recruited during identity analysis. Variation in either gender or race of distractor faces affected identification of an upright face, even when participants searched for an extremely familiar face (i.e., self face), indicating that identity analysis is not encapsulated and separated from visual analysis routes to face gender and race.

More important, our results also rule out two adapted versions of the independent processing model. One possibility is that identity analysis affects the processing of other face properties but not vice versa (Martens et al., 2010; Schweinberger et al., 1999; Schweinberger & Soukup, 1998). This parallel-dependent model would predict asymmetrical influences between identity analysis and gender or race processing. However, our results do not show this pattern. As face identity analysis influences gender and race processing (e.g., Rossion, 2002), so does gender and race processing affect face identification. The other possibility is that identity analysis may run parallel to gender or race processing, but earlier categorization of gender or race might exert influence on the later processing of identity (c.f., Baudouin & Tiberghien, 2002). This weak version of parallel processing cannot account for our results either. Consistent with prior research (Goshen-Gottstein & Ganel, 2000; Rossion, 2002), we found no evidence, at least under our specific tasks, that extraction of identity is slower than extraction of gender or race (Experiment 4).

The present study clearly favors an interdependent account, as implied in Haxby et al.'s (2000) face perception model. Given that invariant face properties are extracted via largely overlapping sets of neural populations, visual analysis of one invariant attribute is probably interlinked with, and therefore affected by, that of another. Ng et al. (2006) have provided some evidence for this assumption. They showed that brain activations for face cues determining identity, gender, and ethnicity fall within a similar brain network distributed across inferior occipital cortex, the fusiform gyrus, and the cingulate gyrus, suggesting that gender, race, and identity are various dimensions of face similarity without necessarily involving independent analysis mechanisms (Ng et al., 2006). The present study provided behavioral evidence for this neurophysiological overlap. The consistent perceptual influence of gender and race variation on face identification suggests that the whole spectrum of invariant face attributes is processed concurrently within the same brain network.

Taken in conjunction with other results in the literature, our results suggest that neither parallel nor interdependent architecture alone are sufficient to account for the relations among the visual analysis of different face properties. While functional independence has been well established between identity and expression analysis, functional interdependency has been shown between processing of identity and other invariant face properties. Similarly, although separated neural substrates are involved in processing of identity and facial expression, processing of face gender, race, and identity seem to share an overlapping neural network. Therefore, any theoretical characterization of face perception in future research should take these heterogeneous relations into consideration.

## Integrative processing of invariant face properties

Integrative processing of invariant face properties is consistent with three other lines of empirical observation. First, brain imaging studies have showed that judgments of face identity, gender, and race activate largely overlapping brain areas (e.g., the fusiform gyrus; Cloutier et al., 2008; Freeman et al., 2010; Golby et al., 2001; Ng et al., 2006; Rotshtein et al., 2005). Second, people have difficulty in selectively processing one invariant face property without influence from processing of another (Baudouin & Tiberghien, 2002; Bruyer et al., 2004, 2007; Ganel & Goshen-Gottstein, 2002; Goshen-Gottstein & Ganel, 2000; O'Toole, Peterson, & Deffenbacher, 1996; Rossion, 2002). As shown in the present study, identifying a face, even one's own face, is not immune from the influence of gender and race processing. Similarly, judgments about the gender of a face are affected by both identity analysis (Rossion, 2002) and race categorization (O'Toole et al., 1996). Finally, event-related potential (ERP) studies have shown that invariant face attributes seem to be processed automatically (e.g., Ito & Urland, 2003, 2005; Kubota & Ito, 2007; Mouchetant-Rostaing & Giard, 2003; Mouchetant-Rostaing, Giard, Bentin, Aguera, & Pernier, 2000). For instance, variation of face gender during a race categorization task produced different ERPs from those observed when gender was fixed, and a similar difference was found when race was varied or held constant in a gender categorization task (Ito & Urland, 2003, 2005). This result suggests that both gender and race are automatically processed when participants attend to only one of these properties.

