Perceptual contributions to racial bias in pain recognition

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Abstract

The pain of Black Americans is systematically under-diagnosed and under-treated, compared to the pain of their White counterparts. Extensive research has examined the psychological factors that might account for such biases, including status judgments, racial prejudice, and stereotypes about biological differences between Blacks and Whites. Across seven experiments (N = 1000) we accumulated evidence that lower-level perceptual processes also uniquely contribute to downstream racial biases in pain recognition. We repeatedly observed that White participants showed more stringent thresholds for perceiving pain on Black faces, compared to White faces. A tendency to see painful expressions on Black faces less readily arose, in part, from a disruption in configural processing associated with other-race faces. Subsequent analyses revealed that this racial bias in pain perception could not be easily attributed to stimulus features (e.g., color, luminance, or contrast), subjective evaluations related to pain tolerance and experience (e.g., masculinity, dominance, etc.), or objective differences in face structure and expression intensity between Black and White faces. Finally, we observed that racial biases in perception were associated with biases in pain treatment decisions, and that this relationship existed over and above biased judgments of status and strength, explicit racial bias, and endorsement of false beliefs regarding biological differences. A meta-analysis across the seven experiments confirmed the robustness and size of these effects. This research establishes a subtle, albeit influential, perceptual pathway to intergroup bias in pain care and treatment. Implications for racial bias, face perception, and medical treatment are discussed.

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Perceptual contributions to racial bias in pain recognition

The United States is host to serious racial disparities in health. Though Black Americans comprise 13% of the U.S. population (National Center for Health Statistics, 2013), they suffer disproportionate outcomes in terms of disease morbidity, mortality, and disability (Mays, Cochran, & Barnes, 2007, Centers for Disease Control and Prevention, 2005). The past 30 years have seen a surge in research aimed at reducing gaps in health outcomes in minority communities, beginning in the mid-1980s with a report commissioned by the Department of Health and Human Services. This report catalogued consistent health gaps and their consequences, including 60,000 excess deaths among Black Americans between 1979 and 1981 (Heckler, 1985), and led to the U.S. Federal Government acknowledging that eliminating health disparities should be a national priority. Although racial health disparities have been observed for decades, new data continue to confirm their ongoing existence in the United States, particularly in the domain of pain care and management (Anderson, Green, & Payne, 2009; Bonham, 2001; Cleeland, Gonin, Baez, Loehrer, & Pandya, 1997; Green et al., 2003; Mossey, 2011; Shavers, Bakos, & Sheppard, 2010; Smedley, Stith, & Nelson, 2009). The current paper examines a novel perceptual pathway that may give rise to such disparities in pain care.

The pain of Black patients is systematically under-diagnosed and undertreated (e.g., Anderson et al., 2009; Green et al., 2003). Black Americans are less likely to be prescribed opioids for their pain, less likely to be prescribed pain medication in general, and when they *do* receive pain medication, they are prescribed lower doses on average (Becker et al., 2011; Chen et al., 2005; Olsen, Daumit, & Ford, 2006; Tamayo-Sarver et al., 2003). These disparities exist across multiple levels of care (pain assessment, treatment, and management), multiple care contexts (emergency room assessments to postoperative care), and types of pain (acute pain,

chronic pain, cancer pain; Green et al., 2003), even after statistically controlling for age, gender, and pain intensity (Mossey, 2011). Research suggests a complicated interplay of contributing factors, including effects specific to healthcare providers, the healthcare system in general, and patients themselves (Green, et al., 2001; Mossey, 2011; Smedley et al., 2009).

One very recent study demonstrates the startling degree to which these disparities are even evident in the treatment of children. Amongst a cohort of Black and White children who had been admitted to emergency rooms for emergency appendectomy procedures, Black children were one-fifth as likely to receive opioids for their pain as their White counterparts, even after taking into account patients' age, sex, pain intensity, insurance status and other factors (Goyal, Kupperman, Cleary, Teach, & Chamberlain, 2015). These data underscore the need to better understand the psychological processes underlying biases in care to eliminate racial disparities in pain care in the Unites States. In particular, we propose that race-based biases in the visual perception of pain may contribute to these disparities in care.

Psychological perspectives on racial disparities in pain care

In general, previous research has identified several high-level social cognitive processes that underlie racial disparities in pain recognition. Research has linked stereotypes about out-group pain tolerance (Hoffman et al., 2016; Trawalter & Hoffman, 2015; Trawalter, Hoffman, & Waytz, 2012; Dore, Hoffman, Lillard, & Trawalter, 2014), beliefs regarding out-group tendencies towards substance abuse (Burgess, Van Ryn, Crowley-Matoka, & Malat, 2006; Hausmann, Gao, Lee, & Kwoh, 2013; Upshur, Luckmann, & Savageau, 2006), and failures to empathize with the out-group (Azevedo et al., 2013 Chiao & Mathur, 2010; Contreras-Huerta, Baker, Reynolds, Batalha, & Cunnington, 2013; Xu, Zuo, Wang, & Han, 2009) to reduced care for and recognition of pain in racial out-groups. For example, while there is significant neural

overlap between the direct experience of pain and empathy for the pain of another (specifically in pain matrix structures such as the anterior cingulate cortex and anterior insula; Botvinick et al., 2005; Budell, Jackson, & Rainville, 2010; Jackson, Meltzoff, & Decety, 2005; Lamm, Decety, & Singer, 2011; Singer et al., 2004; Zaki, Ochsner, Hanelin, Wager, & Mackey, 2007), these empathic neural responses are diminished when we perceive racial out-group members in pain, as compared to racial in-group members (Azevedo et al., 2013; Chiao & Mathur, 2010; Contreras-Huerta et al., 2013; Xu et al., 2009). This growing area of research shows consistent neural differences in responses to the pain of racial minorities.

Recent work in social psychology has also examined how attributions may contribute to racial biases in pain care. For example, adult participants, as well as registered nurses and nursing students attribute higher thresholds for pain to Blacks, compared to Whites (Hoffman et al., 2016; Trawalter & Hoffman, 2015; Trawalter et al. 2012). Moreover, such biases in attributions of pain experience are evident in perceivers as early as age seven (Dore et al., 2014), and may stem from a combination of stereotypes regarding the lower status of Black individuals (Trawalter et al. 2012) and false beliefs concerning biological differences between Blacks and Whites (Hoffman et al., 2016). In contrast, studies of experimentally-induced pain suggest that if anything, Black participants actually exhibit *lower* tolerances for pain and *lower* thresholds for perceiving pain (Campbell et al., 2005; Edwards et al., 2001; Mechlin et al., 2005; Rahim-Williams et al., 2012; Sheffield et al., 2001), potentially stemming from cultural and neurobiological differences in pain beliefs, pain experiences, and coping norms (Anderson & Losin, 2017). Thus, the racial stereotypes in this domain are inaccurate: racial disparities in pain judgments do *not* reflect real differences in pain tolerance.

In the current paper, we examine the possibility that racial disparities in pain care may stem from lower-level, perceptual biases. A long tradition of work suggests that our perceptions are far from perfect (Bruner & Goodman, 1947), and that social perception is subject to a host of situational and motivational influences – in particular, the influence of social identity (Bernstein, Young, & Hugenberg, 2007; Tajfel; 1970; Van Bavel, Packer, Cunningham, 2008; Van Bavel & Cunningham, 2011; Van Bavel, Xiao, & Hackel, 2013; Xiao & Van Bavel, 2012). The Perceptual Model of Intergroup Relations argues that group identities can influence perception, ranging from high-level interpretations to low-level sensory processing (Xiao, Coppin, & Van Bavel, 2016a, 2016b). According to the model, group identities ranging from race to minimal groups created in the lab can alter perceptual judgments of ambiguous stimuli. Further, these perceptual biases are alleged to influence downstream intergroup behavior. This model is consistent with other contemporary models of social perception (e.g., the Dynamic Interactive Model; Freeman & Ambady, 2011; Freeman & Johnson, 2016.) In the current paper, we apply this approach to racial differences in pain perception.

A wealth of evidence suggests that group identities can influence face perception. For example, a region of the occipito-temporal lobe known as the Fusiform Face Area (FFA) represents the race of faces (Contreras, Banaji & Mitchell, 2013; Golby, Gabrieli, Chiao, & Eberhardt, 2001, Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005) and this bias is associated with downstream differences in face memory (Golby et al., 2001). Furthermore, dissimilarities between neural representations of same-race and other-race faces in the FFA are associated with implicit racial bias (Brosch, Bar-David, & Phelps, 2013). Even minimal group membership has been found to impact the FFA (Van Bavel et al., 2011), leading to greater activation for in-group members—a bias that emerges around 170 milliseconds after the

presentation of a face (Ratner & Amodio, 2013). In short, people process out-group faces—particularly racial out-group members—differently than in-group faces. Out-group face processing is typically featural, or component-based, while in-group face processing is more configural and holistic in nature (Hancock & Rhodes, 2008; Hugenberg et al., 2010; Michel, Rossion, Han, Chung, & Caldara, 2006; Rhodes, Hayward, & Winkler, 2006; Sporer, 2001). Owing in part to these differences in processing, perceivers show worse memory for the faces of racial out-group members—a phenomenon typically referred to as the Cross Race Effect or Own-race Memory Bias (Hugenberg & Sacco, 2008; Hugenberg, Young, Bernstein, & Sacco, 2010; Malpass, 1969), which has been linked to real-word outcomes like eyewitness misidentification (Wells & Olson, 2001; Wilson, Hugenberg, & Bernstein, 2013). Moreover, disruptions in configural face processing may underscore the dehumanization and mistrust of Black (versus White) individuals (Cassidy et al., 2017). Similarly, perceivers are less accurate at recognizing emotional expressions on the faces of racial out-groups (Hugenberg & Bodenhausen, 2003; Hugenberg, 2005; Young & Hugenberg, 2010), as well as the size of their bodies (Wilson, Rule, & Hugenberg, 2017), and the speed of their movements (Kenrick et al., 2015). In this way, differential engagement of these social perceptual processes can precipitate serious societal consequences.

As such, we propose that disparities in pain care may stem, in part, from a perceptual basis. Due to disruptions in configural face processing when evaluating Black faces, White perceivers may display more lenient thresholds for pain on White faces and more stringent thresholds for pain on Black faces (e.g., akin to social identity's influence on mind perception; Hackel, Looser, & Van Bavel, 2014). Since this would represent a difference in the visual threshold for identifying pain as a function of race, we will describe such a pattern of results as a

perceptual contribution to racial bias in pain recognition. If so demonstrated, this disparity in the threshold for perceiving other-race pain could trigger a cascade of biased processing, producing divergent medical treatment outcomes, and ultimately manifesting as societal-level racial inequalities in pain care. Identifying the perceptual processes supporting such inequalities would have direct consequences for subsequent interventions. Changing people's explicit beliefs and attitudes – especially about social out-groups – is an especially challenging task (e.g., Paluck et al., 2009; Tankard & Paluck, 2016). Ultimately, the perceptual roots of bias in pain care may prove to be a more tractable target for intervention, rather than stereotypes regarding status, strength, or pain tolerance.

The current research

We present seven experiments examining racial disparities in pain perception and treatment. In Experiment 1, we establish perceptual contributions to racial bias in pain care. In Experiment 2, we replicate this finding using a set of stimuli that were equated in terms of color, contrast, and luminance. In Experiments 3 and 4, we manipulate configural face processing to better understand the perceptual underpinnings of these effects. In Experiments 5 through 7, we apply increasingly conservative tests of our hypotheses by more carefully balancing our stimuli across condition (including creating face stimuli in FaceGen that were perfectly matched on every visual characteristic other than race). Finally, we present a meta-analysis that incorporates data from all seven experiments.

Across these seven experiments, our methodological approach evolved as we ruled out potential confounds. For example, since our overarching research question centers on issues of racial bias in pain perception, balancing the stimuli we used in terms of expression intensity across race presented a distinct methodological challenge. In Experiments 1-4, we initially

attempted to match stimuli as closely as possible via careful visual inspection. In Experiments 5 and 6, we extended this approach by balancing stimuli across raters' subjective social judgments of pain experience and tolerance. Finally, in Experiment 7, we provided the most stringent test we could conceive of, by creating stimuli that were objectively equated in terms of structure and expressions, while still manipulating race. Taken together, these different approaches are complementary and enhance the precision of our inferences: racial bias in pain perception cannot be explained by stimulus confounds, *and* it generalizes across a wide variety of stimuli.

Methodological adjustments also reflected an attempt to enhance the construct validity of our measures. For example, while our treatment recommendation measure in Experiments 1-4 was framed in terms of participants' memory for targets' pain, we adjusted this measure in Experiments 5-7 to be more directly tied to pain perception. Throughout the text we have made an effort to be transparent and forthcoming about the rationale behind each of these modifications.

Taken together, this research finds that 1) White perceivers display a more stringent threshold for recognizing pain on Black faces, as compared to White faces, 2) biases in pain recognition cannot be accounted for by low-level visual differences between Black and White faces (e.g., color, contrast, and luminance), differences in subjective social judgments associated with pain tolerance and experience (e.g., dominance, masculinity, etc.) or objective differences in facial structure and expression intensity, 3) biases in pain recognition predict biases in medical treatment decisions, 4) the influence of biases in pain recognition cannot be fully accounted for by explicit stereotypes about or prejudices against Black Americans, and finally, 5) biases in pain recognition stem, at least in part, from a disruption in configural face processing associated with out-group faces. These studies are the first to establish a perceptual source underlying racial

disparities in pain care.

Experiment 1

Our initial experiment was designed to compare perceptual thresholds for detecting facial expressions of pain as a function of target race. Participants judged whether a series of Black or White face morphs depicting varying percentages of painful expressions were in pain. Subsequently, participants made medical treatment recommendations for a subset of these target faces, in order to determine whether bias in pain perception predicted bias in treatment. Critically, we also assessed participants' explicit racial bias and whether they viewed Black and White targets as differing in status, in an attempt to assess whether biases in perception and treatment were independent of self-reported racial bias.

Method

Participants. We recruited 85 White participants through the Amazon website Mechanical Turk (46 male, mean age = 34.99, *SD* = 12.74). We chose this sample based upon its relative diversity in terms of age, race, gender, and geographic distribution across the United States (Paolacci & Chandler, 2014; Huff & Tingley, 2015), relative to the typical participants in a psychology subject pool (Henrich, Heine, & Norenzayan, 2010). As we predicted that the effect size of the relationship between racial biases in pain perception and treatment would be moderate (e.g., r = .30), we aimed for a correspondingly large sample size (N = 82), in order to afford us appropriate statistical power (e.g., 80%). We chose not to apply a demographic constraint to our recruitment on Mechanical Turk, so as not to alert participants that our hypotheses were related to race. Previous experience with the MTurk subject pool suggested that between 25% and 35% of participants typically identify as non-White. Therefore, in this experiment (and the three that follow), we had to recruit a sufficiently large sample ($N_{overall}$ =

125) to be able to exclude non-White participants from analyses, while still including the appropriate number of White participants. Forty additional non-White participants did take part in the experiment (10 African-American, 12 Asian, 12 Hispanic, 1 Native American, 1 Pacific Islander, 4 Other), though their data will not be analyzed in the present manuscript. We acquired informed consent from all participants, in accordance with approval from the NYU University Committee on Activities Involving Human Subjects.

Stimuli. Prior to Experiment 1, we began collecting photographs in which a racially diverse set of volunteers ("actors") generated posed facial expressions of pain. These efforts continued past Experiment 1, and have resulted in a large database of stimuli (Mende-Siedlecki, Qu-Lee, & Backer; in preparation; osf.io/2x8r5/). Stimuli used specifically in Experiments 1-7 are available for download online (osf.io/dmqy9/).

After obtaining informed consent, actors completed a basic demographic survey. Next, actors were seated inside of a running room, four feet away from the camera with a plain white wall as background. actors were then instructed to pose facial expressions corresponding to a standardized series of prompts – specifically, they were asked to portray how they would likely respond in each scenario. (While a realistic reaction might include changes in posture or gestures that might obscure the face, we asked actors to localize their responses to their facial expressions.) First, actors posed a neutral facial expression. Subsequently, actors posed painful expressions in response to five specific prompts describing potentially painful experiences: receiving an electric shock via electrode, receiving burning heat pain via thermode, having one's arm submerged in a bucket of ice water for a prolonged period of time, cutting one's index finger while chopping garlic, having lemon juice applied to a paper cut on the webbing between one's fingers, and experiencing a migraine while at work.

Critically, actors posed facial expressions in response to each prompt at three levels of pain – a 2 ("annoying, but you can almost ignore it"), 5 ("definitely painful, but you can grit your teeth through it"), and 8 ("almost unbearable, the most pain you'd be willing to experience") on a scale from 1 to 10. To enhance variability within the stimulus set, actors who made similar expressions across prompts were encouraged to try out different facial configurations (e.g., eyes open vs. closed, mouth closed vs. teeth gritted). Actors whose responses did not visibly increase in intensity from level to level were directed to amplify their expressions. Multiple images were taken for each prompt, at each level, and each session generated upwards of 50 images. As such, even if a particular actor produced, on average, images that were lower in intensity than another actor, by carefully combing through the entire sets of images, we could be reasonably sure of selecting two images that were similar in intensity.

All actors gave permission for their images to be used in future research, as well as in documentation of that research (e.g., journal figures, conference talks, etc.).

Procedure. Participants in Experiment 1 first saw morphed images of three Black and three White male actors (all between the ages of 25 and 34). As described above, in this and Experiments 2-4, we attempted to match stimuli as closely as possible in terms of overall expression intensity and structure via careful visual inspection. Experiments 5-7 applied more formal ways of balancing targets on either subjective judgments or objective characteristics.

