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Perceptual Contributions to Racial Bias in Pain Recognition

Peter Mende-Siedlecki
University of Delaware

Jennie Qu-Lee
New York University

Robert Backer
University of Delaware

Jay J. Van Bavel
New York University

The pain of Black Americans is systematically underdiagnosed and undertreated, 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, 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 facilitated 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 9 total experiments (N = 1,289) 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.

Keywords: health disparities, social perception, racial bias, pain perception

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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 disease morbidity, mortality, and disability (Mays, Cochran, & Barnes, 2007, Centers for Disease Control & Prevention, 2005). The past 30 years have seen a surge in research aimed at reducing gaps in health outcomes in minority communities, beginning 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 & U.S. Task Force on Black and Minority Health, 1985), and led to federal acknowledgment 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,

Peter Mende-Siedlecki, Department of Psychological and Brain Sciences, University of Delaware; Jennie Qu-Lee, Department of Psychology, New York University; Robert Backer, Department of Psychological and Brain Sciences, University of Delaware; Jay J. Van Bavel, Department of Psychology, New York University.

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Correspondence concerning this article should be addressed to Peter Mende-Siedlecki, Department of Psychological & Brain Sciences, University of Delaware, Wolf Hall, Newark, DE 19716. E-mail: pmendesiedlecki@psych.udel.edu

1997; Green et al., 2003; Mossey, 2011; Shavers, Bakos, & Sheppard, 2010; Smedley, Stith, & Nelson, 2009). This article examines a novel perceptual pathway that may give rise to such disparities in pain care.

The pain of Black patients is systematically underdiagnosed 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, Hinze, Cydulka, & Baker, 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 adjusting for age, gender, and pain intensity (Mossey, 2011). Research suggests a complicated interplay of contributing factors, including effects specific to health care providers, the health care system in general, and patients themselves (Green et al., 2003; Mossey, 2011; Smedley et al., 2009).

One recent study demonstrates the startling degree to which these disparities are even evident in the treatment of children. Among 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, and insurance status (Goyal, Kuppermann, Cleary, Teach, & Chamberlain, 2015). These data underscore the need to better understand the psychological processes underlying racial disparities in pain care in the United 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

Several high-level social–cognitive processes that underlie racial disparities in pain recognition. Research has linked racial stereotypes about pain tolerance (Hoffman, Trawalter, Axt, & Oliver, 2016; Trawalter & Hoffman, 2015; Trawalter, Hoffman, & Waytz, 2012; Dore, Hoffman, Lillard, & Trawalter, 2014), beliefs regarding tendencies toward substance abuse (Burgess, Van Ryn, Crowley-Matoka, & Malat, 2006; Hausmann, Gao, Lee, & Kwoh, 2013; Upshur, Luckmann, & Savageau, 2006), and gaps in empathy (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, although there is significant neural overlap between the direct experience of pain and empathy for the pain of another (Lamm, Decety, & Singer, 2011; Singer et al., 2004; Zaki, Ochsner, Hanelin, Wager, & Mackey, 2007), these empathic neural responses are diminished when we perceive other-race individuals in pain, as compared to same-race individuals (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). Biases in attributions of pain experience are evident in perceivers as early as age 7 (Dore et al., 2014) and may stem from stereotypes regarding the lower status of Blacks (Trawalter et al., 2012) and false beliefs about 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, Edwards, & Fillingim, 2005; Edwards, Fillingim, & Keefe, 2001; Mechlin, Maixner, Light, Fisher, & Girdler, 2005; Rahim-Williams, Riley, Williams, & Fillingim, 2012; Sheffield, Biles, Orom, Maixner, & Sheps, 2000), potentially arising 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 article, we examine the possibility that racial disparities in pain care may stem from lower-level, perceptual biases. A long tradition of work suggests that social perception is subject to a host of situational and motivational influences (Bernstein, Young, & Hugenberg, 2007; Tajfel, 1970; Van Bavel, Packer, & Cunningham, 2008; Van Bavel & Cunningham, 2010; Van Bavel, Xiao, & Hackel, 2013; Xiao & Van Bavel, 2012). The Perceptual Model of Intergroup Relations argues that social identities from race to minimal groups influence perception, from high-level interpretations to low-level sensory processing (Xiao, Coppin, & Van Bavel, 2016a, 2016b), with particularly strong influence on judgments of ambiguous stimuli. This model is consistent with other contemporary models of social perception (e.g., the Dynamic Interactive Model; Freeman & Ambady, 2011; Freeman & Johnson, 2016) and suggests that such perceptual biases can influence downstream intergroup behavior. Here, we apply this approach to racial disparities in pain perception and treatment decisions.

A wealth of evidence suggests that race influences face perception. First and foremost, other-race face processing is typically featural, or component-based, whereas own-race face processing is more configural and holistic in nature (Hancock & Rhodes, 2008; Hugenberg, Young, Bernstein, & Sacco, 2010; Michel, Rossion, Han, Chung, & Caldara, 2006; Rhodes, Hayward, & Winkler, 2006; Sporer, 2001). This divergence is reflected on the neural level: the Fusiform Face Area (FFA), which is integral to configural face processing (Kanwisher & Yovel, 2006), is differentially activated by other-race versus own-race faces (e.g., Golby, Gabrieli, Chiao, & Eberhardt, 2001; Brosch, Bar-David, & Phelps, 2013; Natu, Raboy, & O'Toole, 2011; Lieberman, Hariri, Jarcho, Eisenberger, & Bookheimer, 2005). Owing in part to these differences in processing, perceivers show worse memory for the faces of racial out-group members—a phenomenon referred to as the *cross race effect* or *own-race memory bias* (Hugenberg & Sacco, 2008; Hugenberg et al., 2010; Malpass & Kravitz, 1969) linked to real-world outcomes like eyewitness misidentification (Wells & Olson, 2001; Wilson, Hugenberg, & Bernstein, 2013). Similarly, perceivers are less accurate at recognizing emotional expressions made by racial out-group members (Hugenberg & Bodenhausen, 2003; Hugenberg, 2005), as well as the size of their bodies (Wil-

son, Hugenberg, & Rule, 2017), and speed of their movements (Kenrick, Sinclair, Richeson, Verosky, & Lun, 2016).

Work on perceptual dehumanization suggests that such effects might not stem from in-group fluency or favoritism alone. Instead, this work associates disruptions in typical (e.g., configural) human face processing to discrimination of marginalized and stigmatized groups (Fincher & Tetlock, 2016; Fincher, Tetlock, & Morris, 2017), including racial minority groups. Indeed, Black Americans are dehumanized compared to Whites (Goff, Eberhardt, Williams, & Jackson, 2008). Moreover, configural processing may drive ascriptions of humanness (Hugenberg et al., 2016), potentially through attention to the eyes (Young, Slepian, Wilson, & Hugenberg, 2014; Kawakami et al., 2014), with downstream consequences for harm toward and neglect of marginalized individuals. Notably, disruptions in typical patterns of face processing and attention may be associated with reduced intergroup contact (Hancock & Rhodes, 2008), group-based stereotypes and prejudice (Kawakami, Amodio, & Hugenberg, 2017), or reduced motivation to individuate (Hugenberg et al., 2010). In turn, disruptions in configural face processing may underscore the dehumanization and mistrust of Black (vs. White) individuals (Cassidy et al., 2017). 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 similar perceptual source. Because of 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. Because 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. This disparity in thresholds could trigger a cascade of biased processing, producing divergent medical treatment outcomes, and ultimately manifesting as societal-level racial inequalities in pain care. Moreover, rather than a product of mere in-group favoritism, we propose that this bias is exacerbated for Black targets. Identifying the perceptual processes supporting such inequalities has direct consequences for subsequent interventions. Changing people's explicit beliefs and attitudes—especially about social out-groups—is a very challenging task (e.g., Paluck et al., 2009; Tankard & Paluck, 2016). Ultimately, the perceptual roots of bias in pain care may be a more tractable target for intervention, rather than stereotypes regarding status, strength, or pain tolerance.

The Current Research

We present seven experiments (and two supplementary 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. Beginning in Experiment 5, we apply increasingly conservative tests of our hypotheses by more carefully balancing our stimuli across condition (including creating face stimuli in FaceGen for Experiments 6 and 7, which were perfectly matched on every visual characteristic other than race). Finally, in Experiment 7, we test whether perceptions of pain are particularly biased for Black targets, or whether this bias generalizes to other racial minority groups. In addition, we present meta-analyses incorporating data across all experiments.

Across these experiments, our methodological approach evolved as we ruled out potential confounds. For example, because 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 Experiment 5, we extended this approach by balancing stimuli across raters' subjective social judgments of pain experience and tolerance. Finally, in Experiments 6 and 7, we provided the most stringent test we could conceive of, by creating stimuli that were objectively equated in structure and expression, while still manipulating race. 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. We also enhanced the construct validity of our measures as these investigations progressed. For example, although 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 more directly reflect pain perception.

In sum, this research finds that (a) White perceivers display more stringent thresholds for recognizing pain on Black faces, compared to White faces; (b) bias in pain recognition cannot be accounted for by low-level visual differences between Black and White faces (e.g., color, contrast, luminance), differences in subjective judgments associated with pain tolerance and experience (e.g., dominance, masculinity, etc.), or objective differences in facial structure and expression intensity; (c) biases in pain recognition predict and facilitate biases in medical treatment decisions;[1] (d) perceptual contributions to racial bias in pain care are distinct from explicit stereotypes about or prejudices against Black Americans; (e) these phenomena are not reflective of a general tendency to misperceive pain on the faces of racial out-group members, as they did not generalize to Asian targets; and, finally, (f) biases in pain recognition stem, at least in part, from disruptions in configural face processing. These studies are the first to establish a perceptual source underlying racial disparities in pain care.

Experiment 1

Our initial experiment compared 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, to determine whether bias in perceiving a target's painful expression was associated with bias in treating that target's pain. Critically, we also assessed participants' explicit racial bias and whether they viewed

[1] In the present article, we assessed whether racial bias in pain perception for a given set of targets was associated with bias in treatment within those targets. We did not, however, test whether racial bias in pain perception for one set of targets is associated with bias in treatment for other targets.

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 Mechanical Turk (46 male, *M* 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 ($N = 82$), 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 identify as non-White. Therefore, in this experiment (and those that follow), we recruited 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 were recorded (10 African American, 12 Asian, 12 Hispanic, one Native American, one Pacific Islander, four Other), though their data will not be analyzed in this article. (A breakdown of non-White participants for Experiments 2–7 can be found in the online supplemental materials.) We acquired informed consent from all participants in all experiments.