How does visual analysis of one invariant face property interlink with the processing of others? We speculate that it may be based upon overlap in either the visual information that is used to extract identity, gender, and race properties, or the cognitive or neurophysiological processes that apply to such judgments, or possibly both. On the one hand, these invariant face properties are influenced by similar processes. For example, the impairment of holistic face processing by face inversion, face scrambling, or the use of face composites (combining the top part of one face with the bottom part of another) showed similar effects on face gender and identity analysis (e.g., Zhao & Hayward, 2010). The overlapping processes probably bundle together analyses of multiple invariant aspects of a face, leading to the interconnections across identity, gender, and race perception (e.g., Ganel & Goshen-Gottstein, 2002). On the other hand, invariant aspects of a face seem to emerge from overlapping visual information. For example, Calder et al. (2001) have demonstrated that gender and identity are coded by overlapping sets of dimensions as derived from a principal components analysis of face images, indicating that representations of both face properties might be rooted in similar visual information within a face. Therefore, independent processing of identity, gender, and race seems unlikely if each is based on the same general information and is analyzed within the same cognitive and neural system.

How could processing of gender or race affect face identification if they are not extracted earlier than face identity? The contradictory finding could be reconciled if we assume that integrative processing occurs at an earlier, automatic analysis stage before those invariant face properties can be explicitly extracted. Recent psychophysiological studies suggest that this earlier integrative processing assumption is plausible. For example, Mouchetant-Rostaing and Giard (2003) found that automatic processing of face gender and age occurs at about 145-185ms after stimulus onset, while explicit gender or age categorization takes place between 200–400ms. This finding is consistent with others showing that automatic race or gender processing occurs relatively earlier at about 150 ms (Ito & Urland, 2003), while explicit classification of face ethnicity is relatively later at about 240 ms (Caldara, Rossion, Bovet, & Hauert, 2004).

The temporal locus of implicit gender or race processing falls exactly within the time window in which the brain individualizes different face identities (120–190 ms, Jacques & Rossion, 2006; see also Harris & Nakayama, 2008). Note that this earlier identity analysis is probably implicit too, as the explicit activation of preexisting or acquired face representations occurs at about 250 ms or later (Bentin & Deouell, 2000; Tanaka, Curran, Porterfield, & Collins, 2006). Therefore, the *emerging* gender or race of distractor faces may be integrated by the *ongoing* identity analysis, and dissimilarity on any dimension of these invariant face properties may facilitate the rejection of a distractor. This assumption can also explain why face familiarity affects gender and race categorizations although familiarity judgments are sometimes slower than responses to face gender or race (Bruyer et al., 2004; Ganel & Goshen-Gottstein, 2002; Rossion, 2002), which cannot be readily explained by an early gender or race categorization account.

The integrative processing hypothesis, by refining Haxby et al.'s (2000) seminal proposal, provides a unified theoretical framework for understanding visual analysis of invariant face properties. Gender, race, and identity are not separable dimensions of face perception as previously thought; instead, they are bundled together perceptually and neurophysiologically for individualizing faces from each other. Therefore, visual analysis of a face cannot be "directed to any of the different representations produced by the structural encoding processes" (Bruce & Young, 1986, p. 313) without processing other representations that are not selectively attended. Previous interpretations that were based on the assumption of either an earlier gender categorization (Baudouin & Tiberghien, 2002) or an earlier identity analysis (Rossion, 2002) have difficulty in readily accounting for the mutual influences.

## Conclusions

The present study demonstrated, for the first time, the consistent influence of gender and race processing on face identification, across variations in face familiarity, and at a relatively early temporal locus. These results suggest that invariant aspects of a face are processed in an integrative way, rather than proceeding separately. The visual system cannot selectively analyze one invariant face attribute without influence from the automatic processing of the others. These results not only provide key evidence to differentiate various theoretical models on how the visual system processes gender, race, and identity of a face, but also suggest a heterogeneous architecture for future models of face perception. Whereas a parallel architecture captures the independence between identity and facial expression processing, integrative processing captures the nature of visual analysis of invariant face properties.

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