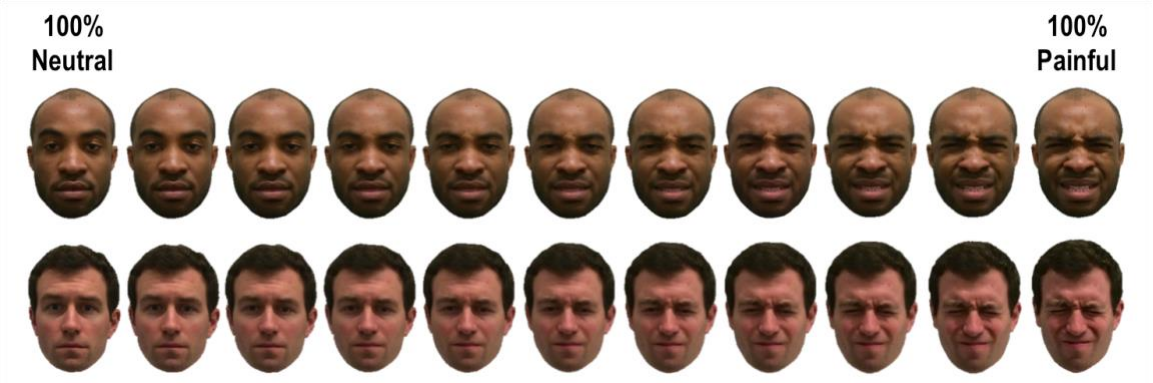

Figure 1. Sample stimuli viewed during the *pain rating phase* in Experiment 1. Participants saw Black (top) and White (bottom) morphs ranging from 100% neutral (left) to 100% painful (right) facial expressions along 11 equidistant points. The individuals depicted in this and all figures throughout granted full permission for their likenesses to appear in this manuscript.

For each target, we constructed 11 morphs using Morpheus PhotoMorpher Pro, ranging from a 100% neutral expression to a 100% painful expression (see Figure 1 for examples). For the 100% painful expressions, we used a level 8 intensity expression from each actor. In the *pain rating phase* of our task, morphs were presented to participants in either "Forward" version of the task (e.g., from neutral to painful; N = 39), or a "Backward" version (e.g., from painful to neutral; N = 46). Assignment to Forward or Backward order was randomized across participants. This allowed us to test whether any racial bias in pain recognition was specific to one order of face presentation (though we had no specific predictions that it would be). For each face participants saw, they made a binary Yes/No judgment of whether the face was in pain. In the "Forward" condition, if participants responded "No," the subsequent face in the continuum appeared, while if the participants responded "Yes," the task advanced to the next target. In the "Backward" condition, if participants responded "Yes," the subsequent face in the continuum appeared, while if the participants responded "No," the task advanced to the next target.

Prior to beginning the task, participants read the following instructions:

"Thanks so much for participating in our experiment! We're interested in visual processing — specifically, how people process visual characteristics associated with pain.

In a moment, you'll see a series of faces of individuals who took part in a laboratory study we conducted in which participants received painful burning stimulations on their forearms, delivered via a device called a thermode.

The images you'll see were taken during these laboratory sessions. The amounts of pain administered varied across the study and the amounts of pain the subjects reported varied as

well. For each series of faces you see, you'll be asked to judge whether the person depicted looks like they are in pain. (i.e., ***Is this face in pain?****) For each face, you'll simply respond "Yes" or "No". We are interested in your first impressions, so please answer as quickly and as accurately as you can! The entire study takes about 10 minutes to complete."*

All in all, participants could potentially view 66 faces in the pain rating phase of the task (3 targets × 2 races × 11 morphs). Once the pain rating phase was complete, participants read the following text:

"You've completed the first part of our task! We're also interested in how people regulate and medicate pain. While the pain administered during our study can last for several hours, our subjects have the opportunity to relieve the pain they experienced during the study with an experimental non-narcotic analgesic cream.

There are no known adverse consequences or side effects related to the use of this cream. However, we only want to administer as much as each subject will need. The maximum dose we can give anyone to take home is 20 grams."

Following the *pain rating phase*, participants completed a series of *treatment recommendations.* They saw neutral versions of one Black and one White target from the *pain rating phase*, selected at random (presented on separate screens, with presentation order randomly counterbalanced), and were asked *"Based on the expression of pain you saw from the individual above, how many grams of the experimental analgesic cream should they be given?"* Participants then determined how much of the non-narcotic, experimental analgesic cream each should be prescribed, on a scale of 0g to 20g. This pain-relieving cream was described as "non-narcotic" in order to ensure that differences in treatment recommendations were independent of

participants' stereotypes regarding the likelihood that either the Black or White target might abuse an opioid-based pain reliever.

Next, participants were asked to make a series of social evaluations of these two targets (one Black, one White; presented on separate screens, with presentation order randomly counterbalanced) on a series of 12 questions (7-point scale; from 1 = "not at all" to 7 = "extremely"). Within these items, we randomly embedded four items related to status (e.g., *How privileged do you think this person is?*, *How hard do you think their life has been?*, *How lucky do you think they have been?*, *How much adversity do you think they've overcome in general?*; adapted from Trawalter et al., 2012; α = .75, averaging across Black and White targets). After reverse scoring the second and fourth items, we averaged across these four responses to create measures of status for the White and the Black target. The difference between these scores (White status – Black status) represented each participant's racial bias in status judgments (*M* = .98, *SD* = 1.22).

Finally, participants completed a series of demographic questions, including their age, race, gender, and political ideology[1] (7-point scale; 1 = "very liberal" to 7 = "very conservative"). Critically, we also asked participants to complete a series of feeling thermometers describing their feelings of warmth (100-point scale; 0 = "very cold" to 100 = "very warm") towards various ten social groups (e.g., "Canadians," "housewives," etc.), within which we randomly embedded "Blacks" and "Whites." Using these feeling thermometer ratings, we calculated the difference between feelings of warmth towards Whites versus Blacks (warmth

[1] We have not yet assessed the influence of political ideology on racial bias in pain perception – in Experiment 1 or any of the experiments contained in this manuscript – as this question was ultimately beyond the bounds of our primary objectives. The political ideology item is a standard question in demographics surveys administered in our lab.

towards Whites – warmth towards Blacks), which we used as a proxy for explicit racial bias (*M* = 6.80, *SD* = 20.91).

Analyses. First, we calculated average thresholds for Black and White targets in the *pain rating phase*, and then rescaled this data from an 11-point scale (representing the point at which participants either began to recognize pain on faces in the "Forward" condition, or stopped seeing pain in the "Backward" condition) to a 0-to-1 scale. Next, we conducted a 2 (target race: Black vs. White) × 2 (presentation order: Forward vs. Backward) ANOVA on this rescaled data to assess a) whether the threshold for pain perception varied as a function of target race, and b) whether the effect of race varied as a function of presentation order. Subsequently, we conducted a series of one-way ANOVAs to examine whether race had an impact on treatment recommendations[2], status judgments, and feeling thermometer ratings.

Next, we tested whether participants' racial bias in pain recognition was related to their subsequent treatment recommendations for Black versus White targets. We reasoned that the most relevant measure of bias in pain recognition would be to calculate the difference in pain perception thresholds *specifically* for the two Black and White targets presented during the *treatment recommendations* phase of the task. These targets will be referred to as "*treated*" targets throughout the text. (Meta-analytic information on the relationship between overall bias in pain recognition and treatment recommendations across the seven experiments presented herein is available in the section titled *Meta-Analyses Across Experiments 1-7*.)

Moreover, we examined whether this relationship between pain recognition and treatment existed over and above both racial bias in status judgments and explicit racial bias. As such, we conducted a multiple regression comparing racial bias in pain recognition ("Treated" Black

[2] Analyses testing potential interactions between race and presentation order on treatment recommendations can be found in the section titled *Meta-Analyses Across Experiments 1-7.*

threshold – "Treated" White threshold), racial bias in status judgments (White status – Black status), and explicit racial bias (White feeling thermometer rating – Black feeling thermometer rating) against each other as competing predictors of racial bias in treatment recommendations (White prescription – Black prescription). Therefore, throughout the text, references to measures of bias (e.g., in pain perception or treatment, or judgments of status, etc.) always represent difference scores between Black and White targets.

Subsequent to the data collection and analysis of Experiment 1, we speculated that the most relevant test of the relationship between the bias in pain perception and treatment might lie within just the participants who experienced the "Forwards" version of the task, for two specific reasons. First, participants in the "Backwards" condition would have all seen the most intense painful expression of each target, therefore, their treatment recommendations might be expected to vary less between Black and White targets, and critically, to be less related to differences in *pain rating phase* thresholds. Second, and perhaps more importantly, the visual criteria for reaching threshold in the "Backwards" condition (e.g., seeing a face *no longer in pain*) are less related to the treatment recommendation measure, as it was framed in the task (e.g., "*Based on the **expression of pain** you saw from the individual above, how many grams of the experimental analgesic cream should they be given?"*).

We identified this issue following Experiment 2, and eventually adapted our design accordingly in Experiments 4-7, in which we employed only the "Forwards" condition. As our understanding of this effect developed over the course of these experiments, we have attempted to be consistent in how we present the most relevant representation of the relationship between biases in perception and treatment, focusing on the effect in the "Forwards" condition. For the sake of transparency, we present both the collapsed and "Forwards only" analyses of this

relationship in Experiment 1. However, in Experiments 2 and 3, we present only "Forwards only" analyses. That said, meta-analyses assessing the impact of design attributes such as presentation order is available in the section titled *Meta-Analyses Across Experiments 1-7*.

Our procedure for determining sample size, all data exclusions, all manipulations, and all measures included in this research are fully reported in this article. Materials and de-identified data have been made available online (osf.io/dmqy9/).

Results

Racial bias in pain recognition. Our initial hypothesis was that people would perceive pain earlier on White versus Black faces. As predicted, we observed a main effect of target race on participants' threshold for pain perceptions ($F(1,83) = 55.63$, $p < .001$, $\eta_p^2 = .40$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.58$, $SD = 0.24$), as compared to White faces ($M = 0.49$, $SD = 0.23$; Figure 4A & Table 1A). These *perceptual judgments* are consistent with earlier work showing racial disparities in *attributions* of pain experience (Hoffman et al., 2016; Trawalter et al., 2012).

Moreover, we tested the interaction between target race and task version, to see if the effect of race on pain perception was robust to presentation order. This interaction was not significant ($F(1,83) = 0.75$, $p = .388$, $\eta_p^2 < .01$), suggesting that that the magnitude of racial bias in pain recognition did not differ depending on whether participants saw the "Forwards" or "Backwards" version of the task.

Differences in treatment recommendation, status judgments, and feeling thermometer ratings as a function of target race. Our second hypothesis was that participants would recommend administering more non-narcotic pain reliever to White versus Black targets. Consistent with our predictions, we observed a marginally significant main effect of target race

on participants' threshold for pain perceptions ($F(1,78^{3}) = 3.10$, $p = .082$; $\eta_p^2 = .04$). Participants prescribed marginally less analgesic cream to Black targets ($M = 4.02$, $SD = 4.90$), as compared to White targets ($M = 4.96$, $SD = 5.08$; see Table 2A). Although this difference did not reach conventional levels of statistical significance, it was nevertheless consistent with real-world evidence suggesting that the pain of Black patients is undertreated (Green, et al., 2001; Mossey, 2011; Smedley et al., 2009)[4].

Moreover, we also observed main effects of race on both judgments of social status ($F(1,84) = 5.96$, $p < .001$; $\eta_p^2 = .40$), as well as on reported warmth towards Blacks and Whites ($F(1,84) = 8.99$, $p = .004$; $\eta_p^2 = .10$). Not only did participants rate the Black target as being significantly lower in social status than the White target ($M_{Black} = 3.53$, $SD_{Black} = 0.79$; $M_{White} = 4.51$, $SD_{White} = 0.80$), but they also reported feeling less warmly towards Blacks than Whites, overall ($M_{Black} = 63.32$, $SD_{Black} = 24.37$; $M_{White} = 70.12$, $SD_{White} = 24.07$).

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain perception would predict racial bias in treatment. As predicted, bias in pain perception thresholds (Black thresholds – White thresholds) was associated with bias in treatment recommendations (White prescriptions – Black prescriptions; $r = .32$, $p = .004$). In other words, comparatively higher thresholds for perceiving pain on Black faces were associated with comparatively less analgesic prescribed to Black targets during the treatment recommendation task. Moreover, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations ($B = 6.86$,

[3] The difference in degrees of freedom between analyses reflects a small number of participants (N = 6) who did not fully complete the *treatment recommendation* task.

[4] The effects of order on racial bias in pain recognition were consistent across Experiments 1 through 3 (e.g., we observed a main effect of order on overall thresholds, but racial bias in pain recognition was not moderated by order). However, the effects of order on treatment recommendations were more heterogeneous between experiments (see Table 2B). A meta-analytic review of these data can be found below under *Meta-Analyses Across Experiments 1-7*.

SE = 2.29, $t(77) = 2.99$, $p = .004$), even after controlling for bias in status judgments and explicit racial bias. No other predictors were significantly associated with racial bias in treatment recommendations (*p*s > .521). Thus, the relationship appeared robust to these other factors.

Finally, we tested the relationship between perception and treatment within only the participants in the "Forwards" condition. First, we observed that the zero-order correlation between racial bias in pain recognition in "treated" targets and subsequent treatment recommendations was significant in the "Forwards" version of the task ($r = .387$, $p = .016$), but only marginally significant in the "Backwards" version of the task ($r = .271$, $p = .091$), though the difference between these correlations was not statistically significant ($p = .582$). Subsequently, we observed that within the "Forwards" version alone, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations ($B = 9.50$, $SE = 3.80$, $t(37) = 2.50$, $p = .017$), when controlling for bias in status judgments and explicit racial bias (for zero-order correlations between all predictors, see Supplementary Tables 1A & 2A). No other predictors were significantly associated with racial bias in treatment recommendations (*p*s > .187). Participants who displayed more stringent thresholds for pain perception on Black faces (compared to White faces) also prescribed Black targets less of a non-narcotic analgesic cream than White targets.

Experiment 2

The results from Experiment 1 suggested that White perceivers saw pain on Black faces less readily than pain on White faces, which predicted discrepancies in treatment—such that people who saw pain more readily on the faces of White targets also prescribed them more of a non-narcotic pain reliever. Critically, this relationship existed over and above the influence of explicit racial bias or racial bias in judgments of social status. Although the stimuli were

ecologically valid visual images of pain, it introduced the possibility that low-level differences in our stimuli, rather than group-biased biases, could explain the results. For example, differences in luminance and contrast could make the signatures of pain more difficult to perceive on a Black face, as compared to a White face. To rule out this alternative explanation, we attempted to directly replicate the results of Experiment 1 using a stimulus set that was matched in terms of color-scale, luminance, and contrast.

Moreover, while Experiment 1 suggested that the relationship between biased perception and biased treatment could not be explained by explicit racial bias or biased judgments of status, other stereotypes and prejudice are potentially relevant to disparities in pain care. In particular, recent research has found that people (including trained medical health professionals) will readily endorse inaccurate statements concerning biological differences between Blacks Whites (e.g., "Blacks have less sensitive nerve endings than Whites"), and that these beliefs are a contributing factor to racial bias in attributions of pain experience (Hoffman et al., 2016). We tested whether the relationship we observed in Experiment 1 between racial biases in pain recognition and subsequent treatment was independent of the endorsement of such false beliefs. If so, it would further reinforce the notion that perceptual biases play a role in pain care and treatment.

Method

Participants. We recruited 80 White participants through the Amazon website Mechanical Turk (33 male, mean age = 35.29, *SD* = 10.92). Sample size was determined *a priori* as in Experiment 1 – we aimed to recruit a large enough sample ($N_{overall}$ = 119) in order to yield enough White participants (N = 82) to obtain the necessary power to detect a moderately sized correlation between bias in pain perception and bias in treatment. As in Experiment 1, we did not

apply a demographic constraint to our recruitment on Mechanical Turk, so as not to alert potential participants that our hypotheses were related to race. As a result, an additional 29 non-White participants took part in the experiment (6 African-American, 10 Asian, 10 Hispanic, 1 Native American, 2 Other) and their data will not be analyzed in the present manuscript. We acquired informed consent from all participants, in accordance with approval from the NYU University Committee on Activities Involving Human Subjects.

Stimuli. Following Experiment 1, we continued to collect images of Black and White male actors posing facial expressions of pain. In Experiment 2, participants saw sets of morphs depicting 6 Black and 6 White male actors, which were depicted in gray-scale, rather than full color. Critically, we used the SHINE Toolbox (Willenbockel et al., 2010) to equate image contrast and luminance across the full set of 132 images (12 actors × 11 morphs per set), and in particular, between stimuli depicting Black and White actors.

Procedure. The procedure for Experiment 2 was identical to Experiment 1, but for two critical differences. First, as our stimulus set had grown by the time we began conducting Experiment 2, participants saw morphed images of 6 Black and 6 White male actors (all between the ages of 21 and 34). This allowed us to collect more observations per participant, as well as generalize to a larger stimulus sample. (As described above, these images were first gray-scaled, and then matched across the set of 66 images in terms of luminance and contrast, using the SHINE Toolbox; Willenbockel et al., 2010. See Figure 2 for examples.) Second, following the *pain rating phase* and *treatment recommendations*, we also asked participants to report on their endorsement of biological differences between Blacks and White (adapted from materials reported in Hoffman et al., 2016). On average, participants endorsed almost two out of the eleven possible false beliefs regarding biological differences between Blacks and Whites as being

possibly, probably, or definitely true (*M* = 1.98, *SD* = 2.50). This level of endorsement was significantly different from 0 in a one-sample *t*-test ($t(79) = 7.08$, $p < .001$). Finally, as in Experiment 1, participants were randomly assigned to a "Forward" (N = 42) or "Backward" version (N = 38) of the task.