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 resulted in a large database of stimuli (Mende-Siedlecki, Qu-Lee, Drain, & Goharzad, 2019; osf.io/2x8r5/). Stimuli used specifically in Experiments 1–7 are available online (osf.io/dmqy9/). We used posed images of pain rather than genuine expressions of individuals experiencing pain in part because this approach allowed us to generate stimuli without harming any volunteers. That said, perceivers have difficulty distinguishing genuine from posed pain expressions (Hadjistavropoulos, Craig, Hadjistavropoulos, & Poole, 1996; Hill & Craig, 2002; Jung & Reidenberg, 2007; Poole & Craig, 1992), with naïve perceivers' accuracy at only 49% (Littlewort, Bartlett, & Lee, 2009). Moreover, there is substantial similarity in the action units involved in posed versus genuine pain expression (though more nonpain action units tend to be present in posed expressions; for review see Craig, Hill, & McMurtry, 1999).

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. (Although 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 prompts describing 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, 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.

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 set, actors who made similar expressions across prompts were encouraged to try different facial configurations (e.g., eyes open vs. closed, mouth closed vs. teeth gritted). Actors whose responses did not visibly increase in across levels were directed to amplify their expressions. Multiple images were taken for each prompt, at each level, and each session generated upward of 50 images. Therefore, even if a given actor produced, on average, images that were lower in intensity than another actor, by 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.

Our approach was adapted from previous work on mind perception (Hackel, Looser, & Van Bavel, 2014; Looser & Wheatley, 2010). For each target, we constructed 11 morphs using Morpheus PhotoMorpher Pro, ranging from a 100% neutral expression to a 100% painful expression (Figure 1). For 100% painful expressions, we used a Level 8 intensity expression from each actor. In the pain rating phase, morphs were presented to participants in either forward version of the task (from neutral to painful; $n = 39$) or a backward version (from painful to neutral; $N = 46$). Assignment to Forward or Backward order was randomized across participants. This allowed us to test whether racial bias in pain recognition was specific to one presentation order (though we had no specific predictions that it would be). Participants made a binary yes/no judgment of whether each face was in pain. In the forward condition, if participants responded "no," the subsequent face in the continuum appeared, whereas 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

Figure 1. Sample stimuli presented 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. Individuals depicted in all figures throughout granted full permission for their likenesses to appear in this article. See the online article for the color version of this figure.

> 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 min to complete.

Participants could potentially view 66 faces in the pain rating phase (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 0 g to 20 g. This pain-relieving cream was described as "non-narcotic" to ensure that differences in treatment recommendations were independent of participants' stereotypes regarding the likelihood of abuse of an opioid-based pain reliever.

Next, participants made 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, rated on a 7-point scale ranging 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; $\alpha = .75$, averaging across Black and White targets). After reverse-scoring the second and fourth items, we averaged across these four values 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 demographic items, including age, race, gender, and political ideology[2] on a 7-point scale ranging from 1 (*very liberal*) to 7 (*very conservative*). Participants also completed feeling thermometers describing their warmth on a 100-point scale ranging from 0 (*very cold*) to 100 (*very warm*) toward 10 social groups ("Canadians," "housewives," etc.), within which we randomly embedded Blacks and Whites. The difference between these values (White warmth−Black warmth) served as an index of 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 (e.g., the point when participants recognized pain in the forward version or stopped seeing pain in the backward version) and rescaled this data from an 11-point scale to a 0-to-1 scale. Next, we conducted a 2 (target race: Black vs. White) × 2 (presentation order: forward vs. backward) analysis of variance (ANOVA) on the rescaled data to test (a) whether thresholds for pain perception varied by target race and (b) whether the effect of race varied by presentation order. Subsequently, we conducted one-way ANOVAs to examine whether

[2] 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 article—as this question was beyond the bounds of our primary objectives. The political ideology item is a standard question in demographics surveys administered in our lab.

race had an impact on treatment recommendations, status judgments, and feeling thermometer ratings.

Multiple regression analyses. 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 task. These targets will be referred to as "treated" targets throughout the text. (A meta-analysis examining the same effect using the "overall" bias in pain recognition appears in the Meta-Analyses Across Experiments section.) This approach necessarily limits our analysis of the relationship between bias in pain perception and treatment to the level of targets. Although we can assess whether biased perception of a given individual's pain was associated with bias in treatment, we did not test whether a tendency to display bias in pain perception for one set of targets will generalize to bias in treatment for others.

Moreover, we examined whether this relationship between pain recognition and treatment existed beyond stereotypes and explicit racial bias. We conducted a multiple regression comparing racial bias in pain recognition (treated Black threshold−treated White threshold), racial bias in status judgments (White status−Black status), and explicit racial bias (White warmth−Black warmth) 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 status, etc.) always represent difference scores between Black and White targets.

Subsequent to 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 in the forward version of the task, for two reasons. First, participants in the backwards condition would have all seen the most intense painful expression of each target, therefore, their treatment recommendations might 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 framed by 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 forward 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 forward condition. In the main text, we present only forwards only analyses. That said, for the sake of transparency, meta-analyses assessing the impact of presentation order are available the online supplementary materials.

Within-subjects mediation analyses. Although the multiple regression analyses above test whether racial bias in pain perception and treatment are associated above and beyond the influence of factors like explicit prejudice, an even more critical question is whether bias in perception facilitates the influence of race on treatment. To assess this, we used the SPSS macro MEMORE (Montoya & Hayes, 2017) to perform a within-subjects mediation analysis. Here, *X* takes the form of an independent variable manipulated across two measurements (in this case, target race), whereas *M* and *Y* are the values of the proposed mediator and outcome variables at either level of *X* (in this case, the thresholds for recognizing pain on Black and White treated targets and treatment recommendations for Black and White targets, respectively). MEMORE calculates the difference between values for *M* (Black treated thresholds−White treated thresholds) and *Y* (Black treatment recommendations−White treatment recommendations) separately and tests for mediation in a procedure adapted from Judd and colleagues (2001).

In Experiment 1 (and all experiments that follow), we estimated the indirect effect of race on treatment recommendations through bias in pain perception (as well as the total and direct effects of race on treatment recommendations) compared in parallel against other potential mediators[3] of this relationship (in Experiment 1, explicit racial bias and judgments of social status), using percentile bootstrapping (10,000 samples). As in the regression analyses, we restrict these analyses to upright presentations in forward versions of the pain rating task.

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 deidentified 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 2A). These perceptual judgments are consistent with earlier work showing racial disparities in attributions of pain experience (Hoffman et al., 2016; Trawalter et al., 2012).

We also 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 ($F(1, 83) = 0.75$, $p = .388$, $\eta_p^2 < .01$): the magnitude of racial bias in pain recognition did not differ depending on whether participants saw the forward 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'

[3] A version of this analysis for Experiment 1 (and all following experiments) testing only the difference in perceptual thresholds between Black and White targets as a potential mediator is found in the online supplementary materials.

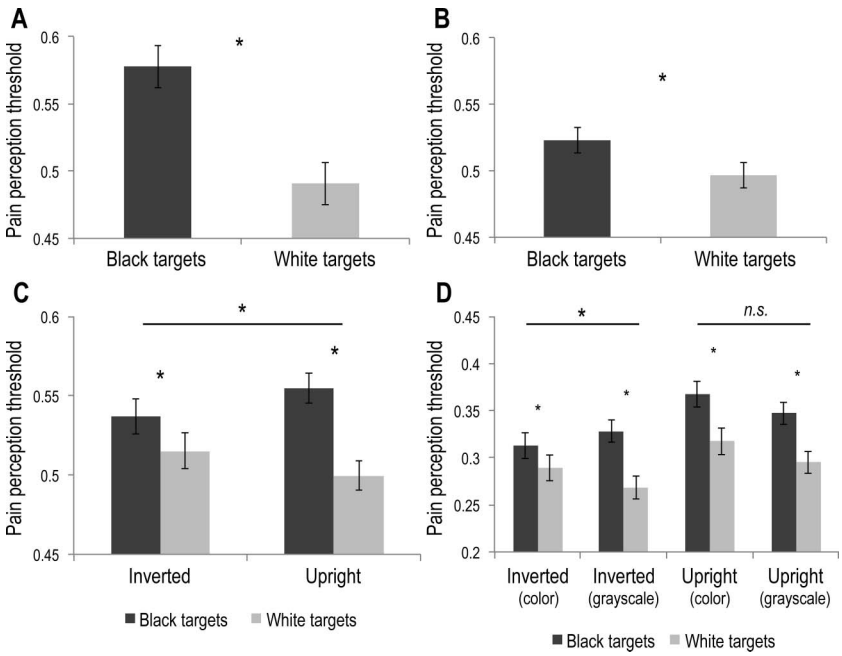

Figure 2. Racial bias in pain recognition. White perceivers showed more stringent thresholds for perceiving pain on Black faces, compared to White faces. This effect was observed for both (A) full-color stimuli in Experiment 1, as well as (B) gray-scale stimuli that had been equated on contrast and luminance 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—although 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 used the forward condition.) Error bars represent adjusted 95% within-subject confidence intervals (cf. Morey, 2008). * $p < .05$.

threshold for pain perceptions, $F(1, 78)$[4] $= 3.10$, $p = .082$; $\eta_p^2 = .04$. Participants prescribed marginally less analgesic cream to Black targets ($M = 4.02$, $SD = 4.90$), compared to White targets ($M = 4.96$, $SD = 5.08$). Although this difference was not statistically significant, the trend is nevertheless consistent with real-world evidence suggesting that the pain of Black patients is undertreated (Green et al., 2003; Mossey, 2011; Smedley et al., 2009).[5]

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 toward 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 ($M_{Black} = 3.53$, $SD_{\text{Black}} = 0.79$; $M_{White} = 4.51$, $SD_{\text{White}} = 0.80$), but they also reported feeling less warmly toward Blacks than Whites, overall ($M_{Black} = 63.32$, $SD_{\text{Black}} = 24.37$; $M_{White} = 70.12$, $SD_{\text{White}} = 24.07$).

