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Consciousness and Cognition xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Conscious awareness is necessary for processing race and gender information from faces

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ARTICLE INFO

Article history:
Received 4 March 2010
Available online xxxx

Keywords:
Continuous-flash-suppression
Face processing
Face aftereffects
Subordinate categorization
Gender
Race
Conscious awareness

ABSTRACT

Previous studies suggested that emotions can be correctly interpreted from facial expressions in the absence of conscious awareness of the face. Our goal was to explore whether subordinate information about a face's gender and race could also become available without awareness of the face. Participants classified the race or the gender of unfamiliar faces that were ambiguous with regard to these dimensions. The ambiguous faces were preceded by face-images that unequivocally represented gender and race, rendered consciously invisible by simultaneous continuous-flash-suppression. The classification of ambiguous faces was biased away from the category of the adaptor only when it was consciously visible. The duration of subjective visibility correlated with the aftereffect strength. Moreover, face identity was consequential only if consciously perceived. These results suggest that while conscious awareness is not needed for basic level categorization, it is needed for subordinate categorization. Emotional information might be unique in this respect.

1. Introduction

A large number of studies have convincingly demonstrated that images can be extensively processed by the visual system and influence subsequent performance even when the observer is not aware of the visual input. For example, it was suggested that words or pictures rendered invisible by different masking procedures can facilitate the processing of subsequent visible words or pictures (e.g. Dell'Acqua & Grainger, 1999; Draine & Greenwald, 1998; Lamy, Mudrik, & Deouell, 2008), that stimuli presented below the level of conscious awareness elicit category specific neural activity (e.g. Diaz & McCarthy, 2007; Morris, Pelphrey, & McCarthy, 2007; Moutoussis & Zeki, 2002), and that patients with neurological symptoms that prevent awareness such as unilateral neglect (e.g. Berti et al., 1992) or blindsight (e.g. Trevethan, Sahraie, & Weiskrantz, 2007) can process certain aspects of a stimulus whose presence they are not aware of (for reviews see Driver, Vuilleumier, Eimer, & Rees, 2001; Kouider & Dehaene, 2007). Whereas the mere processing of visual input without awareness of the stimuli seems to be well established,[1] the type of information that can be extracted during such processing (particularly in healthy individuals) is still debated. Performance measures suggested that consciously unperceived stimuli activate elaborate representations including semantic attributes (e.g. Abrams & Grinspan, 2007; Marcel, 1983; Mcglinchey-Berroth, Milberg, Verfaellie, Alexander, & Kilduff, 1993; Sackur et al., 2008). Yet, imaging studies showed that the processing of subliminal stimuli is significantly reduced and limited to relative low-perceptual levels (e.g. Gaillard et al., 2009; Jiang & He, 2006). This debate can be addressed

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[1] Note, however, that this position is not unanimously maintained (e.g. Merikle & Reingold, 1998).

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doi:10.1016/j.concog.2010.08.004

more systematically using a level of categorization approach. From this perspective, the question is how specific is the information extracted from subliminal stimuli. This approach was taken here using faces.

Human faces convey information which allows subordinate categorization at a group level such as a person's race, gender, and affect, as well as at the individual exemplar level identity. Therefore they are ideal stimuli for implementing a level of categorization approach to the study of processing without awareness. Indeed, it has been shown that faces can be discriminated from other stimuli (basic level categorization) when they are presented below the level of conscious awareness. For instance, several studies showed that the Fusiform Face Area (FFA) is selectively activated by heavily masked faces particularly in the right hemisphere (Morris et al., 2007, see also Moutoussis and Zeki (2002)). In unilateral neglect patients, Driver and colleagues (2001) found specific brain activity in response to faces that are presented in the extinguished field even when the patient denied seeing those faces (see also Driver & Vuilleumier, 2001; Rees et al., 2000). In addition, faces that participants are not aware of can modulate the electrophysiological activity elicited by subsequent, visible faces (Hoshiyama, Kakigi, Takeshima, Miki, & Watanabe, 2006).

The above cited evidence suggests that, at least in some cases, there is categorical specificity for faces in the brain even if the person viewing them is not aware of their presence. However, the type of subordinate information that can be extracted from faces without awareness is not clear. For example, there is no strong evidence for individual face identification without awareness (Moradi, Koch, & Shimojo, 2005; Stone & Valentine, 2005a). However, there is evidence that affect associated with faces might be, indeed, perceived even when the face is not consciously perceived. For example, the orientation of attention towards familiar faces that were not consciously perceived was modulated by the observer's affective evaluation of the person whose face was presented (Stone & Valentine, 2005b). Further, it has been shown that fearful faces are faster to escape continuous-flash-suppression and emerge into conscious awareness than neutral faces (Yang, Zald, & Blake, 2007), and facial expressions may impart an aftereffect so that the processing of neutral faces presented unmasked is biased (Adams, Gray, Garner, & Graf, 2010).