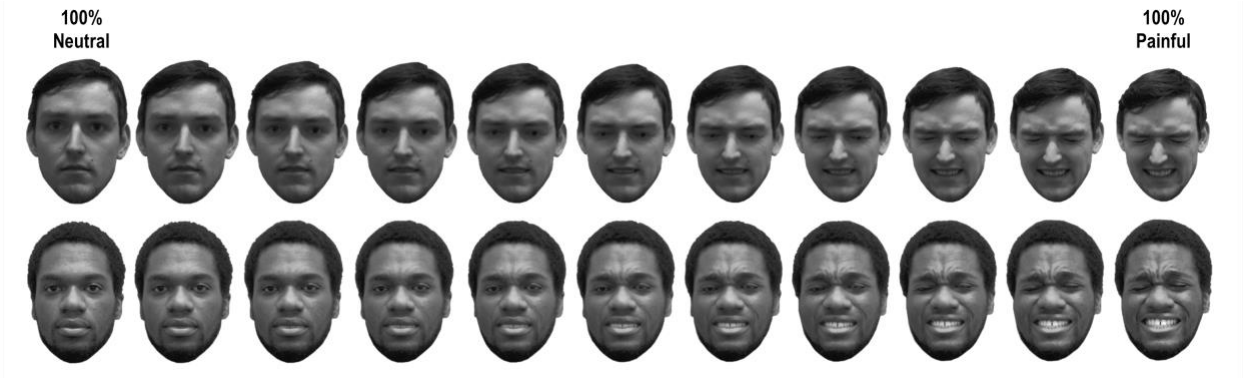

Figure 2. Sample stimuli viewed during the *pain rating phase* in Experiment 2. Participants saw gray-scaled, contrast- and luminance-matched morphs between neutral (left) and painful (right) facial expressions along 11 equidistant points.

Analyses. Analyses for Experiment 2 were essentially identical to Experiment 1, with the addition of endorsement of false beliefs concerning biological differences between Blacks and Whites as a competing predictor in the multiple regression examining influences on bias in treatment recommendations. We re-scored responses on this scale as a 0 for all false items that participants rated as *definitely untrue*, *probably untrue*, or *possibly untrue*, and as a 1 for all false items that participants rated as *possibly true*, *probably true*, or *definitely true*, and added together the rescored values for all 11 false items[5]. As such, participants' rescored values on the false beliefs measure could range from 0 to 11.

Finally, within participants receiving the "Forwards" version of the task (see Experiment

[5]This rescoring procedure is described in the caption to Table 1 in Hoffman et al., (2016), and aids with the interpretability of this measure by framing at a concrete number (out of a possible 11) of false beliefs endorsed. However, this was not the method ultimately employed by Hoffman and colleagues in their analyses, and one might argue that our use of it here minimizes meaningful variation in the scale. Instead, we could have simply summed participants' responses for each item (which ranged from 1, "definitely untrue," to 6, "definitely true) across all 11 false beliefs. Ultimately, these two approaches are highly correlated with each other ($r = .832$), and results do not change appreciably from experiment to experiment (or across experiments) when this alternate scoring method is used (see Supplementary Materials).

1 Analyses), we conducted a multiple regression pitting racial bias in pain recognition against racial bias in status judgments (α = .47, averaging across Black and White targets), explicit racial bias, and endorsement of false beliefs concerning biological differences between Blacks and Whites against each other as competing predictors of racial bias in treatment recommendations.

Results

Racial bias in pain recognition. Again, we predicted that people would perceive pain earlier on White versus Black faces. Replicating the results of Experiment 1, we observed a main effect of target race on participants' threshold for pain perceptions ($F(1,78) = 14.33$, $p < .001$, $\eta_p^2 = .16$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.52$, $SD = 0.24$), as compared to White faces ($M = 0.50$, $SD = 0.25$; see Figure 4B and Table 1A). This result extended the pattern we observed in Experiment 1 to gray scale faces, suggesting that racial bias in pain recognition cannot be fully explained by low-level differences between Black and White stimuli.

Moreover, we tested the interaction between target race and task version, to see if the effect of race on pain perception was robust to presentation order. Consistent with the results of Experiment 1, this interaction was not significant ($F(1,78) = 0.19$, $p = .661$, $\eta_p^2 < .01$). This suggests that that the magnitude of racial bias in pain recognition did not differ depending on whether participants saw the "Forwards" or "Backwards" version of the task.

Differences in treatment recommendation, status judgments, and feeling thermometer ratings as a function of target race. Our second hypothesis was that participants would administer more non-narcotic pain reliever to White versus Black targets. However, contrary to what we observed in Experiment 1, the main effect of target race on participants' treatment

recommendations was not statistically significant ($F(1,78^6) = 0.03$, $p = .858$, $\eta_p^2 < .01$). Participants' prescriptions of the analgesic cream was not significantly lower for Black targets ($M = 6.03$, $SD = 6.13$) compared to White targets ($M = 6.12$, $SD = 6.12$; see Table 2A). This suggested that this particular set of stimuli might not have elicited that same degree of racial bias in treatment.

However, as in Experiment 1, we once again observed main effects of race on both judgments of social status ($F(1,78) = 31.23$, $p < .001$, $\eta_p^2 = .29$) and reported warmth towards Blacks and Whites ($F(1,79) = 7.79$, $p = .007$, $\eta_p^2 = .09$). Participants rated the Black target as being significantly lower in status than the White target ($M_{Black} = 3.45$, $SD_{Black} = 0.76$; $M_{White} = 4.22$, $SD_{White} = 0.92$), and also reported feeling less warmly towards Blacks than Whites, overall ($M_{Black} = 65.45$, $SD_{Black} = 25.48$; $M_{White} = 72.18$, $SD_{White} = 23.76$).

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain perception would predict racial bias in treatment. As in Experiment 1, we tested this relationship only within participants who received the "Forwards" version of the task, and once again, we observed that bias in thresholds for perceiving pain (Black thresholds – White thresholds) was associated with bias in treatment recommendations (White prescriptions – Black prescriptions; $r = .309$, $p = .050$). White participants with comparatively higher thresholds for perceiving pain on Black faces prescribed comparatively less analgesic prescribed to Black targets during the treatment recommendation task.

Moreover, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations ($B = 6.00$, $SE = 2.90$, $t(40) = 2.07$, $p = .045$), when controlling for bias in status judgments, explicit racial bias, and false beliefs

[6] The difference in degrees of freedom between analyses reflects one participant who did not fully complete the treatment recommendations and social evaluations portion of the experiment.

regarding biological differences between Blacks and Whites (for zero-order correlations between all predictors, see Supplementary Tables 1B & 2B). No other predictors were significantly associated with bias in treatment recommendations (ps < .257). This result replicated and extended our final finding in Experiment 1: racial bias in the threshold for pain perception was associated with bias in subsequent treatment recommendations, independent of explicit stereotypes and prejudice and when controlling for low-level differences in stimuli.

Experiment 3

Experiments 1 and 2 demonstrated robust biases in White perceivers to show more stringent thresholds for recognizing pain on the faces of Black targets, as compared to White targets. What's more, this perceptual bias predicted subsequent racial disparities in treatment recommendations (at least, when presented in "Forwards" order), and could not be accounted for through low-level visual differences in hue, contrast, or luminance. That being said, the precise perceptual nature of these effects remains unclear. Indeed, Experiments 1 and 2 could not confirm that the biases in pain recognition and treatment were *truly* perceptual in nature, or if they were in fact the downstream consequence of differential attributions of pain tolerance to Blacks and Whites. Furthermore, despite our best efforts to systematize the process of collecting posed images of painful facial expressions, and subsequently balancing those images as best we could in terms of pain intensity, it is possible that the images of Black faces depicting pain that we selected were simply less intense.

We therefore designed a follow-up experiment that addressed these concerns, as well as pinpointing the precise perceptual contributions to racial bias in pain recognition. As noted in the introduction, in-group face processing is more holistic or configural in nature, while out-group face processing is typically featural, or component-based (Rhodes, Hayward, & Winkler, 2006;

Hancock & Rhodes, 2008). Disruptions in configural processing – frequently associated with viewing out-group faces – might help explain racial bias in pain perception. Notably, face inversion also disrupts configural processing (Freire, Lee, & Symons, 2000; Maurer, Le Grand, & Mondloch, 2002), and has been previously employed to examine altered configural processing of other-race faces (Caharel et al., 2011; Hancock & Rhodes, 2008; Rhodes et al., 1989; Valentine & Bruce, 1986). As such, we predicted that if racial bias in the visual perception of pain stems from differential deployment of configural processing for Black and White faces, then this bias should be observed when participants saw upright morphs of Black and White targets, but that this bias should be attenuated when participants were presented with inverted morphs of Black and White targets. If so, this would provide more compelling evidence that race biases perceptions of pain.

Method

Participants. We recruited 158 White participants through the Amazon website Mechanical Turk (74 male, mean age = 36.39, *SD* = 12.84). Sample size was determined *a priori.* As in Experiments 1 and 2, we aimed to recruit a large enough sample ($N_{overall}$ = 196) in order to yield enough White participants (N = 82) per cell to obtain the necessary power to detect a moderately sized correlation between bias in pain perception and bias in treatment. As in the preceding experiments, we did not apply a demographic constraint to our recruitment on Mechanical Turk, so as not to alert potential participants that our hypotheses were related to race. As a result, an additional 48 non-White participants did take part in the experiment (16 African-American, 13 Asian, 11 Hispanic, 4 Native American, 4 Other) and their data will not be analyzed in the present manuscript. We acquired informed consent from all participants, in accordance with approval from the NYU University Committee on Activities Involving Human

Subjects.

Stimuli and procedure. The procedure for Experiment 3 was identical to Experiment 1, but for two critical differences. First, participants saw morphed images of 5 Black and 5 White male actors (all between the ages of 21 and 34). Second, participants were randomly assigned to either an "Upright" (N = 81) or an "Inverted" (N = 77) version of the task, constituting a 2 (Target race: Black vs. White) × 2 (Presentation orientation: Upright vs. Inverted) mixed factorial design. This manipulation of interest was designed to either conserve (upright) or disrupt (inverted) configural face processing (see Figure 3 for examples). For participants in the "Inverted" condition, targets randomly selected to be presented in the *treatment recommendations* portion of the task were also presented in the inverted orientation. As in Experiments 1 and 2, participants were randomly assigned to a "Forwards" (N = 81) or "Backwards" version (N = 77) of the task.

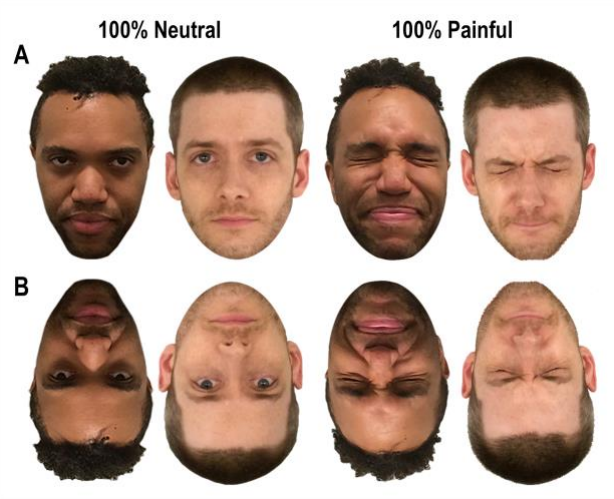

Figure 3. Sample stimuli viewed during the *pain rating phase* in Experiment 3. Participants saw A) upright (top) and B) inverted (bottom) versions of morphs between neutral and painful facial expressions along 11 equidistant points.

Analyses. Analyses for Experiment 3 were patterned off of Experiment 1, with a few key alterations. First, we now conducted a 2 (target race: Black vs. White) × 2 (presentation

orientation: Upright vs. Inverted) × 2 (presentation order: Forward vs. Backward) ANOVA on this rescaled data to assess a) whether the threshold for pain perception varied as a function of target race, b) whether the effect of target race was influenced by disrupting configural face processing, and c) whether the effect of race and the interaction between race and orientation varied as a function of presentation order. Subsequently, we conducted two 2 (target race: Black vs. White) × 2 (presentation orientation: Upright vs. Inverted) ANOVAs to examine the effects of target race and presentation orientation on treatment recommendations and status judgments. Finally, we conducted a one-way ANOVA to examine whether feeling thermometer ratings varied as a function of race.

Next, we conducted a series of multiple regressions to examine the degree to which racial bias in pain perception was associated with racial bias in treatment recommendations. We were primarily concerned with testing this relationship in participants who viewed upright versions of the morphs. The "Upright" condition a) represented the more ecologically valid instantiation of pain recognition and care in our experiment, and further, b) allowed us to assess the replicability of the relationship between bias in perception and treatment observed in the first two experiments. Ultimately, while we were relatively agnostic as to whether the relationship between pain recognition and care would break down when inverted faces were presented, we first formally tested whether the nature of this relationship varied significantly as a function of presentation orientation.

Within participants receiving the "Forwards" version of the task (see Experiment 1 Analyses), we conducted a multiple regression pitting racial bias in pain recognition against racial bias in status judgments (α = .72, averaging across Black and White targets), explicit racial bias, presentation orientation (dummy-coded), and three interaction terms (pain recognition bias

× orientation, status bias × orientation, explicit racial bias × orientation) against each other as competing predictors of racial bias in treatment recommendations. We then ran separate multiple regressions within the "Upright" and "Inverted" conditions (criterion: racial bias in treatment recommendations; predictors: racial bias in pain recognition, racial bias in status judgments, explicit racial bias).

Results

Racial bias in pain recognition. Replicating the results of the first two experiments, we again observed a main effect of target race on participants' threshold for pain perceptions ($F(1,154) = 35.21$, $p < .001$, $\eta_p^2 = .19$). Overall, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.55$, $SD = 0.25$), as compared to White faces ($M = 0.51$, $SD = 0.25$). Moreover, as in Experiments 1 and 2, the effect of race on pain perception was not moderated by presentation order ($F(1,154) = 1.40$, $p = .239$, $\eta_p^2 < .01$).

To test the role of perception in racial bias, we compared upright and inverted faces. As predicted, we observed a significant interaction between target race and presentation orientation ($F(1,154) = 6.91$, $p = .009$, $\eta_p^2 = .04$). Decomposing this two-way interaction suggested that the simple effect of target race was stronger when faces were presented upright ($F(1,80) = 44.51$, $p < .001$, $\eta_p^2 = .36$; $M_{Black} = 0.55$, $SD_{Black} = .26$; $M_{White} = 0.50$, $SD_{White} = 0.27$), than when faces were presented in the inverted orientation ($F(1,76) = 4.82$, $p = .031$, $\eta_p^2 = .06$; $M_{Black} = 0.54$, $SD_{Black} = 0.24$; $M_{White} = 0.52$, $SD_{White} = 0.24$; see Figure 4C and Table 1A), although both conditions revealed evidence of racial bias. Finally, the interaction between race and presentation orientation was not moderated by presentation order (three-way interaction between race, presentation orientation, and presentation order: $F(1,154) = .006$, $p = .940$, $\eta_p^2 < .01$). In other words, disrupting configural face processing dampened racial bias in pain perception.

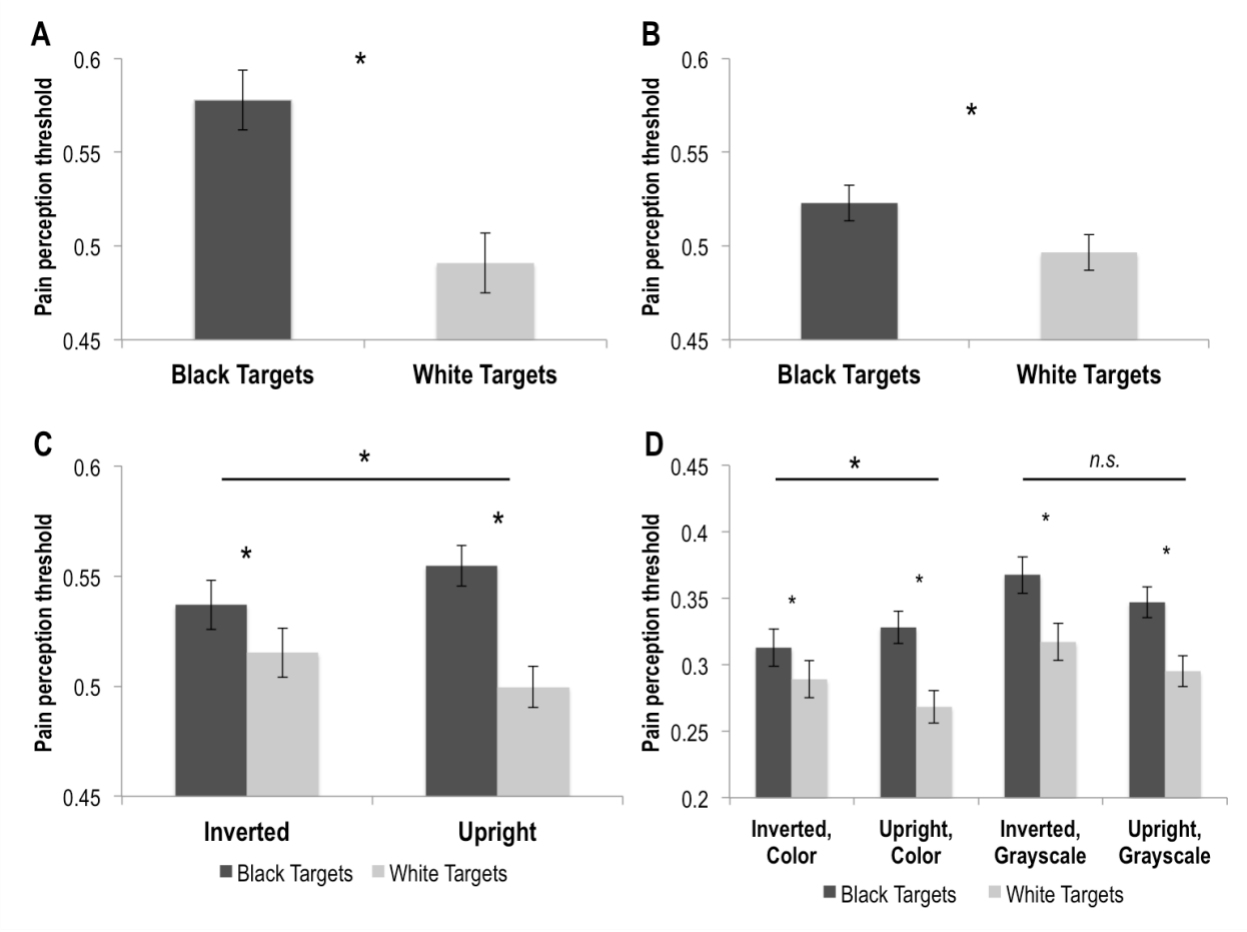

Figure 4. Racial bias in pain recognition. White perceivers showed more stringent thresholds for perceiving pain on Black faces, compared to White faces. This effect was observed for both (A) full-color stimuli in Experiment 1, as well as (B) gray-scale stimuli that had been equated on contrast and luminance in Experiment 2. This bias was diminished when (C) faces were presented in an inverted orientation in Experiment 3, suggesting that racial bias in pain perception stems, at least in part, from a disruption in configural face processing associated with viewing the faces of racial out-group members. This effect was replicated in Experiment 4 (D) with one qualification – while facial inversion diminished the effect of race on pain recognition for faces presented in full-color, this effect did not obtain for contrast- and luminance-matched faces presented in gray-scale. (Note that thresholds for pain perception are considerably lower in Experiment 4 because that experiment only employed the "Forwards" condition.) Error bars represent adjusted 95% within-subject confidence intervals (cf., Morey, 2008); * < .05.

