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## **Is Threat Detection Black and White? Race Effects in Threat-Related Perceptual Decision-Making**

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# Is Threat Detection Black and White? Race Effects in Threat-Related Perceptual Decision-Making

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There is a vast literature base indicating that people respond differently to Black and White individuals based on differential perceptions of threat. As facial affect is a fundamental way that individuals communicate their emotional state, studies have examined differences in how Black and White threatening facial expressions are perceived. However, perceptual decisions regarding threatening and neutral stimuli often occur in familiar contexts or in environments where explicit cues indicate the presence or absence of threat. Furthermore, these decisions often occur in “noisy” (i.e., ambiguous) environments where the quality of sensory evidence is poor, requiring us to rely on perceptual “sets” or expectations to interpret such evidence. Therefore, in the present study we used a two-alternative perceptual decision-making task in which participants used threatening and neutral cue-elicited perceptual sets to discriminate between subsequently presented threatening and neutral Black and White faces. Threatening cues led to a greater tendency to decide that both Black and White faces were threatening, as well as faster and greater discriminability between threatening and neutral Black and White faces. However, race-related differences revealed that, following both cue types, discriminability between threatening and neutral Black faces was worse compared to White faces. Therefore, using a paradigm that is ecologically valid, our findings highlight the importance of examining basic aspects of visual perception to understand race-related differences in threat-related perceptual decision-making. Furthermore, these findings emphasize the importance of anticipatory top-down factors when making perceptual decisions about the presence or absence of threat in faces of different races.

**Keywords:** perception, emotion, race, decision-making, threat




**Supplemental materials:** <http://dx.doi.org/10.1037/emo0000754.supp>

In the United States, Black males are 2.5 times more likely to be killed by police officers than White males (Edwards, Lee, & Esposito, 2019). Additionally, experimental studies using first-person shooter tasks show that Black targets are shot more frequently and more quickly than Whites (Correll, Park, Judd, & Wittenbrink, 2002; Correll, Urland, & Ito, 2006; Greenwald, Oakes, & Hoffman, 2003), and simply viewing threatening Black faces has been shown to prime responses to perceived weapons to a greater extent than White faces (Kubota & Ito, 2007; Payne,

2001). Similarly, emotional expressions on Black faces have been shown to be evaluated more negatively and less accurately than expressions on White faces (Halberstadt, Castro, Chu, Lozada, & Sims, 2018; Hugenberg, 2005; Hugenberg & Bodenhausen, 2003; Hugenberg & Bodenhausen, 2004; Hutchings & Haddock, 2008), and Black children are perceived as exhibiting more hostile behaviors than White children by new teachers (Halberstadt et al., 2018). While several systemic institutional factors, overt discrimination, and other social determinants are critical to understanding differential responses to Black individuals, the present study focuses on visual perceptual decision-making in order to understand the extent to which basic perceptual factors contribute to these discrepant behaviors toward Black people.

The differential behaviors toward Black and White individuals are downstream consequences of a series of cognitive processes. As perception serves as a gateway to such higher-level cognitive processes, any errors in perceptual decision-making are likely to influence these higher-order processes and result in maladaptive or fatal behaviors, such as those described above. Furthermore, as facial expressions represent a fundamental way by which individuals communicate their emotional state and provide information regarding their intentions (Niedenthal, Halberstadt, Margolin, &

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Innes-Ker, 2000; Salovey & Mayer, 1990), perceptual decisions regarding facial affect are implicated in all of the threat-related decision-making processes described in the previous examples. Therefore, to understand the differential threat responses to Black individuals described above, it is important to examine how we make perceptual decisions regarding the presence or absence of threat in Black and White faces. In most scenarios, such perceptual decisions are made based on sensory input that tends to be noisy (i.e., ambiguous or unclear), requiring us to use our prior knowledge of what is relevant and/or what is likely to interpret the sensory evidence. For example, for a person giving a speech, a relevant stimulus may be a disapproving face in the crowd, even when the probability of encountering a critical expression is unknown. In the present study, we examined how cues that indicate the threat-related relevance of upcoming targets influence subsequent perceptual decision-making regarding threatening and non-threatening facial expressions in Black and White faces.

Several studies suggest differences in how threatening expressions are perceived in Black and White faces. For example, faces that were racially categorized as Black were also reported as displaying more intense anger compared to faces that were categorized as White (Hutchings & Haddock, 2008). Additionally, angry and sad expressions of Black faces were categorized faster than in the case of White faces, while the reverse was true for happy facial expressions (Hugenberg, 2005). Taken together, these studies suggest a tendency to perceive Black faces as threatening. In general, threatening expressions as well as salient stimuli, such as snakes and spiders, are detected more quickly than nonthreatening stimuli, such as flowers or neutral faces (Hansen & Hansen, 1988; Horstmann, 2007; Öhman, Lundqvist, & Esteves, 2001). Additionally, accuracy is improved for threatening compared to neutral stimuli, even when image presentation is quite rapid (Anderson, 2005).

To understand factors that contribute to the perceptual prioritization of threatening stimuli, much of the literature thus far has focused on bottom-up factors, such as their physical features and evolutionary salience (Bannerman, Milders, de Gelder, & Sahraie, 2009; Öhman et al., 2001). Accordingly, the affective neuroscience literature has provided evidence that threat-related perception is associated with relatively automatic neural processes and pathways (Méndez-Bértolo et al., 2016; Vuilleumier & Pourtois, 2007). For example, evidence from eye saccade tasks indicates that visual orientation is faster for threatening compared to nonthreatening faces (Bannerman et al., 2009). Threat-related facial features such as the whites of the eyes have also been shown to be associated with increased amygdala activation, even when these features were purposefully masked to reduce conscious awareness (Whalen et al., 2004). Although some studies have examined the role of top-down factors in threat or emotion processing in general, the top-down factors investigated in most studies are orthogonal or irrelevant to the perception of threatening targets. Such factors tend to be studied by directing attention or working memory resources away from task-irrelevant emotional targets. For example, by matching houses or attending to words while ignoring emotional faces or by using cognitive strategies to actively suppress processing of emotional stimuli (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Ochsner & Gross, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001). Hence, our understanding of the prioritized perception of threatening targets is based primarily on

the importance of bottom-up factors, and top-down factors that voluntarily guide threat perception are largely ignored.

