

INNOVATIONS IN SOCIAL PSYCHOLOGY

Scarcity Disrupts the Neural Encoding of Black Faces:
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When economic resources are scarce, racial minorities are often devalued and disenfranchised. We proposed that this pattern extends to visual processing, such that the encoding of minority group faces is disrupted under scarcity—an effect that may facilitate discrimination and contribute to racial disparities. Specifically, we used EEG and fMRI to test whether scarce economic conditions induce deficits in neural encoding of Black faces, and we examined whether this effect is associated with discriminatory resource allocation in behavior. In Study 1, framing resources as scarce (vs. neutral) selectively impaired the neural encoding of Black (vs. White) faces, as indexed by a delayed face-related N170 ERP response, and the degree of this encoding deficit predicted anti-Black allocation decisions. In Study 2, we replicated and extended this effect using fMRI: Resources framed as scarce (vs. neutral) reduced face-sensitive fusiform activity to Black (vs. White) faces. Furthermore, scarcity-decreased fusiform activity to Black faces corresponded with decreased valuation-related striatum activity to predict anti-Black allocation decisions. These findings suggest that impaired visual processing and devaluation occur selectively for minorities under scarcity—an implicit effect that may promote discrimination and contribute to rising disparities observed during economic stress.

Keywords: scarcity, face perception, race, prejudice, fMRI, N170

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When economic resources are scarce, minorities are often devalued, derogated, and treated as less deserving of those resources. For example, during the *Great Recession* of 2008, minorities were forced to work fewer hours, take more unpaid leave, and switch from full-time to part-time work more often than their White counterparts (Taylor, Kochhar, & Fry, 2011). Indeed, empirical work has shown that threats to resources promote antiminority attitudes, stereotypes, policy support, and violence (e.g., Bianchi,

Hall, & Lee, 2018; Esses, Jackson, & Armstrong, 1998; Hovland & Sears, 1940; Lauritsen & Heimer, 2010; Riek, Mania, & Gaertner, 2006)—a pattern of prejudice and discrimination that appears to reinforce socioeconomic disparities and perpetuate inequality.

Scarcity also affects the social perception of individuals, revealing a point of contact between socioeconomic factors and social cognition. In recent work, even subtle indicators of scarcity led perceivers to view African American faces as “blacker” (Krosch & Amodio, 2014; Rodeheffer, Hill, & Lord, 2012)—a perceptual bias that predicted reduced monetary allocations (Krosch & Amodio, 2014), consistent with research linking the perception of darker skin tone and Afrocentric features to devaluation and discrimination (e.g., Maddox, 2004). These effects appear to operate implicitly, without a perceiver’s overt intention or awareness, indicating they may be especially resistant to control.

Collectively, these findings suggest that when resources are scarce, decision makers may actually *see* minority group members as less valuable and less worthy—a perception that may perpetuate deprivation and harm. However, two important assumptions underlying this conclusion remain unsubstantiated. First, because prior research relied on classification judgments, rather than direct assessments of visual processing, it remains unclear whether scarcity-induced changes in face representations relate to visual processes, as opposed to cognitive judgments (e.g., stereotypes). Second, although scarcity has been shown to influence perceptions of facial features (e.g., skin tone,

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Afrocentricity), prior work has not determined whether scarcity influences a more basic form of perceptual processing: the initial encoding of a racial minority member's *face*, which represents the starting point of a social impression and social interaction. Both issues have important implications for theories of intergroup social cognition and for potential interventions.

The present research addressed these critical assumptions directly: Using two different neural indicators of face processing, we asked whether conditions of scarcity impede the configural encoding of minority faces—the initial process through which facial features and configurations are extracted from visual input to form the representation of a face—and, if so, whether this effect was associated with economic deprivation in behavior. We proposed that, under scarcity, majority group decision makers encode minority group member faces less extensively—an effect that may serve to facilitate the behavioral devaluation and unfair treatment of racial minorities in economic decisions.