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 described above, we tested this relationship specifically within participants receiving the forward version of our task. As predicted, bias in pain perception thresholds (Black thresholds−White thresholds) was associated with bias in treatment recommendations (White prescriptions−Black prescriptions; $r = .387$, $p = .016$). 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 ($B = 9.50$, $SE = 3.80$, $t(37) = 2.50$, $p = .017$), even after adjusting for bias in status judgments and explicit racial bias. No other predictors were significantly associated with racial bias in treatment recommendations ($ps > .187$). Thus, the relationship appeared robust to these other factors. In sum, 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.

[4] 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.

[5] 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. A meta-analytic review of these data can be found in the online supplementary materials.

Finally, we tested whether biases in perception facilitate the effect of race on treatment recommendations (once again, within participants who received forward versions of the task). Within-subjects mediation analysis yielded a point estimate of −0.998 for the indirect effect of race on treatment recommendations through bias in pain perception (95% confidence interval [CI]: [−2.530, −0.040]; explicit racial bias and judgments of status also included as competing within-subjects mediators). No other measures mediated the relationship between race and treatment. In other words, participants prescribed .998 fewer grams of pain reliever as a result of differences in thresholds for perceiving pain on treated Black versus White targets' faces.

Experiment 2

Experiment 1 suggested that White perceivers saw pain on Black faces less readily than pain on White faces, which facilitated discrepancies in treatment—to the extent that participants saw pain more readily on the faces of White targets, they also prescribed them more of a non-narcotic pain reliever. Notably, this relationship existed over and above the influence of explicit racial bias or bias in social status judgments. Although the stimuli were ecologically valid visual images of pain, it introduced the possibility that low-level differences in our stimuli 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, although 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) 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 Mechanical Turk (33 male, mean age = 35.29, *SD* = 10.92). Sample size was determined a priori as in Experiment 1: We recruited a large enough sample ($N_{overall}$ = 119) to yield enough White participants for the power necessary to detect a moderate correlation between biases in pain perception and treatment.

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 (Figure 3).

Procedure. The Experiment 2 procedure was identical to Experiment 1, with two critical differences. First, as our stimulus set had grown by the start of Experiment 2, participants now saw morphed images of 6 Black and 6 White male actors (equated on color, contrast, and luminance). Second, following the pain rating phase and treatment recommendations task, we also asked participants to report on their endorsement of biological differences between Blacks and White (Hoffman et al., 2016). On average, participants endorsed 1.98 (*SD* = 2.50) of the 11 possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true. This endorsement was significantly different from 0 in a one-sample *t* test, $t(79) = 7.08$, $p < .001$. As in Experiment 1, participants were randomly assigned to a forward (*N* = 42) or backward version (*N* = 38) of the task.

Analyses. Analyses for Experiment 2 were essentially identical to Experiment 1, with the addition of a measure of endorsement of false beliefs concerning biological differences between Blacks

Figure 3. Sample stimuli presented in Experiment 2. Participants saw gray-scaled, contrast-, and luminance-matched morphs between neutral (left) and painful (right) facial expressions along 11 equidistant points.

and Whites as a competing predictor in the multiple regression examining influences on bias in treatment recommendations. We rescored responses as a 0 for all false items that participants rated as definitely, probably, or possibly untrue, and as a 1 for all false items that participants rated as possibly, probably, or definitely true, and we added together the rescored values for all 11 false items.[6] As such, rescored values on this measure could range from 0 to 11.

Finally, within participants receiving the forward version of the task (see Experiment 1 analyses), we conducted both multiple regression and within-subjects mediation analysis pitting racial bias in pain recognition against racial bias in status judgments ($\alpha = .47$, averaging across Black and White targets), explicit racial bias, and endorsement of false beliefs[7] 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 White participants would see 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 perception, $F(1, 78) = 14.33$, $p < .001$, $\eta_p^2 = .16$. Participants displayed more stringent thresholds for perceiving pain on Black faces ($M = 0.52$, $SD = 0.24$), versus White faces ($M = 0.50$, $SD = 0.25$; Figure 2B). This extends the pattern we observed previously 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 assessed the interaction between target race and task version, to test 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 the magnitude of racial bias in pain recognition did not differ vary based on whether participants saw morphs in a forward or backward order.

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, $F(1, 78)$[8] $= 0.03$, $p = .858$, $\eta_p^2 < .01$. Participants' prescriptions of the analgesic cream was not significantly lower for Black targets ($M = 6.03$, $SD = 6.13$) compared to White targets ($M = 6.12$, $SD = 6.12$). 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 toward 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 ($M_{Black} = 3.45$, $SD_{\text{Black}} = 0.76$; $M_{White} = 4.22$, $SD_{\text{White}} = 0.92$) and also reported feeling less warmly toward Blacks than Whites overall ($M_{Black} = 65.45$, $SD_{\text{Black}} = 25.48$; $M_{White} = 72.18$, $SD_{\text{White}} = 23.76$).

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 forward 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 adjusting for bias in status judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites (for zero-order correlations between all predictors, see Supplementary Tables S1B and S2B in the online supplementary material). No other predictors were significantly associated with bias in treatment recommendations ($ps < .257$).

That being said, when we tested for evidence of mediation, we observed an indirect effect of race on treatment through perceptual bias of 0.042 with a 95% CI of [−0.298, 0.349], suggesting that this effect was not significantly different from zero. No other measures (e.g., explicit bias, status judgments) mediated the relationship between race and treatment. Together, these results partially replicate and extended our final findings 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. However, this perceptual component did not statistically mediate the influence of race on treatment.

Experiment 3

Experiments 1 and 2 demonstrated that White perceivers showed more stringent thresholds for recognizing pain on the faces of Black targets, versus White targets. What's more, this perceptual bias was associated subsequent racial disparities in treatment recommendations (though evidence for mediation was not ob-

[6] 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. One might argue that our use of it here minimizes meaningful variation. Instead, we could have simply summed participants' responses for each item 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 the online supplementary materials).

[7] Because the false beliefs scale is not a repeated measure consisting of separate items regarding Black and White individuals, it could not be entered as competing mediator in the within-subjects mediation analysis.

[8] 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.

tained), and could not be accounted for through low-level visual differences in hue, contrast, or luminance. That 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 simply the downstream consequence of differential attributions of pain tolerance to Blacks and Whites. Furthermore, despite our efforts to systematize the process of collecting posed images of painful facial expressions, and to balance 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 designed a follow-up experiment to address these concerns and pinpoint the precise perceptual contributions to racial bias in pain recognition. Other-race face processing is more holistic or configural in nature, while same-race face processing is typically featural, or component-based (Rhodes et al., 2006; Hancock & Rhodes, 2008). Disruptions in configural processing—not only associated with viewing other-race faces, but also the putative perceptual dehumanization of marginalized individuals (Fincher & Tetlock, 2016)—might underscore racial bias in pain perception. Notably, face inversion also disrupts configural processing (Freire, Lee, & Symons, 2000; Maurer, Grand, & Mondloch, 2002) and has been used to examine altered configural processing of other-race faces (Caharel et al., 2011; Hancock & Rhodes, 2008; Rhodes, Tan, Brake, & Taylor, 1989; Valentine & Bruce, 1986). We predicted that if racial bias in the visual perception of pain stems from differential deployment of configural processing for Black and White faces in White perceivers, then this bias should be observed for upright morphs of Black and White targets but attenuated when participants were presented with inverted stimuli. This pattern would provide compelling evidence that race biases perceptions of pain.

Method

Participants. We recruited 158 White participants through Mechanical Turk (74 male, *M* age = 36.39, *SD* = 12.84). As in Experiments 1 and 2, we recruited a large enough sample ($N_{overall}$ = 196) to yield enough White participants per cell to obtain the power necessary to detect a moderate correlation between biases in pain perception and treatment.

Stimuli and procedure. The procedure for Experiment 3 was identical to Experiment 1, with two differences. First, participants saw morphed images of five Black and five White male actors. 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 was designed to either conserve (upright) or disrupt (inverted) configural face processing (Supplementary Figure S1 in the online supplementary material). For participants in the inverted condition, targets also appeared in inverted orientation in the treatment recommendations task. As in Experiments 1–2, participants were randomly assigned to a forward (*n* = 81) or backward version (*n* = 77) of the task.

Analyses. Analyses for Experiment 3 were based on Experiment 1, with a few key alterations. First, we conducted a 2 (target race: Black vs. White) × 2 (presentation orientation: upright vs. inverted) × 2 (presentation order: forward vs. backward) ANOVA to assess (a) whether the threshold for pain perception varied by 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 by presentation order. We also 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.

We once again examined whether racial bias in pain perception was associated with racial bias in treatment recommendations, via multiple regression. 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 and (b) allowed us to assess the replicability of the relationship between bias in perception and treatment observed in Experiments 1–2. Ultimately, although we were agnostic as to whether the relationship between pain recognition and care would be reduced for inverted faces, we first formally tested whether this relationship varied significantly as a function of orientation.

Within participants receiving the forward 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, testing bias in pain recognition, bias in status judgments, and explicit racial bias as predictors of bias in treatment.

Finally, we ran a within-subjects mediation analysis similar to those in Experiments 1–2, focused specifically on upright presentations in the forward version of the task.

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 inverted, $F(1, 76) = 4.82$, $p = .031$, $\eta_p^2 = .06$ ($M_{Black} = 0.54$, $SD_{Black} = 0.24$; $M_{White} = 0.52$, $SD_{White} = 0.24$; Figure 2C), 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, orientation, and order, $F(1, 154) = .006$, $p = .940$, $\eta_p^2 < .01$). In other words, disrupting configural face processing dampened racial bias in pain perception.

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, $F(1, 135)$[9] $= 0.89$, $p = .347$, $\eta_p^2 = .01$. 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 said, we observed a marginally significant interaction between target race and presentation orientation on participants' treatment recommendations, $F(1, 135) = 2.84$, $p = .094$, $\eta_p^2 = .02$: participants who saw upright faces did not prescribe significantly different amounts of analgesic to Black and White targets, $F(1, 68) = 0.23$, $p = .631$, $\eta_p^2 < .01$ ($M_{Black} = 4.30$, $SD_{\text{Black}} = 5.00$; $M_{White} = 4.54$, $SD_{\text{White}} = 4.98$), but participants who saw inverted faces prescribed Black targets significantly more analgesic, $F(1, 67) = 4.23$, $p = .044$; $\eta_p^2 = .06$ ($M_{Black} = 4.64$, $SD_{\text{Black}} = 4.66$; $M_{White} = 3.80$, $SD_{\text{White}} = 4.54$). In other words, Black targets were actually recommended more analgesic than White targets when configural face processing was disrupted.