Supporting the behavioral data, neuroimaging studies suggest that emotional information can be extracted from human facial expressions and affect neural activity, even when the presence of these faces is not detected (e.g. Balconi, 2006; Balconi & Lucchiari, 2005; Vuilleumier et al., 2002; Williams et al., 2004). For example, it was shown that when fearful faces are shown below the level of conscious awareness, the amygdala (Pessoa, 2005, see also Tsuchiya, Moradi, Felsen, Yamazaki, and Adolphs (2009)), as well as the superior temporal sulcus can be activated (STS; Jiang & He, 2006; Jiang et al., 2009). The possibility that different types of physiognomic information pertinent to different levels of subordinate categorization differentially depend on conscious awareness is conceivable since the different kinds of information that are attained from faces are distinctly analyzed, and are not part of a single unitary process (Haxby, Hoffman, & Gobbini, 2002). Therefore, it is plausible that some aspects of face processing can be processed when faces are perceived without awareness, while others cannot.

In the current experiment we applied the "face aftereffects" paradigm (Webster, Kaping, Mizokami, & Duhamel, 2004) in order to gain insight into whether physiognomic information that allows subordinate categorization of a face's gender and race could be extracted from consciously unperceived faces. In their study, Webster and colleagues created pairs of faces that were ambiguous with regard to certain perceptual categories (e.g. their race, gender or expression) and which were shown after a face that was unambiguous with respect to that same category (e.g. if the ambiguous face did not have a clear gender appearance, the unambiguous face was either clearly male or clearly female). The results showed that the participants were biased away from the category of the previously seen unambiguous face when they estimated the relevant subordinate category of the ambiguous face (following the same example, if the unambiguous face was female, the ambiguous face tended to be perceived as male). Here, we investigated whether a similar bias occurs when participants are not consciously aware of the presence of the initially presented unambiguous image, while requested to categorize faces either by gender or by race. The occurrence of a bias would indicate that subordinate information about gender and race could be extracted from faces presented below the level of conscious awareness. To achieve this goal we used a binocular rivalry procedure with continuous-flash-suppression (CFS).

CFS is a variation of the binocular rivalry paradigm. Colored patterns that change at a high rate are presented to one eye, causing the image presented simultaneously to the other eye to remain invisible for rather long periods (Jiang & He, 2006; Tsuchiya & Koch, 2005). Previous studies showed that this procedure is efficient in hiding face-images from conscious awareness, while still eliciting face-specific brain responses (Jiang et al., 2009; Sterzer, Jalkanen, & Rees, 2009). Furthermore, a recent study showed that the processing of facial expressions can be adapted by previously shown faces rendered unconscious by CFS (Adams et al., 2010). In the current experiment, we used the Webster and colleagues (2004) paradigm, while shunning the initially presented unambiguous face-images from conscious awareness.

Although this study was designed primarily to explore the need of conscious awareness for the extraction of physiognomic information required to classify faces by gender and race, we also investigated whether individual face features can influence performance when the face is not consciously perceived. For this purpose we manipulated the similarity in identity between the ambiguous and unambiguous faces: for half the trials, the computer generated face prototype used to create the ambiguous and unambiguous faces (see Section 2) was the same, so that the two faces differed only with regard to the manipulated perceptual category. For the other half of the trials different face prototypes were used to create the two images, therefore the identity of the two faces also differed (see Fig. 1). Previous studies suggested that increased identity resemblance between the unambiguous and ambiguous faces might augment the categorization bias (Kovacs, Zimmer, Harza, & Vidnyanszky, 2007; Webster et al., 2004). If information about identity is preserved during unconscious

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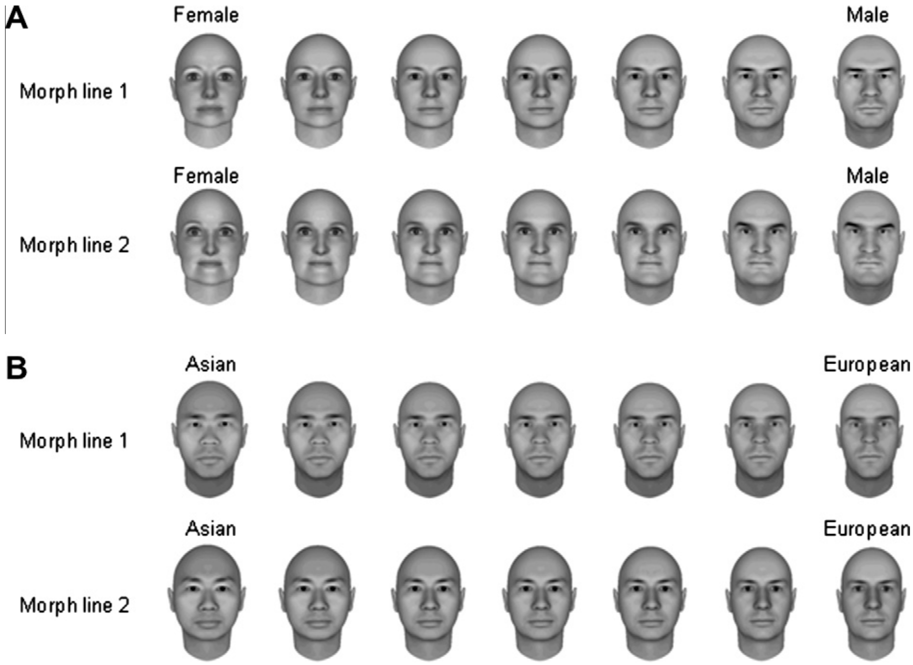

Fig. 1. Examples of stimuli used in the pilot experiment. Panel A shows two sample continua (out of 48 used) of images with varying degrees of masculinity and femininity, and panel B shows two sample continua of images with varying degrees of Asian and European appearance. The images that were found to be most difficult to categorize within each row were selected as the ambiguous images for the main experiment. For the 'Identical' condition, the adaptors were selected from the same continuum as the ambiguous image. For the 'Different' condition the adaptor was taken from one continuum and the ambiguous image from another.

viewing, we should see a similar effect of identity regardless of whether the faces were visible or invisible to the participant.