Differences in treatment recommendation, social status, and feeling thermometer ratings as a function of target race and presentation orientation. As in Experiment 2, the main effect of target race on participants' treatment recommendations was not statistically significant

($F(1,135^{7}) = 0.89$, $p = .347$, $\eta_p^2 = .01$). Participants' prescriptions of the analgesic cream were not significantly greater for White targets ($M = 4.17$, $SD = 4.76$) than Black targets ($M = 4.46$, $SD = 4.82$). That being said, we did observe a marginally significant interaction between target race and presentation orientation on participants' treatment recommendations ($F(1,135) = 2.84$, $p = .094$, $\eta_p^2 = .02$). Surprisingly, participants who saw upright faces did not prescribe significantly different amounts of analgesic to Black and White targets ($F(1,68) = 0.23$, $p = .631$, $\eta_p^2 < .01$; $M_{Black} = 4.30$, $SD_{Black} = 5.00$; $M_{White} = 4.54$, $SD_{White} = 4.98$), but participants who saw inverted faces prescribed Black targets significantly more analgesic ($F(1,67) = 4.23$, $p = .044$; $\eta_p^2 = .06$, $M_{Black} = 4.64$, $SD_{Black} = 4.66$; $M_{White} = 3.80$, $SD_{White} = 4.54$; see Table 2A). In other words, Black targets were actually recommended more treatment than their White counterparts when configural face processing was disrupted.

However, replicating Experiments 1 and 2, we observed a main effect of race on judgments of status ($F(1,155) = 82.73$, $p < .001$, $\eta_p^2 = .35$), though the interaction between race and presentation orientation did not reach statistical significance ($F(1,155) = 2.70$, $p = .102$, $\eta_p^2 = .02$). Participants rated the Black target as being significantly lower in status than the White target ($M_{Black} = 3.43$, $SD_{Black} = 0.75$; $M_{White} = 4.32$, $SD_{White} = 0.87$). Similarly, we observed a main effect of race on reported warmth towards Blacks and Whites ($F(1,156) = 17.41$, $p < .001$, $\eta_p^2 = .10$): participants reported feeling less warmly towards Blacks than Whites, overall ($M_{Black} = 64.14$, $SD_{Black} = 22.84$; $M_{White} = 72.32$, $SD_{White} = 19.98$), once again replicating Experiments 1 and 2.

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain recognition would predict racial bias in treatment**,**

[7] The difference in degrees of freedom between sections reflects a number of participants (N = 21) who did not fully complete the *treatment recommendations* task.

particularly within subjects who saw upright versions of morphs. After entering our predictors and interaction terms into a multiple regression predicting bias in treatment recommendations, we observed a marginally significant effect of the interaction between racial bias in pain recognition and presentation orientation (B = 10.32, SE = 5.60, t(73) = 1.84, p = .070). No other predictors were significantly associated with bias in treatment recommendations (ps < .521).

To decompose this marginal interaction, we ran two separate multiple regressions within the "Upright" and "Inverted" conditions. Replicating the results of Experiments 1 and 2, we observed that racial bias in pain recognition for upright "treated" targets was a marginally significant predictor of racial bias in treatment recommendations (B = 9.09, SE = 5.04, t(34) = 1.81, p = .081), when controlling for bias in status judgments and explicit racial bias (zero-order correlation between bias in pain recognition and bias in treatment recommendations, "Upright" condition: r = .338, p = .047; for zero-order correlations between predictors, see Supplementary Tables 1C & 2C). No other predictors were significantly associated with bias in treatment recommendations in the "Upright" condition (ps < .241).

Among participants who saw inverted faces, racial bias in pain recognition for "treated" targets was not associated with racial bias in treatment recommendations (B = -1.96, SE = 3.59, t(38) = -0.55, p = .589; zero-order correlation between bias in pain recognition and bias in treatment recommendations, "Inverted" condition: r = -.084, p = .606; for zero-order correlations between predictors, see Supplementary Tables 1C & 2C). No other predictors were significantly associated with bias in treatment recommendations in the "Inverted" condition (ps < .503).

Taken together, these findings replicate the results of Experiments 1 and 2, suggesting that racial bias in the threshold for pain perception was associated with bias in subsequent treatment recommendations, independent of explicit stereotypes and prejudice. Although the

interaction between race and presentation orientation was only marginally significant, it appeared that this relationship was only observed in participants for whom configural processing was not disrupted.

Experiment 4

Experiment 3 provided initial confirmation that racial biases in the recognition and treatment of pain do indeed stem, at least in part, from a perceptual source. Combining the logic of Experiments 2 and 3, we assessed whether the inversion effect generalized to gray-scaled, contrast- and luminance-matched stimuli, or if this effect could only be obtained in participants who saw full color stimuli. Finally, we measured participants' endorsement of biological differences between Blacks and Whites, as well participants' subjective evaluations of targets' physical strength in order to see if this variable could account for racial bias in the perception and treatment of pain. We also sought to replicate the inversion effect with a substantially larger sample to ensure the influence of perception was robust and generate a more precise estimate of effects.

Method

Participants. We recruited 307 White participants through the Amazon website Mechanical Turk (150 male, mean age = 37.28, SD = 12.88). Sample size was determined *a priori* based as in Experiments 1 through 3 – we aimed to recruit a large enough sample ($N_{overall}$ = 328) in order to yield enough White participants (N = 82) per cell to obtain the necessary power to detect a moderately sized correlation between bias in pain perception and bias in treatment. As in the preceding experiments, we did not apply a demographic constraint to our recruitment on Mechanical Turk, so as not to alert potential participants that our hypotheses were related to race. As a result, 110 additional non-White participants did take part in the experiment

(40 African-American, 30 Asian, 31 Hispanic, 4 Native American, 5 Other) and their data will not be analyzed in the present manuscript. We acquired informed consent from all participants, in accordance with approval from the NYU University Committee on Activities Involving Human Subjects.

Stimuli and procedure. The procedure for Experiment 4 was adapted from Experiment 3, with five critical differences. First, participants saw morphed images of 5 Black and 5 White male actors (all between the ages of 21 and 34). Second, we manipulated *both* presentation orientation and stimulus color between subjects, and randomly assigned participants to each of the four possible conditions of the experiment: 72 participants saw upright color images, 76 participants saw inverted color images, 72 participants saw upright gray-scaled images, and 87 participants saw inverted gray-scaled images. (For images depicted in gray-scale, we used the SHINE Toolbox (Willenbockel et al., 2010) to equate image contrast and luminance across the full set of 110 images (10 actors × 11 morphs per set), and in particular, between stimuli depicting Black and White actors.) Ultimately, Experiment 4 constituted a 2 (Target race: Black vs. White) × 2 (Presentation orientation: Upright vs. Inverted) × 2 (Stimulus coloring: color vs. gray-scale) mixed factorial design. Third, having established that racial bias in pain perception was robust to presentation order in the first three experiments, we employed only the "Forwards" task version in Experiment 4, in order to maximize power necessary to observe the relationship between bias in pain perception and bias in treatment recommendations. Fourth, within the *social evaluations* following the *treatment recommendations*, we embedded one additional evaluation of interest – an item related to the targets' strength (*"How strong do you think this person is?"*) Recent work suggests that people may perceive young Black men as being more physically formidable than their White counterparts (Wilson et al., 2017), a bias which could potentially

influence pain perception and judgments of pain tolerance. We subtracted participants' ratings of the White target's strength from their ratings of the Black target's strength to create a measure of bias in strength judgments (M = 0.67; SD = 1.36).

Finally, similar to Experiment 2, we once again asked participants to report on their endorsement of biological differences between Blacks and White (adapted from materials reported in Hoffman et al., 2016). On average, participants endorsed a little more than two out of the eleven possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true (M = 2.18, SD = 2.71). This level of endorsement was significantly different from 0 in a one-sample t-test ($t(306) = 14.10$, $p < .001$).

Analyses. Analyses for Experiment 4 were patterned off of Experiment 3, with a few key alterations. First, we now conducted a 2 (target race: Black vs. White) × 2 (presentation orientation: Upright vs. Inverted) × 2 (hue: Color vs. Gray-scale) ANOVA on this rescaled data to assess a) whether the threshold for pain perception varied as a function of target race, b) whether the effect of target race was influenced by disrupting configural face processing, and c) whether the effect of race and the interaction between race and orientation varied as a function of hue. Subsequently, we conducted three 2 (target race: Black vs. White) × 2 (presentation orientation: Upright vs. Inverted) × 2 (hue: Color vs. Gray-scale) ANOVAs to examine the effects of target race, presentation orientation, and hue on treatment recommendations, status judgments, and strength judgments. Finally, we conducted a one-way ANOVA to examine whether feeling thermometer ratings varied as a function of race.

Finally, we tested whether racial bias in pain recognition was associated with biased treatment recommendations (over and above the influence of explicit stereotypes and prejudices), and whether this relationship varied as a function of presentation orientation. First, we conducted

a multiple regression pitting racial bias in pain recognition against racial bias in status judgments (α = .58, averaging across Black and White targets), racial bias in strength judgments, explicit racial bias, false beliefs concerning biological differences between Blacks and Whites, presentation orientation (dummy-coded), and four interaction terms (pain recognition bias × orientation, status bias × orientation, strength bias × orientation, explicit racial bias × orientation, false beliefs × orientation) against each other as competing predictors of racial bias in treatment recommendations. Subsequently, we ran separate multiple regressions within the "Upright" and "Inverted" conditions (criterion: racial bias in treatment recommendations; predictors: racial bias in pain recognition, racial bias in status judgments, racial bias in strength judgments, explicit racial bias, false beliefs concerning biological differences between Blacks and Whites).

Results

Racial bias in pain recognition. Replicating the results of the first three experiments, we once again observed a main effect of target race on participants' threshold for pain perceptions ($F(1,303) = 95.06$, $p < .001$, $\eta_p^2 = .24$). Overall, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.34$[8], $SD = .17$), as compared to White faces ($M = 0.29$, $SD = .17$). This pattern of perceptual bias appears highly replicable in this sample.

Replicating Experiment 3, we observed a significant interaction between target race and presentation orientation ($F(1,303) = 3.93$, $p = .048$, $\eta_p^2 = .01$), as well as a marginal three-way interaction between target race, stimulus color, and presentation orientation ($F(1,303) = 3.28$, $p = .071$, $\eta_p^2 = .01$). We set out to decompose the three-way interaction, first assessing the two-way interaction between target race and presentation orientation at either level of stimulus color.

[8] Note that the marked difference in pain perception threshold values is due to the fact that Experiment 4 only employed the "Forwards" version of the task. For additional comparison between versions, see the section titled *Meta-Analyses Across Experiments 1-7.*

For participants who saw gray-scale images in the morph task, the interaction between target race and presentation orientation was not significant ($F(1,157) = 0.15$, $p = .902$, $\eta_p^2 < .01$), though the main effect of target race was ($F(1,157) = 57.76$, $p < .001$, $\eta_p^2 = .27$). Collapsing across presentation orientation, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.36$, $SD = .18$), as compared to White faces ($M = 0.31$, $SD = .17$). This replicates the pattern of racial bias in pain perception observed in Experiment 2.

In contrast, for participants who saw full color images in the morph task, the interaction between target race and presentation orientation *was* statistically significant ($F(1,146) = 7.21$, $p = .008$, $\eta_p^2 = .05$), as was the main effect of target race ($F(1,146) = 38.48$, $p < .001$, $\eta_p^2 = .21$). Collapsing across presentation orientation, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.32$, $SD = .17$), as compared to White faces ($M = 0.28$, $SD = .16$). Finally, replicating the results of Experiment 3, the simple effect of target race was stronger when full color faces were presented upright ($F(1,71) = 45.89$, $p < .001$, $\eta_p^2 = .39$; $M_{Black} = 0.33$, $SD_{Black} = .15$; $M_{White} = 0.27$, $SD_{White} = 0.14$), than when full color faces were presented in the inverted orientation ($F(1,75) = 5.51$, $p = .022$, $\eta_p^2 = .07$; $M_{Black} = 0.31$, $SD_{Black} = 0.19$; $M_{White} = 0.29$, $SD_{White} = 0.18$; see Figure 4D & Table 1A). Thus, the dampening effect of face inversion on racial bias in pain perception was larger for the color faces. Taken together, these results suggested that disrupting configural face processing diminished racial bias in pain perception for color faces, while gray-scaled images might represent a boundary condition for the effect of inversion on pain perception.

Differences in treatment recommendation, status and strength perceptions, and feeling thermometer ratings as a function of target race and presentation orientation. While we initially predicted that race would bias participants' treatment recommendations, the main effect

of target race on participants' treatment recommendations was not statistically significant ($F(1,303) = 0.65$, $p = .419$, $\eta_p^2 < .01$), as in Experiments 2 and 3. Collapsing across presentation orientation and hue, participants' prescriptions of the analgesic cream did not differ between Black targets ($M = 5.19$, $SD = 4.88$) and White targets ($M = 5.33$, $SD = 5.06$).

However, we found a significant interaction between target race and presentation orientation ($F(1, 303) = 6.41$, $p = .012$, $\eta_p^2 = .02$). We observed a main effect of target race when on participants' treatment recommendations when targets were presented upright ($F(1, 143) = 4.51$, $p = .036$, $\eta_p^2 = .03$). In particular, participants who saw upright targets prescribed more analgesic cream to White targets ($M = 5.85$, $SD = 5.37$), as compared to Black targets ($M = 5.18$, $SD = 4.92$; see Table 2A). When targets were presented in the inverted orientation, there was no main effect of target race ($F(1, 162) = 1.54$, $p = .216$, $\eta_p^2 = .01$). In other words, disrupting configural face processing influenced participants' subsequent treatment recommendations. Notably, this pattern of data coheres with the results of Experiment 3, to a certain extent – in both cases, Black targets fared better in the "Inverted" condition, though the nature of the race-by-orientation interaction varied across the two experiments.

Replicating the results of the first three experiments, we also observed a main effect of target race on judgments of status ($F(1 ,303) = 131.78$, $p < .001$, $\eta_p^2 = .30$), such that participants rated the Black target as being significantly lower in social status than the White target ($M_{Black} = 3.36$, $SD_{Black} = 0.76$; $M_{White} = 4.19$, $SD_{White} = 0.87$), collapsing across hue and presentation orientation. However, the effect of target race did not interact with hue or orientation on judgments of status (ps > .517). Likewise, we observed a main effect of target race on reported warmth towards Blacks and Whites ($F(1, 303) = 21.09$, $p < .001$, $\eta_p^2 = .07$), such that collapsing across hue and presentation orientation, participants reported feeling less warmly towards Blacks

than Whites, overall (M_{Black} = 66.90, SD_{Black} = 26.35; M_{White} = 73.42, SD_{White} = 22.25).

Finally, we predicted that participants would rate Black targets as being stronger than White targets. Examining the new item we embedded in our list of social evaluations, we observed a main effect of target race on perceptions of target strength (F(1, 303) = 74.80, p < .001, η_p^2 = .20), such that collapsing across hue and presentation orientation, participants reported that the Black targets were stronger than the White targets (M_{Black} = 4.78, SD_{Black} = 1.09; M_{White} = 4.11, SD_{White} = 1.13). We also observed a marginally significant interaction between target race and hue (F(1, 303) = 3.45, p = .064, η_p^2 = .01). Specifically, while participants who saw color images perceived the Black targets to be stronger than their White counterparts (F(1,158) = 48.63, p < .001, η_p^2 = .15; M_{Black} = 4.64, SD_{Black} = 1.11; M_{White} = 4.11, SD_{White} = 1.11), this effect was somewhat larger among participants who saw gray-scale images (F(1, 147) = 26.09, p < .001, η_p^2 = .24; M_{Black} = 4.92, SD_{Black} = 1.06; M_{White} = 4.12, SD_{White} = 1.14). Taken together, these results suggest that participants did indeed judge the Black targets to be stronger than their White counterparts, and that this effect was somewhat amplified by the gray-scale presentation format.

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain recognition would predict racial bias in treatment. While we were once again primarily concerned with testing this relationship in the "Upright" condition, given the result observed in Experiment 3, we began by testing for an interactive effect of racial bias in pain recognition and presentation orientation on bias in treatment recommendations. However, this effect did not reach statistical significance (B = 2.14, SE = 1.76, t(306) = 1.21, p = .226). In addition, we did observe a marginally significant interaction between number of false beliefs endorsed and presentation orientation (B = 0.22, SE = 0.13, t(306) = 1.76, p = .080), and a

significant effect of the interaction between racial bias in strength judgments and presentation orientation (B = 0.63, SE = .29, t(306) = 2.15, p = .032). No other predictors were significantly associated with bias in treatment recommendations (ps > .180).