However, replicating the results of 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 was not statistically significant, $F(1, 155) = 2.70$, $p = .102$, $\eta_p^2 = .02$. Participants rated the Black target as being lower in status than the White target ($M_{Black} = 3.43$, $SD_{\text{Black}} = 0.75$; $M_{White} = 4.32$, $SD_{\text{White}} = 0.87$). We also observed a main effect of race on warmth toward Blacks and Whites, $F(1, 156) = 17.41$, $p < .001$, $\eta_p^2 = .10$: participants reported feeling less warmly toward Blacks than Whites, overall ($M_{Black} = 64.14$, $SD_{\text{Black}} = 22.84$; $M_{White} = 72.32$, $SD_{\text{White}} = 19.98$), again replicating the results of 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, 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 ($B = 9.09$, $SE = 5.04$, $t(34) = 1.81$, $p = .081$), adjusting 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 S1C and S2C in the online supplementary material). 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 S1C and S2C in the online supplementary material). No other predictors were significantly associated with bias in treatment recommendations in the inverted condition ($ps < .503$).

Finally, we tested for evidence of mediation within participants in the upright condition. Although we observed an indirect effect of race on treatment through perceptual bias in the predicted direction ($-.778$), the 95% CI bounding this effect included zero [-2.212, .534]. No other measures mediated the relationship between race and treatment.

In sum, these findings broadly replicate the results of Experiments 1 and 2, suggesting that racial bias in the threshold for pain perception is 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. That said, evidence for mediation was once again not obtained.

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 with full color stimuli. Finally, we measured participants' endorsement of biological differences between Blacks and Whites and tested whether participants' subjective evaluations of targets' physical strength might account for racial bias in the perception and treatment of pain. We also sought to replicate the inversion effect with a larger sample to generate a more precise estimate of effects.

Method

Participants. We recruited 307 White participants through Mechanical Turk (150 male, M age $= 37.28$, $SD = 12.88$). As in Experiments 1 through 3, we recruited a large enough sample ($N_{\text{overall}} = 328$) to yield enough White participants per cell to obtain the necessary power to detect a moderate correlation between bias in pain perception and bias in treatment.

Stimuli and procedure. The procedure for Experiment 4 was adapted from Experiment 3, with five critical differences. First, participants saw morphed images of five Black and five White

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

male actors. Second, we manipulated both presentation orientation and stimulus hue 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 gray-scale images, 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 used only the forward task version in Experiment 4, 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 recommendation task, 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 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 asked participants to report on their endorsement of biological differences between Blacks and White (Hoffman et al., 2016). On average, participants endorsed 2.18 (SD = 2.71) of 11 possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true. This endorsement was significantly different from 0 in a one-sample t test, $t(306) = 14.10$, $p < .001$.

Analyses. Experiment 4 analyses were based off of Experiment 3, with several alterations. First, we conducted a 2 (target race: Black vs. White) × 2 (presentation orientation: upright vs. inverted) × 2 (hue: color vs. gray-scale) ANOVA to assess (a) whether thresholds 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 effects of race, orientation, and their interaction 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, 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. 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) and 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 regressions within the "Upright" and "Inverted" conditions (criterion: racial bias in treatment recommendations; predictors: racial bias in pain recognition, status judgments, and strength judgments; explicit racial bias; false beliefs). Finally, we ran a within-subjects mediation analysis similar to those in Experiments 1–3, specifically within participants who saw upright presentations.

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, SD = .17),[10] as compared to White faces (M = 0.29, SD = .17). This pattern of perceptual bias appears highly replicable in this sample.

As in 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 ($F(1, 303) = 3.28$, $p = .071$, $\eta_p^2 = .01$). To decompose the three-way interaction, we assessed the interaction between target race and presentation orientation at either level of hue.

For participants who saw gray-scale morphs, 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 orientation, participants displayed more stringent thresholds for pain on Black faces (M = 0.36, SD = .18), versus 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 morphs, 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 orientation, participants displayed more stringent thresholds for perceiving pain on Black faces (M = 0.32, SD = .17) versus 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; Figure 2D). Thus, the dampening effect of face

[10] Note that the difference in pain perception threshold values is because Experiment 4 only used the forward version of the task. For additional comparison between versions, see the online supplementary materials.

inversion on racial bias in pain perception was larger for color faces: 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.[11]

Differences in treatment recommendation, status and strength perceptions, and feeling thermometer ratings as a function of target race and presentation orientation. Although 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 on treatment recommendations when targets were presented upright, $F(1, 143) = 4.51$, $p = .036$, $\eta_p^2 = .03$. Participants who saw upright targets prescribed more analgesic to White targets ($M = 5.85$, $SD = 5.37$) than Black targets ($M = 5.18$, $SD = 4.92$). When targets were inverted, 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 treatment recommendations. This pattern coheres broadly with Experiment 3: In both cases, Black targets fared better in the inverted condition, though the nature of the Race × Orientation interaction varied across experiments.

Replicating the results of the first three experiments, we also observed a main effect of target race on judgments of social status ($F(1, 303) = 131.78$, $p < .001$, $\eta_p^2 = .30$. Participants rated the Black target as being significantly lower in status than the White target ($M_{Black} = 3.36$, $SD_{\text{Black}} = 0.76$; $M_{White} = 4.19$, $SD_{\text{White}} = 0.87$), collapsing across hue and presentation orientation. However, 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 warmth toward Blacks and Whites, $F(1, 303) = 21.09$, $p < .001$, $\eta_p^2 = .07$. Overall, participants felt less warmly toward Blacks than Whites ($M_{Black} = 66.90$, $SD_{\text{Black}} = 26.35$; $M_{White} = 73.42$, $SD_{\text{White}} = 22.25$).

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, $F(1, 303) = 74.80$, $p < .001$, $\eta_p^2 = .20$, such that collapsing across hue and presentation orientation, participants reported that the Black targets were stronger than the White targets ($M_{Black} = 4.78$, $SD_{\text{Black}} = 1.09$; $M_{White} = 4.11$, $SD_{\text{White}} = 1.13$). We also observed a marginally significant interaction between target race and hue, $F(1, 303) = 3.45$, $p = .064$, $\eta_p^2 = .01$. Specifically, although participants who saw color images judged Black targets to be stronger than their White counterparts, $F(1, 158) = 48.63$, $p < .001$, $\eta_p^2 = .15$ ($M_{Black} = 4.64$, $SD_{\text{Black}} = 1.11$; $M_{White} = 4.11$, $SD_{\text{White}} = 1.11$), this effect was somewhat larger among participants who saw gray-scale images, $F(1, 147) = 26.09$, $p < .001$, $\eta_p^2 = .24$ ($M_{Black} = 4.92$, $SD_{\text{Black}} = 1.06$; $M_{White} = 4.12$, $SD_{\text{White}} = 1.14$). 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 observed 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 ($ps > .180$).

Next, we ran separate multiple regressions within the upright and inverted conditions, to test whether the pattern of results in Experiment 3 could be replicated. These analyses collapsed across 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: racial bias in pain recognition for the treated targets was positively associated with racial bias in treatment recommendations ($B = 3.85$, $SE = 1.50$, $t(143) = 2.57$, $p = .011$), adjusting 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 S1D and S2D in the online supplementary material). Bias in strength judgments was also related to bias in treatment, adjusting for the other predictors ($B = 0.55$, $SE = 0.23$, $t(143) = 2.40$, $p = .018$): 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.

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 in the inverted condition ($ps > .156$).

Finally, we tested for evidence of mediation within participants in the upright condition. We observed an indirect effect of race on treatment through perceptual bias of $-.104$, however, the 95% CI bounding this effect included zero [-0.298, 0.027]. No other measures mediated the relationship between race and treatment.

These results provide an additional replication of a pattern observed across the first three experiments: for upright faces, racial bias in pain perception was associated with subsequent bias in

[11] We note that in a subsequent investigation, we replicated this null inversion effect for gray-scale faces. See Supplementary Experiment 1 in the online supplementary materials for details.

treatment recommendations, and this relationship was independent of the influence of explicit stereotypes and prejudices. However, although 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. As for our mediation analysis, while the trend was once again in the predicted direction, evidence for statistical mediation was not obtained.

Interim Discussion

Taken together, Experiments 1–4 consistently demonstrate that White perceivers display different thresholds for recognizing pain on Black and White faces. Consistent with a wide body of literature on 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 depend on our ability to balance Black and White stimuli based on their facial structure and, more importantly, the intensity of their painful expressions. If Black actors in our stimulus set were less expressive than their White counterparts, this would introduce a confound that could account for differences in thresholds for recognizing 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, 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 such differences—first, based on subjective judgments of our stimuli (Experiment 5; see also Supplementary Experiment 2 in the online supplementary material), and by using new stimuli that were objectively equated in facial structure and expression intensity (Experiments 6 and 7). Together, these experiments provided a stronger test of our central hypotheses. Moreover, in Experiment 7, we added a third group of Asian targets, to test whether racial bias in pain perception is generalized to racial minority groups other than Black targets.

Experiment 5

In Experiment 5, we examined racial bias in pain perception using stimuli that were subjectively equated on factors related to pain expression and tolerance. Specifically, we characterized our stimuli in terms of expression intensity, believability, and specificity, as well as social factors like masculinity, status, and strength, and then selected a subset of targets that were balanced across these subjective ratings. If White perceivers do have more stringent thresholds for perceiving pain on Black faces, then this is a particularly conservative approach, because subjective ratings of Black targets' expressions likely underestimate their intensity.

We also adjusted our measure of treatment recommendations. While racial bias in pain perception was consistently associated with racial bias in treatment in Experiments 1–4, the treatment measure was always framed in terms of memory for targets' expressions, rather than perception of those expressions. In the real world, medical practitioners are usually required to make medication decisions based on assessments of pain in the moment—rather than from memory. As such, this design potentially conflates memory-based and perceptual influences on racial bias in pain perception and treatment. To provide a more valid test of the relationship between perception and treatment decisions, Experiment 5 presented ambiguously painful expressions in the treatment recommendations task. Based on the Perceptual Model of Intergroup Relations, biases should alter perceptions and behavior when visual input is ambiguous (see Xiao et al., 2016a). In sum, 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 bias in treatment.

Method

Participants. We recruited 129 White participants through Mechanical Turk (70 female, mean age = 36.03, SD = 10.60). We revised our sample size upward based on the results of Experiments 1–4: Having established the average strength of the relationship between racial biases in pain perception and treatment (r = .250 within upright presentations in the forward version in Experiments 1–4; online supplementary materials), Experiments 5–7 aimed for a large enough sample (N = 120) afford us appropriate statistical power (e.g., 80%).