2. Methods

2.1. Participants

The participants were 32 undergraduate students at the Hebrew University (mean age = 23.8, 20 female, four left handed) who were either paid or received course credit for their participation. They all had normal or corrected to normal vision, reported no neurological or psychiatric symptoms and were free of medication for the duration of the study. Participants signed an informed consent prior to their participation.

2.2. Stimuli

Computer software was used to create a series of synthetic faces that were used in the experiment (FaceGen; Singular Inversions™, Canada). Using this program, we manipulated the gender and race appearance of face-images, forming 200 sets of seven images each. A different face prototype was used in each set. In 100 sets, the prototype face varied in gender from extreme masculinity to extreme femininity. In the other 100 sets, the prototype face varied in race, from extreme European physiognomy to extreme Asian physiognomy (Fig. 1). In order to determine the level of gender ambiguity of each face in the Gender sets and the level of race ambiguity of each face in the Race sets we conducted a pilot study in which we presented the faces one at a time to a group of 18 participants who did not participate in the main experiment (mean age = 22.7). Gender and Race sets were blocked, with the order of block presentation counterbalanced. The participants were instructed to determine the gender of each face in the Gender sets block and the race (European/Asian) of each face in the Race sets block. Within each block the 700 images were presented in random order without time constraints. A short break was allowed between blocks.

For each face we calculated the ratio between "male" and "female" answers in the Gender block and the ratio between "Asian" and "European" answers in the Race block, and selected the 48 faces within each block for which this ratio was closest to 1 (M = 1.07 and 0.99 for Gender and Race, respectively). These faces were used as the Gender ambiguous and the Race ambiguous face-targets. In addition we selected 48 faces that were unequivocally categorized at one end of the Gender (or Race) continuum in each set and 48 faces that were unequivocally categorized at the other end of the Gender (or Race) continuum and used them as the adaptors in the main experiment.

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2.3. Task and design

The experiment was conducted in a within-participant blocked design. There were two categorization tasks, Gender and Race, which were blocked, and two levels of conscious awareness, CFS and non-CFS, which were mixed within each block. In each trial the participant had to judge the gender or the race (depending on block) of an ambiguous face which was preceded by a non-ambiguous adaptor face. In the CFS condition, the adaptor was presented to the non-dominant eye along with a dynamic Mondrian image (the suppressor) presented to the dominant eye while the adaptor was exposed. The suppressor consisted of colorful patterns that changed their structure every 100 ms, and was presented to the dominant eye in order to enhance its visibility advantage over the face stimulus. Presenting stimuli to the dominant or non-dominant eye is presumed to impact the length of time that they are subjectively visible for (Mapp, Ono, & Barbeito, 2003). In order to promote the dominance of the suppressor over the adaptor, the contrast of the adaptor was gradually ramped up at onset from 0 to 100% during a period of 700 ms, and afterwards remained constant (cf. Jiang, Costello, & He, 2007). The non-CFS condition was identical except that the dynamic Mondrian image was not presented.

Two additional factors were manipulated in each block: Adaptor duration and Face identity. The adaptor faces were presented for 1000, 2500, 4000 or 5000 ms. For the face identity manipulation we used the fact that the faces were synthetic, created digitally by manipulating features of a face prototype. Thus, for half the trials, the adaptor and the ambiguous image were variations of the same face prototype (Same Identity). For the other half, different face prototypes were used for the adaptor and ambiguous image (Different Identity).

In the gender blocks, the targets were European faces that were ambiguous with respect to their gender and the adaptors were either unambiguous male or unambiguous female European faces. The task was to classify the target face as male or female, by pressing one of two alternative buttons. In the race block, the targets were faces that were ambiguous with regard to their race appearance (between European and Asian) and the adaptors were either unambiguous European or unambiguous Asian faces. The task was to classify each target as European or Asian.

Finally, the efficiency of the suppressor across time was tested by instructing the participants to press a button when and for as long as they were able to detect the presence of the adaptor. This stage was performed during each trial in the main experiment.

2.4. Procedure

Eye dominance was determined prior to the experiment, by instructing the participants to cover a distant spot in the room with their fingertip, and afterward blinking each eye in succession. The dominant eye was the one for which the finger appeared to move more while it was shut. A second test included having the participants cover a distant spot with their fingertip, and then slowly move their fingertip toward their face, keeping the distant spot covered. The eye that the finger more closely moved toward was determined as the dominant eye. The results of these tests were highly consistent. Seventeen participants were found to have a right dominant eye and 15 a left dominant eye.

The participants were seated in front of a computer screen inside a sound attenuated chamber. The stimuli were shown through a mirror stereoscope mounted on a chin rest. Each trial began with a frame presented to each eye, inside of which there was a black square (45×45 pixels) in one eye and a rectangular outline (60×60 pixels) in the other eye. The eye to which the black square and outline were presented was counterbalanced across participants. Knobs on the sides of the stereoscope were used to adjust the mirrors so that the frames were fully visible in each eye separately, and when viewed with both eyes the frames fused and the black square appeared inside the rectangular outline. After the stereoscope was adjusted, the participant pressed a button to begin a trial.