Face Encoding and Outgroup Devaluation

Our impression of another person often begins with the sight of their face, and several recent findings reveal that the initial configural processing of a face has implications for high-level social judgments. For example, Hugenberg et al. (2016) found that participants judged faces as less thoughtful, empathic, considerate, creative, and humanlike when configural encoding was impeded—a pattern that characterizes devalued and dehumanized attributions of traits and emotions (e.g., Gray, Gray, & Wegner, 2007; Harris & Fiske, 2006; Hugenberg et al., 2016; Kteily, Bruneau, Waytz, & Cotterill, 2015; Leyens et al., 2000; see also Wilson, Young, Rule, & Hugenberg, 2018). Although these relatively high-level impressions influence many forms of judgment and can facilitate negative treatment of racial and ethnic outgroup members (Haslam & Loughnan, 2014; Opatow, 1990), economic decisions often rely on rapid decisions, with scant information and little time with which to form an impression. Thus, examining initial encoding of a face may be especially useful for understanding the effects of scarcity on decisions made in the face-to-face interactions that characterize much everyday discrimination.

The strong historical and present-day devaluation of Black people in the United States may make them especially vulnerable to perceptual encoding deficits. This devaluation was most overtly seen in the notorious “3/5ths Compromise,” where individual Black Americans were counted as less than a White person in the eyes of the law, and it persists today in stereotypes and prejudiced beliefs, often with grave consequences. For example, Black Americans continue to be represented as ape-like by individuals and in the media, a representation which has been related to capital conviction and state execution (Goff, Eberhardt, Williams, & Jackson, 2008). Black Americans are also believed to feel less pain than White Americans, which leads to racial disparities in pain assessment and treatment (Hoffman, Trawalter, Axt, & Oliver, 2016). Indeed, recent research suggests that such devalued and dehumanized impressions of Black (compared with White) targets are more strongly related to perceptual encoding deficits (Cassidy et al., 2017).

In light of research suggesting widespread devaluation of Black Americans, and links between these devalued social perceptions and visual encoding deficits, we proposed that Black recipients might be especially susceptible to scarcity effects on decision

makers' visual processing, such that the encoding of Black faces is impeded when resources are scarce. Moreover, we proposed this perceptual effect would be associated with the deprivation of Black recipients in the allocation of resources, suggesting the possibility that impaired face encoding serves to implicitly facilitate or justify discrimination.

Intergroup Effects on Face Encoding

How might scarcity influence the early visual encoding of a face? Although early face perception was once thought to be impenetrable to top-down influences (e.g., Bruce & Young, 1986), recent research suggests that intergroup goals and motivations can influence face encoding (Amodio, 2014). For example, more motivationally relevant minimal ingroup faces tend to be more extensively encoded, as evidenced by neural and behavioral indices (e.g., Hugenberg & Corneille, 2009; Ratner & Amodio, 2013; Van Bavel, Packer, & Cunningham, 2008, 2011; Young, Bernstein, & Hugenberg, 2010; Young & Hugenberg, 2010), and classic works suggests that motivationally *irrelevant* targets like outgroup members are often afforded fewer processing resources (e.g., Brewer, Srull, & Wyer, 1988; Fiske & Neuberg, 1990; Rodin, 1987; Sporer, 2001). Only as outgroup members become more motivationally relevant do they receive prioritized encoding (e.g., Van Bavel & Cunningham, 2012). In the context of race, outgroup faces similarly experience more or less extensive encoding, relative to ingroup faces, depending on participants' social motivations and task goals (Kaul, Ratner, & Van Bavel, 2014; Ofan, Rubin, & Amodio, 2011, 2014; Ratner & Amodio, 2013; Schmid & Amodio, 2017; Senholzi & Ito, 2013; Walker, Silvert, Hewstone, & Nobre, 2008).