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 Mechanical Turk participants (130 female; mean age = 34.41, SD = 10.65; 194 White), who rated selections from our stimulus set in terms of social, emotional, and demographic characteristics. (For details on the pilot sample, procedure, and results, see the online supplementary materials.) The 16 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.

We also obtained a separate set of pilot ratings of all painful expressions in our broader stimulus set. We recruited 407 Mechanical Turk participants (223 female; mean age = 35.41, SD = 12.99; 289 White), who rated selections from our broader stimulus set in terms of their emotional characteristics (see the online 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 truly captured expressions of pain.

Procedure. Participants in Experiment 5 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 pilot ratings of neutral and painful expressions, as described above. In a departure from Experiments 1–4, participants then saw ambiguously painful expressions (e.g., 50% neutral/50% painful morphs) from two Black and two White targets in the treatment recommendations task. We also changed the instructions for this 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?" By having participants make recommendations for targets who are visibly in pain, 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, from which we calculated 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 items, including the 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 Whites (Hoffman et al., 2016). On average, participants endorsed 2.91 ($SD = 3.05$) out of the 11 possible false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true. This endorsement was significantly different from 0 in a one-sample t test, $t(128) = 10.82$, $p < .001$.[12]

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 ($M = 0.31$, $SD = 0.13$), versus White faces ($M = 0.26$, $SD = 0.13$; Figure 4A). This 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 ($M = 11.67$, $SD = 4.72$).[13] Once again, participants still recommended giving less pain reliever to Black targets than White targets.

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 Black targets as being both lower in social status than White targets ($M_{Black} = 3.35$, $SD_{\text{Black}} = 0.74$; $M_{White} = 4.38$, $SD_{\text{White}} = 0.77$), and stronger than White targets ($M_{Black} = 4.72$, $SD_{\text{Black}} = 0.89$; $M_{White} = 4.10$, $SD_{\text{White}} = 0.95$). This discrepancy may reflect a difference in wordings used in the norming survey and the present experiment. While stimuli were chosen based on ratings specific to the targets' faces ("How strong does this face look?"), participants in the present experiment made more holistic judgments of these targets ("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 ($M_{White} = 76.35$, $SD_{\text{White}} = 23.07$), than Blacks ($M_{Black} = 67.73$, $SD_{\text{Black}} = 27.94$).

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, $B = 8.04$, $SE = 2.52$, $t(128) = 3.20$, $p = .002$, adjusting 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 S2E in the online supplementary materials. No other predictors were significantly associated with bias in treatment recommendations ($ps < .139$).

As in Experiments 1–4, we tested whether biases in perception facilitate the effect of race on treatment recommendations. Within-subjects mediation analysis yielded a point estimate of −0.453 for the indirect effect of race on treatment recommendations *through*

[12] We also asked participants if they used any strategies during the pain rating phase. Although analyses of these data do not appear in the main text of this article, additional information can be found in the online supplementary materials.

[13] 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.

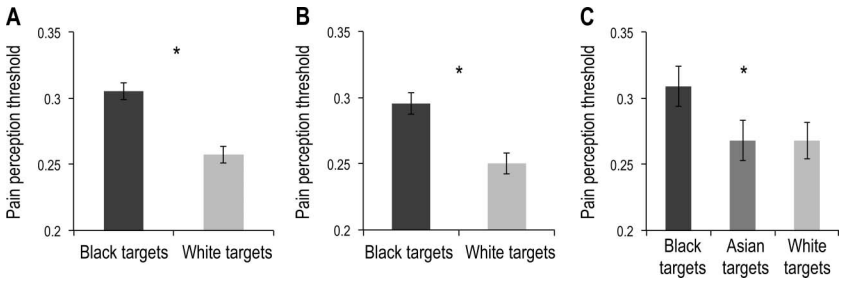

Figure 4. Racial bias in pain recognition, independent of potential stimulus confounds. White perceivers continued to display more stringent thresholds for perceiving pain on Black faces, compared to White faces. This effect was observed even when stimuli were balanced based on social judgments related to pain tolerance (e.g., dominance, masculinity, strength, etc.) and experience (e.g., pain intensity, believability) in Experiment 5 (A) and when stimuli were digitally rendered to be objectively identical in facial structure and expression in Experiment 6 (B). Moreover, Experiment 7 provided initial evidence suggesting that this bias did not generalize to Asian targets (C). Error bars represent adjusted 95% within-subject confidence intervals (cf., Morey, 2008). * $p < .05$.

bias in pain perception (95% CI [−0.803, −0.183]; explicit racial bias and judgments of status and strength also included as competing within-subjects mediators). No other measures mediated the relationship between race and treatment. In other words, participants prescribed .453 fewer grams of pain reliever as a result of differences in thresholds for perceiving pain on treated Black versus White targets' faces.

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 equated in pain intensity, specificity, and believability, among other possible confounds.[14] Moreover, replicating Experiment 1 and in line with trends observed in Experiments 3 and 4, we obtained evidence suggesting that this perceptual bias directly facilitated the relationship between race and treatment recommendations.

Experiment 6

Experiment 5 suggested that racial bias in pain perception persists independent of stimulus confounds related to subjective judgments of pain tolerance or experience. These data provide additional confidence in the results of Experiments 1–4 and illustrate that the perceptual underpinnings of racial disparities in pain care are particularly robust. Given the similarity to the effect sizes observed in Experiment 5, it is unlikely that systematic differences in our stimuli could explain the effects obtained in Experiments 1–4. (Retrospective analysis of the stimuli used in Experiments 1–4 suggests that, for the most part, these sets were balanced in pain intensity; the online supplementary materials.) However, despite our attempts to balance these 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. To overcome this hurdle, we created a set of objectively balanced stimuli: computer-generated Black and White faces making exactly the same expressions of pain, and identical in terms of facial shape and structure. Therefore, Experiment 6 represents the most conservative test of our hypotheses, as observation of a bias in the threshold for pain perception in these stimuli could only be attributable to race.

Method

Participants. We recruited 124 White participants through Mechanical Turk (75 female, *M* age = 35.81, *SD* = 11.22).

Stimuli. First, we created 41 expressions of pain in FaceGen Modeller v3.5 (Singular Inversions; Figure 5A), and recruited participants from Mechanical Turk ($N = 81$; 45 female, mean age = 37.48, $SD = 11.92$) to rate these stimuli based on the emotional expressions they resembled (see the online supplementary materials). We selected eight expressions that were consistently recognized as pain and visually discernible from each other. Each selected expression was rated as resembling pain more so than anger (all $ps < .0031$), disgust (all $ps < .0002$), fear (all $ps < .0001$), happiness (all $ps < .0001$), sadness (all $ps < .0002$), surprise (all $ps < .0001$), or threat (all $ps < .0001$). Averaged ratings across the set suggested that these eight expressions were clearly recognized 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: $M = 1.87$, $SD = 0.31$; and threat: $M = 2.08$, $SD = 0.57$).

Next, we created 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, we manipulated skin-tone to make Black and White versions of each head, and applied preloaded skin textures to further enhance the distinctiveness of each face.

Procedure. Participants in Experiment 6 first saw morphed images of eight Black and eight White male targets. For each

[14] Moreover, we replicated each result in a subsequent experiment (Supplementary Experiment 2), using an entirely different set of Black and White stimuli also balanced based on subjective ratings of social and emotional content.

Figure 5. Sample stimuli, Experiments 6 and 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 task version, 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) In Experiment 6, participants saw morphs between neutral and painful facial expressions along 11 equidistant points. The Black and White targets pictured here are making the same facial expression of pain. (C) Participants in Experiment 7 saw additional sets of Asian targets making the same expressions as their Black and White counterparts. See the online article for the color version of this figure.

target, we constructed 11 morphs. For precision's sake, we did not use morphing software (as we did in Experiments 1–5), but rather, created incremental versions of each target using FaceGen sliders, ranging from a 100% neutral expression to a 100% painful expression (Figure 5A). Each final slider value was divided by 11: a slider with a final value of 1 would be 0 in the first morph, .09 in the second, .18 in the third, and so on.

To ensure that our results were solely attributable to race, we partially counterbalanced race, expression, head shape, and texture across four versions of the task. Within each version, each expression appeared on different White and Black heads, with different skin textures (Figure 5B), and each texture also appeared on different White and Black heads. Across versions, each expression appeared on every possible head, with every possible texture.

We adjusted the instructions of the *pain rating phase* in Experiment 6 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 subset of Black and White faces making pain expressions of ambiguous intensity, and 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 completed the false beliefs measure and endorsed 2.19 ($SD = 2.68$) of the 11 false beliefs regarding biological differences between Blacks and Whites as being possibly, probably, or definitely true, on average—significantly different from 0, 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 ($M = 0.30$, $SD = 0.16$), as compared to White faces ($M = 0.25$, $SD = 0.15$; Figure 4B). This result replicates and further extends the pattern observed in Experiment 5, suggesting this bias exists even when the pain intensity is completely equated across stimuli.

Moreover, taken together with Experiment 5, a lack of stimulus balance does not seem to have inflated the size of this particular effect in Experiments 1–4. If anything, the average effect size (weighted by sample size) in Experiments 5–6 ($\eta_p^2 = .393$) is slightly larger in magnitude than the effect size in Experiments 1–4 ($\eta_p^2 = .331$; within upright presentations only).

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 treatment recommendations, $F(1, 123) = 14.45$, $p < .001$; $\eta_p^2 = .11$. Participants prescribed fewer grams of analgesic cream to Black targets ($M = 11.14$, $SD = 5.53$), versus White targets ($M = 12.27$, $SD = 5.16$), replicating the results of the majority of the previous six experiments. Moreover, and somewhat startlingly, this 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 versus 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 ($M_{Black} = 3.64$, $SD_{\text{Black}} = 0.65$; $M_{White} = 4.04$, $SD_{\text{White}} = 0.69$), participants also rated the Black targets as being stronger than the White targets ($M_{Black} = 4.88$, $SD_{\text{Black}} = 1.03$; $M_{White} = 4.63$, $SD_{\text{White}} = 1.03$). 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, $F(1, 121)$[15] $= 0.02$, $p = .893$, $\eta_p^2 < .01$. In a departure from the previous six experiments, participants reported no differences in feelings of warmth toward Blacks versus Whites, overall ($M_{Black} = 71.73$, $SD_{\text{Black}} = 22.80$; $M_{White} = 71.48$, $SD_{\text{White}} = 23.84$).