The first event in each trial was the simultaneous presentation of the adaptor face to the non-dominant eye and the dynamic CFS mask to the dominant eye (or just the adaptor face during non-CFS trials), for a period of 1000, 2500, 4000 or 5000 ms. The target face was presented inside a red-frame to the dominant eye after an inter-stimulus-interval (ISI) of 300 ms from the offset of the adaptor and CFS (see Fig. 2) and remained exposed for 300 ms. Presenting the adaptor faces and the target faces to separate eyes prevented low-level retinal effects from influencing the performance. The participants were instructed to press and hold a designated button when and for as long they could see the adaptor, and then press one of two alternative buttons to classify the gender or the race.

There were four Gender and four Race blocks that were presented in alternation. In each block there were 48 trials: 24 CFS and 24 non-CFS presented in random order. In addition there were two practice blocks, one for Gender and one for Race, with six trials (three CFS and three non-CFS) in each, using stimuli that were not presented in the main experiment. After the two practice blocks were completed, the experimental blocks ensued, yielding a sequence of 10 blocks with alternating tasks. The first task (which determined the order of the alternating sequence) was counterbalanced across participants.

For each participant and condition, the bias effect was calculated as the difference between the percentage of trials in which the ambiguous target was classified as different than the adaptor (that is, trials in which putatively the adaptor biased the classification of the target) and the percentage of trials in which the ambiguous face was classified in the same category as the adaptor (that is, trials in which putatively the adaptor did not bias the classification of the target). The bias was calculated separately for Gender and Race tasks, and for the CFS and non-CFS conditions, and for the Same Identity and Different

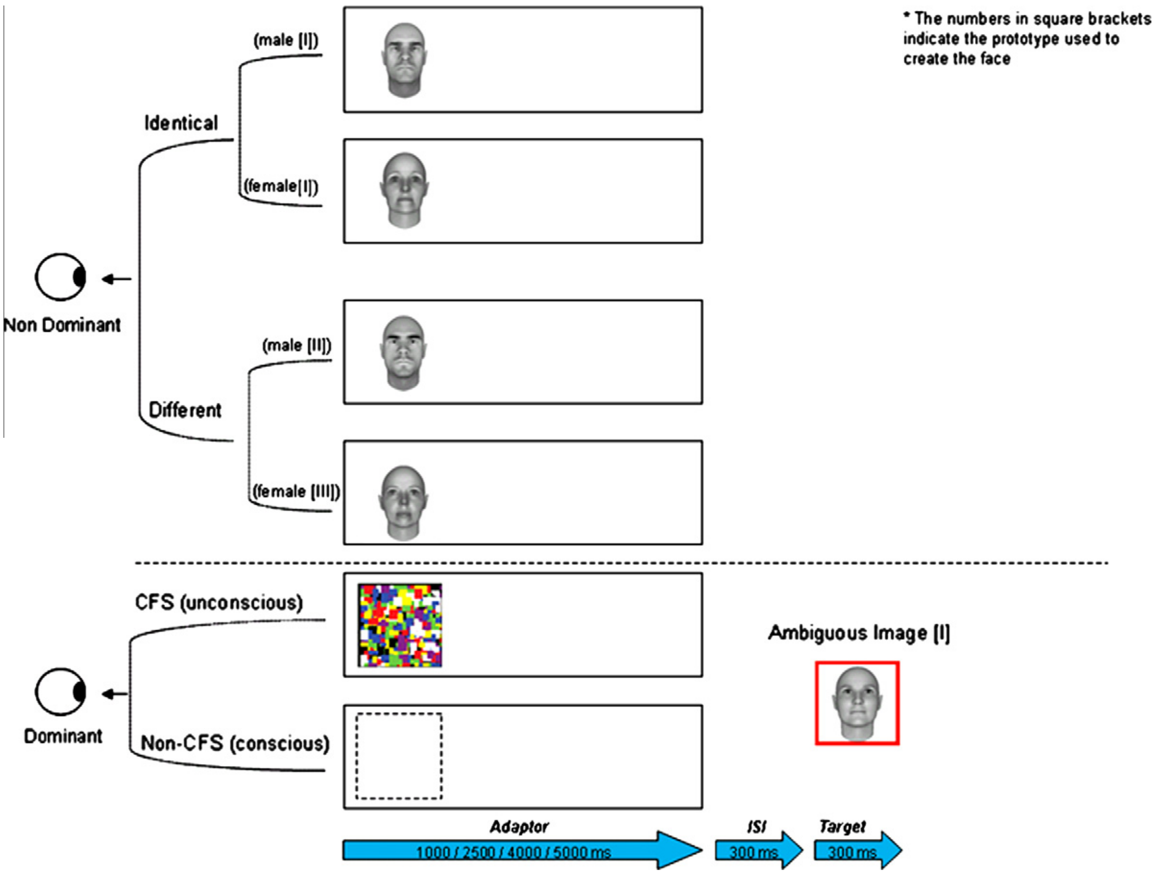

Fig. 2. Experimental setup for the gender condition (an analogous setup was implemented for the race condition): adaptors were displayed to the non-dominant eye, which during CFS trials concurred with colorful images presented to the dominant eye. After a brief inter-stimulus interval (ISI), the target was presented to the dominant eye. The adaptor stimuli were either comprised of the same prototype as the target (Identical condition), or of a different prototype (Different condition). The adaptors were male or female faces, and the targets were images with an ambiguous gender appearance. During the Race task an identical setup was used, with the exception that the primes were European or Asian faces and the targets were images with an ambiguous race appearance.