An important determinant of intergroup processing resources is the degree of *threat* an outgroup member poses in a particular context (see Chang, Krosch, & Cikara, 2016; Ofan et al., 2011, 2014; Schmid & Amodio, 2017). In economic decisions, the potential threat posed by outgroup members—and subsequent encoding effects—depends on who controls the resources (e.g., realistic group conflict theory; LeVine & Campbell, 1972), and thus an outgroup member is only threatening to the extent they are able or likely to take resources from the ingroup (e.g., Esses et al., 1998). When minority outgroup members lack decision power and thus pose no direct threat, White decision makers afford them less attention and consideration. Indeed, there is mounting evidence that perceivers with decision power and higher status attend less to faces (e.g., Dietze & Knowles, 2016) and tend to dehumanize lower status others (e.g., Gwinn, Judd, & Park, 2013) and outgroup members, presumably in order to justify harmful treatment (e.g., Lammers & Stapel, 2011). Such encoding deficits (dubbed *perceptual dehumanization*; Cassidy et al., 2017; Fincher & Tetlock, 2016; Hugenberg et al., 2016) have been shown to facilitate harm (Fincher & Tetlock, 2016; Fincher, Tetlock, & Morris, 2017), especially in the case of instrumental harm for personal gain (Rai, Valdesolo, & Graham, 2017).

Thus, in contexts where a White American decision maker controls the allocation of resources, scarcity should impede the decision makers' encoding of racial minority recipient faces relative to White recipients. Furthermore, this effect may then promote devaluation and unfair treatment of minority recipients in the economic decisions.

Overview of Studies

To understand how scarcity leads to deficits in the perception of minorities in face-to-face social interactions, we examined the effect of scarcity on decision makers' visual processing of Black faces during economic decisions. We hypothesized that in conditions of resource scarcity, White decision makers would exhibit impaired encoding of Black faces relative to White faces, compared with a neutral decision context. In Study 1, we used electroencephalography (EEG) to examine scarcity-impaired early visual processing of Black relative to White faces, and the association between this impairment and increased discrimination. Using functional MRI (fMRI) in Study 2, we replicated the effect of scarcity on impaired visual processing and explored whether its effect on discrimination involved neural processes associated with devaluation.¹

Study 1

Study 1 was designed to provide initial evidence for the effect of economic scarcity on impaired visual processing of Black (compared with White) faces and to determine whether this effect predicts behavioral discrimination. To this end, we used an event-related potential (ERP) approach to test whether perceived scarcity selectively interfered with the early visual encoding of Black faces (Amodio, Bartholow, & Ito, 2014). Specifically, we manipulated scarcity (vs. a neutral context) and examined the N170 component of the ERP to the faces of Black and White recipients in an allocation task.

The N170 component of the ERP is the most direct known index of early configural face processing.² Emerging just ~170 ms after face onset, the N170 response to a face reflects multiple neural sources, including activation in fusiform, temporo-occipital, and occipital regions (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Herrmann, Ehlis, Muehlberger, & Fallgatter, 2005), with activity in the fusiform most directly supporting the configural encoding process (e.g., Gauthier et al., 2000; Haxby, Hoffman, & Gobbini, 2000; Kanwisher & Yovel, 2006). The N170 response is interpreted as representing the initial encoding of a face in visual processing (e.g., Bentin et al., 1996; Eimer, 2000a)—an obligatory perceptual process that unfolds rapidly and automatically.

Although N170 *amplitude* typically differentiates faces from nonface objects, a disruption to configural processing of faces is most directly evident in the N170 *latency* (e.g., Rossion et al., 2000). This is illustrated by the highly reliable N170 delay to misaligned, scrambled, and eyeless human faces compared with normal human faces, to animal faces compared with human faces, and to inverted compared with upright faces (e.g., Balas & Koldewyn, 2013; Bentin et al., 1996; Eimer, 2000b; George, Evans, Fiori, Davidoff, & Renault, 1996; Itier, Alain, Sedore, & McIntosh, 2007; Jacques & Rossion, 2010).