Moving forward, we ran two separate multiple regressions within the "Upright" and "Inverted" conditions, in order to test whether the general pattern of results in Experiment 3 could be replicated. These analyses collapsed across both participants who saw full color images and those who saw gray-scale images. Within the "Upright" condition, we replicated the results of the first three experiments, observing that racial bias in pain recognition for the "treated" targets was positively associated with racial bias in treatment recommendations (B = 3.85, SE = 1.50, t(143) = 2.57, p = .011), when controlling for bias in judgments of social status, explicit racial bias, false beliefs regarding biological differences between Blacks and Whites, and bias in judgments of strength (zero-order correlation between bias in pain recognition and bias in treatment recommendations, "Upright" condition: r = .199, p = .017; for zero-order correlations between all predictors, see Supplementary Tables 1D & 2D). Bias in strength judgments was also a significant predictor of racial bias in treatment recommendations, controlling for the other predictors (B = 0.55, SE = 0.23, t(143) = 2.40, p = .018), such that the extent to which participants viewed "treated" Black targets as being stronger than "treated" White targets predicted participants' likelihood to recommend prescribing more analgesic cream to White targets than Black targets. Notably, it seems that judgments of strength had an independent effect from perceptions of pain on treatment recommendations.

However, within participants who saw inverted faces, racial bias in pain recognition for "treated" targets did not predict racial bias in treatment recommendations (B = 1.44, SE = 1.04, t(162) = 1.38, p = .169; zero-order correlation between bias in pain recognition and bias in

treatment recommendations, "Inverted" condition: $r = .130$, $p = .098$). No other predictors were significantly associated with bias in treatment recommendations in the "Inverted" condition (ps > .156).

These results provide an additional replication of the pattern observed across the first three experiments: for upright faces, racial bias in pain perception was associated with subsequent bias in treatment recommendations, and this relationship was independent of the influence of explicit stereotypes and prejudices. However, while the interaction between race and presentation orientation was not statistically significant, this relationship was only observed in participants for whom configural processing was not disrupted.

Interim Discussion

Taken together, Experiments 1 through 4 consistently demonstrate that White perceivers display different thresholds for recognizing expressions of pain on Black and White faces. Consistent with a wide body of literature characterizing racial disparities in pain care, these biases in pain perception were associated with divergent patterns of treatment recommendations. However, as we noted in Experiment 1, clear interpretations of these data depends on our ability to have balanced Black and White stimuli based on their facial structure and, more importantly, the intensity of their painful expressions. If, for example, the Black actors in our stimulus set were less expressive than their White counterparts, this would introduce a confound that could potentially account for the difference in thresholds for Black and White expressions of pain. Race-based differences in judgments of the actors' strength, status, or masculinity might also exert unwanted influence on thresholds for pain perception. That said, we note that such confounds would not have any bearing on the inversion effects observed in Experiments 3 and 4. Nevertheless, we took further steps to control for any such differences – first, based on

subjective social judgments of our stimuli (Experiments 5 and 6), and by using new stimuli that were objectively equated in terms of facial structure and expression intensity (Experiment 7). Together, these experiments provided a stronger test of our central hypotheses.

Experiment 5

In Experiment 5, we examined racial bias in pain perception using a set of stimuli that had been subjectively equated on factors related to pain expression and tolerance. Specifically, we characterized our stimuli in terms of expression intensity, believability, and discriminability from other emotional expressions, as well as demographic and social factors like masculinity, status, strength, and dominance, and then selected a subset of targets that were balanced across these subjective ratings. If White perceivers *do* indeed have more stringent thresholds for perceiving pain on Black faces compared to White faces, then this represents a particularly conservative approach. Consider an expression of pain on a Black face that is judged to be comparable to an expression of pain on a White face. Given our hypotheses, the subjective rating of the Black target is likely an underestimation of that individual's pain. Therefore, by balancing our Black and White stimuli in this manner, we are essentially stacking the deck against the effect we previously observed.

Additionally, we adjusted our measure of treatment recommendations. While racial bias in pain perception consistently predicted racial bias in treatment recommendations in Experiments 1 through 4, the treatment measure was always framed in terms of *memory* for targets' expressions, rather than perception of those expressions themselves. In the real world, medical practitioners are usually required to make medication decisions based on their assessments of pain in the moment—rather than drawing from memory. To provide a more valid test of the relationship between perceptions and treatment decisions, Experiment 5 required

participants to make treatment recommendations directly for faces making ambiguously painful expressions. Based on the Perceptual Model of Intergroup Relations, biases should alter perceptions and behavior when visual input in ambiguous (see Xiao et al., 2016). Taken together, Experiment 5 represents both an especially conservative test of racial bias in pain perception, as well as a more direct assessment of the relationship between that bias in perception and subsequent biases in treatment.

Methods

Participants. We recruited 129 White participants through Amazon's Mechanical Turk (70 female, mean age = 36.03, *SD* = 10.60). We revised our sample size upwards based on the results of Experiments 1 through 4. Specifically, having established the average strength of the relationship between racial biases in pain perception and treatment (r = .250 within upright presentations in the "Forwards" version in Experiments 1-4, see Supplementary Materials), we aimed for a large enough sample size (N = 120) afford us appropriate statistical power (e.g., 80%). As in previous experiments, we did not apply a demographic constraint to our recruitment and an additional 61 non-White participants took part in the experiment (18 African-American, 22 Asian, 17 Hispanic, 4 Other). Their data will not be analyzed in the present manuscript.

Initial stimulus selection. We selected eight Black and eight White targets, which did not differ significantly in terms of pilot ratings related to attributions of pain tolerance and pain experience. Pilot ratings of neutral faces were obtained by recruiting 269 participants (130 female; mean age = 34.41, *SD* = 10.65; 194 White) from Amazon's Mechanical Turk, who rated selections from our stimulus set in terms of social, emotional, and demographic characteristics. (For additional details on the pilot sample, procedure, and results, see Supplementary Materials.) Selected targets' neutral faces did not differ on ratings of masculinity ($t(14) = -0.42$, $p = .683$),

trustworthiness ($t(14) = -1.02$, $p = .326$), dominance ($t(14) = -0.48$, $p = .642$), attractiveness ($t(14) = -1.13$, $p = .276$), unusualness ($t(14) = -0.67$, $p = .513$), strength ($t(14) = -1.41$, $p = .181$), high status ($t(14) = 0.74$, $p = .473$), low status ($t(14) = -0.85$, $p = .409$), competence ($t(14) = -0.30$, $p = .767$), intelligence ($t(14) = -0.29$, $p = .780$), resting physical pain ($t(14) = 0.49$, $p = .630$), resting disgust ($t(14) = 1.04$, $p = .314$), and resting anger ($t(14) = 0.85$, $p = .408$), or perceived age ($t(14) = 0.82$, $p = .429$) as a function of race. Moreover, these targets' painful expressions did not differ on ratings of pain intensity ($t(14) = 1.06$, $p = .309$), disgust intensity ($t(14) = 1.38$, $p = .190$), anger intensity ($t(14) = -0.13$, $p = .896$), expression believability ($t(14) = -0.56$, $p = .582$), or expression genuineness ($t(14) = 0.98$, $p = .345$), as a function of race. (A complete breakdown of all stimulus comparisons on these and additional dimensions can be accessed online.)

We also obtained a separate set of pilot ratings of all painful expressions in our broader stimulus set. We recruited 407 participants (223 female; mean age = 35.41, *SD* = 12.99; 289 White) from Amazon's Mechanical Turk, who rated selections from our broader stimulus set in terms of their emotional characteristics (see Supplementary Materials for full details). The 16 painful expressions we selected were also easily recognizable as conveying pain. With regards to the emotion resemblance ratings of these expressions (e.g., "How much does this face look like it's in physical pain?", "How angry does this face look?", etc.), each expression we chose was rated as most strongly resembling physical pain, rather than any other emotion (e.g., anger, fear, surprise, etc.). The selected expressions' pain intensity ratings were also significantly higher than the next highest emotion intensity ratings, both across race ($t(15) = 9.60$, $p < .001$), and within Black ($t(7) = 8.03$, $p < .001$) and White stimuli ($t(7) = 5.65$, $p = .001$). Specificity of pain categorization (e.g., pain intensity rating minus the next highest emotion intensity rating) did not

vary between Black and White stimuli ($t(14) = 0.80$, $p = .437$). This provides evidence of discriminant validity—ensuring that our stimuli captured the precise expression of pain.

Procedure. Participants in Experiment 5 first saw and rated full-color morphed images of eight Black and eight White male actors (all between the ages of 18 and 34), in a *pain rating phase* identical to those in the first four experiments. Black and White actors were matched based on ratings of neutral and painful expressions, as described above. Next, in a departure from Experiments 1 through 4, participants saw *ambiguously* painful expressions (e.g., 50% neutral/50% painful morphs) from two Black and two White targets from the *pain rating phase*, (presented on separate screens, with presentation order randomly counterbalanced) in the *treatment recommendations* task. Participants were asked *"Based on the expression of pain you see from the individual above, how many grams of the experimental analgesic cream should they be given?"* Target selection was randomized across subjects within Black and White targets. In response to each of these four ambiguous displays of pain, participants determined how much of the non-narcotic, experimental analgesic cream each should be prescribed, on a scale of 0g to 20g. By having participants make treatment recommendations for targets who are visibly displaying painful expressions, we can more directly relate racial biases in pain perception to racial biases in pain care.

Following these *treatment recommendations*, participants once again made a series of social evaluations of the same four targets, including status (adapted from Trawalter et al., 2012; $\alpha = .60$, averaging across Black and White targets) and strength. We used these evaluations to calculate participants' racial bias in status judgments ($M = 1.03$, $SD = 1.19$) and strength judgments ($M = 0.62$, $SD = 1.02$). Finally, participants completed a series of demographic questions, including the same feeling thermometer measure that we previously used as a proxy

for explicit racial bias (M = 8.62, SD = 28.26), and the measure of participants' endorsement of biological differences between Blacks and White (adapted from materials reported in Hoffman et al., 2016). On average, participants endorsed 2.91 (SD = 3.05) out of the eleven possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true, on average. This level of endorsement was significantly different from 0 in a one-sample t-test ($t(128) = 10.82$, $p < .001$)[9].

Analyses. First, we calculated average thresholds for Black and White targets in the *pain rating phase*, and then rescaled this data from an 11-point scale (representing the point at which participants began to recognize pain on faces) to a 0-to-1 scale. Next, we conducted a one-way ANOVA on this rescaled data to assess whether the threshold for pain perception varied as a function of target race. Subsequently, we conducted a series of one-way ANOVAs to examine whether race had an impact on treatment recommendations, status judgments, strength judgments, and feeling thermometer ratings.

We then tested whether participants' racial bias in pain recognition was related to their subsequent treatment recommendations for Black versus White targets. Moreover, we examined whether this relationship existed over and above other potential sources of bias stemming from explicit prejudice and stereotypes. Specifically, we conducted a multiple regression pitting 1) racial bias in pain recognition ("Treated" Black threshold – "Treated" White threshold), 2) racial bias in status judgments (White status – Black status), 3) racial bias in strength judgments (White strength – Black strength), 4) explicit racial bias (White feeling thermometer rating – Black feeling thermometer rating), and 5) number of false beliefs endorsed overall against each other as

[9] We also asked participants if they used any particular strategies during the *pain rating phase*. While analyses of these data will not appear in the main text of this manuscript, additional information on this item can be found in Supplementary Materials.

competing predictors of racial bias in treatment recommendations (White prescription – Black prescription).

Results

Racial bias in pain recognition. Our initial hypothesis was that people would perceive pain earlier on White versus Black faces, even though we attempted to carefully control for differences in subjective evaluations of these stimuli. Replicating the previous experiments, we continued to observe a main effect of target race on participants' threshold for pain perceptions ($F(1,128) = 107.06$, $p < .001$, $\eta_p^2 = .46$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.31$, $SD = 0.13$), as compared to White faces ($M = 0.26$, $SD = 0.13$; see Figure 5A and Table 1A). This result replicates the results of Experiments 1 through 4, and extends this work by demonstrating that this bias exists even when stimuli are carefully balanced in terms of pain intensity, specificity, and believability, as well as other potential stimulus confounds.

Differences in treatment recommendation, status & strength judgments, and feeling thermometer ratings as a function of target race. Our second hypothesis was that participants would recommend administering more non-narcotic pain reliever to White versus Black targets – again, using carefully balanced stimuli. As predicted, the main effect of target race on participants' treatment recommendations was statistically significant ($F(1,128) = 4.02$, $p = .047$, $\eta_p^2 = .03$). Participants' prescribed fewer grams of analgesic cream to Black targets ($M = 11.12$, $SD = 5.01$) versus White targets ($M = 11.67$, $SD = 4.72$; see Table 2A[10]). Once again, participants still recommended giving less pain reliever to Black targets than White targets.

[10]We note that treatment recommendation means here are higher overall than in the previous four experiments, due to the adjustment in the framing of this task. Whereas in Experiments 1-4, participants saw neutral faces and were asked to recall how much pain each target appeared to be in during the *pain rating phase*, here, participants saw ambiguously painful expressions and were asked to base their recommendations on those expressions themselves.

Notably, while we attempted to balance stimuli on status and strength, we nevertheless observed main effects of race on judgments of social status ($F(1,128) = 96.01$, $p < .001$; $\eta_p^2 = .43$) and judgments of strength ($F(1,128) = 47.25$, $p < .001$; $\eta_p^2 = .27$). Participants rated the Black targets as being both significantly lower in social status than the White targets ($M_{Black} = 3.35$, $SD_{Black} = 0.74$; $M_{White} = 4.38$, $SD_{White} = 0.77$), and significantly stronger than the White targets ($M_{Black} = 4.72$, $SD_{Black} = 0.89$; $M_{White} = 4.10$, $SD_{White} = 0.95$). This discrepancy may reflect a difference in wordings used in the norming survey and the present experiment. While stimuli were selected and balanced based on ratings that were specific to the targets' faces (e.g., "How strong does this face look?"), participants in the present experiment were making more holistic judgments of these targets (e.g., "How strong do you think this person is?").

Moreover, we continued to observe a robust main effect of race on feeling thermometer ratings ($F(1,128) = 12.00$, $p = .001$, $\eta_p^2 = .09$). Participants reported feeling more warmly to Whites ($M_{White} = 76.35$, $SD_{White} = 23.07$), than Blacks ($M_{Black} = 67.73$, $SD_{Black} = 27.94$).

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain perception would continue to be positively associated with racial bias in treatment. As predicted, comparatively higher thresholds for perceiving pain on Black faces were positively correlated with comparatively less analgesic prescribed to Black targets during the treatment recommendation task ("treated" bias in perception: $r = .294$, $p < .001$). Moreover, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations ($B = 8.04$, $SE = 2.52$, $t(128) = 3.20$, $p = .002$), even after controlling for bias in status and strength judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites in a multiple regression. (For zero-order correlations between all predictors, see Supplementary Table 2E.) No

other predictors were significantly associated with bias in treatment recommendations (*p*s < .139).

These results replicate and extend our initial investigations of the perceptual contributions to racial bias in pain care. Despite this particularly conservative test of our hypotheses, racial bias in pain perception continued to predict racial bias in treatment recommendations (above and beyond explicit prejudice and stereotypes), even when stimuli were balanced in terms of pain intensity, specificity, and believability, among other possible confounding factors.

Experiment 6

Next, we attempted to replicate the results of Experiment 5 with an entirely new set of balanced stimuli. This allowed us to assess the generalizability of the Experiment 5 results, while still offering a conservative test of our hypotheses. In addition, we addressed the possibility that race-based differences in status and strength judgments in Experiment 5 stemmed from the wording of our social evaluation items. Specifically, we changed this wording to better match the items used to balance these stimuli.

Methods

Participants. We recruited 117 White participants through Amazon's Mechanical Turk (88 female, 2 transgender; mean age = 35.07, *SD* = 11.12). As in Experiment 5, we aimed for a large enough sample size (N = 120) afford us appropriate statistical power (e.g., 80%) to detect the established relationship between racial biases in pain perception and treatment (*r* = .250 in Experiments 1-4). Once again, we did not apply a demographic constraint to our recruitment and an additional 52 non-White participants took part in the experiment (14 African-American, 17 Asian, 18 Hispanic, 3 Other). Their data will not be analyzed in the present manuscript.

Procedure. The procedure for Experiment 6 was identical to Experiment 5, with several minor adjustments. We selected sixteen new[11] sets of morphs (eight Black targets and eight White targets; for full details). As in Experiment 5, these targets were once again selected such that Black and White targets did not differ significantly on pilot ratings related to attributions of pain tolerance and pain experience collected for both neutral (N = 269) and painful expressions (N = 407). (For details on pilot sample, procedure, and results, see Supplementary Materials.) Specifically, these targets' neutral faces did not differ on ratings of masculinity ($t(14) = -0.44$, $p = .670$), femininity ($t(14) = -1.36$, $p = .196$), trustworthiness ($t(14) = -0.68$, $p = .509$), dominance ($t(14) = -0.29$, $p = .776$), unusualness ($t(14) = 0.17$, $p = .868$), attractiveness ($t(14) = -.82$, $p = .429$), strength ($t(14) = -1.07$, $p = .305$), high status ($t(14) = 1.46$, $p = .165$), low status ($t(14) = -0.75$, $p = .469$), competence ($t(14) = -0.03$, $p = .974$), intelligence ($t(14) = 0.34$, $p = .739$), resting physical pain ($t(14) = -.04$, $p = .970$), resting disgust ($t(14) = 0.15$, $p = .887$), resting anger ($t(14) = 1.01$, $p = .332$), or perceived age ($t(14) = 1.72$, $p = .107$) as a function of race. Moreover, these targets' painful expressions did not differ on ratings of pain intensity ($t(14) = 0.23$, $p = .820$), disgust intensity ($t(14) = -0.04$, $p = .966$), anger intensity ($t(14) = -0.07$, $p = .949$), expression believability ($t(14) = 0.22$, $p = .831$), or expression genuineness ($t(14) = -0.28$, $p = .785$) as a function of race.

As in Experiment 5, we made sure that the 16 painful expressions we selected were also easily recognizable as conveying pain. Each expression we chose was rated highest in terms of physical pain (e.g., "How much does this face look like it's in physical pain?"), more so than any other emotion (e.g., anger, fear, surprise, etc.). The selected expressions' pain intensity ratings were also significantly higher than the next highest emotion intensity ratings, both across race

[11]Some actors appear in the stimulus sets from both Experiments 5 and 6, making different painful expressions in either experiment. While our ultimate intention was to create an *entirely* new stimulus set, unfortunately, one White male stimulus (NYU23) appeared in both sets making the same expression, due to a miscommunication.