Identity conditions in each task. Responses that occurred within 200 ms after the ambiguous face was presented were excluded from the analysis, and consisted of 2.9% of the overall number of responses.

The effects of Consciousness (CFS, non-CFS), Adaptor duration (1000, 2500, 4000, 5000 ms) and Identity (Same, Different face prototypes) on the bias effect were assessed using within-participant ANOVA analyses.

3. Results

3.1. Visibility during the CFS condition

As expected, continuous-flash-suppression dramatically shortened subjective perception of the adaptor, as indicated by the duration that the participants pressed the response button (Fig. 3). Notably, when participants were able to detect the face in the CFS condition, they typically perceived it at some point along the trial, and then until the very end of the adaptor's presentation duration. In only one participant the face was perceived initially and then disappeared in a significant number of trials, and the performance of this participant was close to the group's average.

In the CFS condition, the lengths of the detection time increased with the lengths of the exposure time [$F(1,31) = 38.858$, MSe = 14,77,376, $p < .0001$]. There was no main effect of task on the length of detection [$F(1,31) < 1$], and no interaction between the two factors [$F(3,93) = 1.267$, MSe = 21,784, $p > .29$].

3.2. Bias effect during conscious and unconscious viewing

As presented in Fig. 4 (see also Fig. 5 and the Supplementary Material "raw data tables"), for both tasks the bias effect was considerably larger in the non-CFS than in the CFS condition. Moreover, only in the non-CFS condition did the bias effect

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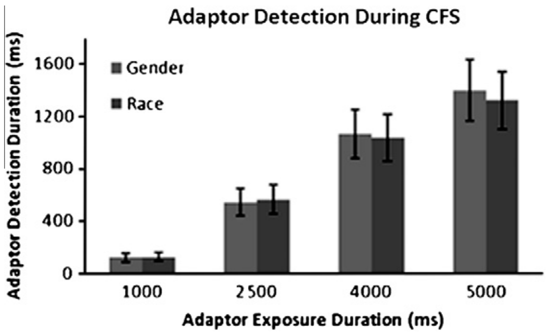

Fig. 3. Visibility of the adaptors during the CFS condition, as indicated by the amount of time that the response button was pressed during the presentation of the adaptor. Error bars depict the standard error of the mean across participants.

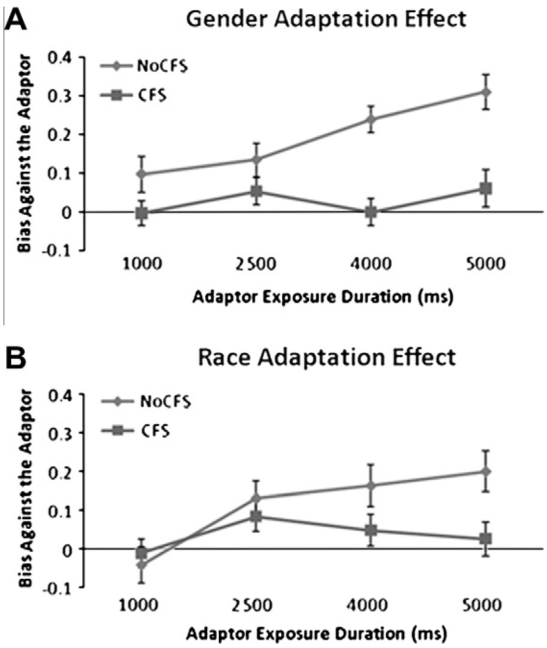

Fig. 4. Effect of exposure duration on the bias effect. The duration of exposure to the adaptor affected the magnitude of bias in the non-CFS condition, but not in the CFS condition. Error bars depict the standard error of the mean across participants.

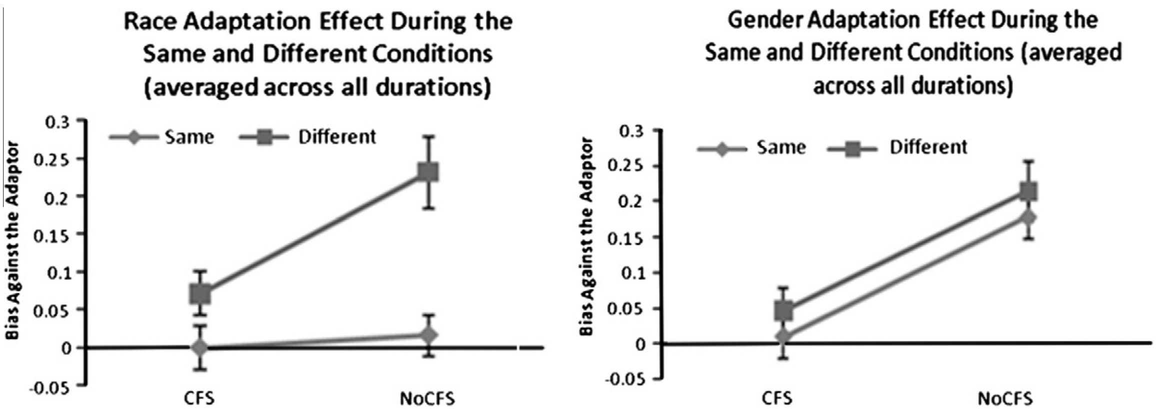

Fig. 5. Effects of conscious awareness and Identity on the bias effect. The categorization bias induced by the adaptor occurred only when the adaptor was subjectively visible, in the non-CFS condition. In the Race task no bias effect was found in the non-CFS condition if the adaptor and target were derived from the same face prototype.