The N170 delay has been related to reduced activity in the fusiform gyrus (Rossion & Gauthier, 2002). This delay represents a reduced reliance on configural processing, while featural processing is preserved, and it reflects difficulty in resolving a percept as a face (e.g., Itier et al., 2007; Jacques & Rossion, 2010; Latinus & Taylor, 2006; Rossion et al., 2000; Rossion & Jacques, 2012). The delayed N170 sometimes occurs in tandem with a small amplitude increase (e.g., Bentin et al., 1996; Eimer, 2000b; Itier et al., 2007), reflecting signal from inferior occipital gyrus, which supports featural processing, rather than the fusiform (Eimer,

2011; Rossion et al., 2000). Thus, the N170 delay and reduced fusiform activity (examined in Study 2) provide the most common and reliable indicators of face encoding impairment (e.g., Balas & Koldewyn, 2013; Bentin et al., 1996; Eimer, 2000b; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; George et al., 1996; Goffaux, Rossion, Sorger, Schiltz, & Goebel, 2009; Itier et al., 2007; Jacques & Rossion, 2010; Kanwisher, Tong, & Nakayama, 1998; Yovel & Kanwisher, 2005; Zhang, Li, Song, & Liu, 2012).

Method

Participants. Eighty-one right-handed, native English-speaking undergraduate psychology students at New York University participated in return for partial course credit. Sample size for this EEG experiment was determined as the maximum number of participants we were able to recruit in the semester; we aimed for $N > 62$ to achieve 90% power to detect a medium interaction effect of interest in our mixed-design, assuming a (conservative) .3 correlation between repeated measurements (calculated using GPower 3.1).

Eight participants were excluded from analysis because their EEG data were unusable due to malfunctioning electrode (which caused either no signal, signal composed of 60 Hz noise, or intermittent signal), failed blink correction, or no discernable ERP response. Two were removed for noncompliant responding (e.g., they pressed the 0 key on each trial). These exclusions yielded 71 participants for analysis (mean age = 19.62, $SD = 1.43$; 51 female, 20 male; 67 self-identified as White, one as Asian, and three as Latino; none identified as Black or African American³).

Procedure and materials. Participants arrived at the lab, provided consent in a manner approved by the Committee on Activities Involving Human Subjects, and were prepared for EEG recording. Participants learned they would be playing a money allocation game in which they would be randomly assigned to either allocate funds ("allocator") or receive funds ("recipient"), as in Krosch, Tyler, and Amodio (2017). To ensure that participants believed the game was authentic, with real financial consequences, participants were further told that if they were assigned the role of allocator, they would distribute money to past players who had been assigned the role of recipient. If assigned the role of recipient, participants were told their photo would be entered into our participant database making them eligible to receive funds distributed by future players, and they would move on to perform a different study during the experimental session. In practice, all participants were assigned the role of allocator. Participants were then randomly assigned to a scarce or control condition.

¹ Although neither study was formally preregistered, these hypotheses, procedures, sample sizes, and analyses were proposed in advance in a grant application (NSF BCS 1551826) and dissertation proposal prior to data collection completion.

² The N170 and the VPP (vertex positive potential) represent negative and positive dipoles indexing the same brain processes, although the N170 is more commonly studied. The N170 is best observed at the right temporal-occipital electrode site when using an average earlobe or nose reference, whereas the VPP is best observed in frontal sites using a mastoid reference (Joyce & Rossion, 2005). Thus, we focused our analyses on the N170 given our average earlobe reference.

³ Data patterns and inferences from significance tests are identical when the four non-White participants are excluded (see online supplemental materials). See General Discussion section for a discussion of the benefits of future studies examining the influence of participant race.