However, perceptual decision-making for nonthreatening or threatening stimuli rarely occurs in the complete absence of top-down factors. Indeed, research in the basic visual perception literature shows that perceptual decision-making frequently occurs with the help of top-down information provided by cues, contexts, anticipatory attention, goals, expectations, previous experiences, and perceptual sets (Doshier & Lu, 1998; Hopfinger, Buonocore, & Mangun, 2000; Itti & Koch, 2001; Moran & Desimone, 1985; Navalpakkam & Itti, 2005; Rao & Ballard, 2005; Schmidt & Zelinsky, 2009; Summerfield & De Lange, 2014; Summerfield et al., 2006; Summerfield & Koechlin, 2008; Treue & Martínez Trujillo, 1999). The literature in basic visual perception conceptualizes such perceptual or attentional sets as top-down influences in perceptual decision-making (for references, see Rao & Ballard, 1999; Schmidt & Zelinsky, 2009; Summerfield & De Lange, 2014; Summerfield et al., 2006; Summerfield & Koechlin, 2008). Visual search models propose that prior knowledge regarding a target's features forms a perceptual template that can be used in a top-down manner to match against sensory evidence (Duncan & Humphreys, 1989; Schmidt & Zelinsky, 2009; Wolfe, Horowitz, Kenner, Hyle, & Vasan, 2004; Zelinsky, 2008). Furthermore, prior cues may lead to an attention-related top-down prioritization of stimulus processing based on the task-relevance of stimulus features or motivational goals (Desimone & Duncan, 1995; Mohanty, Egner, Monti, & Mesulam, 2009; Mohanty, Gitelman, Small, & Mesulam, 2008). Importantly, basic visual perceptual decision-making research involving top-down factors has differentiated the nature of different types of prior knowledge that can guide perception. For example, a cue may provide information about what is relevant (e.g., a blue or red target), but not the probability or likelihood of encountering a relevant stimulus. These two types of information are orthogonal and may be implemented via different mechanisms of anticipatory attention versus expectation (Jiang, Summerfield, & Egner, 2013; Summerfield & De Lange, 2014; Summerfield & Egner, 2009).

While the role of perceptual and attentional sets in guiding perception is well examined in the field of basic visual perception, the study of threat-related perceptual or attentional sets in perceptual decision-making is relatively novel in the affective and social perception literature. From the viewpoint of threat perception, the present study is ecologically valid, because we frequently use perceptual sets to detect threats—for example, when cues such as park signs warn us to look out for rattlesnakes, road signs warn us to look out for black ice, or a dispatcher informs a police person to watch out for a threatening suspect. Hence, individuals often have knowledge regarding the context in which threatening stimuli are encountered, and/or explicit cues may indicate which threats are likely or salient, allowing them to detect potentially threatening targets (for review, see Mohanty & Sussman, 2013). In line with this view, threatening cues and contexts have been shown to facilitate the sensitivity and speed of perceptual decisions in comparison to neutral cues (Imbriano, Sussman, Jin, & Mohanty, 2019; Sussman, Jin, & Mohanty, 2016; Sussman, Szekely, Hajcak, & Mohanty, 2016; Szekely, Rajaram, & Mohanty, 2017). More recently, in the field of social perception, researchers have applied models of perceptual decision-making to understand how social knowledge and stereotypes can shape visual perception in a top-

down manner (Hinton, 2017; Otten, Seth, & Pinto, 2017). It is hypothesized that stereotypes can exert top-down influence on perceptual processes, as stereotypes are linked with the perceived probability or relevance of certain types of characteristics in members of stereotyped social categories (Devine, 1989; Hinton, 2017). Additionally, top-down perceptual templates are hypothesized to be instantiated as multivariate patterns of neural activity (Jiang et al., 2013; Kok, Jehee, & De Lange, 2012). In accordance with this, neural representations associated with stereotypically linked categories, such as “Black” and “Angry,” are more similar than stereotypically nonlinked categories (Stolier & Freeman, 2016a; 2016b), and these similarities in patterns of neural activation predicted biases in their subjective visual perceptions. Overall, these studies show that higher-order social-cognitive processes can influence basic visual processes.

However, neither of the top-down nor bottom-up effects reviewed above work in isolation; rather, visual perception involves an interaction of these two factors. For example, studies of basic visual perception show that prior knowledge of a target stimulus location leads to top-down spatial biasing toward that location and subsequently reduces the bottom-up, potentially distracting effects of salient stimuli at other locations (Theeuwes, 1991; Yantis & Jonides, 1984). Interactions between top-down and bottom-up influences also show that threatening compared to neutral cues lead to more accurate and faster detection of threatening compared to neutral faces (Sussman, Szekely, et al., 2016). While these interactions have not often been examined with faces of different races, there is preliminary evidence indicating that top-down information may not be as impactful in guiding decisions regarding the threat potential of Black targets. In particular, one study showed worse discrimination between dangerous and harmless objects as well as a greater tendency to endorse objects as harmful when the objects were held by Black individuals, even when participants were given prior information indicating that the Black individuals did not pose a threat (Greenwald et al., 2003).

