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**Gender differences in face prioritization for consciousness**Yuval Harris, Yaniv Abir and Ran R. Hassin

**From the day we are born we are surrounded by countless stimuli of all types. from sounds to sights, from touches to scents, our senses are constantly occupied. Because we become aware to only a small fraction of these external stimuli, understanding the determinants of conscious experience is crucial for anyone wanting to understand our conscious perception. Here we use a recently developed data-driven approach to explore the determinants for consciousness. We investigate gender differences in conscious perception, using an especially important social stimulus: the human face. In a 106 participants experiment, we uncover dimensions capable of explaining the speed in which certain faces will reach conscious awareness. We looked for differences in these dimensions between males and females, while observing male or female faces. We found that male faces tend to come into female observers’ consciousness slower the more dominant the male face is. On the contrary, we found that male faces tend to come into male observers’ consciousness slower the more trustworthy the male face is. Thereby, we show a distinct difference between the two genders in prioritization for consciousness, as females and males tend to prioritize faces for consciousness based on different criteria.**

**Introduction**

The number of external stimuli constantly surrounding us is countless. If we were aware all of the time to the feel of clothes on our bodies, to the annoying ticking sound of the clock, or to each and every little object located in our field of view, we could have never been able to focus on anything productive. Luckily for us, we humans become aware to just a small portion of the stimuli surrounding us, and mostly to those that are relevant and important at the time1-4. Presumably, conscious awareness to only some preferred stimuli contributes to the individual’s functioning. That being the case, there are criteria in our mind that help distinguish which stimuli need to access our consciousness quickly, and which stimuli can stay unconscious. Those factors determining our conscious awareness are off great interest for anyone wanting to understand why we perceive the world us we do, and how it shapes our behavior.

Research into the factors determining conscious awareness is often conducted by examining the speed in which we become aware to different visual stimuli5,6. The more quickly people become aware to a certain visual stimulus, we will consider it as being ‘prioritized’ more for consciousness. Certain methods allow us to measure the time it takes for a stimulus to access one’s consciousness, or to ‘break’ into consciousness. Chief among this is the continuous flash suppression (CFS) method7, which is a presentation technique in which awareness can be dissociated from other cognitive processes. In this experiment, we used a recently developed method- repeated masked suppression (RMS)8- that preserves the CFS’s ability in measuring breaking times, while allowing to conduct the experiment on the subjects’ computers through the internet, and not constraining us to experimenting only with special equipment in the lab.

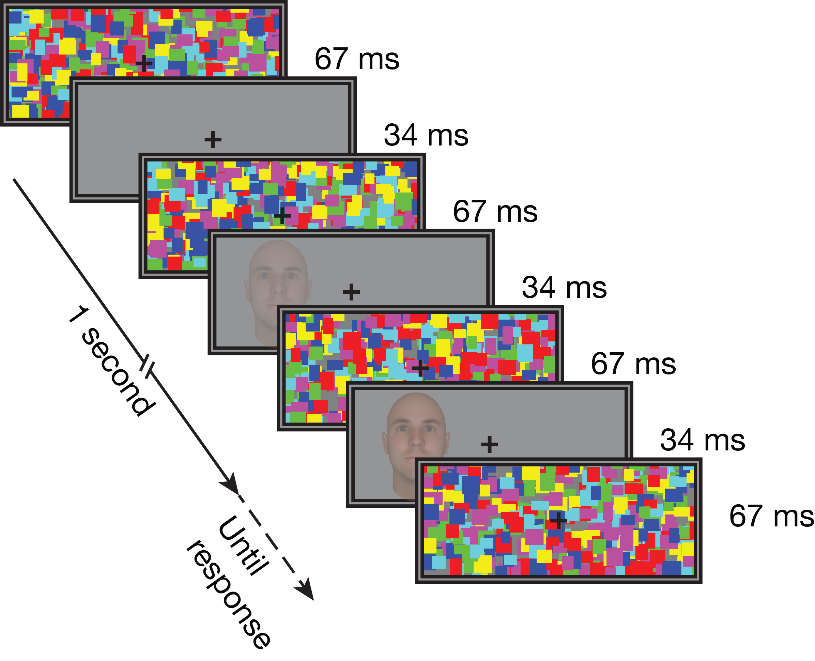
In RMS, a target stimulus is rendered invisible by a rapidly alternating presentation between the stimulus itself and a high-contrast suppressor. Presentation parameters can be tuned for the stimulus to become visible after several hundred milliseconds (or even longer). Participants in such experiment are asked to respond as soon as they become aware of the stimulus by indicating the side of the screen in which they notice it appear- a paradigm called breaking RMS or bRMS (Fig. 1). As mentioned, response times- or breaking times (BTs)- are a measure of how long it takes for participants to become aware of a stimulus, thus they are a measure of the degree of prioritization to consciousness.