Scarcity manipulation. Although scarcity is associated with a wide range of socioeconomic conditions and psychological experiences, the core construct involves the perception that a resource is limited. Thus, our manipulation focused on the perception of a limited resource. Participants in the scarcity condition were informed that they could have up to \$100 to distribute to each recipient, and that the computer would randomly assign them an amount to distribute. Participants then viewed an animated pie chart that depicted changing portions of money and ultimately, and ostensibly randomly, assigned them \$10 (of \$100) to distribute. Participants in the control condition, by contrast, were informed that the computer would randomly assign them a proportion of up to \$10 to distribute. These participants watched as the animated pie chart assigned them \$10 to distribute (see Supplemental Figure S1). Importantly, participants in both conditions were assigned \$10, and thus the actual amount to be allocated never varied between conditions; only the amount participants *could* have been assigned varied. In prior validation studies of this manipulation, \$10 out of a possible \$100 was perceived as significantly more scarce than \$10 out of a possible \$10, which was perceived as neither scarce nor abundant (see Krosch & Amodio, 2014; Krosch, Tyler, & Amodio, 2017).

Resource allocation task. Following the scarcity manipulation, participants performed a resource allocation task in which they could allocate from \$0 to \$10 to each recipient (in \$1 increments), in a series of independent choices. Only the recipients' race changed systematically from one trial to the next. Participants were told that people make judgments every day based on very little information, and that they should base their decisions on subtle perceptions of a recipients' deservingness.

Allocation trials began with a fixation cross (2 s) and a reminder of the participant's allocation allowance (always \$10), accompanied by the pie chart image. Participants then viewed the recipient's face, which remained onscreen until their allocation decision was made via key press. Following six practice trials, participants completed 150 critical trials, in which they viewed and responded to a recipient face, in randomized order. Face stimuli included 75 Black and 75 White male faces from the Eberhardt Laboratory Face Database (Eberhardt, Dasgupta, & Banaszynski, 2003),

equated for luminance and contrast using the SHINE toolbox for MATLAB (Willenbockel et al., 2010; see Figure 1).

This design ensured that decisions would be based on race and that allocation to one recipient would not affect allocation to any other recipients (i.e., a non-zero-sum choice). This design permitted us to examine relative responses to Black versus White recipients in the absence of self-interest. This task was ideally suited for EEG data collection because it permitted multiple trials and an easily administered pretrial manipulation, without memory demand or complex calculations.

Following task completion, participants indicated the extent to which the resource pool available to them in the task felt scarce or abundant using a scale anchored from -5 (*extremely scarce*) to 5 (*extremely abundant*), with 0 as the midpoint (*neither scarce nor abundant*), as a manipulation check. Participants then completed demographic questionnaires to report their age, race, and gender.

EEG recording and processing. EEG was recorded continuously during task completion from 11 Ag/AgCl electrodes, embedded in a stretch-lycra cap with midline and temporo-occipital channels (Electrode Arrays, El Paso, TX), and referenced to the left earlobe (<5 k Ω)—a widely used reference shown to be valid for N170 scoring when rereferenced to average ears (e.g., Joyce & Rossion, 2005). Signal was amplified using a Neuroscan Synamps2 amplifier, bandpass-filtered (.15–100 Hz), and digitized at 1000 Hz. Offline, EEG was rereferenced to average earlobes, scored for movement artifact, and submitted to a regression-based eyeblink-correction procedure. This resulted in a rejection of 2.16% of trials (~ 3.24 of 150 trials per participant, $SD = 5.93$, range 0–42). EEG was then digitally filtered through a 2–15 Hz bandpass to isolate the N170 component. This bandpass removed low-frequency negative-going prebaseline activity associated with the manipulation reminder on the fixation slides. ERP waveforms were created by selection of a 900-ms stimulus-locked epoch for each artifact-free trial beginning 100 ms prior to the face onset. Epochs were baseline-corrected (subtracting average prestimulus activity) and averaged as a function of trial type.