In sum, there is considerable evidence suggesting that perceptual decision-making regarding threatening stimuli can be influenced by bottom-up factors such as threatening expressions and racial features; top-down factors such as perceptual sets, contexts, or cues indicating threat relevance of upcoming stimuli; as well as an interaction between the two. However, no study of which we are aware has directly investigated how bottom-up and threat-relevant top-down factors influence perceptual decision-making regarding threat in Black and White faces. As decisions regarding threat in Black and White faces frequently occur in contexts where threat is relevant, it is critical to examine potential interactions between these two factors and their effect on perceptual decision-making.

Therefore, in the present study, we used a simple two-alternative forced-choice perceptual decision-making task in which participants utilized threatening and neutral cues to discriminate between threatening and neutral Black and White faces. The cues indicated a “threatening or not” or a “neutral or not” decision to encourage participants to use a threatening or neutral perceptual “set” while making decisions about threatening and neutral faces of different races. Unlike most previous studies that have examined top-down factors and emotion processing, the threat-related top-down cues in our study were not orthogonal, irrelevant, or to be suppressed; rather, the cues are relevant and meant to be used actively in the

service of perception. Furthermore, the cues represent a top-down manipulation because they provide information about what is relevant when perceptual decisions are made, as opposed to making the decision based solely on physical characteristics or salience of the stimuli. Specifically, the cues provided information about the relevance (threatening or neutral) but not the probability of encountering upcoming targets. Following the prestimulus cues, participants viewed threatening and neutral faces that were perceptually degraded to each participant’s predetermined perceptual threshold, encouraging participants to use the perceptual sets activated by the cues in making decisions regarding the presence or absence of the cued stimuli. Furthermore, the stimuli were equalized for low-level physical properties such as contrast and luminance, and the same sets of threatening and neutral stimuli were presented following both cues, which allowed us to better examine the effects of the cues on perceptual decision-making.

Signal Detection Theory (SDT) parameters were used to examine perceptual sensitivity ( $d'$ ) and response bias ( $c$ ) related to the cues and the race of the faces (Green & Swets, 1966). Unlike simple categorization paradigms, which tend to assess accuracy alone, SDT provides a more specific framework that integrates different response types to create a nuanced picture of perceptual decision-making. Specifically, SDT breaks down perceptual decisions into hits (e.g., correctly identifying a threatening face as threatening), false alarms (e.g., incorrectly identifying a neutral face as threatening), correct rejections (e.g., correctly rejecting a neutral face as being threatening), and misses (e.g., incorrectly rejecting a threatening face as being threatening). As described by Green and Swets (1966), hit rate and false alarm rate are z-transformed in order to estimate their respective population parameters and subsequently used to calculate perceptual sensitivity ( $d'$ ) and response bias ( $c$ ). Perceptual sensitivity as measured by  $d'$  provides a description of discriminability between two stimulus types (threatening and neutral faces in the present study), by subtracting z-transformed false alarms from z-transformed hits. In contrast, accuracy, which is often used in categorization tasks, simply describes correct responses regarding relevant stimuli. Response bias as measured by  $c$  represents the decision-making criterion, which is also calculated using z-transformed hits and false alarms (see Stanislaw & Todorov, 1999). Specifically,  $c$  indicates how likely it is that a participant will endorse certain types of perceptual decisions (e.g., a threatening or neutral face decision). Additionally, response bias may be considered liberal or conservative, where liberal response bias indicates that a participant is more likely to endorse a stimulus as a target type (e.g., to decide that a stimulus is threatening), whereas conservative response bias indicates that a participant is more likely to endorse a stimulus as not a target type (e.g., to decide that a stimulus is not threatening). Clearly, the specification of decision types afforded by  $d'$  and  $c$  are particularly important in our study, as they may more thoroughly elucidate the role of top-down factors (i.e., cued perceptual sets) in threat-related perceptual decision-making for Black and White faces.

In accordance with previous literature indicating that the expressions on Black faces are generally misperceived to a greater extent than expressions on White faces (Halberstadt et al., 2018; Hugenberg, 2005; Hugenberg & Bodenhausen, 2003; Hugenberg & Bodenhausen, 2004; Hutchings & Haddock, 2008), we hypothesized that participants would exhibit worse discriminability (i.e.,

worse  $d'$ ) between threatening and neutral Black versus White faces. Additionally, given previous findings indicating enhanced discriminability (i.e., greater  $d'$ ) for threatening versus nonthreatening faces following threatening cues (Sussman, Jin, et al., 2016; Sussman, Szekely, et al. 2016), we hypothesized that threatening versus neutral prestimulus cues in our study would lead to more sensitive perceptual decision-making regarding subsequent faces. Finally, given the finding that top-down information may not be as impactful in guiding perceptual sensitivity and response bias for threatening and nonthreatening objects held by Black individuals (Greenwald et al., 2003), we further anticipated that threat cue related improvement in perceptual sensitivity for threatening versus nonthreatening faces would be reduced for Black compared to White faces. In other words, we anticipated that gains in discriminability (i.e., perceptual sensitivity) following threatening cues would not be as great for Black faces compared to White faces. Furthermore, we anticipated that participants would exhibit more liberal response bias following threatening cues (i.e., higher tendency to endorse the faces as threatening) and more conservative response bias following neutral cues (i.e., higher tendency to endorse the faces as not neutral) in the case of Black faces compared to White faces.