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 previously, and as predicted, comparatively higher thresholds for perceiving pain on Black faces were associated with comparatively less analgesic prescribed to Black targets, $r = .357$, $p < .001$. 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 adjusting for bias in status and strength judgments, explicit racial bias, and false beliefs regarding biological differences between Blacks and Whites. (For zero-order correlations between all predictors, see Supplementary Table S2F in the online supplementary materials. We also 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 ($ps > .252$).

As before, we conducted a within-subjects mediation analysis and obtained a point estimate of -0.531 for the indirect effect of race on treatment recommendations through bias in pain perception (95% CI [-0.929, -0.190]; explicit racial bias and judgments of status and strength also included as competing within-subjects mediators). No other measures mediated the relationship between race and treatment.

Taken together, Experiment 6 provides an additional replication and extension of the effects observed in the first five experiments—here, in the most conservative test yet. Not only does bias in the threshold for pain perception facilitate the influence of race on treatment recommendations (independent of explicit prejudice and stereotypes relevant to judgments of pain experience and tolerance), but this effect was even observed after eliminating all differences in structure and expression between Black and White targets.

Experiment 7

Experiment 6 demonstrates that even when facial structure and expression intensity are completely equated, White participants continue to see pain less readily on Black faces than White faces. However, does this disparity reflect an enhanced sensitivity to pain appearing on faces belonging to one's in-group, or a disruption in perceiving pain on Black faces? To further address the nature of this effect, we conducted an experiment in which we presented computer-generated stimuli portraying expressions of physical pain, manipulated to appear Black, White, or Asian. On one hand, White perceivers might display similar biases in thresholds for pain on Asian faces. While the Asian targets used in Experiment 7 do not represent a neutral third group (as they bear their own stereotype content and associated attitudes and prejudices), this pattern of data would be reflective of a more general, group-based bias in the visual perception of pain. On the other hand, White perceivers might see pain on Asian faces as readily as pain on White faces. This latter finding would represent initial evidence that certain minority groups are more susceptible to biased perceptions of their pain than others. Thus, Experiment 7 represents a conceptual replication of the previous study, with an additional test of whether racial bias in pain perception generalizes to other racial minority groups.

Method

Participants. We recruited 122 White participants through Mechanical Turk (63 female, M age $= 38.21$, $SD = 11.46$).

Procedure. Experiment 7 was directly adapted from Experiment 6, with the additional inclusion of Asian targets (Figure 5C). Moreover, to reduce task time, we only presented six targets per race, each making a different painful facial expression.[16] To ensure that our results were independent of the influence of other features, we partially counterbalanced race, expression, head shape, and texture across six versions of the task.[17] In total, participants could potentially view 198 faces in the pain rating phase of the task (6 targets $\times$ 3 races $\times$ 11 morphs).

Participants once again made treatment recommendations for a random subset of two Black, two White, and two Asian targets from the pain rating phase making pain expressions of ambiguous intensity, and then made social evaluations of these targets including status and strength. 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 referred directly to each target's face (e.g., "How strong does this face look?"). Further, rather than embedding the four items related to status (e.g., privilege, experience with adversity, etc.) used before, we asked participants to explicitly report on both high and low status (e.g., "How [high/low] status does this face look?"). For calculation of Black-specific biases in status and strength judgments, see the Analyses section below.

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

[16] As in Experiment 6, each expression was rated as resembling physical pain more so than anger, disgust, fear, happiness, sadness, surprise, or threat (all $ps < .003$). Moreover, these six expressions were clearly recognized as depicting pain ($M = 5.30$, $SD = 0.40$), rather than any other emotion (anger: $M = 2.57$, $SD = 0.96$; disgust: $M = 2.83$, $SD = 0.33$; fear: $M = 2.33$, $SD = 0.35$; happiness: $M = 1.29$, $SD = 0.19$; sadness: $M = 2.38$, $SD = 0.49$; surprise: $M = 1.84$, $SD = 0.35$; threat: $M = 2.15$, $SD = 0.65$).

[17] Within each version, each expression appeared on different White, Black and Asian heads, with a different skin texture within each race category. (Within each version, each texture also appeared on different White, Black, and Asian heads.) Moreover, we ensured that any expression/head pairing appearing in one version of the task was also presented in two other versions of the task, with different skin tones each time. For example, Head1 was paired with expression "AJ2" and presented with Black skin tone in Version 1, while this pairing appeared as Asian in Version 2, and White in Version 3. The full counterbalancing scheme can be accessed online: osf.io/dmqy9/.

Participants also completed feeling thermometers, from which we calculated their explicit racial bias ($M = 7.18$, $SD = 24.63$). Finally, participants completed the false beliefs measure and endorsed 2.51 ($SD = 3.15$) of the 11 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; $t(121) = 8.80$, $p < .001$).

Analyses. Analyses for Experiment 7 were similar to those in Experiment 6, with the added inclusion of Asian targets. As such, we created a measure of Black target-specific bias in pain perception, analogous to measures of outgroup-specific harm in prior research of intergroup bias (Cikara, Botvinick, & Fiske, 2011), calculated as (ThresholdBlack−ThresholdWhite) − (ThresholdAsian−ThresholdWhite). Using this formula, a participant whose thresholds for pain on White and Asian faces both equaled .5, but who had a threshold of .75 for pain on Black faces would receive a Black target-specific bias score of .25, while a participant with a threshold of .5 for pain on White faces but thresholds of .75 for both Black and Asian faces would receive Black target-specific bias score of 0. This method allows us to produce a measure reflecting a disregard for pain on Black faces in particular, adjusting for a general tendency to see pain more readily on White faces. We also calculated Black target-specific biases in pain management, status judgments, and strength judgments using similar formulas.

While we distinguished between judgments of high and low social status, these two sets of judgments showed weak internal consistency across race ($\alpha = .35$, averaging across Black, White, and Asian targets). That being said, Black target-specific bias in high status and low status judgments were strongly correlated with each other, $r = .711$, $p < .001$, as were the uncorrected (e.g., Black vs. White) measures of bias, $r = .697$, $p < .001$. Therefore, for simplicity's sake, we chose to create composite across the two items (reverse-scoring the low status measure and averaging across the pair), where positive numbers indicate a greater tendency to judge White targets as being of higher status than Black targets, controlling for judgments of Asian targets' status ($M = -0.35$, $SD = 1.18$), in addition to a Black target-specific measure of bias in strength judgments ($M = 0.39$, $SD = 1.03$).

Results

Racial bias in pain recognition. We observed a significant main effect of target race on thresholds for pain perception ($F(2, 242) = 33.66$, $p < .001$, $\eta_p^2 = .22$). Specifically, participants displayed more stringent thresholds for perceiving pain on Black faces ($M = .31$, $SD = .17$) compared to both White ($M = .27$, $SD = .16$; $p < .001$) and Asian faces ($M = .27$, $SD = .16$; $p < .001$; Figure 4C). However, the difference in pain perception thresholds for White and Asian faces was not significant ($p = .919$). These results suggest that the disparities observed in White perceivers in Experiments 1–6 do not reflect a general pattern of group-based bias, as these biases did not generalize to Asian targets.

Differences in treatment recommendation, status & strength judgments, and feeling thermometer ratings as a function of target race. We also observed a significant main effect of target race on subsequent treatment recommendations ($F(2, 242) = 10.98$, $p < .001$, $\eta_p^2 = .08$). Participants prescribed less analgesic cream to Black targets ($M = 10.21$, $SD = 5.19$) than either White ($M = 10.79$, $SD = 5.04$; $p = .024$) or Asian targets ($M = 11.34$, $SD = 5.07$; $p < .001$). To our surprise, our sample of White participants actually prescribed more analgesic cream to Asian targets than White targets ($p = .014$). These data replicate the pattern observed in our previous investigations: the same expressions of pain received significant more analgesic cream on average when they appeared on a White face, compared to a Black face. On the other hand, these data also demonstrate a novel discrepancy in pain management, such that Asian targets actually received even more analgesic than their White counterparts making the same expressions of pain.

With regards to participants' social evaluations of these targets, we observed significant main effects of target race on judgments of social status, $F(2, 240) = 14.40$, $p < .001$, $\eta_p^2 = .11$. In a departure from patterns observed in the previous experiments, Black targets were judged as looking higher in status ($M = 4.50$, $SD = 0.89$) than White targets ($M = 3.95$, $SD = 0.93$, $p < .001$), as well as Asian targets ($M = 4.14$, $SD = 0.94$, $p = .001$). In addition, Asian targets were also rated as looking higher in social status ($p = .010$) than White targets. Although this result was not expected, it coheres with data from Supplementary Experiment 2 in the online supplementary materials (which also used more face-specific social evaluation items, rather than the holistic judgments used in Experiments 1–6), where participants no longer judged Black faces as looking lower status than White faces.

Moreover, we observed a significant main effect of target race on judgments of strength, $F(2, 240) = 21.32$, $p < .001$, $\eta_p^2 = .15$. Participants rated Black faces ($M = 5.00$, $SD = 1.07$) as looking stronger than both Asian ($M = 4.61$, $SD = 1.05$; $p < .001$) and White faces ($M = 4.37$, $SD = 1.17$; $p < .001$). In addition, participants rated Asian faces as looking stronger than White faces ($p = .013$). This is broadly consistent with our finding in Experiment 6 that even when structure was identical, Black targets were judged to be both stronger than targets from other races.

Finally, we observed a significant main effect of target race on feeling thermometer ratings, $F(1, 121) = 10.37$, $p < .001$, $\eta_p^2 = .08$. Participants reported feeling less warm toward Blacks ($M = 65.93$, $SD = 25.18$) than Whites ($M = 73.11$, $SD = 22.93$).

Bias in pain recognition predicts bias in treatment recommendations. Finally, increased Black target-specific biases in pain perception were associated with similar Black target-specific biases in prescriptions during the treatment recommendation task, $r = .180$, $p = .047$. Moreover, Black-specific bias in pain recognition for the treated targets remained a marginally significant predictor of racial bias in treatment recommendations, $B = 3.82$, $SE = 1.97$, $t(120) = 1.94$, $p = .055$, adjusting for bias in status and strength judgments, explicit anti-Black bias, and false beliefs regarding biological differences between Blacks and Whites (for zero-order correlations between all predictors, see Supplementary Table 2G in the online supplementary materials). No other predictors were significantly associated with bias in treatment recommendations ($ps > .527$).