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increase with the increase in exposure time. Indeed, in the CFS condition the bias effect was very close to zero across exposure times.

The statistical significance of this pattern was examined separately for each task by ANOVA with repeated measures contrasting the following factors: Consciousness (CFS, non-CFS), Identity (Same, Different), and Adaptor duration (1000, 2500, 4000, 5000 ms).

3.3. Classification by gender

The ANOVA of the gender task data showed a significant main effect of Consciousness [$F(1, 31) = 29.44$, MSe = 0.11, $p < .0001$] which interacted with Adaptor duration [$F(3, 93) = 3.3$, MSe = 0.08, $p < .025$]. The effect of Identity (Fig. 5A) was not significant [$F(1, 31) = 2.1$, MSe = 0.09, $p > .15$]. The Consciousness × Adaptor duration interaction was further elaborated by separate ANOVAs for CFS and non-CFS conditions.

When the adaptor was visible (non-CFS condition) its duration significantly affected the size of the bias effect [$F(3, 93) = 8.5$, MSe = 0.035, $p < .0001$], and a polynomial contrast showed that a linear function fits the data [$F(1, 31) = 22.7$, MSe = 0.04, $p < .0001$]. The effects were significant (against zero) for the three longest durations ($p < .05$, Bonferroni corrected), whereas at the shortest bias (1000 ms) the effect was significant only uncorrected.

When the adaptor was invisible most of the time (CFS condition) there was no effect of Duration [$F(3, 93) = 1.1$, MSe = 0.035, $p > .366$]. Importantly, the bias effect in this condition was not significantly different from zero at any level of the Adaptor duration factor ($p = .9$, .15, .97 and .22 for durations of 1000, 2500, 4000, and 5000, respectively).

3.4. Classification by race

Like for Gender, the Race ANOVA showed a significant effect of Consciousness [$F(1, 31) = 6.3$, MSe = 0.12, $p < .02$] and a significant interaction between the Consciousness and Adaptor duration [$F(3, 93) = 3.1$, MSe = 0.08, $p < .032$]. In addition, a significant Identity effect showed that the bias to race was larger when the adaptor and the target were based on different face prototypes than when they were based on the same face prototype [$F(1, 31) = 28.1$, MSe = 0.11, $p < .0001$, see Fig. 5B]. However the identity effect also interacted with Consciousness [$F(1, 31) = 10.628$, MSe = 0.087, $p < .003$]. As for Gender, these interactions were elaborated by analyzing separately the bias effect by Adaptor duration × Identity ANOVA separately for CFS and non-CFS.

In the non-CFS condition, Adaptor duration effect on the bias was significant [$F(3, 93) = 6.9$, MSe = 0.05, $p < .0003$]. A polynomial contrast showed that a linear function fits the data [$F(1, 31) = 15.3$, MSe = 0.06, $p < .0005$]. Contrasted with zero, t-tests with Bonferroni correction revealed that the bias was significant at 2500, 4000, and 5000 ms adaptor durations ($p < .05$) but not when the adaptor lasted for only 1000 ms ($p < .05$). There was also a significant effect of Identity [$F(1, 31) = 28.5$, MSe = 0.13, $p < .0001$]. Contrasting the bias effects for Same and Different levels of the Identity factor with zero by t-tests with Bonferroni correction (significant alpha level set to $p < .00625$) we found that none of the bias effects were significant when the adaptor and the target were based on the same face. In contrast, when they were based on different faces the bias was significant at all adaptor durations higher than 1000 ms.

In contrast, in the CFS condition there was no effect of Adaptor duration [$F(3, 93) = 1.1$, MSe = 0.05, $p > .347$]. Moreover, the contrast of the bias effect with zero showed no significant effects at any Adaptor duration level for both Same and Different levels of Identity (Same Identity: $p = .89$, .34, .84, and .49, for durations of 1000, 2500, 4000, and 5000, respectively; Different Identity: $p = .43$, .06, .1, and .13, for durations of 1000, 2500, 4000, and 5000, respectively).

3.5. Correlation analysis

Participants differed in their ability to detect the faces in the CFS condition. Since our analysis indicated that the bias effect is highly influenced by the conscious awareness of the adaptors, we calculated for each participant the average length of time across trials, during which the participant was able to see the adaptor during CFS, as indicated by the duration of the button-presses during each CFS block, and correlated this with the bias effect of that participant. This correlation was calculated only for the 5000 ms adaptation duration condition, in which enough variability could be obtained, and was done separately for the Gender and Race tasks. A strength of this correlation analysis is that it is done within the CFS condition, therefore any correlation between visibility duration and performance cannot be ascribed to objective physical differences between conditions. A significant correlation was found between the length of awareness of the adaptor in the CFS condition and the effect size in the Race task (Pearson $r = .35$, $p < .025$, one-tailed). The same calculation for the gender task revealed a trend in the same direction although this was not statistically significant ($r = .211$, $p > .123$, one-tailed). To further examine this relationship we pooled all the single trials from the 5000 ms duration condition across participants, and divided the trials into 5 bins based on the duration of subjective visibility. For both Race and Gender, there was a very high correlation between the length of subjective visibility and the perceptual bias against the adaptor (Pearson's $r = .9$ (Race) and .94 (Gender), $p < .05$ for both, two-tailed). In fact, as illustrated in Fig. 6, for both the gender and the race condition, there is little bias up to 2000–3000 ms visibility, and thereafter the bias increases with visibility duration. Note that for all these trials, objective conditions, including duration of adaptor presentation, presence of the suppressor, and all other parameters, were identical across the trials.