## Method

### Participants

One hundred eighty-six participants completed the task. Overall, 3 participants were excluded due to extreme behavioral performance (i.e., nonresponse rate >15% or overall accuracy <50%), and 14 were excluded due to technical error, resulting in a sample of 169 participants (119 females; mean age = 20.20 years,  $\pm$  2.34 years). No outliers were found for  $d'$ ,  $c$ , or reaction time. All participants were recruited via the Stony Brook University Psychology Department subject pool. Informed consent was obtained for each participant, per the protocol approved by the Stony Brook University institutional review board. Sample size was informed by previous research utilizing a similar experimental paradigm (Sussman, Szekely, et al. 2016). See Table 1 for demographic information.

### Stimuli

Sixteen angry faces (AF) and 16 neutral faces (NF) were obtained from the NimStim Set and the Chicago Face Database,

resulting in a total of 32 face stimuli (Ma, Correll, & Wittenbrink, 2015; Tottenham et al., 2009). Sixteen models were used in the creation of the 32 face stimuli, with each model providing a neutral expression and an angry expression. Eight of the angry faces and 8 of the neutral faces were Black, and the remaining of each set were White. All images were equalized for spatial frequency, luminance, and pixel size ( $512 \times 512$ ) using the SHINE toolbox for Matlab (Willenbockel et al., 2010). In previous literature regarding the role of top-down factors in face processing, these procedures have been shown to control for differences in low-level image properties (Fiset et al., 2008). Poststimulus masks were created by breaking down images of several faces of different emotion types into squares of 100 pixels and subsequently randomly rearranging the pixels to create masks with similar low-level characteristics as the face stimuli.

### Threshold Task

The perceptual threshold (75% correct) for each race-facial affect pairing (i.e., Black AF, White AF, Black NF, and White NF) was calculated individually for each participant using a two-alternative forced-choice perceptual discrimination task similar to Summerfield and colleagues (2006). Our threshold task consisted of eight blocks with 32 trials in each block, and each face type (i.e., Black AF, White AF, Black NF, White NF) was presented an equal number of times during the experiment. This resulted in a total of 128 angry face trials and 128 neutral face trials. Similarly, there were 128 Black face trials and 128 White face trials. Stimuli were presented in counterbalanced random order such that the faces were presented in random order during each block, and each face was shown only once per block. At the beginning of each trial, a fixation cross was presented in the center of the screen for 2–3 s (see Figure 1). Subsequently, an angry face or neutral face was presented for 100 ms, followed by a mask (300 ms). After the onset of an angry or neutral face, participants indicated whether the face was angry or neutral by pressing one of two adjacent keys on a computer keyboard.

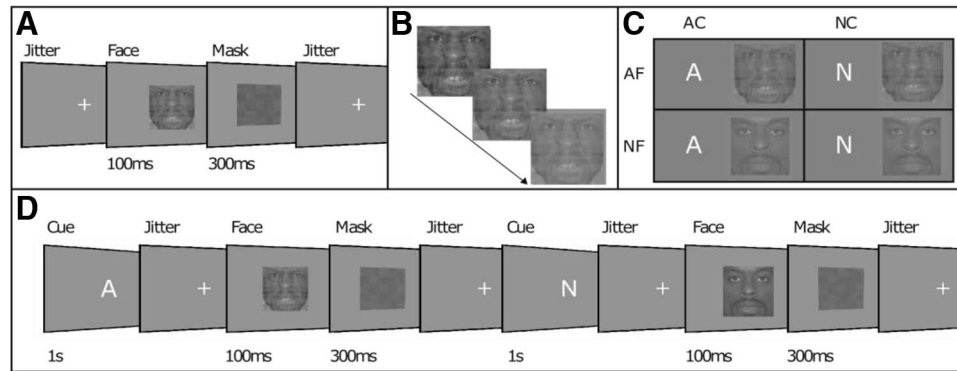
The contrast of the angry or neutral face was manipulated on a scale ranging from 100% to 0%, such that 100% corresponded to no contrast degradation, and 0% corresponded to complete removal of contrast, leaving the image as a gray square. Angry and neutral face images were initially presented at a reduced contrast level at 10%, making images visible but not easy to see. The contrast degradation of the images for all subsequent trials was adjusted based on correct or incorrect responses using four adaptive staircases for each race-facial affect type (i.e., Black AF, White AF, Black NF, and White NF) until the degradation threshold of 75% correct for each race-facial affect type was determined separately. As a result, if a participant correctly categorized the facial affect in the target stimulus, then the next trial of the same race-facial affect type would be presented at lower contrast value (i.e., the target stimulus for that facial affect and race type would be more difficult to see on the next trial). Conversely, if the participant responded incorrectly, then the contrast degradation for the next trial of that race-facial affect type would be higher (i.e., easier to see). The aforementioned staircases, which were utilized for the purposes of altering contrast degradation based on participants' individual behavioral performance, used the QUEST algorithm to assess the Bayesian estimate of each participant's percep-

Table 1  
Demographic Information

Characteristic	Full sample ( $N = 169$ )
Age ( $M$ , $SD$ )	20.20 (2.34)*
Gender (% female)	70.41
Race (%)	
Asian	52.07
White	23.67
Hispanic/Latino	10.65
Black	4.73
Other/Did not report	8.88

\* Two subjects did not complete the demographic survey. Thus, the mean age and  $SD$  were calculated for 167 participants.





**Figure 1.** A. Time line of threshold task. Perceptual thresholds (75% accuracy) were approximated for angry and neutral faces. B. Image contrasts for Black and White AF and NF were adjusted using four adaptive staircases. C. Cue and stimulus pairs for both Black and White faces consisted of the following: AC/AF, AC/NF, NC/AF, NC/NF. D. Time line of cue task. Participants were asked to respond to perceptually degraded Black and White AF and NF after viewing either an AC or NC. Faces in this figure, as well as some of the faces used in the tasks described in this article, are from the Nim Stim Face Stimulus Set (Tottenham et al., 2009), which is a publicly available dataset of faces displaying different emotions. Both the creators of the Nim Stim Face Stimulus Set and the model in the photographs in the figure above consented to have the included pictures utilized in scientific publications.

tual thresholds (Watson & Pelli, 1983). Psychopy was utilized for task presentation and data collection (Peirce, 2007).