($t(15) = 6.80$, $p < .001$), and within Black ($t(7) = 5.08$, $p = .001$) and White stimuli ($t(7) = 4.29$, $p = .004$). Specificity of pain categorization (e.g., pain intensity rating minus the next highest emotion intensity rating) did not vary between Black and White stimuli ($t(14) = 0.09$, $p = .928$). Demographic information concerning the norming sample can be found above in Supplementary Materials.

Aside from using a different set of stimuli in Experiment 6, we also changed the phrasing of the social evaluation items presented following the treatment recommendations portion of the task. Whereas previous versions of these social evaluations asked participants to consider the targets holistically (e.g., "How strong do you think this person is?"), items in the current task were framed in reference to each target's face specifically (e.g., "How strong does this face look?"). This new wording better reflects the rating items upon which these stimuli were initially balanced.

Judgments of high- and low-status were positively related to each other ($\alpha = .87$, averaging across Black and White targets), so we reverse-scored the low-status judgments, created composite status measures for Black and White targets, and subtracted judgments of Black status from White status to arrive at a measure of racial bias in status judgments ($M = 0.49$, $SD = 1.04$). We also calculated each participant's racial bias in strength judgments ($M = 0.38$, $SD = 1.25$) and explicit racial bias ($M = 5.56$, $SD = 27.33$). Participants once again completed the false beliefs measure and endorsed 2.50 ($SD = 3.08$) of the eleven possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true, on average (significantly different from 0 in a one-sample *t*-test; $t(116) = 8.81$, $p < .001$).

Analyses. Analyses for Experiment 6 were essentially identical to Experiment 5.

Results

Racial bias in pain recognition. As in Experiment 5, we hypothesized that participants would have lower thresholds for perceiving pain on White versus Black faces. Indeed, we observed a main effect of target race on participants' threshold for pain perceptions ($F(1,116) = 17.00$, $p < .001$, $\eta_p^2 = .13$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.31$, $SD = 0.11$), as compared to White faces ($M = 0.29$, $SD = 0.13$; see Figure 5B and Table 1A). This result replicated all our previous experiments – robust racial bias in pain perception, even when ecologically valid stimuli were rigorously balanced – and demonstrated the generalizability of this effect within an entirely new set of stimuli.

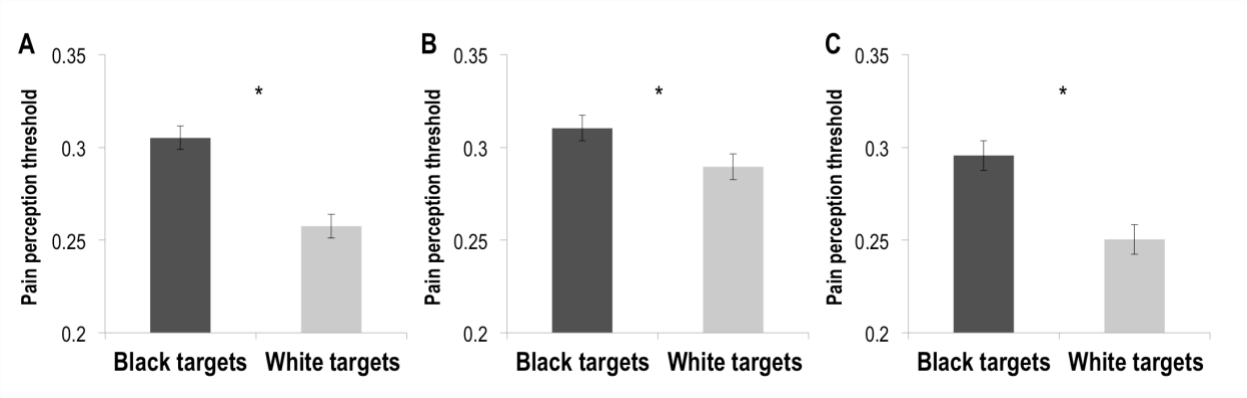

Figure 5. Racial bias in pain recognition, independent of potential stimulus confounds. White perceivers continued to display more stringent thresholds for perceiving pain on Black faces, compared to White faces. This effect was observed even when stimuli were thoroughly balanced based on pilot ratings of social judgments related to pain tolerance (e.g., dominance, masculinity, strength, etc.) and experience (e.g., pain intensity and believability) in both Experiments 5 (A) and 6 (B). This bias was still observed in Experiment 7, in which we presented participants with computer generated stimuli that were objectively identical in terms of facial structure and expression (C), save for the manipulation of race via skin tone.

Differences in treatment recommendation, status & strength judgments, and feeling thermometer ratings as a function of target race. Second, we hypothesized that, as in Experiment 5, participants would administer more non-narcotic pain reliever to White versus Black targets. However, the main effect of target race on participants' treatment recommendations was not statistically significant ($F(1,116) = 0.39$, $p = .534$, $\eta_p^2 < .01$).

Participants' prescriptions of analgesic cream did not differ between Black targets (M = 11.59, SD = 5.27) and White targets (M = 11.37, SD = 4.91; see Table 2A).

In light of our adjustments to the social evaluations of status, we did *not* observe main effects of race on judgments of social status ($F(1,116) = 0.26$, $p = .611$; $\eta_p^2 < .01$). Participants' ratings of Black targets' social status (M = 3.90, SD = 0.86) did not differ from ratings of White targets' social status (M = 3.95, SD = 0.80). This pattern did not differ between judgments of high or low social status.

However, despite the adjustment to the strength measure, we still observed a main effect of race on judgments of strength ($F(1,115$[12]$) = 10.40$, $p = .002$; $\eta_p^2 = .08$). Participants still rated Black targets as being stronger, on average (M = 4.32, SD = 1.07), than White targets (M = 3.94, SD = 1.06). Taken together, these data suggest that difference in question wording between Experiments 5 and 6 (e.g., holistic vs. face-specific) had an influence on social evaluations – particularly on judgments of status. Black and White stimuli in Experiment 2 did not differ significantly in terms of judgments of high or low status, mirroring the norming data they were initially balanced on. However, despite this balancing effort, differences in strength judgments persisted – though the size of this effect appeared to be smaller in Experiment 6, compared to Experiment 5.

Finally, we once again observed a main effect of race on feeling thermometer ratings ($F(1,116) = 4.83$, $p = .030$; $\eta_p^2 = .04$). As in Experiment 5, participants reported feeling more warmly to Whites (M_{White} = 73.35, SD_{White} = 23.99), than Blacks (M_{Black} = 67.79, SD_{Black} = 28.49).

Bias in pain recognition predicts bias in treatment recommendations. Finally, we predicted that racial bias in pain perception would again be associated with racial bias in

[12]The difference in degrees of freedom between the strength comparison and other analyses reflects one participant who did not complete any strength ratings during the social evaluation phase.

treatment. Replicating the results of Experiment 5, comparatively higher thresholds for perceiving pain on Black faces were positively correlated with comparatively less analgesic prescribed to Black targets during the treatment recommendation task (r = .504, p < .001). Moreover, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations (B = 13.06, SE = 2.45, t(115) = 5.34, p < .001), even when controlling for bias in high and low status judgments, strength judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites in a multiple regression. (For zero-order correlations between all predictors, see Supplementary Table 2F. We note that bias in judgments of status was also marginally associated with bias in treatment outcomes, B = -0.52, SE = 0.31, t(115) = -1.70, p = .092, albeit in the negative direction. No other predictors were significantly associated with bias in treatment recommendations; all ps < .205).

These results directly replicate Experiment 5, generalizing its findings to a new set of stimuli: even when taking conservative measures to rule out possible stimulus confounds, racial bias in the threshold for pain perception was still associated with bias in treatment recommendations, independent of explicit stereotypes and prejudice.

Experiment 7

Experiments 5 and 6 suggested that racial bias in the threshold for pain perception persists independent of possible stimulus confounds related to attributions of pain tolerance and pain experience. These data provide additional confidence in the results described in Experiments 1 through 4, and illustrate that the perceptual underpinnings of racial disparities in pain care are particularly robust. Given the similarity to the effect sizes observed in Experiments 5-6, it seems unlikely that systematic differences in our stimuli could explain the effects obtained

in Experiments 1-4. (Moreover, retrospective analysis of the stimuli used in Experiments 1-4 suggests that, for the most part, these sets were also balanced with regards to pain intensity; see Supplementary Materials.) However, despite the lengths we went to in order to balance these sets of stimuli, the images of Black and White faces ultimately come from different actors, and therefore, cannot be *truly* equated in terms of facial structure or expression type.

In order to overcome this hurdle, we created a set of *objectively* balanced stimuli – Black and White faces making *exactly* the same expressions of pain. Specifically, we created a new set of computer-generated faces ranging in their expressions from neutral to painful, and manipulated skin tone while systematically controlling pain intensity, head shape, and skin texture across these stimuli. Therefore, Experiment 7 represents the *most* conservative test we could conceive of our hypotheses, as observation of a bias in the threshold for pain perception in these stimuli could *only* be attributable to race.

Methods

Participants. We recruited 124 White participants through Amazon's Mechanical Turk (75 female, mean age = 35.81, *SD* = 11.22). As in Experiments 5 and 6, we recruited a sample large enough (N = 120) to afford the statistical power (e.g., 80%) necessary to detect the established relationship between racial biases in pain perception and treatment (r = .250 in Experiments 1-4). We did not apply a demographic constraint to our recruitment, and as a result, 47 additional non-White participants did take part in the experiment (11 African-American, 18 Asian, 14 Hispanic, 1 Native American, 3 Other). Their data will not be analyzed in the present manuscript.

Stimuli. First, we created a total of 41 expressions of pain in FaceGen Modeller v3.14 (Singular Inversions, https://facegen.com/modeller.htm; see Figure 6), and recruited a group of

participants from Amazon's Mechanical Turk (81 participants (45 female, mean age = 37.48, *SD* = 11.92) to rate these stimuli in terms of the emotional expressions they most strongly resembled (see Supplementary Materials for full details on the piloting procedure). From this initial set of possible stimuli, we selected eight that were most consistently recognized as pain, while still being visually discernible from each other. (In other words, we aimed for a diverse representation of facial expressions of pain in this final sub-set.) Each expression was rated as resembling physical pain more so than anger (all *p*s < .0031), disgust (all *p*s < .0002), fear (all *p*s < .0001), happiness (all *p*s < .0001), sadness (all *p*s < .0002), surprise (all *p*s < .0001), or threat (all *p*s < .0001). Average ratings across the set suggested that taken together, these eight expressions were clearly recognized as depicting pain (*M* = 5.27, *SD* = 0.32), rather than any other emotion (anger: *M* = 2.53, *SD* = 0.86; disgust: *M* = 2.72, *SD* = 0.35; fear: *M* = 2.27, *SD* = 0.32; happiness: *M* = 1.32, *SD* = 0.18; sadness: *M* = 2.29, *SD* = 0.47; surprise: *M* = 1.87, *SD* = 0.31; threat: *M* = 2.08, *SD* = 0.57).

Our next step was to create eight individual identities in FaceGen that would be distinguishable from one another and that could be manipulated to appear Black or White. We created eight such "heads," whose structural components varied minimally so as not to contain more Eurocentric or Afrocentric features. Next, while holding structure constant, we manipulated skin-tone to make Black and White versions of each head. To further enhance the distinctiveness of each face, we applied skin textures to each head that come pre-loaded in FaceGen. (See Figure 6A for examples of each expression.)

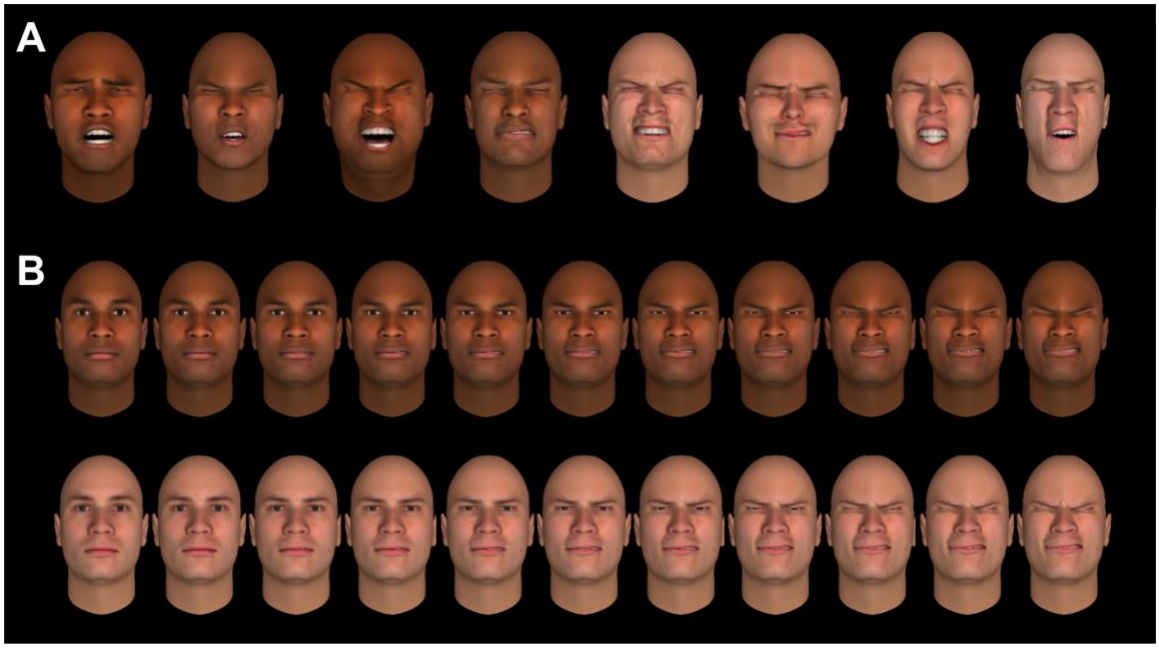

Figure 6. Sample stimuli, Experiment 7. A) Eight facial expressions of pain, chosen based on normed ratings of resemblance to physical pain versus other emotions. Each expression appears on a different "head" identity, with a different skin texture. Within each version of the task, each expression was made by one Black target and one White target. Stimuli do not have hair or other features that might be cues to race, and moreover, pairings of expression, head, race, and texture were partially counterbalanced across participants. B) Participants saw morphs between neutral and painful facial expressions along 11 equidistant points. The Black and White targets pictured in B are making the same facial expression of pain.

Procedure. Participants in Experiment 3 first saw morphed images of eight Black and eight White male targets. For each target, we constructed 11 morphs. For the sake of precision, we chose not to use morphing software (as we did in Experiments 1-6), but rather, created incremental versions of each target using FaceGen sliders, ranging from a 100% neutral expression to a 100% painful expression (see Figure 6B for example stimuli). Each final slider value was divided by 11, so that a slider with a final value of 1 would be set to 0 in the first morph, .09 in the second, .18 in the third, and so on.

To ensure that our results were independent of the influence of the other features of our stimuli, we partially counterbalanced race, expression, head shape, and texture across four separate versions of the task. Within each version, each expression appeared on different White and Black heads, with different skin textures. (Within each version, each texture also appeared

on different White and Black heads.) Across versions, each expression appeared on every possible head, and with every possible texture.

We adjusted the instructions of the *pain rating phase* in Experiment 7 to explain the use of the FaceGen stimuli. Specifically, we included the following text:

"In a moment, you'll be seeing computer-rendered versions of actual subjects who participated in a laboratory study we conducted in which participants received painful burning stimulations on their forearms, delivered via a device called a thermode. Subjects were video-recorded during these previous sessions, and these images were then digitally rendered using the program FaceGen. (We decided to take this additional step to maintain subjects' confidentiality and privacy.)"

Elsewhere in the instructions, we referred to "digitally-rendered faces," where previous versions of the instructions had simply referred to "faces."

Subsequent to the *pain rating phase*, participants once again made treatment recommendations for a random sub-set of Black and White faces making pain expressions of ambiguous intensity, and then made social evaluations of these targets including status (measured as in Experiment 5; $\alpha = .80$, averaging across Black and White targets; $MD = 0.40$, $SD = 1.04$) and strength ($MD = 0.25$, $SD = 1.14$). Participants also completed feeling thermometers, from which we calculated their explicit racial bias ($M = -0.25$, $SD = 20.71$). Finally, participants again completed the false beliefs measure and endorsed 2.19 ($SD = 2.68$) of the eleven possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true, on average (significantly different from 0 in a one-sample *t*-test; $t(123) = 9.07$, $p < .001$).

Results

Racial bias in pain recognition. First, we hypothesized that participants would once again perceive pain earlier on White versus Black faces. As predicted, we once again observed a main effect of target race on participants' threshold for pain perceptions ($F(1,123) = 60.67$, $p < .001$, $\eta_p^2 = .33$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.296$, $SD = 0.163$), as compared to White faces ($M = 0.250$, $SD = 0.150$; Figure 5C & Table 1A). This result replicates and further extends the pattern observed in Experiments 5 and 6, suggesting that such a bias exists even when the intensity of pain expressions is completely equated across stimuli.

Moreover, we note that taken together with the previous two experiments (Experiments 5 and 6), there does not seem to be any evidence that a lack of stimulus balance led to an inflation of the size of this particular effect in Experiments 1-4. Specifically, the average effect size (weighted by sample size) is not appreciably different in Experiments 1-4 ($\eta_p^2 = .327$; within Upright presentations only) versus Experiments 5-7 ($\eta_p^2 = .312$).

Differences in treatment recommendation, status & strength judgments, and feeling thermometer ratings as a function of target race. Our second hypothesis was that participants would recommend administering more non-narcotic pain reliever to White versus Black targets. As predicted, we observed a significant main effect of target race on participants' treatment recommendations ($F(1,123) = 14.45$, $p < .001$; $\eta_p^2 = .11$). Participants prescribed fewer grams of analgesic cream to Black targets ($M = 11.14$, $SD = 5.53$), as compared to White targets ($M = 12.27$, $SD = 5.16$; see Table 2A), replicating the results of the majority of the previous six experiments. Moreover, and somewhat startlingly, this data suggests that an objectively identical expression of pain received more than one additional gram of analgesic on average when it appeared on a White face, as compared to a Black face.