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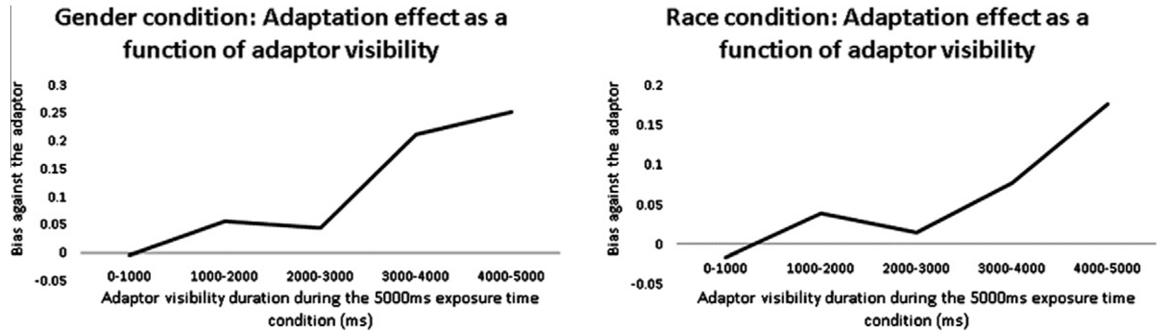

Fig. 6. Effect of visibility duration on the bias effect in the 5000 ms adaptor exposure duration. Trials were pooled across participants and binned according to the subjective visibility duration.

4. Discussion

The goal of the present study was to examine whether the physiognomic information which characterizes the gender and the race of a face is available when the face itself is not consciously perceived. To achieve this goal, we examined whether faces with strong and unequivocal masculine or feminine features (in one task), or unequivocal Asian or European features (in another task), can bias the classification of an ambiguous face by gender or race (respectively) even if the adaptor is presented below the threshold of conscious awareness. Confirming the bias paradigm, when the adapting face was visible and the observers were aware of it, we found a significant bias to classify faces in the opposite category than that of the adaptor. This bias increased linearly with the exposure duration of the adaptor. In contrast, removing the adapting face from conscious awareness eliminated the biasing aftereffect both in the Gender and Race tasks. To this end it is revealing that although the duration of subjective awareness of the CFS-masked face was linearly correlated with objective exposure duration, on the average, even the longest duration of subjective awareness did not exceed the shortest exposure duration by much (1000 ms); at this duration no bias effects were found even in the non-CFS condition. A possible confound of the comparison between the CFS and the non-CFS conditions is that they differ not only in subjective visibility but also in the objective conditions (that is, presence of the flickering suppressor). However, even within CFS, and holding objective duration constant, the amount of bias increased as a function of the duration of visibility, both when measured across subjects, and when measured across trials, suggesting that the length of visibility affects the degree of adaptation. This pattern suggests that when a face is not consciously perceived, the detailed information which is needed for subordinate categorization by race and gender is not processed.

As an ancillary finding, we also found that increased similarity between the personal identity of the adaptor and the target reduced the bias effect for visible adaptors in the Race task but was inconsequential when the adaptors were invisible. While the absence of individual face feature effects in the CFS condition might have reflected a floor effect this result goes along with previous studies that failed to find evidence for the ability to identify faces in the absence of conscious awareness (e.g. Moradi et al., 2005).

Together, these results indicate that although, as demonstrated by several neuroimaging and behavioral studies, the categorical specificity of faces is reflected in the brain even if the observer is not consciously aware of the stimuli, the processing of more specific facial information, which is required to distinguish among faces within category, requires conscious awareness. This differs from findings indicating that the emotions hinted by expressive faces could be identified even in the absence of conscious awareness (Adams et al., 2010; Balconi, 2006; Balconi & Lucchiari, 2005; Jiang & He, 2006; Jiang et al., 2009; Killgore & Yurgelun-Todd, 2004; Kiss & Eimer, 2008; Pegna, Landis, & Khateb, 2008; Pessoa, 2005; Vuilleumier et al., 2002; Williams et al., 2004; Yang et al., 2007). A possible account for this difference is that the processing of emotional information is mediated by evolutionary ancient limbic circuits that automatically react to emotional (especially negative) information with or without awareness and might facilitate top-down the classification of face expressions, whereas the processing of a face's gender or race is mediated by a neural mechanism which relies primarily on neocortical circuits that seemingly depend on conscious awareness. Indeed, in this respect, the ability to perceive the emotion expressed by faces without awareness to the face might be a unique case. This conclusion should be bolstered in the future by contrasting adaptation to emotional face expressions vs. gender and race within the same experiment.