That being said, when we tested for evidence of mediation, we observed an indirect effect of race on treatment through perceptual

bias[18] of −0.047 with a 95% confidence interval of [−0.372, 0.189], suggesting that this effect was not significantly different from zero.

Taken together, these data provide one final replication of our previous findings: racial bias in pain perception is positively associated with racial bias in treatment recommendations, such that White perceivers who have more stringent thresholds for recognizing pain on Black faces also recommend prescribing less pain reliever to these Black individuals. This association exists even when adjusting for explicit stereotypes and prejudice related to judgments of pain experience and pain tolerance, and does not seem to reflect a general, group-based bias in the visual perception of painful expressions. That being said, evidence for mediation was not obtained, reflecting some of the heterogeneity across the previous experiments.

Meta-Analysis Across Experiments

Given the procedural similarity across experiments, we collapsed across these data to get a meta-analytic estimate of the effects of race on the perception and treatment of pain. To assess the size of our primary measures of interest (racial bias in pain perception, racial bias in treatment, and the association between treated bias in perception and bias in treatment) we conducted separate, sample size-weighted meta-analyses in R (Version 3.5.1) using *metafor* (Viechtbauer, 2010). We focused specifically on upright presentations for the first two measures, to isolate conditions in which configural face processing was not manipulated, and upright presentations in forward tasks for the last measure, for purposes detailed in Experiment 1. For each measure, we present a table and forest plot detailing data across all seven experiments in the main text, plus two supplementary investigations (Supplementary Experiments 1 and 2 in the online supplementary materials), as well as a meta-analytic effect size estimate derived from a random effects model.

Meta-Analytic Evidence for Bias in Pain Perception

We observed a large effect of race on thresholds for pain perception (within upright presentations): White perceivers had more stringent thresholds for recognizing pain on Black faces versus White faces (Figure 6A), with an average difference of .05 between Black and White targets ($z = 8.07$, $p < .0001$; 95% CI [.04, .06]).[19] Moreover, racial bias in pain perception was moderated by the disruption of configural face processing (via inversion) across studies, though this effect varied by stimulus hue: the meta-analytic estimate of the difference in perceptual bias between upright and inverted conditions was significant for full-color stimuli ($z = 2.84$, $p = .004$), but not for gray-scale stimuli ($z = -1.41$, $p = .159$). This suggests the effects might be due, in part, to visual cues that make race vivid to perceivers, which is important since this more closely represents information available to providers during real medical interactions.

Meta-Analytic Evidence for Racial Bias in Treatment Recommendations

We observed a large effect of race on treatment recommendations (within upright presentations): White perceivers prescribed more analgesic to White targets versus Black targets (Figure 6B), with an average difference of .55 g between Black and White targets ($z = 4.05$, $p < .0001$; 95% CI [.28, .82]).[20] Therefore, treatment varied as a function of race, mirroring the bias in perception described above, and an extensive public health literature detailing disparities in pain care (Anderson et al., 2009; Green

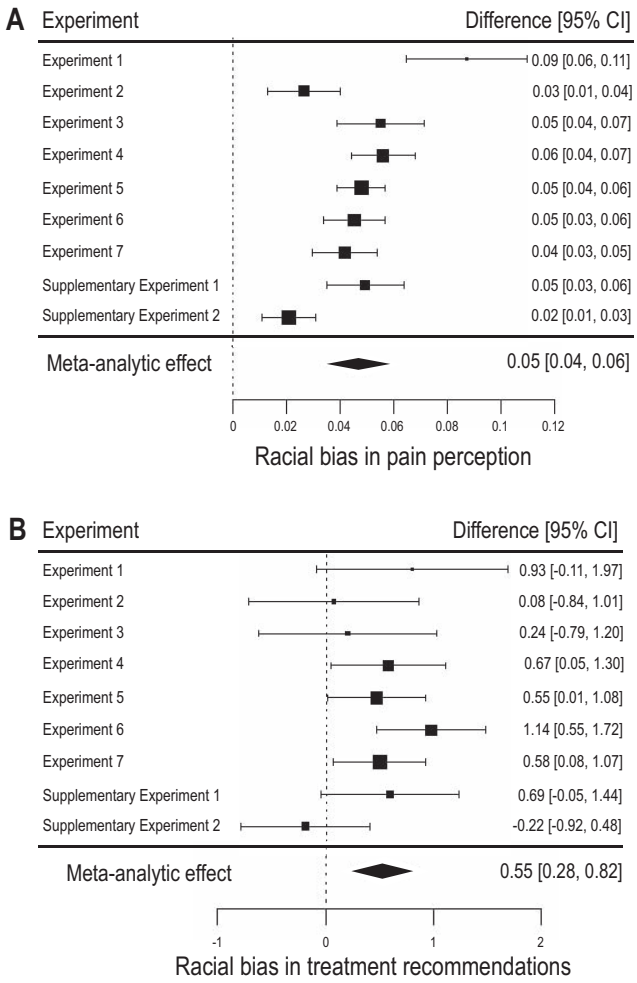

Figure 6. Forest plots of racial bias in pain perception and treatment. Positive values indicate (A) more stringent thresholds for recognizing pain on Black versus White faces and (B) more analgesic prescribed to White versus Black targets (within upright presentations). For each study, we report the raw mean difference between Black and White targets on both measures, and the corresponding 95% confidence interval. Larger boxes in the plot represent larger sample sizes.

[18] The within-subjects mediation analysis in Experiment 7 only compared between Black and White targets and did not use the Black-specific indices of bias we calculated.

[19] Notably, the variability in estimates of effect size suggested greater heterogeneity than would be expected due to chance ($\tau = 0.02$, $I^2 = 86.13\%$, $H^2 = 7.21$, $Q_8 = 48.16$, $p < .001$), suggesting the possible influence of a moderator.

[20] Variability in estimates of effect size did not differ from what would be expected due to chance ($\tau = 0.22$, $I^2 = 28.42\%$, $H^2 = 1.40$, $Q_8 = 11.33$, $p = .184$).

et al., 2003). In addition, the meta-analytic estimate of the difference in treatment between upright and inverted conditions was once again significant for full-color stimuli ($z = 4.35$, $p < .001$), but not gray-scale stimuli ($z = 0.29$, $p = .770$).

Racial Bias in Pain Perception Is Associated With Racial Bias in Treatment Recommendations

Finally, we observed a consistent positive association between treated[21] racial bias in pain perception and racial bias in treatment recommendations (estimated $r = .300$, $z = 6.28$, $p < .0001$; 95% CI [.20, .39]; within upright presentations and forward task versions, Figure 7).[22] Notably, this association was stronger within upright presentations and forward task versions versus all other presentation combinations ($z = 3.31$, $p < .001$).

In sum, these meta-analytic results suggest that racial bias in pain perception is indeed positively associated with racial bias in treatment. 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 better predictor of bias in treatment. 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 Black faces.

As noted early in the text, a stronger test of whether differences in perceptual thresholds for recognizing pain on Black versus White faces facilitates gaps in treatment is afforded by within-subjects mediation. Though we tested for mediation in each experiment, there was considerable heterogeneity in these results. As such, we conducted a mediation synthesis in R (Huang et al., 2016), to combine across within-subjects mediation results (Montoya & Hayes, 2017) from all nine experiments (including Supplementary Experiments 1–2 in the online supplementary materials). The meta-analytic estimate of the indirect effect of race on treatment recommendations *through* differences in perceptual thresholds for pain on Black versus White faces across all experiments was −0.331 (95% CI [−0.403, −0.266]). In other words, participants gave .331 fewer grams of analgesic to Black (vs. White) as a consequence of having more stringent thresholds for seeing pain on treated Black targets' faces. No other measures mediated the relationship between race and treatment.[23] This meta-analysis provides convergent evidence indicating that racial bias in pain perception facilitates bias in subsequent treatment recommendations, and further, does so over and above the influence of explicit stereotypes and prejudice.

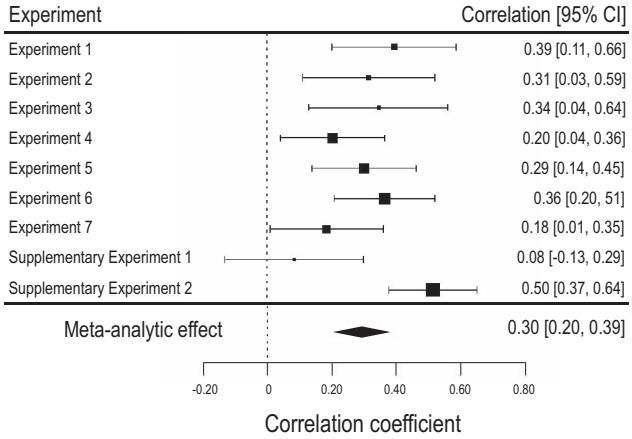

Figure 7. Forest plots of the association between racial bias in pain perception and treatment recommendations. Positive values indicate an association between participants' tendency to see pain later on Black targets' faces and a tendency to prescribe less analgesic to those same Black targets. (These data reflect this association for the treated measure of bias in pain perception, within upright presentations in forward tasks. Additional information on the overall measure of bias in pain perception can be found in Footnote 22 and in the online supplementary materials.) For each study, we report the correlation between bias measures, and the corresponding 95% confidence interval. Larger boxes in the forest plot represent studies with larger sample sizes.

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, versus White faces. This result was highly replicable, generalized across stimuli, could not be attributed to differences in low-level features or subjective evaluations between Black and White faces, and consistently associated with behavior. Specifically, participants who had more stringent thresholds for perceiving pain on Black faces continually prescribed

[21] Although we used the treated bias in pain perceptions thresholds as a predictor throughout (because this represented the bias in pain perception specifically for targets "receiving" treatment), we could have used participants' overall bias in pain perception instead. We examined the extent to which this association was both robust to this analytic decision. We still observed a consistent positive association between "overall" racial bias in pain perception and bias in treatment (estimated $r = .156$, $z = 3.06$, $p = .002$; within upright presentations and forward task versions; 95% CI [.06, .26]). All experiments' estimates were between −.09 and .34. (Variability in estimates of effect size differed from what would be expected due to chance ($\tau = 0.11$, $I^2 = 53.88\%$, $H^2 = 2.17$, $Q_8 = 17.10$, $p = .029$).