### Cued Facial Affect Identification Task

The four threshold values obtained from the threshold task were utilized in the cue task to determine the contrast degradation at which to present the target stimuli for each participant. Similar to the threshold task, all cues and stimuli were presented in counterbalanced random order. In other words, the face stimuli were presented in random order throughout each block, and each stimulus was presented no more than once per block. The cue task consisted of eight blocks of 16 trials, for a total of 64 angry face trials and 64 neutral face trials. Similarly, 64 trials consisted of Black face targets and the other 64 consisted of White face targets. To avoid the impact of practice effects on task performance, target images were presented at one of eight contrast values ranging from  $-6\%$  to  $+8\%$  contrast around the participants' perceptual thresholds (Adini, Wilkonsky, Haspel, Tsodyks, & Sagi, 2004; Sussman, Szekely, et al., 2016).

The cue task was presented similarly to the threshold task except for the inclusion of prestimulus cues. At the beginning of each trial, a cue was presented that represented the type of decision that the participant should make regarding each target stimulus. If the letter "A" was presented (anger cue; AC), then the participant was to make a decision whether the subsequently presented target face was "angry or not." Similarly, if an "N" was presented (neutral cue; NC), then the participant was to make a decision whether the target face was "neutral or not." Similar to the target stimuli, each cue was presented in counterbalanced random order, for a total of 64 angry cue trials and 64 neutral cue trials. The cue at the beginning of each trial was presented for one second. The time line for the task is presented in Figure 1. Decisions were made using two adjacent keys on the keyboard such that participants pressed "Y" if the face matched the cue and "N" if it did not match.

Although the cue provided information to the participant regarding the type of decision that should be made regarding the target stimuli, the cue did not provide probabilistic information regarding the facial affect of the following target stimulus. Following each cue, there was an equal probability of the presentation of an angry or neutral face. As low-level image properties were equalized for all target stimuli, differences in behavioral performance could not be due to differential frequency, luminance, pixel size, or visibility.

Behavioral performance was calculated as the following measures: hit rate, false alarm rate,  $d'$ , and  $c$ . Hit rate and false alarm rate were calculated separately for each cue type (angry/neutral). Two SDT parameters,  $d'$  and  $c$ , were calculated using z-transformed hit rate (zHR) and z-transformed false alarm rate (zFAR), as described by Stanislaw and Todorov (1999). Similar to the hit and false alarm rates, both  $d'$  and  $c$  were calculated separately for each cue (angry/neutral). In the present study, higher  $d'$  values indicated a greater ability to differentiate between target and nontarget facial expressions. Additionally, positive  $c$  values indicate a general tendency to make decisions that are inconsistent with a preceding cue (i.e., a "no" decision), whereas negative  $c$  values indicate a general tendency to make decisions that are consistent with a preceding cue (i.e., a "yes" decision). All behavioral measures were calculated for each race-facial affect pairing.

### Results

First, to examine if racial features and cue type influence discriminability between angry and neutral faces, we conducted a  $2$  (cue: angry vs. neutral)  $\times 2$  (race: Black vs. White) repeated-measures analysis of variance (rm-ANOVA) on  $d'$ , with cue and race as within-subject factors. In accordance with our hypotheses regarding better discrimination following threatening versus neutral cues, results revealed a main effect of cue,  $F(1, 168) = 104.29$ , mean square error ( $MSE$ ) = 90.45,  $p < .001$ ,  $\eta_p^2 = .383$ , such that

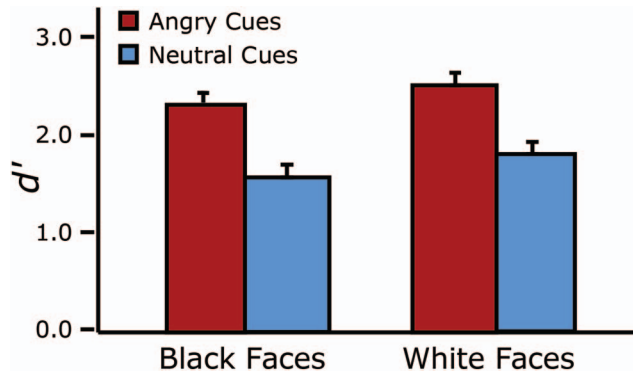


Figure 2. Mean  $d'$  for angry and neutral cues, separated by race. Greater  $d'$  values correspond to better perceptual sensitivity (i.e., ability to discriminate between angry and neutral faces). Error bars represent the within-subject 95% CI. See the online article for the color version of this figure.

participants were better at discriminating angry from neutral faces following angry cues compared to neutral cues (see Figure 2). Additionally, we hypothesized worse discrimination of threatening and neutral Black faces compared to White faces. In line with this, there was a main effect of race,  $F(1, 168) = 10.08$ ,  $MSE = 8.04$ ,  $p = .002$ ,  $\eta_p^2 = .06$ , such that participants were significantly worse at discriminating between angry and neutral Black faces compared to angry and neutral White faces (see Figure 2). However, contrary to our hypotheses regarding reduced threat cue-related improvement in discrimination of threatening and neutral Black compared to White faces, there was no interaction between race and cue type. Overall, our findings indicate that, compared to neutral cues, angry cues lead to better discrimination of angry and neutral faces, irrespective of whether they were Black or White. However, discrimination of angry and neutral Black faces remained worse than White faces, irrespective of preceding angry and neutral cues.