Given the social importance of faces among humans, it is of little surprise that they have become widely used to examine prioritization for consciousness9. Faces enjoy favored processing in the cognitive system10, conscious or unconscious, and this processing is supported by exclusive neural circuitry11-13. Previous studies have shown that faces are prioritized for consciousness compared to control stimuli consisting of the same low-level visual features14. Moreover, different face qualities have been shown to effect prioritization for consciousness, among them face expression15, gaze direction16,17, personal familiarity18 and perceived social traits6.

In this experiment, we used an approach rarely applied in the research field of prioritization for consciousness. We used a computational, data-driven approach, distinguished from hypothesis-driven approach, that enabled us to reveal the complete nature of the factors contributing to face prioritization, as we were unbound to any hypothesis presuming those factors19. Usually, in a breaking suppression experiment, stimuli are selected by the researcher according to his hypothesis. Stimuli in those experiments differentiate along a hypothesized dimension(s) that the researcher believe as having a key role in contributing to BTs. While this method does enable a tight experimental control, it also limits any findings to the dimension(s) examined. Data-driven approach uses randomly generated stimuli, differentiating in a vast variety of dimensions. After attaining BTs for each of the stimuli, a priority dimension that contributes the most to BT can be revealed. This priority dimension will be richer and more comprehensive than the one that can be achieved using a hypothesis-driven method20.

To be used as stimuli, 300 female and 300 male faces were selected from a broad pool of computer-generated human faces. This pool was derived from a large sample of real human faces, and the faces in it differ from one another in 50 orthogonal dimensions representing shape and 50 orthogonal dimensions representing reflectance, resembling the way real human faces differ from each other19,21. Crucially, our stimuli were randomly drawn from a normal distribution on each of these parameters.

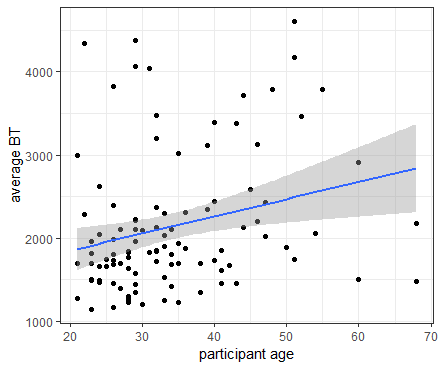
Previous study using this data-driven method, while using similar computer-generated faces, revealed a rich dimension that determines the speed in which different faces come into conscious awareness5. This priority dimension was found to strongly and negatively correlate with the perceived degree of dominance of a face. That is, the more a face is perceived as dominant, the more prioritized to consciousness it tends to be. It was also found to correlate positively, though not so strongly, with the perceived degree of trustworthiness of a face, meaning the less trustworthy a face is, the more prioritized for consciousness it is. While it did show a reliable priority dimension for the participant group it examined, it is not unlikely that some details were lost due to the gender of the participants taking part in these experiments, as well as the gender of the stimuli faces. A large majority of participants were female, and all stimuli were of male faces. As differences between genders in their priority dimensions are probable, in dependence or not to the stimuli gender, the priority dimension and conclusions found are limited to this combination only. In this experiment, we try to decipher the priority dimension differences between the different genders, while referring separately to stimuli of each gender.