ERPs. ERP amplitudes and latencies were derived from event-related potentials stimulus-locked to face onset. For each subject, N170 latency was determined as the time point at which

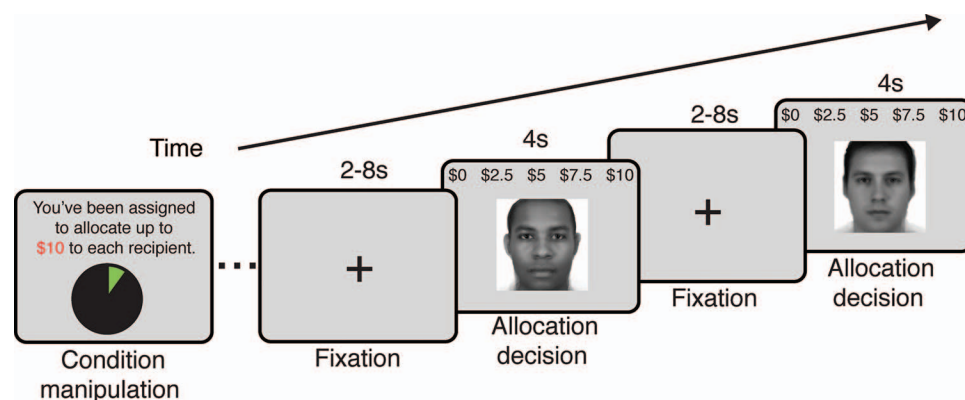


Figure 1. Schematic of the experimental task. Participants first saw the scarcity (or neutral) condition manipulation. On each trial, a fixation cross appeared for 2 s (Study 1) or 2 s–8 s (Study 2) followed by a White or Black face for 4 s, during which time participants registered their allocation choice from \$0 to \$10. See the online article for the color version of this figure.

the area under the curve was equal on both sides (i.e., split-half scored; Luck, 2014), within a 120 to 220 ms window following face onset at temporo-occipital scalp sites (CB1 and CB2, where the N170 effect was maximal). Amplitude was scored as the peak negative amplitude during this window (see online supplemental materials for alternative *area-under-the-curve* analyses using the same time window).

Results

Our main hypothesis was that under conditions of scarcity, participants would exhibit a delayed N170 to Black relative to White faces. N170 latency was not expected to differ by race in the control condition. Furthermore, we hypothesized that this scarcity-induced N170 delay to Black faces would relate to anti-Black behavior in the allocation task, such that this N170 delay effect would mediate the impact of scarcity on anti-Black allocation decisions.

Manipulation check. Participants in the scarcity condition ($n = 35$) rated resources as more limited ($M = -1.46$, $SD = 1.69$) than subjects in the control condition ($n = 36$; $M = 1.02$, $SD = 2.43$), $t(69) = 4.97$, $p < .001$; Cohen's $d = 1.18$, thereby validating the manipulation of scarcity.

N170 validation. Preliminary analyses were performed to validate inferences of the N170 response by examining its voltage topography (e.g., Joyce & Rossion, 2005; Ofan et al., 2011; Ofan, Rubin, & Amodio, 2014; Ratner & Amodio, 2013). As expected, peak N170 amplitude (μV) was larger in the right hemisphere (CB2; $M = -3.67$, $SD = 2.24$) than left hemisphere (CB1; $M = -2.71$, $SD = 1.54$), $t(70) = 5.87$, $p < .001$. Furthermore, a topographic voltage map indicated peak activation of the N170 over the right temporo-occipital cortex (Figure 2A inset). Thus, as planned, analyses focused on the right hemisphere where the N170 was maximal and where it is commonly scored.

Scarcity and race effects on N170 latency. To test our main hypothesis that scarcity selectively impedes the configural processing of Black faces, we tested the interactive effects of scarcity condition and face race on N170 delay scores using repeated measures analysis of variance (ANOVA). We predicted a delayed N170 response to Black faces, relative to White faces, in the scarcity condition but not in the control condition. We found a significant effect of Race, $F(1, 69) = 6.48$, $p = .013$, such latency was delayed to Black compared with White faces, and a marginal main effect of Condition, $F(1, 69) = 2.49$, $p = .119$, such latency was delayed to faces in the scarcity compared with control condition. Importantly, these effects were qualified by the predicted significant Condition \times Race interaction, $F(1, 69) = 4.97$, $p = .029$: under scarcity, N170 latency was significantly delayed to Black faces ($M = 175.26$ ms, $SD = 11.67$) relative to White faces ($M = 172.74$ ms, $SD = 11.60$), $F(1, 69) = 11.24$, $p = .001$, whereas in the control condition, the latency did not differ between Black faces ($M = 169.72$ ms, $SD = 11.57$) and White faces ($M = 169.50$ ms, $SD = 12.50$), $F(1, 69) = 0.05$, $p = .822$ (see Figure 2B).