[22] Once again, variability in estimates of effect size suggested greater heterogeneity than would be expected due to chance ($\tau = 0.10$, $I^2 = 52.94\%$, $H^2 = 2.12$, $Q_8 = 17.14$, $p = .029$).

[23] This meta-analysis was conducted across within-subjects mediation analyses in which other potential mediators (e.g., status, explicit racial bias) were also included. For results and meta-analysis of supplementary analyses with bias in pain perception as the sole mediator, see the online supplementary materials.

those Black targets less non-narcotic pain reliever. These effects were even obtained when Black and White stimuli were objectively equated in facial structure and expression intensity. However, these gaps in pain perception and treatment did not generalize to Asian targets, suggesting that these phenomena are not reflective of a more general, group-based bias. Meta-analysis across this work confirmed these results.

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 toward Blacks, and endorsed several distinctions between Blacks and Whites that either have been linked to differences in pain care (status, Trawalter et al., 2012; biological differences, Hoffman et al., 2016) or might play a role in pain tolerance (e.g., strength, Wilson et al., 2017). However, no measures of explicit prejudice or stereotypes were reliably associated with bias in pain perception or treatment recommendations. More importantly, bias in pain perception was repeatedly associated with a bias to prescribe less non-narcotic pain reliever over and above all additional measures we collected and was the only mediator through which race influenced participants' treatment recommendations. In other words, the influence of perceptual bias on treatment was distinguishable from the influence of stereotypes concerning status or strength, inaccurate medical beliefs, or explicit racial prejudice.

Although this consistent pattern of data was a necessary condition for identifying a 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 et al., 2006), which has been linked to discrimination and harm toward marginalized groups, including racial minorities (Fincher & Tetlock, 2016; Fincher et al., 2017). 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. Indeed, we later replicated the null inversion effect in a separate sample using only gray-scale faces (see Supplementary Experiment 1 in the online supplementary materials; data online at osf.io/dmqy9/), suggesting this reflects 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. Although this speculation is outside of the scope of the current investigation, future work should examine the boundaries of these effects, and confirm the perceptual nature of these effects.

We also observed that racial bias in treatment recommendations was less consistent across experiments than 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 health care 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 said, meta-analysis suggested that Black targets received less analgesic overall, particularly when faces were presented upright, once again suggesting a critical role for configural processing. Ultimately, this divergence between perception and treatment has potentially interesting implications: in health care contexts, disparities in care might 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 care has considerable implications for future interventions aimed at reducing health disparities. That 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 experience—subsequent, or at least adjacent to visual perception (e.g., Hoffman et al., 2016; Trawalter et al., 2012)—along with gaps in empathy and perspective-taking (Drwecki, Moore, Ward, & Prkachin, 2011). However, because explicit beliefs and attitudes about social outgroup 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, if disrupting configural face processing reduces bias in pain perception by increasing perceivers' thresholds for recognizing pain on White faces, then it follows that novel interventions should aim to enhance configural processing of Black faces. Future work should assess perceptual strategies that can be feasibly deployed and tested in the medical context, among medical trainees or practitioners. Previous work highlights manipulations that bolster configural face processing in the context of race: enhancing individuation motives (Hugenberg, Miller, & Claypool, 2007; Hugenberg et al., 2010), highlighting a shared in-group identity (Bernstein et al., 2007; Hehman, Mania, & Gaertner, 2010), experiencing increased intergroup contact (Hancock & Rhodes, 2008; Rhodes, Locke, Ewing, & Evangelista, 2009), or perceptual other-race training (Lebrecht, Pierce, Tarr, & Tanaka, 2009) all might reduce racial bias in pain care by intervening on the perceptual pathway illustrated across these experiments. Moreover, the present work makes novel predictions about the underlying process that can be interrogated with not only behavioral methods, but neuroscientific approaches as well. For instance, our approach would make the novel prediction that racial bias in pain perception should emerge in structures associated with configural face processing, such as the FFA (Kanwisher & Yovel, 2006). This prediction can be formally tested using fMRI or in lesion patients, as can the success of theoretically motivated interventional approaches.

Taken together, these data both illuminate the perceptual underpinnings of disparities in pain care and lay the groundwork for developing interventions to bridge those gaps. However, equality in care will not be achieved by clever perceptual interventions alone. Gaps in thresholds for pain perception are downstream

symptoms of more systemic inequalities, which must be addressed to fully alleviate these disparities (Feagin & Bennefield, 2014).

Although we feel this work sheds new light on a perceptual source of racial bias in pain care, numerous questions remain unanswered. First, as all 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. Even if the same pattern is observed in Black perceivers, their differences in pain thresholds might be supported by different (e.g., nonperceptual) processes, and further, might not predict biases in treatment. Future work should resolve these uncertainties.

Moreover, it is critical to test whether these perceptual biases observed in the population wherein they would pose the most societal risk: medical health professionals. It's possible that individuals with medical training are not susceptible to the same race-based differences in thresholds for pain recognition. Indeed, some previous work has observed that health care trainees (Wandner et al., 2010) and nurses (Hirsh, George, & Robinson, 2009) rated facial expressions of pain as being more intense when displayed by Black (vs. White) avatars. However, these studies assess a different measure (e.g., evaluation of high-intensity painful expressions, rather than thresholds for pain perception), and further, this pattern does not accord with a broad literature suggesting that the pain experiences of Black patients are underestimated (e.g., Mathur, Richeson, Paice, Muzyka, & Chiao, 2014; Wandner, Scipio, Hirsh, Torres, & Robinson, 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 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.

Subsequent investigations should also test whether biases in the visual perception of pain extend to genuine pain expressions, since our actors were merely posing pain. That said, we note again the difficulty perceivers have in distinguished genuine from posed pain (e.g., Littlewort et al., 2009) and the relative similarity between genuine and posed expressions of pain (e.g., Hill & Craig, 2002, though see Craig et al., 1999). We also note that Black and White targets in Experiments 1–5 did not differ on subjective ratings of believability ($M_{Black} = 5.70$, $SD_{Black} = 0.75$; $M_{White} = 5.58$, $SD_{White} = 0.80$; $p = .708$; on a 1–9 scale), which were both above the scale's midpoint ($ps < .001$; one-sample t tests vs. 5), and further, that computer-generated expressions in Experiments 6–7 were selected specifically because of their resemblance to pain. That aside, gaps in pain care are not simply a function of perceiver (e.g., provider) effects, but also target and interactive (e.g., Patient × Provider) effects as well—which future work should consider.

Future work should strenuously pursue the generalizability of these results. For example, these experiments revealed that biased pain perception and treatment are associated within the same targets. Other work could and should test whether bias in perception is predictive of gaps in care for a separate sample. Future work should also test whether these effects generalize to other methods, for example, by leveraging perceptual aftereffects (Jaquet, Rhodes, & Hayward, 2008; Michel, Corneille, & Rossion, 2010), manipulating spatial frequency (Goffaux, Hault, Michel, Vuong, & Rossion, 2005), or using a mouse-tracking (Freeman, Pauker, Apfelbaum, & Ambady, 2010) or reverse-correlation paradigm (Dotsch, Wigboldus, Langner, & van Knippenberg, 2008).

We also note that although factors like explicit racial bias were not reliably related to racial bias in pain perception or treatment, such relationships may be strongest when both variables are measured (a) at the same level (e.g., both at the level of individual targets or both at the level of groups), or (b) within the same individual targets. These possibilities are in line with work suggesting that attitudes are most predictive of behavior when both variables are measured to the same level of precision (e.g., Fishbein & Ajzen, 1974). Here, we measured explicit racial bias at the level of groups (e.g., feeling thermometers regarding Black and White Americans), but pain perception at the level of a few targets, and found no relationship—consistent with other work on disparities in pain care (Mathur et al., 2014; Hirsh, Hollingshead, Ashburn-Nardo, & Kroenke, 2015).

Furthermore, certain relationships may be evident at the population or community-level that are more difficult to detect at the individual level (e.g., Chae et al., 2015; Lee, Muennig, Kawachi, & Hatzenbuehler, 2015; Leitner, Hehman, Ayduk, & Mendoza-Denton, 2016). Similarly, although Experiments 5–7 (and Supplementary Experiment 2 in the online supplementary material) eliminate potential memory-based influences on the relationship between bias in treatment and perception, some potential issues remain. Specifically, although we consistently observed a relationship between bias in perception and treatment, participants' exposure to pain intensity in the pain rating phase obviously varied as a function of race, since it took longer to recognize pain on Black versus White targets. Although on some level, this makes for an even more conservative test of our hypotheses, a design in which exposure is equated across race would be ideal. Ultimately, future work should pursue a more precise understanding of this across multiple levels of analysis.

Finally, it's crucial that we continue to grapple with whether the biases studied herein are specific to or generalize beyond Black individuals. For example, differences in pain perception for Asian and Black targets in Experiment 7 may reflect differences in stereotype content, prejudice, or attitudes (especially regarding status) between these two groups—which may extend to other marginalized, undertreated, or understudied groups. More generally, the experiments presented herein used only adult male targets. Although we held gender and age constant in these initial investigations for purposes of experimental control, we've since expanded the diversity of our stimulus set. Indeed, Latinx Americans (Green et al., 2003; Hollingshead, Ashburn-Nardo, Stewart, & Hirsh, 2016; Shavers et al., 2010) and female patients' pain is subject to similar disparities in treatment (Chen et al., 2008; Hoffmann & Tarzian, 2001; Hirsh, Hollingshead, Matthias, Bair, & Kroenke, 2014). The effect of gender on pain perception may also be amplified by race, putting Black women at even greater risk. Therefore, an intersectional perspective is necessary to fully understand these disparities (Hankivsky, 2012). Future work should examine whether perceptual processes underlie disparities in pain care experienced by women, as well as other racial and ethnic minorities.

Conclusion

Taken together, these results are conceptually consistent with work on the malleability of social perception in general (Van Bavel et al., 2013; Xiao & Van Bavel, 2012; Xiao et al., 2016a, 2016b), and disruptions in the typical social perception of marginalized individuals in particular (Fincher & Tetlock, 2016; Fincher et al., 2017). 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 et al., 2017), their speed (Kenrick et al., 2016), and, as we've demonstrated, their experience of pain. In addition, these data suggest this bias can spring from a perceptual foundation that is separate and distinct from the influence of stereotypes regarding status, strength, or biological differences in pain tolerance. Although 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 will inform the creation of new approaches designed to fight that bias at its earliest stages.

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