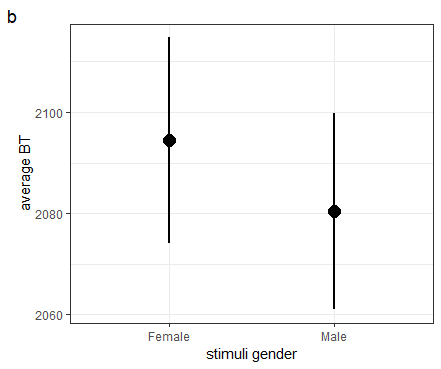
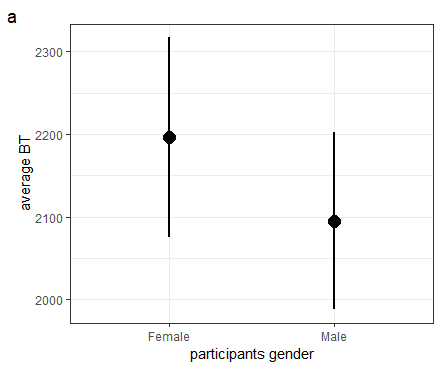
**Fig. 1 | Experimental paradigm.** Schematic of a breaking repeated masked suppression trial. Stimuli contrast increase from zero to 40% during the first second. Participants see mondrian pattern and are instructed to press the ‘left’ or ‘right’ key as fast as they can as soon as they notice the face image appear.

**Results**

BTs of each of the 600 faces were measured in a sample of 106 participants using bRMS. Each participant was allocated only female or only male stimuli, was informed about the gender of the faces he was going to see, and was instructed to indicate with a key press, as quickly as possible, whether the face appeared right or left of fixation (Fig 1). On average, participants became aware of the faces after 2,138 ms (s.d.=823.6 ms). Age have been found to significantly correlate with BTs, r=0.26, P<0.01, as the older a participant the longer his average BT tends to be (Fig. 2). Neither participant gender (Fig. 3a) nor stimuli face gender (Fig. 3b) had any significant effect on BTs.



**Fig. 2 | Participant age and personal average BT.** Personal average BT per participant show a significant positive correlation between participant age and average BT. Linear regression line also plotted.



**Fig. 3 | Participant gender and stimuli gender general effects on BT. a.** Average BT for female and male participants overall. Error bars denote s.e. No significant effect found for participant gender. **b.** Average BT of female and male stimuli overall. Error bars denote s.e. No significant effect found for stimuli gender.

In order to find gender differences in face prioritization for consciousness, we used reverse correlation to model the facial properties predictive of BT. The vector of parameters defining the shape of each of the stimulus faces was multiplied by the average within-participant z score representing the BT of each stimulus face. These vectors were then averaged, producing a dimension we call the priority dimension, predictive of the time it will take for a face to become conscious5. A priority dimension was produced for each one of the four groups examined: females perceiving female faces (referred to as “fXf”), males perceiving female faces (“mXf”), males perceiving male faces (“mXm”) and females perceiving male faces (“fXm”). These derived priority dimensions correlated significantly each with its own group’s BTs (r=0.39, p<0.001; r=0.41, p<0.001; r=0.36, p<0.001 and r=0.39, p<0.001, respectively), implying that the derived priority dimensions do in fact capture a large part of the variables contributing to prioritization for consciousness, explaining 15.21%, 16.81%, 12.96% and 15.21% of the variance in BTs, respectively. Thus, we identified four different dimensions in face-space that correlate with prioritization for conscious awareness, each for its appropriate gender perceiving male or female faces. remarkably, these dimensions are each exclusive to its own group, as no significant correlation was found between none of the four priority dimensions (all r’s<0.16, all p’s>0.29).

In order to examine the social meaningfulness of the priority dimension, in dependence of a person’s gender and the gender of the face perceived, we correlated each one of the priority dimensions with the two central social traits inferred from faces: trustworthiness and dominance (Fig. 3). These social traits dimensions have been utilized separately by using male and female participants’ assessments of male and female faces, meaning that there are two social trait dimensions (dominance and trustworthiness) that express the values relevant to each one of the four groups examined22. Two correlations have been found to be significant: in the fXm group, a positive correlation (r=0.31, p=0.03) was found between the priority dimension and the dimension of face dominance. Thus, the more dominant a male face is, the longer it takes for it to break into consciousness in females; in the mXm group, a positive correlation (r=0.31, p=0.03) was found between the priority dimension and the dimension of face trustworthiness. Thus, the more trustworthy a male face is, the longer it takes for it to break into consciousness in males. These results indicate that in females, the less dominant a male’s face is, the more prioritized to consciousness it is, while in males, the less trustworthy a male’s face is, the more prioritized to consciousness it is. Another correlation that was not significant (r=0.23, p=0.12), but does show a fairly clear trend, is the correlation between the priority dimension and the trustworthiness dimension in the fXf group. Therefore, it is conceivable that the less trustworthy a female’s face is, the more prioritized to consciousness it is in females. Other correlations are not sufficiently significant to regard to them as valid findings.