Continuous-flash-suppression was used here as it is unique in its ability to suppress awareness of a visual stimulus, presented in full contrast, and uninterrupted to the retina, for a prolonged period of time. Indeed, subjects in many cases did not consciously perceive the adaptor at all for the full duration of even the longest trials. This is quite different from methods like masking which usually require brief presentations which would not cause adaptation even if not masked, or methods reducing visibility, e.g. by presenting stimuli at threshold contrast. It remains to be seen whether the evolution of new paradigms allowing prolonged suppression will replicate the current findings (Arnold, Law, & Wallis, 2008).

Notwithstanding the above limitation, in concert with previous reports, the present study supports the notion that the processing of facial details requires conscious awareness, while the processing of faces as a category may not. Evidence for categorical processing of faces without awareness has been provided by neuroimaging studies using fMRI (e.g. Moutoussis & Zeki, 2002, but see Tong, Nakayama, Vaughan, and Kanwisher (1998)) as well as EEG (Vuilleumier et al., 2001, but see Reiss & Hoffman, 2007) and MEG (e.g. Sterzer et al., 2009; Hoshiyama, Kakigi, Watanabe, Miki & Takeshima, 2003). Moreover, categorical distinctions, at the level of brain activity, without conscious awareness of the stimuli, might not be peculiar to faces (Fang & He, 2005). There is also behavioral evidence indicating that unconsciously presented pictures of different objects can prime subsequent picture naming and word categorization (e.g. Dell'Acqua & Grainger, 1999, but see Avons et al. (2009)), and that recognizable words can break interocular suppression faster than words in an unfamiliar alphabet (Jiang et al., 2007).

This pattern suggests a certain hierarchy within the cognitive processing stream, where unconscious information serves as a sort of foundation for the conscious processes that depend upon them. Unconscious processes provide the brain with basic information about the world, perhaps information that is crucial for survival, whereas conscious mechanisms come to the scene only later on and not in every case, in order to make more complex information available. This view is congruent with the reverse hierarchy theory (Ahissar & Hochstein, 2004; Hochstein & Ahissar, 2002), which suggests a fast feed-forward pathway that transfers global aspects of the stimulus from V1 to higher-level categorically sensitive visual areas, whereas local, detailed information follows a slower processing time course based primarily on feedback activity and depends on task demands. Since categorical processing is based primarily on the fast-transferred global information it might not need awareness of the stimulus to activate categorical selective mechanisms in the higher-level visual cortex (for a similar view see Bars et al. (2001)). On the other hand, the current data suggest that a more detailed analysis, which requires top-down guidance, cannot be accomplished without conscious awareness. This hypothesis is supported by recent findings showing that local processing can be interrupted by a visual mask, which does not interfere with global processing of the same stimuli (Ishizu, Ayabe, & Kojima, 2009).

The present results can also be conceptualized within the type-token model (Kanwisher, 1987). This model distinguishes between general types and their particular instantiations (tokens). For example, in rapid serial visual presentations, observers find it hard to note that an item like a letter or word has been repeated, even if the two presentations are different physically, a phenomenon known as repetition blindness (RB). This happens presumably because observers cannot individuate two tokens of the same type within a short time, although they can activate their type (Kanwisher, 1987). Using a version of the attentional blink paradigm, Shapiro, Driver, Ward, and Sorensen (1997) showed that even if a letter or word is not consciously perceived, it can still facilitate subsequent detection of a similar word – a process attributed to type processing – rather than causing RB. This suggests that without conscious awareness, types can be discerned, but individual tokens cannot be extracted. The question is what constitutes a type vs. a token. In the present case, while one can think of "face" as type and a particular individual as its token, it can also be that types are parallel to basic level categories, and all lower level divisions (e.g. Gender, Race) constitute tokens, explaining the current results.

Finally, aside from the question of conscious awareness, it is worth mentioning that our experiment, which implemented synthetic faces generated by a computer program, differed in an interesting aspect from experiments that showed these bias effects by using ambiguous face-images that were morphed from real face pictures. In those experiments, the bias effect was larger when the ambiguous image was morphed out of the adaptor and another face, relative to when it was created from two different faces that did not include the adaptor (Kovacs et al., 2007; Webster et al., 2004). In contrast, we found that when the prototype used to create the ambiguous face and the adaptor was the same, the bias decreased relative to when a different prototype was used. We can only speculate that when the ambiguous face and adaptor were created from the same face prototype, the perceptual resemblance between the adaptor and the target images was very close, much closer than in morphs created from the same face and an entirely different face image in previous experiments (at least in the case of race manipulation where this effect was significant). As a consequence, the participants might have perceived the adaptor and target as two instances of the same person, which mitigated the bias toward classifying the target in the opposite category.

In conclusion, the present study showed that when the visibility of a face is reduced (or eliminated) by CFS masking, detailed information which allows subordinate categorization of the face is not processed. This outcome indicates that processing details in faces requires conscious awareness.

Acknowledgments

This study was supported by National Institute of Mental Health Grant RO1-64458 to S.B. We thank Liron Levin for programming the experiment and Shir Ben Zvi for skillful assistance in testing participants.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.concog.2010.08.004.

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Please cite this article in press as: Amihai, I., et al. Conscious awareness is necessary for processing race and gender information from faces. *Consciousness and Cognition* (2010), doi:10.1016/j.concog.2010.08.004