In addition, we also observed main effects of race on both judgments of social status ($F(1,123) = 18.69$, $p < .001$; $\eta_p^2 = .13$) and judgments of strength ($F(1,123) = 6.01$, $p = .016$; $\eta_p^2 = .05$). Not only did participants rate the Black targets as being significantly lower in social status, on average, than the White targets ($M_{Black} = 3.64$, $SD_{Black} = 0.65$; $M_{White} = 4.04$, $SD_{White} = 0.69$), participants also rated the Black targets as being stronger than the White targets ($M_{Black} = 4.88$, $SD_{Black} = 1.03$; $M_{White} = 4.63$, $SD_{White} = 1.03$). These results mirror similar patterns observed across the previous experiments, suggesting that White participants rate Black individuals as having lower status and being stronger than their White counterparts in this paradigm, even when structural differences are equated across stimuli.

Notably however, we did not observe a main effect of race on feeling thermometer ratings ($F(1,121$[13]$) = 0.02$, $p = .893$; $\eta_p^2 < .01$). In a departure from the previous six experiments, participants reported no differences in feelings of warmth towards Blacks versus Whites, overall ($M_{Black} = 71.73$, $SD_{Black} = 22.80$; $M_{White} = 71.48$, $SD_{White} = 23.84$).

Bias in pain recognition predicts bias in treatment recommendations. Our third hypothesis was that racial bias in pain perception would once again predict racial bias in treatment. As observed in Experiments 1 and 2, and as predicted, comparatively higher thresholds for perceiving pain on Black faces were associated with comparatively less analgesic prescribed to Black targets during the treatment recommendation task ($r = .357$, $p < .001$). Moreover, racial bias in pain recognition for the "treated" targets remained a significant predictor of racial bias in treatment recommendations ($B = 12.17$, $SE = 3.02$, $t(122) = 4.02$, $p < .001$), even after controlling for bias in status judgments, strength judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites. (For zero-order correlations

[13]The difference in degrees of freedom between sections reflects a number of participants (N = 2) who did not fully complete the *feeling thermometers* measure.

between all predictors, see Supplementary Table 2G.) In addition, we note that explicit racial bias was a significant predictor of racial bias in treatment recommendations (B = 0.05, SE = 0.01, $t(122) = 3.43$, $p = .001$). No other predictors were significantly associated with racial bias in treatment recommendations (ps > .252).

Taken together, Experiment 7 provides one final replication and extension of the effects observed in the first six experiments – here, in the most conservative test yet. Not only is racial bias in the threshold for pain perception associated with bias in subsequent treatment recommendations (independent of explicit prejudice and stereotypes relevant to judgments of pain experience and tolerance), but this relationship was even observed after eliminating all differences in structure and expression between Black and White targets.

Meta-Analyses Across Experiments 1-7

Finally, given the procedural similarity across experiments, we collapsed across these data to get a meta-analytic perspective on the effects of race on the perception of pain and its subsequent treatment. This allowed us to assess the size and robustness of our key effects (e.g., racial bias in pain recognition), as well as the boundary conditions governing other, more heterogeneous effects (e.g., racial bias in treatment recommendations).

Robust evidence for bias in pain perception

We created a novel task designed to examine whether there are perceptual contributions to persistent racial health disparities in pain care in the United States. Specifically, we predicted that our participants would show more stringent thresholds for perceiving pain on Black faces, as compared to White faces. Indeed, collapsing across all seven experiments and across orientation, order, and hue, race had a significant influence on pain perception ($F(1,999) = 327.66$, $p < .001$, $\eta_p^2 = .25$). Black targets had to display more pain on their faces than White targets to be

recognized as being in pain (*MD* = .044, *SE* = .002). Moreover, the effect of race did not interact with hue ($F(1,998) = 0.08$, $p = .772$, $\eta_p^2 < .01$) or presentation order[14] ($F(1,998) = 0.52$, $p = .473$, $\eta_p^2 < .01$; see Table 1A-C).

However, we also observed a three-way interaction between race, presentation orientation, and hue across the seven experiments ($F(1,998) = 9.97$, $p = .002$, $\eta_p^2 = .01$). Decomposing this interaction by hue, we observed a significant interaction between race and presentation orientation when full-color stimuli were presented ($F(1,759) = 15.74$, $p < .001$, $\eta_p^2 = .02$), but that the race × presentation orientation interaction did not achieve significance when gray-scale stimuli were presented ($F(1,237) = 1.28$, $p = .260$, $\eta_p^2 < .01$). Within the full-color stimuli, decomposing the two-way interaction between race and presentation orientation revealed that while participants in the "Inverted" condition still showed more stringent thresholds for perceiving pain on Black faces ($F(1,152) = 10.39$, $p = .002$, $\eta_p^2 = .06$; *MD* = .023, *SE* = .007), this bias was even stronger among participants in the "Upright" condition ($F(1,607) = 285.52$, $p < .001$, $\eta_p^2 = .32$; *MD* = .050, *SE* = .003). Taken together, these results suggest that race does indeed shape the recognition of facial expressions of pain, which can result in White perceivers showing increased thresholds for perceiving pain on Black faces. In addition, this effect seems to arise from a disruption in configural face processing associated with out-group faces[15].

Mixed evidence for racial bias in treatment recommendations

[14]While we would have preferred to test the effects of race, orientation, order, and hue simultaneously in a 2 × 2 × 2 × 2 ANOVA, not all possible cells would have been represented across these seven experiments. (For example, none of the experiments featured gray-scale stimuli presented in inverted orientation in backwards order.) Given this complication, we chose to test the interaction between race, orientation, and hue in one 2 × 2 × 2 ANOVA, and the interaction between race and order in a separate 2 × 2 ANOVA.

[15]In addition, even when collapsing across hue, we still observed an interaction between race and presentation orientation on pain perception thresholds ($F(1,998) = 6.90$, $p = .009$, $\eta_p^2 = .01$) across the seven experiments. Decomposing this interaction, we observed that while participants in the "Inverted" condition still showed more stringent thresholds for perceiving pain on Black faces ($F(1,239) = 31.51$, $p < .001$, $\eta_p^2 = .12$; *MD* = .033, *SE* = .006), this bias was even stronger among participants in the "Upright" condition ($F(1,759) = 333.17$, $p < .001$, $\eta_p^2 = .31$, *MD* = .048, *SE* = .003).

Decades of research in public health have suggested that Black patients receive less treatment for their pain than White patients. As such, we predicted that our participants would prescribe less of a non-narcotic analgesic cream to Black targets in our experiments. However, while the effects of race on pain perception were consistent and replicable across the seven experiments we conducted, we observed somewhat more heterogeneity in the effects of race on pain management.

Collapsing across all seven experiments (and across orientation, order, and hue), race had a small, but statistically significant influence on treatment recommendations ($F(1,971) = 5.44$, $p = .020$, $\eta_p^2 = .01$). However, a marginally significant three-way interaction between race, presentation orientation, and hue was observed ($F(1,968) = 3.55$, $p = .060$, $\eta_p^2 = .004$)[16]. Decomposing this interaction by hue, we observed a pattern of results mirroring the pain perception threshold data: we observed a significant interaction between race and presentation orientation when full-color stimuli were presented ($F(1,732) = 16.18$, $p < .001$, $\eta_p^2 = .02$), but that the race × presentation orientation interaction did not achieve significance when gray-scale stimuli were presented ($F(1,236) = 0.22$, $p = .642$, $\eta_p^2 < .01$).

Within the full-color stimuli, participants in the "Upright" condition prescribed more non-narcotic pain reliever to White targets than Black targets ($F(1,589) = 13.11$, $p < .001$, $\eta_p^2 = .02$; $MD = .556$, $SE = .154$), while in the "Inverted" condition, this pattern reversed: Black targets were prescribed more of the analgesic cream than White targets ($F(1,143) = 8.18$, $p =$

[16]Similar to the pain perception threshold results, we note that even when collapsing across hue, we still observed an interaction between race and presentation orientation on treatment recommendations ($F(1,970) = 12.44$, $p < .001$, $\eta_p^2 = .01$) across the seven experiments. Decomposing this interaction, we observed that participants in the "Inverted" condition prescribed comparatively more pain reliever to Black targets ($F(1,230) = 4.73$, $p = .031$, $\eta_p^2 = .02$; $MD = .471$, $SE = .217$), but that participants in the "Upright" condition prescribed comparatively more pain reliever to White targets ($F(1,740) = 13.34$, $p < .001$, $\eta_p^2 = .02$; $MD = .512$, $SE = .140$). Finally, we note that race did not interact with presentation order to influence treatment recommendations ($F(1,970) = 2.32$, $p = .128$, $\eta_p^2 < .01$), though we observed a main effect of presentation order ($F(1,970) = 57.25$, $p < .001$, $\eta_p^2 = .06$), accounted for by the change in the treatment recommendations task in Experiment 5-7, which only used the "Forwards" condition.

.005, η_p^2 = .05; *MD* = -.817, *SD* = .286; see Table 2A-C). One possible interpretation of these results is that racial bias in treatment recommendations was dependent on differential engagement of configural face processing, which would have been preserved with upright face presentations but disrupted with facial inversion.

Racial bias in pain perception predicts racial bias in treatment recommendations

Throughout the seven experiments we conducted, we observed a consistent pattern of association between a tendency to perceive pain less readily on Black faces and a tendency to prescribe less non-narcotic pain relieve to Black targets. However, the nature of the association seemed to be moderated by factors influencing configural face processing (e.g., upright versus inverted stimulus orientation) and aspects of the design (e.g., the order in which morphs were presented). Moreover, while we used the "treated" bias in pain perceptions thresholds as a predictor throughout (since this represented the bias in pain perception specifically for targets "receiving" treatment recommendations), a case could be made for using participants' overall bias in pain perception instead. Therefore, we examined the extent to which this association was both robust to and constrained by these features and analytic decisions.

Collapsing across presentation orientation, order, and hue, we observed a statistically significant, positive relationship between racial bias in pain recognition for the "treated" targets and racial bias in treatment recommendations (B = 4.02, SE = 0.62, $t(968)$ = 6.46, $p < .001$), when controlling for bias in social status judgments and explicit racial bias (zero-order correlation between "treated" bias in pain recognition and bias in treatment recommendations: r = .206, $p < .001$; for overall zero-order correlations between all predictors, see Supplementary Table 3A; for means and standard deviations of additional predictors like explicit racial bias split by study, see Supplementary Table 4). Moreover, these results held when using participants'

overall racial bias in pain recognition instead (B = 8.37, SE = 1.54, t(969) = 5.43, p < .001; zero-order correlation between overall bias in pain recognition and bias in treatment recommendations: r = .172, p < .001; for overall zero-order correlations between predictors, see Supplementary Table 3A). No other predictors were significantly associated with bias in treatment recommendations in either analysis (ps > .245).

Next, we tested whether this association was stronger within participants who saw upright faces in the "Forwards" version of the task (e.g., morphs that progressed from neutral to painful), as compared to the other possible combinations of conditions. We created a dummy variable in which Upright/Forwards participants received a value of 1 and Upright/Backwards, Inverted/Forwards, and Inverted/Backwards participants received a value of 0, and multiplied this variable against bias in pain perception for "treated" targets, status bias, and explicit racial bias to create interaction terms. Including these predictors and interaction terms in a multiple regression predicting bias in pain management, we observed a significant effect of the interaction between condition and bias in "treated" pain perception (B = 5.61, SE = 1.23, t(968) = 4.57, p < .001). Aside from the dummy variable (p = .034) and the "treated" pain perception predictor itself (p = .093), no other predictors were significantly associated with bias in treatment recommendations (ps > .505).

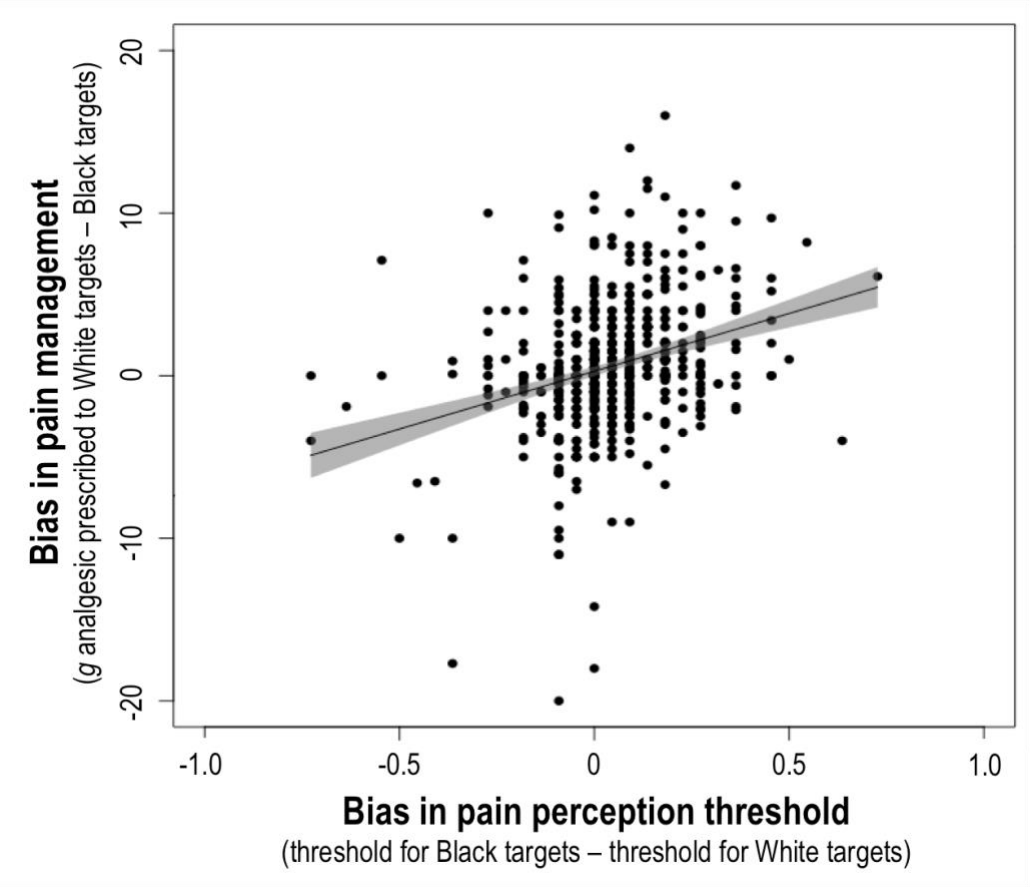

Figure 7. Racial bias in pain recognition is positively associated with racial bias in treatment recommendations. Collapsing across all seven experiments, we observed a relationship between bias in thresholds for pain perception (*difference score*: Black thresholds – White thresholds) and bias in treatment recommendations (*difference score*: *g* analgesic prescribed to Black targets - *g* analgesic prescribed to White targets). In other words, perceiving pain less readily on Black faces was associated with prescribing less non-narcotic analgesic cream to Black targets. Data on the graph reflect this relationship within only participants who saw upright images in "Forwards" versions of the task, and using the bias in pain perception assessed specifically for "treated" targets (r = .300, p < .001). For the same relationship plotted for *all* participants (e.g., collapsing across presentation orientation and order; r = .206, p < .001), see Supplementary Figure 1. Error bands represent 95% confidence intervals.

Subsequently, we ran separate multiple regressions within either condition. Within Upright/Forwards participants, we observed that racial bias in pain recognition for the "treated" targets was positively associated with racial bias in treatment recommendations (B = 7.02, SE = 0.91, $t(626)$ = 7.75, p < .001), when controlling for bias in social status judgments and explicit racial bias (zero-order correlation between bias in pain recognition and bias in treatment recommendations, Upright/Forwards participants: r = .300, p < .001, Figure 7; for zero-order correlations between all predictors, see Supplementary Table 3B). However, within participants

who experienced other combinations of presentation order and orientation, racial bias in pain recognition for "treated" targets was only marginally associated racial bias in treatment recommendations (B = 1.41, SE = 0.83, t(341) = 1.70, p = .090; zero-order correlation between bias in pain recognition and bias in treatment recommendations in other condition combinations: r = .091, p = .092; for zero-order correlations between all predictors, see Supplementary Table 3B). No other predictors were significantly associated with bias in treatment recommendations in either analysis (ps > .200).

Finally, we performed a final set of meta-analyses including participants' beliefs regarding biological differences and bias in strength judgments as additional predictors. Once again, collapsing across order, orientation, and hue, bias in treatment recommendations was associated with bias in pain recognition towards "treated" targets (B = 4.43, SE = 0.75, t(674) = 5.89, p < .001; as well as overall bias in pain recognition: B = 6.78, SE = 1.89, t(674) = 3.59, p < .001), when controlling for bias in status judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites[17]. This relationship also varied as a function of stimulus presentation (B = 5.60, SE = 1.49, t(674) = 3.77, p < .001) – bias in pain perception continued to predict bias in treatment for Upright/Forwards participants (B = 7.19, SE = 0.95, t(511) = 6.89, p < .001)[18], but not participants in other conditions (B = 1.44, SE = 1.04,

[17]In the results above, participants' false beliefs regarding biological differences between Blacks and Whites were calculated by scoring responses of "definitely untrue," "probably untrue," and "possibly untrue" as a 0, and scoring responses of "possibly true," "probably true," and "definitely true" as a 1. While this approach was described by Hoffman and colleagues (2016) for ease of interpretability, their actual analyses used an alternative scoring procedure, which simply summed participants' responses to the 11 false items without first making this transformation – essentially yielding participants' extent of false beliefs in these items, rather than the number of items endorsed to some extent. Ultimately, the two approaches are highly correlated (r = .876) across all seven experiments contained herein. Further, we note that when using this alternative approach, this pattern of results does not change: collapsing across the five experiments that employed the false beliefs measure, extent of false belief endorsement was not associated with either bias in pain perception or bias in treatment (all ps > .10). Moreover, the association between bias in perception and treatment *and* the significant influence of inversion on this relationship all held when controlling for extent of false belief endorsement (all ps < .05; see Supplementary Materials).