**Fig. 4 | Priority dimensions correlations with the two summary dimensions of face social traits.** By group coefficients for the correlations of the priority dimension with the dominance and trustworthiness dimensions. \*P<0.15; \*\*P<0.05.

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**Discussion**

In this experiment, we have used the data-driven method for modeling prioritization for consciousness, while conducting this kind of experiment using RMS for the first time. That enabled us operating the experiment on the subjects’ computers as a fast and cheap means for reaching a wide range of participants online. Because of this nature of the experiment, participants vary largely in age, ranging from 21 up to 68 (mean=34), unlike most experiments in this field that are usually conducted in the university and take young students as participants. As shown, age have been found to be a significant contributor to BTs, and as such, when trying to make assumptions about the general population, it is essential to have a participant population that encompasses a wide range of ages. This experiment, thanks to the RMS method, succeeded in this.

Trying to uncover any gender differences that may exist in face prioritization for consciousness, we modeled the face attributes contributing to face BTs in dependence of the gender of the observer and the gender of the face observed. We obtained four priority dimensions, each for its respective group. These dimensions could substantially explain BTs, each within its own group. Moreover, these dimensions significantly differ from each other, meaning that in each group there are different face parameters determining BTs.

These priority dimensions correlated with the two facial social attributes dimensions, dominance and trustworthiness, in an interesting way. While perceived by females, male faces took longer to break into consciousness as the face perceived was more dominant. That is since the priority dimension was found to correlate positively and significantly with the dominance dimension in this group (r=0.31, p=0.03). Unlike that, while perceived by *males*, male faces took longer to break into consciousness as the face perceived was more *trustworthy*. In this group, the priority dimension was found to correlate positively and significantly with the *trustworthiness* dimension (r=0.31, p=0.03), while the correlation with the *dominance* dimension wasn’t significant but did show a minor negative connection (r=-0.15, p=0.30).

These results seemingly contradict the results of the previous experiment modeling face prioritization and using the same data-driven method5. In this previous 2018 experiment, a priority dimension was constructed without intentionally controlling for participants gender, although a great majority of them were female, and while only male faces were used as stimuli. Therefore, conclusions from this experiment can be reasonably made about females perceiving male faces. In that experiment it has been found that face dominance has a strong negative correlation with the priority dimension. Therefore, according to those results, male faces, while perceived by females, take shorter to break into consciousness as the face perceived is more dominant. As stated, this seemingly contradicts the results obtained in the current experiment, as we found a *positive* correlation between the priority dimension and the dominance dimension within the fXm group.

An explanation to this contradiction may lie in the difference between the participant populations of the two studies. This current experiment was conducted upon English speaking participants in the United States only, while the previous experiment was conducted upon Hebrew speaking participants in Israel. Moreover, a 2012 hypothesis-driven experiment conducted in the United Kingdom23, have found that dominant faces took longer to break into consciousness, across all genders, resembling our results with American participants and different from the Israeli participants experiment results. In both previous studies the results have been validated thoroughly, and it is unlikely that there was a methodological problem in any one of them. Hence, it *is* possible that cultural differences can account for some, or all, these differences discovered in face prioritization.

An aspect that was found before to effect BTs, and we can interpret our results in the light of it, is individual differences in personality traits23. Especially, the fact that individuals characterized by submissive behavior have been found to have a ‘dominance avoidance’ effect and longer BTs for dominant faces23. As it was found that women in general tend to more submissive behavior than man, and man in general tend to more dominant behavior than women24, it is possible that ‘dominance avoidance’ is what lies in the base of this positive correlation between face dominance and BT in the fXm group.