This effect was evident in within-race comparisons as well: N170 latency to Black faces was significantly delayed in the scarcity condition compared with the control condition, $F(1, 69) = 4.03$, $p = .049$, whereas the latency to White faces did not differ by condition, $F(1, 69) = 1.24$, $p = .270$. Together, these results

revealed a selective effect of scarcity on Black face encoding. Indeed, only the processing of Black faces under scarcity was significantly delayed beyond the typical latency of 170 ms, $t(34) = 2.66$, $p = .012$, 95% CI = 1.25, 9.27 (all other p 's $> .171$).⁴

Scarcity and race effects on discrimination. Previous work indicates that direct effects of scarcity on allocation behavior are moderated by explicit attitudes and more deliberative processing (Krosch et al., 2017), whereas perceptual biases (i.e., implicit processes) tend to mediate allocation behavior indirectly (Krosch & Amodio, 2014). Thus, we expected the observed effect on face encoding would mediate the effect of scarcity on allocation indirectly and that we may not observe direct effects of scarcity and race on allocation. As expected, a repeated measures ANOVA suggested no main effect of race, scarcity condition, nor an interaction on allocation amounts (F s < 1.06 , p s $> .31$).

Scarcity and race effects on discrimination mediated by N170 latency. To test whether scarcity indirectly influenced allocation bias via the N170 latency effect,⁵ we created two difference scores: (a) *anti-Black allocation bias* (average amount given to White recipients minus the average amount given to Black recipients; positive scores indicated pro-White allocation bias); and (b) *N170 delay* (average Black N170 latency minus average White N170 latency; positive scores indicate more delayed N170 to Black than White faces). We then used a bootstrapping mediation approach to test effects of scarcity on anti-Black allocation as mediated by the N170 delay difference score (Shrout & Bolger, 2002).

Consistent with our hypotheses, the mediation analysis revealed an indirect effect: The N170 delay for Black relative to White faces significantly mediated the effect of scarcity on anti-Black allocation ($A \times B$ cross product = 0.14, $SE = 0.09$, 95% CI [.04, .35], $p = .039$; Figure 2C; see online supplemental materials for details of the full mediation model).⁶ These results support the proposal that the disruption of Black face encoding induced by scarcity may be associated with anti-Black allocation bias in behavior.

⁴ This delay was accompanied by a negative-going amplitude increase for Black faces ($M = -3.74$ μV , $SD = 2.32$) compared with White faces ($M = -3.21$ μV , $SD = 1.98$) in the scarcity condition, $F(1, 69) = 8.12$, $p = .006$, further supporting the interpretation of this effect as an encoding impairment (e.g., Rossion et al., 2000; see online supplemental materials for more detail).

⁵ Tests of indirect effects are recommended in the absence of total effects because they often have greater power, especially when the mediator is more precise than the dependent variable and when the independent variable has more influence on the mediator than the dependent variable (Hayes, 2009; Kenny & Judd, 2014; O'Rourke & MacKinnon, 2015; Preacher & Hayes, 2008; Shrout & Bolger, 2002; Zhao, Lynch, & Chen, 2010). Because visual encoding of faces (our mediator) occurs more rapidly and unconsciously than allocation behavior (our dependent variable) and is indicated by a specific neural signal, it is likely a more reliable measure, less vulnerable to presentational concerns, and more proximally related to our manipulation than allocation behavior.