To investigate whether the difference in false alarms and/or hits was driving the cue effect on perceptual discriminability, we further examined the effect of cue type on zHR and zFAR; Figure 3). As described in the introduction, these parameters are utilized in the calculations for  $d'$ , and therefore evaluating these components shows which specific types of responses are driving the  $d'$

results. Paired  $t$  tests revealed a significant effect of cue type on z-transformed hit rate, such that zHR following angry cues ( $M = 1.20$ ,  $SD = .61$ ) was greater than zHR following neutral cues ( $M = .72$ ,  $SD = .63$ ),  $t = 7.88$ ,  $p < .001$ ,  $d = 0.61$ . Additionally, there was a significant effect of cue type on z-transformed false alarm rate, such that zFAR was greater following neutral cues ( $M = -.87$ ,  $SD = .52$ ) compared to angry cues ( $M = -1.09$ ,  $SD = .65$ ),  $t = -3.93$ ,  $p < .001$ ,  $d = 0.30$ . In sum, these results indicate that improved perceptual sensitivity following angry cues can be attributed to 1) higher zHR following angry cues (i.e., more accurate identification of angry faces when present), and 2) lower zFAR following angry cues (i.e., fewer misidentifications of neutral faces as angry).

Similarly, to investigate whether the difference in false alarms and/or hits was driving the race effect on perceptual discriminability, we examined the impact of race on z-transformed hit rate and z-transformed false alarm rate, collapsed across cue type. Paired  $t$  tests results revealed a trending difference in zHR between Black and White faces, such that zHR for Black faces ( $M = .98$ ,  $SD = .54$ ) was lower than zHR for White faces ( $M = 1.06$ ,  $SD = .61$ ),  $t = -1.85$ ,  $p = .066$ ,  $d = 0.23$ . Additionally, results revealed a significant difference in zFAR between Black and White faces, such that zFAR was higher for Black faces ( $M = -.98$ ,  $SD = .56$ ) compared to White faces ( $M = -1.12$ ,  $SD = .58$ ),  $t = 3.04$ ,  $p = .003$ ,  $d = 0.14$ . Thus, these results indicate that reduced perceptual sensitivity for Black versus White faces collapsed across cue type can be attributed to 1) lower zHR for Black faces following both cues, and 2) slightly higher zFAR for Black faces following both cues (although this finding was only trending in significance).

Finally, we examined if race and cue type influenced whether participants were more likely to endorse seeing an angry or neutral face, by conducting a 2 (cue: angry vs. neutral)  $\times$  2 (race: Black vs. White) rm-ANOVA on  $c$ , with cue and race as within-subject factors. See Figure 4 for response bias results. Results revealed a main effect of cue,  $F(1, 168) = 11.36$ ,  $MSE = 4.43$ ,  $p = .001$ ,  $\eta_p^2 = .06$  such that there was liberal response bias following angry compared to neutral cues. Furthermore, there was an interaction of cue and race,  $F(1, 168) = 7.67$ ,  $MSE = 1.73$ ,  $p = .006$ ,  $\eta_p^2 = .04$ , such that this difference in response bias following angry and neutral cues was greater for White compared to Black faces. Specifically, participants exhibited more liberal ( $c < 0$ ) response

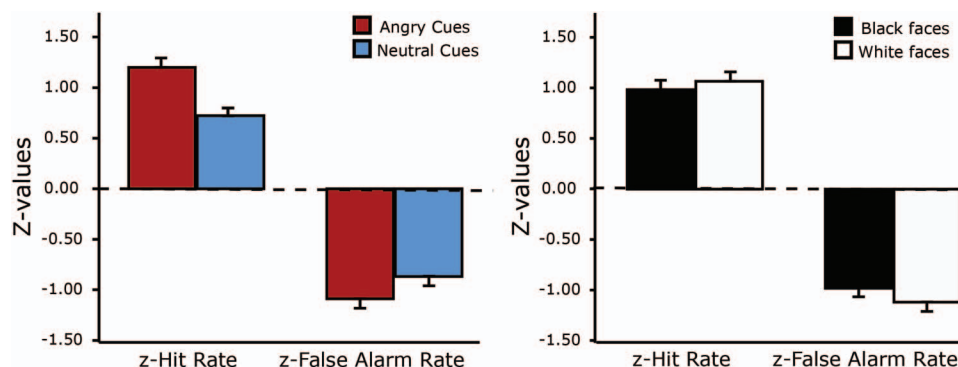
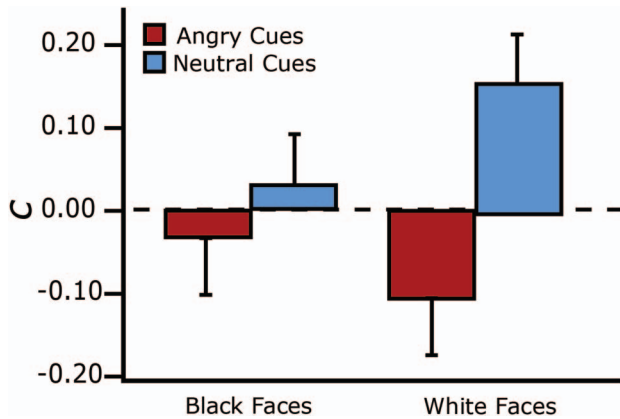


Figure 3. zHR and zFAR values for angry cues, neutral cues, Black faces, and White faces. Bars in the graph on the right represent angry and neutral cues. Bars in the graph on the left represent Black and White faces. Error bars represent the within-subject 95% CI. See the online article for the color version of this figure.