[18]In this particular analysis, explicit racial bias was also positively associated with racially biased treatment recommendations (B = 0.01, SE = .01, t(511) = 1.91, p = .057), though the effect was marginally significant.

$t(162) = 1.39$, $p = .166$).

We note that one false belief item in the measure compiled by Hoffman and colleagues (2016) explicitly focused on differences in the sensitivity of Blacks' and Whites' nerve endings. Including the extent of endorsement of this item ($M = 2.06$, $SD = 1.17$) as a predictor did not fundamentally alter the multiple regression results described above (see Supplementary Materials): ultimately, biases in perception and treatment were still observed, even when controlling for this additional predictor.

Interestingly, racial bias in strength judgments ($B = 0.19$, $SE = 0.11$, $t(674) = 1.72$, $p = .086$) and explicit racial bias ($B = 0.01$, $SE = 0.01$, $t(674) = 1.80$, $p = .072$) had similar, though marginally significant effects on treatment recommendations, specifically when "treated" bias in perception was included in the model. Moreover, the effect of bias in strength judgments varied (albeit weakly) as a function of stimulus presentation ($B = 0.47$, $SE = 0.25$, $t(674) = 1.90$, $p = .058$) – such that a tendency to judge Black targets as being stronger on average than White targets predicted bias in treatment for Upright/Forwards participants ($B = 0.31$, $SE = 0.13$, $t(511) = 2.49$, $p = .013$), but did not influence treatment in the other conditions ($B = -0.15$, $SE = 0.20$, $t(162) = -0.75$, $p = .458$).

In sum, these meta-analytic results suggest that racial bias in pain perception is indeed positively associated with racial bias in treatment. We find this to be a consistently replicable effect, which persists independently of other non-perceptual influences and is robust across multiple analytic approaches. That being said, this relationship seems to be accentuated under certain circumstances. In particular, racial bias in perceiving the emergence of pain (as opposed to the dissipation of pain) was a more consistent predictor of bias in treatment recommendations. Moreover, this relationship was more consistently observed when configural face processing was

preserved through upright face presentation (as opposed to disrupted through facial inversion). This pattern of boundary conditions offers novel insights into the constraints under which racial biases in pain perception might be particularly likely to trigger gaps in treatment, but also sheds light on a possible pathway to alleviating these biases – bolstering configural face processing of other-race faces. Moreover, we also observe some evidence that other established, non-perceptual factors (e.g., race-based differences in strength judgments, explicit racial bias) may make additional contributions to racial bias in treatment recommendations. Taken together, these findings provide us with a comprehensive perspective on a novel perceptual pathway to racial bias in pain care.

General Discussion

Despite decades of awareness, persistent racial and ethnic disparities exist in health care, especially in the domain of pain treatment. To determine whether biases in pain care might stem from an underlying perceptual source, we tested whether White participants display different thresholds for perceiving pain on Black faces versus White faces. Moreover, we examined the specific perceptual process supporting bias in pain recognition, whether biased thresholds for pain perception were associated with subsequent biases in treatment recommendations, and finally, whether this association existed over and above the influence of explicit stereotypes and prejudices operating independent of visual perception.

Across seven experiments, we obtained a consistent pattern of results: White participants showed more stringent thresholds for perceiving pain on Black faces, as compared to White faces. This result was consistently replicable, generalized across different sets of stimuli, was not merely attributable to differences in low-level features or subjective evaluations between Black and White faces, and consistently predicted behavior. Specifically, we continually observed an

association between bias in pain recognition and bias in subsequent treatment: participants who displayed more stringent thresholds for perceiving pain on Black faces also prescribed those Black targets less of a non-narcotic pain reliever. These effects were even obtained when Black and White stimuli were objectively equated in terms of facial structure and expression intensity. A meta-analysis across the seven experiments suggested that these results were also robust across multiple analytic approaches.

That being said, one might have predicted that the racial bias in pain perception we observed was simply a downstream consequence of other explicit stereotypes and prejudices. Indeed, our participants repeatedly reported feeling less warm towards Blacks, and endorsed several distinctions between Blacks and Whites that either have been linked to differences in pain care (e.g., status, Trawalter et al., 2012; biological differences, Hoffman et al., 2016) or might potentially play a role in pain tolerance (e.g., strength, Wilson et al., 2017). However, collapsing across manipulations from all seven experiments, bias in strength judgments was the only other measure that was positively correlated with bias in pain recognition, albeit weakly (r = .076, p = .048; all other ps > .230; in "Upright" condition in "Forwards" order participants only, all ps > .124; Supplementary Tables 3A & 3B). More importantly, bias in pain perception was associated with a bias to prescribe less non-narcotic pain reliever over and above all additional measures in each of the seven experiments we conducted. In other words, the influence of perceptual bias on treatment outcomes was distinguishable from the influence of stereotypes concerning status or strength, inaccurate medical beliefs, or explicit anti-Black prejudice.

While this consistent pattern of data was a necessary condition for identifying a truly perceptual source of racial bias in pain care, it was not sufficient. We also sought to confirm the specific nature of the perceptual bias. Drawing on previous work in the social perception

literature, we used facial inversion to manipulate configural face processing, a likely candidate for supporting potential differences in face perception as a function of race (e.g., Hancock & Rhodes, 2008; Rhodes, Hayward, & Winkler, 2006). In Experiments 3 and 4, we observed that racial bias in pain perception was diminished for inverted faces, suggesting that a disruption in configural face processing associated with other-race faces is a driving force behind racial disparities in pain care. Notably, this result was obtained for faces depicted in full color, but not for gray-scale faces. On the one hand, this suggests that the inversion effect is more robust and reliable in the most ecologically valid versions of our stimuli: aside from those individuals suffering from color-blindness, medical health professionals typically evaluate full-color versions of their patients. On the other hand, this result demonstrates a potentially intriguing boundary condition of the inversion effect, at least in the context of race and pain perception. Indeed, we later replicated the null inversion effect in a separate sample using only gray-scale faces (for complete details, including an updated meta-analysis, see Supplementary Materials; data available online at osf.io/dmqy9/), suggesting that this data may reflect a meaningful difference between color and gray-scale faces in this task. For example, differences in skin tone and luminance may be a critical prerequisite for observing the effects of inversion on pain perception. While this speculation is outside of the scope of this particular investigation, future work should continue to examine the boundaries of these effects, and to confirm the perceptual nature of biased pain perception.

We also observed that racial bias in treatment recommendations was somewhat less consistent across these seven experiments than racial bias in pain perception. One possible explanation is that while participants may have rapidly made judgments in the *pain rating phase*, they may have been aware of racial disparities in healthcare in the United States, and as a result,

they may have attempted to correct their own personal biases out of a desire to appear unprejudiced. That being said, collapsing across all seven experiments, we did observe a small, but statistically significant difference between the amount of non-narcotic pain reliever prescribed to Black targets versus White targets, which was enhanced when faces were presented in the upright orientation, once again suggesting a critical role for configural processing. Ultimately, this divergence between perception and treatment has potentially interesting implications: in healthcare contexts, disparities in care might potentially be larger for decisions based primarily on perceptual input, and smaller when perceptual input can be corrected for or ignored.

Limitations and future directions

Identifying a perceptual source of racial bias in pain recognition and treatment has considerable implications for future interventions aimed at reducing racial disparities in health care. That being said, we do not mean to suggest that perceptual bias is the only meaningful contributor to such gaps in treatment. Explicit stereotypes and prejudices likely play a considerable role in attributions of pain tolerance and pain experience – subsequent, or at least adjacent to visual perception (e.g., Hoffman et al., 2016; Trawalter et al., 2012). However, since explicit beliefs and attitudes about social out-group members are often resistant to change (Paluck et al., 2009; Tankard & Paluck, 2016), this novel perceptual pathway may represent a more feasible target for future inventions. For example, enhancing configural processing of Black faces may decrease perceivers' thresholds for pain perception. Previous work highlights a number of possible manipulations that might achieve this aim – specifically, enhancing individuation motives (Hugenberg, Miller, & Claypool, 2007; Hugenberg, Young, Bernstein & Sacco, 2010), highlighting a shared in-group identity (Bernstein, Young, & Hugenberg, 2007;

Hehman, Mania, & Gaertner, 2010), experiencing increased intergroup contact (Hancock & Rhodes, 2008; Rhodes et al., 2009), or undergoing perceptual other-race training (Lebrecht, Pierce, Tarr, & Tanaka, 2009) might all have dampening influences on racial bias in pain perception. Taken together, the present data not only illuminate the perceptual underpinnings of disparities in pain care, but they also lay the groundwork for developing interventions to bridge those gaps. More broadly, it is imperative to note that equality in care will not be achieved by clever perceptual interventions alone. Gaps in the thresholds for pain perception are downstream symptoms of more systemic inequalities, which would need to be addressed to fully alleviate these disparities.

While we feel this work shed new light on a perceptual source of racial bias in pain care, several questions remain unanswered. First, as all seven experiments focused on White perceivers, it remains unclear whether Black perceivers would display similar patterns of bias in pain perception, or alternatively, whether this bias would reverse in Black perceivers. (If these effects are solely a function of group membership, the latter pattern of results might be predicted.) Even if the same pattern is observed in Black perceivers, their differences in pain thresholds might be supported by different (e.g., non-perceptual) processes, and further, might not predict biases in treatment. Future work should resolve these uncertainties.

Moreover, it is critical to test whether these same biases are obtained in the individuals for whom these biases would pose the most societal risk: medical health professionals. It remains possible that individuals with medical training will not be susceptible to the same race-based differences in thresholds for pain recognition. Indeed, some previous work has observed that healthcare trainees (Wandner et al., 2010) and nurses (Hirsh, George, & Robinson, 2009) rated facial expressions of pain as being more intense when displayed by *Black* (versus White) avatars.

However, these studies ultimately assess a different measure (e.g., evaluation of high-intensity painful expressions, rather than the threshold for recognition of pain), and further, that this pattern does not seem to accord with a broad literature suggesting that the pain experiences of Black patients are underestimated (e.g., Mathur et al., 2014; Wandner et al., 2012), even by those with medical training (Hoffman et al., 2016; Staton et al., 2007; Trawalter et al., 2012). Furthermore, we note that the perceptual biases we demonstrated in the present work are not only relevant to medical providers, but also to anyone who might be in a position to evaluate and respond to pain in an interracial context (e.g., teachers, coaches, parents, etc.). Ultimately, future work must test whether training in a medical field alleviates disparities in thresholds for the visual recognition of pain.

Finally, while we tested for and observed racial biases in pain care and treatment in a large sample that was diverse with respect to age and political ideology, future work should assess the generalizability of these results. For example, the seven experiments presented herein used only adult male targets between approximately 20 and 35 years of age. While we chose to hold gender and age constant in these initial investigations for purposes of experimental control, we have continued to expand the diversity of our novel stimulus set. Indeed, other research suggests that the pain of female patients is subject to similar disparities in treatment (Chen et al., 2008; Hoffmann & Tarzian, 2001; Hirsh, Hollingshead, Matthias, Bair, & Kroenke, 2014). Furthermore, the effects of gender on pain perception (and care) may be amplified by race, putting Black women at even greater risk. Therefore, an intersectional perspective is necessary to fully understand these disparities (Hankivsky, 2012). Moreover, Latino Americans are also subject to similar gaps in care (Green et al., 2003; Hollingshead, Ashburn-Nardo, Stewart, & Hirsh, 2016; Shavers et al., 2010). Future work should examine whether perceptual processes

underlie disparities in pain management experienced by women and other racial and ethnic minorities.

More broadly, these results are conceptually consistent with a long tradition of social psychological research indicating that the groups we belong to shape the way that we see the world and the other people in it (Van Bavel, Xiao, & Hackel, 2013; Xiao & Van Bavel, 2012; Xiao, Coppin, & Van Bavel, 2016a; 2016b). In particular, the present work dovetails with similar race-based biases in social perception, implying multiple perceptual sources of racial disparities. Black individuals are more likely to be misperceived in terms of their emotional expressions (Hugenberg & Bodenhausen, 2003; Hugenberg, 2005), their mental agency (Cassidy et al., 2017), their size (Wilson, Rule, & Hugenberg, 2017), their speed (Kenrick et al., 2015), and according to the seven experiments we conducted, their experience of pain. In addition, the present data suggest that this bias can spring from a perceptual foundation that is separate and distinct from the influence of stereotypes regarding status (Trawalter et al., 2012) or biological differences in pain tolerance (Hoffman et al., 2016). While one might infer a potentially negative takeaway – that we have simply identified one more avenue to an already-pernicious problem – a more optimistic conclusion may be warranted: by understanding this perceptual basis for racial bias in pain, we hope to inform the creation of new approaches designed to fight that bias at its earliest stages.

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Author contributions

PMS and JVB designed the research. PMS, JQL, and RB created the stimulus set and collected the data. PMS analyzed the data and wrote the initial draft of the manuscript. JQL assisted with figures. PMS and JVB edited the manuscript, with input from JQL and RB.

Tables

A. Racial bias in pain perception, split by stimulus orientation and experiment			
Experiment	Average racial bias[a] in pain perception (Upright stimuli; N = 760)	Average racial bias in pain perception (Inverted stimuli; N = 240)	*p* (race × orientation interaction)
1	0.087 (0.106)*	-	-
2	0.026 (0.061)*	-	-
3	0.055 (0.074)*	0.022 (0.087)*	.009*
4[b]	0.056 (0.073)*	0.038 (0.092)*	.048*
5	0.048 (0.052)*	-	-
6	0.021 (0.056)*	-	-
7	0.045 (0.065)*	-	-
Overall	0.048 (0.072)*	0.033 (0.090)*	.009*

B. Influence of stimulus hue on racial bias in pain perception			
	Average racial bias in pain perception (Color stimuli; N = 761)	Average racial bias in pain perception (Gray-scale stimuli; N = 239)	*p* (race × hue interaction)
Overall	0.044 (0.077)*	0.043 (0.078)*	.772
Upright only	0.050 (0.073)*	0.038 (0.068)*	.079

C. Influence of presentation order on racial bias in pain perception			
	Average racial bias in pain perception (*Forwards* order; N = 839)	Average racial bias in pain perception (*Backwards* order; N = 161)	*p* (race × version interaction)
Overall	0.043 (0.076)*	0.048 (0.084)*	.473
Upright only	0.046 (0.069)*	0.058 (0.086)*	.084

Table 1. Racial bias in pain perception as a function of stimulus orientation, hue, and order. A) Bias in pain perception, split by experiment, and as a function of stimulus orientation. Average racial bias in pain perception was calculated as the mean difference between the average threshold for pain perception on Black targets minus the average threshold for pain perception on White targets. The row labeled *Overall* collapses across all participants in all experiments. We consistently observed racial bias in pain perception, such that participants had higher thresholds for perceiving pain on Black faces. Moreover, this bias repeatedly interacted with stimulus orientation – facial inversion dampened racial bias in pain perception. B) Bias in pain perception as a function of stimulus hue. The row labeled *Upright only* collapses across just participants who viewed upright stimuli, across all seven experiments. Racial bias in pain perception did not vary overall as a function of stimulus hue overall, and only did so marginally within participants who saw upright presentations. C) Bias in pain perception as a function of presentation order. Racial bias in pain perception did not vary as a function of presentation order overall, and only did so marginally within participants who saw upright presentations. ([a]We report mean differences, rather than separate threshold averages for Black and White targets, in order to prevent the unequal number of participants receiving the "Forwards" version of the task from skewing averages across experiments. [b]Values for Experiment 4 collapse across color and gray-scale stimuli. *$p < .05$)

A. Racial bias in treatment recommendations, split by stimulus orientation and experiment

Experiment	Average racial bias[a] in treatment recommendations (Upright stimuli; N = 741)	Average racial bias in treatment recommendations (Inverted stimuli; N = 231)	*p* (race × orientation interaction)
1	0.933 (4.71)	-	-
2	0.123 (4.18)	-	-
3	0.236 (4.07)	-0.840 (3.37)*	.094
4[b]	0.674 (3.81)*	-0.317 (3.26)	.015*
5	0.547 (3.10)*	-	-
6	-0.222 (3.85)	-	-
7	1.137 (3.33)*	-	-
Overall	0.515 (3.81)*	-0.471 (3.29)*	<.001*

B. Influence of stimulus color on racial bias in treatment recommendations

	Average racial bias in treatment recommendations (Color stimuli; N = 734)	Average racial bias in treatment recommendations (Gray-scale stimuli; N = 238)	*p* (race × hue interaction)
Overall	0.287 (3.71)*	0.264 (3.74)	.899
Upright	0.556 (3.73)*	0.356 (4.12)	.530

C. Influence of presentation order on racial bias in treatment recommendations

	Average racial bias in treatment recommendations (*Forwards* order; N = 831)	Average racial bias in treatment recommendations (*Backwards* order; N = 141)	*p* (race × version interaction)
Overall	0.356 (3.69)*	-0.162 (3.88)	.128
Upright	0.575 (3.78)*	0.185 (3.98)	.323

Table 2. Racial bias in treatment recommendations as a function of stimulus orientation, hue, and order. A) Bias in treatment recommendations, split by experiment, and as a function of stimulus orientation. Average racial bias in treatment recommendations was calculated as the mean difference between the average amount of analgesic prescribed to White targets minus the average amount of analgesic prescribed to Black targets. The row labeled *Overall* collapses across all participants in all experiments. While patterns within individual experiments varied somewhat, overall, racial bias in treatment recommendations interacted with stimulus orientation – participants prescribed relatively fewer grams of analgesic to upright Black targets, but relatively more analgesic to inverted Black targets. B) Bias in treatment recommendations as a function of stimulus hue. The row labeled *Upright* collapses across just participants who viewed upright stimuli, across all seven experiments. Racial bias in treatment recommendations did not consistently vary as a function of stimulus hue. C) Bias in treatment recommendations as a function of presentation order. Racial bias in pain perception did not consistently vary as a function of presentation order. ([a]We report mean differences, rather than separate treatment recommendation averages for Black and White targets, in order to prevent differences in the treatment recommendation task between Experiments 1-4 and 5-7 from skewing averages across experiments. [b]Values for Experiment 4 collapse across color and gray-scale stimuli. *$p < .05$)

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