As for the significant positive correlation between face trustworthiness and the priority dimension in the mXm group, and also for the not significant, but apparent, tendency for positive correlation between these dimensions in the fXf and mXf groups, it does fit the results found in the previous 2018 experiment. As mentioned, a link was found there between face trustworthiness and BTs, such as that the more trustworthy a face is the longer it will take for it to break into consciousness.

It is worth mentioning that the number of participants in our experiment might be too small at this point to jump into conclusions. Running this experiment on more participants should show us if the trends observed become clearer and more significant or not.

It does seem, then, that this work has not answered more questions than it has raised, but it did answer the big question about gender differences in prioritization for consciousness. This experiment brings strong evidence that there *are* gender differences in prioritization for consciousness. It still is an interesting question that should be researched furthermore as to the complete nature of these differences and the explanations for them.

A question remained is the basis of the yet unresolved differences between each one of these experiment conclusions. It appears that the next step should be to look for any cultural differences in the social aspect of the priority dimensions (especially Israeli verses American or British cultures), while controlling for the method used. Replicating this experiment in Israel, while still using the reverse correlation method with data collected using RMS on Israeli subjects, can reveal if cultural difference really *can* explain completely different priority dimensions. A finding of such will be another great discovery for the research of prioritization for consciousness.

**Methods**

**Participants.** online workers (n = 122, 57 women; age: M = 34.09, s.d. = 10.02) participated through Amazon MTurk for payment of $1.50. All reported normal vision or corrected to normal vision.

**Materials.** Stimuli consisted of multicolor suppressors (‘Mondrians’—random amalgams of partly overlapping rectangles of varying sizes and colours) and target stimuli. The target pictures were 300 male and 300 female faces generated using FaceGen 3.1 and adapted from previous studies. Stimuli were presented on the subjects’ computers. Stimuli size was adjusted to the size of each participant screen using the adjustment of a circle on the screen to fit a coin.

**Procedure.** First, participant computers were briefly checked for animation compatibility to the experiment. Participants whose animation presentation was not good enough were discarded at this point. Then, participants read the instructions for the experiment. They were asked to calibrate the experiment to their screen’s size by placing any coin against the screen and adjusting a circle to it.  
 After completing the calibration phase, instructions for the bRMS task were presented on the screen. On each trial of the bRMS task, participants were presented with Mondrians changing at 10 Hz, while the face image faded in during the first second of presentation (maximum contrast of 40%). Participants had to indicate by pressing one of two keys if the face appeared right or left of fixation. They were instructed to respond as soon as they knew the location of the face. This response time, relative to trial onset, served as our measure of BT. If no response was given, the trial ended after 10 s. Stimuli order and presentation location were randomized. Participants performed a training block of 25 stimuli. Participants incorrect more than twice during the training block were discarded at this point. The main block consisted of four shuffled repeats of 50 face stimuli, not containing stimuli used in the training block. Between repeat blocks, participants were able to take a break.  
 After completing the task participants were asked to answer a questionnaire, including questions regarding their age, sex and sexual orientation, English fluency, and political stance. They were also asked to report any special strategy employed during the experiment.

**Statistics.** Analysis were carried out using the R statistical environment 3.5.1, with the data.table, ggplot2, rjson, ez, plyr and Hmisc packages. Outlier removal procedure were based on previous bCFS studies. Data from trials with animation problems were excluded from analysis (n = 1,925, 0.08%), and participants with less than 160 acceptable animation trials were excluded from analysis (n = 16), leaving the data of 106 participants. Data from incorrect trials were also excluded (n = 473, 0.02%). Next, unusually short (<200 ms) and unusually long (>15,000 ms) trials were excluded (n = 451, 0.02%). Data from trials in which the BT was more than 3 s.d. from the participant’s mean were excluded from analysis (n = 372, 0.02%).  
 Following the methods in previous studies, in each group we computed the reverse correlation dimension as the average of the 50 FaceGen shape parameters for each of the 300 faces, weighted by their corresponding relative BT across participants. Predicted BTs were computed from the dimension as the projection of each face on the dimension.

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