**Figure 4.** Response bias ( $c$ ) for AC and NC, separated by race. Positive  $c$  values indicate decisions that are inconsistent with preceding cues (i.e., a “not” decision). Negative  $c$  values indicate decisions that are consistent with preceding cues. Error bars represent the within-subject 95% CI. See the online article for the color version of this figure.

bias (i.e., they were more likely to decide that the emotion on a face stimulus was consistent with a preceding cue) following angry cues compared to neutral cues, and this pattern of responding was observed for both Black and White faces. However, participants exhibited more conservative ( $c > 0$ ) response bias (i.e., they were more likely to decide that the emotion on a face stimulus was inconsistent with a preceding cue) following neutral cues, and this response tendency was more pronounced for White compared to Black faces. Simple effects tests comparing response bias between angry and neutral cues within each race condition revealed that the difference in response bias for angry and neutral cues described above was only significant for White faces ( $p < .001$ ) and not Black faces ( $p = .326$ ). Additionally, simple effects tests comparing response bias for Black and White faces within each cue condition showed that there was a significant difference in response bias for Black and White faces following neutral cues ( $p = .003$ ) but not angry cues ( $p = .140$ ). Overall, the response bias results show a greater tendency to endorse both Black and White faces as angry following angry cues, and a greater tendency to endorse White faces as not neutral following neutral cues. This is in contrast to our hypotheses, as we anticipated that, following angry cues, participants would exhibit more liberal response bias to Black compared to White faces.

Finally, it should be noted that our results did not reveal a significant main effect of gender or significant interactions between gender and any within-subjects variables. For response time results, please refer to the online supplemental materials.

## Discussion

When making perceptual decisions regarding the presence or absence of threat, we frequently rely on information provided by facial expressions. The majority of existing research has focused on the role of bottom-up factors, such as physical features, that are processed relatively automatically. However, perceptual decisions regarding the presence or absence of threats are often made in complex and dynamic environments, making decisions more challenging due to the poor quality of sensory evidence. In such

environments, we often rely on top-down factors such as our prior learning, expectations, prior information, cues, and perceptual sets to interpret sensory evidence. Although previous studies have investigated the impact of threatening faces and race on the categorization of emotional faces (Halberstadt et al., 2018; Hugenberg, 2005; Hugenberg & Bodenhausen, 2003; Hugenberg & Bodenhausen, 2004; Hutchings & Haddock, 2008), no study of which we are aware has directly investigated how bottom-up and top-down factors regarding the relevance of upcoming threat interact to influence perceptual decision-making in such situations. Thus, in the present study, we used a simple two-alternative forced choice perceptual decision-making task in which participants utilized threatening and neutral cues to discriminate between threatening and neutral Black and White faces. These threatening and neutral faces were perceptually degraded to each participant’s predetermined perceptual threshold, encouraging participants to use cues in their decision-making.

We applied SDT to analyze our behavioral data, because this framework can be used to measure perceptual sensitivity and response bias in decision-making and can successfully elucidate trade-offs between hits and false alarms. A major purpose of the present study was to examine how threat-related perceptual sets influence perceptual decision-making regarding the presence or absence of threat in Black and White faces. As expected, we found that threatening cues lead to more sensitive perceptual decisions overall. Specifically, threatening cues lead to greater hits (i.e., accurate detection of threatening faces when present) and fewer false alarms (i.e., incorrect identification of neutral faces as threatening). However, contrary to our hypotheses, the facilitatory effect of threatening cues did not vary by race, suggesting that cued threat-related perceptual sets are used similarly to discriminate between subsequent faces irrespective of race.

Threatening cues can enhance subsequent perceptual decisions via several mechanisms. Prestimulus cues can increase attention prior to stimulus onset, which improves subsequent detection by biasing sensory processing in favor of the attended location or feature (Desimone & Duncan, 1995). For example, attention-related increases in prestimulus activity are observed in cortical areas that code attended locations (Hopfinger et al., 2000; Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999) or features (Serences & Boynton, 2007; Shulman et al., 1999; Stokes, 2011), and are observed in regions such as the superior temporal sulcus that code threat-related emotional expressions (Sussman, Szekely, et al., 2016). Additionally, threatening cues could facilitate the formulation of more detailed perceptual templates that may be triggered by prestimulus cues, which may subsequently enhance behavioral responses by providing a cognitive model against which bottom-up characteristics can be matched (Rao & Ballard, 1999; Schmidt & Zelinsky, 2009; Sussman, Jin, et al., 2016; Sussman, Szekely, et al., 2016). Furthermore, evidence indicates that threatening cues may generate more detailed perceptual templates compared to neutral cues (Imbriano et al., 2019), which may in turn allow for heightened behavioral performance such as enhanced discriminability between threatening and nonthreatening stimuli.

Overall, threatening cues can be used more effectively than neutral cues to discriminate between subsequently presented threatening and neutral faces. However, our study also showed that when using either cue, discrimination of threatening and neutral

Black faces was worse compared to White faces. In further attempting to elucidate these perceptual sensitivity findings, we discovered that the results were driven both by marginally fewer hits (i.e., not detecting threatening and neutral faces when they were present) and higher false alarms (i.e., incorrectly identifying neutral faces as threatening and threatening faces as neutral) for Black versus White faces. It is important to note that the contrast level at which Black and White faces in our study were presented corresponded to each participant's own 75% performance threshold determined using adaptive stair casing. Thus, even though their performance was equated in the threshold task, performance differences emerged when the same faces were presented within the context of the cue task, where participants used threatening or neutral cue-related perceptual sets to decide whether the faces were "threatening or not" or "neutral or not." Therefore, it is possible that when using top-down attentional and perceptual strategies outlined above, other race-related top-down factors impact perceptual decision-making.

For example, familiarity or "perceptual expertise" may play a role, such that perceptual decisions are less attuned for Black compared to White faces (e.g., Lindsay, Jack, & Christian, 1991), which may be due to less contact with Black individuals. This is congruent with the visual perception literature, which has found evidence that perceptual expertise increases through repeated encounters with stimuli, resulting in improvements in behavioral performance (Gauthier & Nelson, 2001; Gauthier, Skudlarski, Gore, & Anderson, 2000). As our sample is largely non-Black, it could be the case that perceptual expertise is driving our findings, in that less exposure to Black compared to White individuals may have directly led to worse discriminability between expressions of Black faces. This potential explanation is further supported by the fact that the population of self-identifying Black/African American individuals at the sample site and in the surrounding area is low, at approximately 6.37% and 8.7%, respectively (Stony Brook University, 2019; U.S. Census Bureau, 2019). The predictive coding framework (Friston & Kiebel, 2009; Rao & Ballard, 1999) may also suggest a possible mechanism underlying the differences in perceptual sensitivity for Black versus White faces, as threatening top-down information may trigger more effective perceptual templates for the racial group with the largest population base rate, in this case White faces. According to this view, the deficits in discriminability that we observed for Black faces could potentially be attenuated through repeated exposure to facial expressions of Black individuals. In line with this, previous research has shown that the difference in neural response to Black and White faces was less pronounced for participants who had more experience interacting with both these individuals (Tortosa, Lupiáñez, & Ruz, 2013). Harkening back to the aforementioned examples of differences in threat-related responses toward Black individuals, this view provides a framework by which threat-related perceptual decision-making training could help individuals with less familiarity become more perceptually attuned to Black individuals in threatening contexts.

Another factor that may have impacted discriminability results is the expectations generated from stereotypes. Empirical evidence indicates that stereotypes linking threat and Black males can be triggered automatically (Devine, 1989; Eberhardt, Goff, Purdie, & Davies, 2004), and that the deactivation of such stereotypes requires increased utilization of executive resources (Devine & El-

liot, 1995; Macrae, Bodenhausen, Milne, & Wheeler, 1996). Thus, it could be the case that, when actively using cue-related perceptual templates in a top-down manner, implicit biases or internal threat stereotypes for Black males were activated, resulting in poorer discrimination of threatening and neutral Black faces. While evidence from another study shows worse discrimination for threatening versus neutral stereotypically Black faces (Kleider-Offutt, Bond, Williams, & Bohil, 2018), our study shows that worse discrimination for Black faces may occur even when individuals are using top-down information to differentiate between facial expressions. Additionally, several studies have provided evidence indicating that implicit biases are associated with differences in behavioral performance for Black and White faces in face categorization and learning tasks (e.g., Greenwald, McGhee, & Schwartz, 1998; Hugenberg & Bodenhausen, 2003; Hutchings & Haddock, 2008). Future research is needed to determine if perceptual sensitivity for Black facial expressions is associated with implicit or explicit prejudice (i.e., stereotypes), and if participants with greater abilities to discriminate between facial expressions on Black faces report greater motivation to respond without prejudice. Future studies are also needed to investigate if implicit or explicit prejudice impacts the utilization of other top-down information, such as threatening cues and contexts, when making perceptual decisions regarding Black and White faces.

Contrary to what we hypothesized, our results showed the same degree of liberal response bias following threatening cues for Black and White faces. At first glance, our response bias results may appear to conflict with Kleider-Offutt and colleagues' (2018) study, which revealed more liberal response bias to threatening stereotypical versus nonstereotypical Black faces. However, their study did not manipulate cues, perceptual sets, or other top-down information; rather, subsequent to each face trial, participants were asked to decide if the face was stereotypical/ nonstereotypical or if the face was angry/neutral. Hence, participants were not primed with specific, relevant information beforehand that would initiate the utilization of one type of perceptual set over another. In that sense, the Kleider-Offutt et al. (2018) study manipulated bottom-up factors in perceptual decision-making for both racial and emotional characteristics, although top-down factors may be implicated in their results, given that stereotypically Black faces were more likely to be perceived as threatening and threatening Black faces were more likely to be deemed stereotypical. It could be the case that the threatening cues in our study attenuated the race-based differences in response bias, resulting in the application of a threatening cue-related response bias for discriminating White faces, as well. This is in line with studies showing that threatening top-down information can offset differences in perceptual decision-making for Black compared to White faces (Ackerman et al., 2006; Correll, Wittenbrink, Park, Judd, & Goyle, 2011). For example, in a first-person shooter task study, Correll and colleagues (2011) found that the general tendency to shoot Black targets more frequently than White targets was completely reduced when target individuals were presented in a threatening context.

There is a vast literature indicating differences in how police officers, educators, and so forth react when evaluating threat posed by Black versus White individuals. We sought to understand how differences in perceptual decision-making regarding threatening and neutral stimuli may contribute to these behavioral differences. Perceptual decisions regarding threatening and neutral stimuli of-

ten occur in familiar contexts or in environments where there are explicit cues indicating their relevance. Hence, we examined whether threatening and neutral cues lead to differential discrimination of subsequently presented threatening and neutral Black and White faces. Our results showed that threatening cues lead to a greater tendency to decide that Black and White faces were threatening, as well as more sensitive and faster discrimination of threatening and neutral Black and White faces. However, we also saw race-related differences, such that, no matter which cue was being used, discriminability between threatening and neutral Black faces was worse compared to White faces. Using a paradigm that is ecologically valid, our findings highlight the importance of examining basic aspects of visual perception to understand race-related differences in evaluations of threat. Future research is needed to elucidate whether and how perceptual expertise, racial biases, and stereotypes interact with these cue-related effects to influence perceptual decision-making as well as how malleable these top-down effects are via training.

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