⁶ Following recent concerns about such use of a single index of mediation and resulting Type I error inflation (Yzerbyt, Muller, Batailler, & Judd, 2018), we also used a "component" approach to provide convergent evidence for indirect mediation using the JSmediation R package. Specifically, we found that both the a and b paths were significant (a point estimate = $-.77$, $SE = .09$, $t = 9.10$, $p < .001$; b point estimate = $.19$, $SE = .03$, $t = 5.75$, $p < .001$), as was our indirect effect (point estimate = $.14$, 95% CI [.02, .37], 5,000 Monte Carlo iterations).

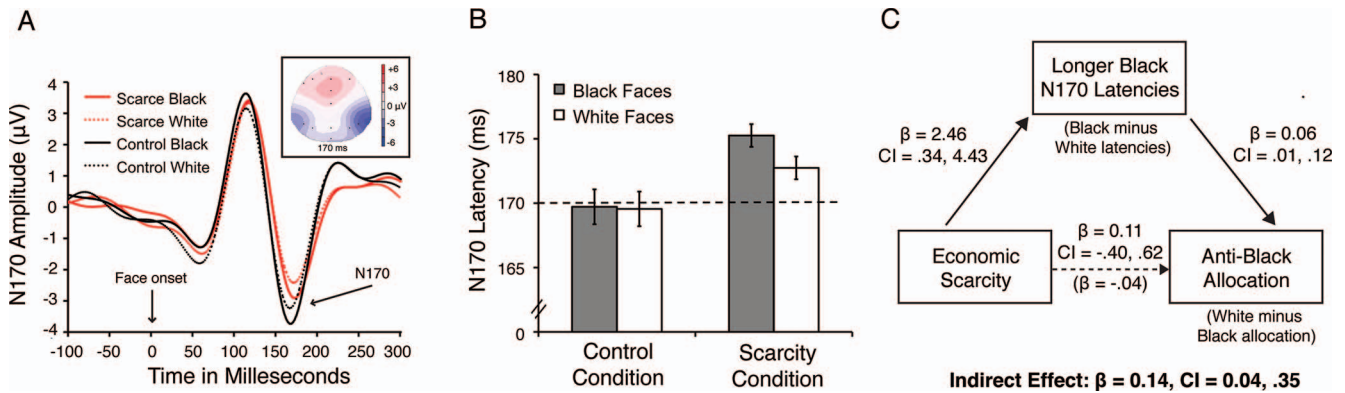


Figure 2. Scarcity effects on N170 latency and behavior ($n = 71$). (A) N170 waveforms for Black and White faces in the scarcity and control conditions, measured at the right temporo-occipital site (CB2) where the N170 was maximal (see inset topographic voltage map). These waveforms validate the N170 component; however, due to individual variability in timing and amplitude, they do not depict reliable individual scores (see scored means in main text). (B) N170 peak latency to Black and White faces as a function of condition ($\pm 1 SE$). Dotted line represents 170 ms, the typical latency of the N170 ERP component. (C) Mediation model illustrating the indirect effect of scarcity condition on pro-White/anti-Black allocation through delayed N170 latencies to Black compared with White faces. See the online article for the color version of this figure.

Discussion

Study 1 tested our main hypothesis that White perceivers' encoding of Black recipient faces is impeded under conditions of scarcity. Consistent with this hypothesis, we found that when resources were framed as scarce (compared with a control condition), participants exhibited a delayed N170 response, characteristic of impaired face encoding, to Black but not White faces. This selective effect, observed under scarcity but not a control condition, suggests that scarcity may prompt White American perceivers to deprioritize the visual processing of Black recipients at this early stage of face processing—a rapidly occurring and automatic perceptual effect that may represent a form of implicit racial bias. The emergence of this effect in the N170 latency further indicates that it represents a difference in the visual processing of Black compared with White faces and not merely an attentional effect, and that it is specific to the configural encoding of a face—the first step toward recognizing an object as a human individual.

We further hypothesized that this selective processing deficit may function to facilitate harmful behavior toward the outgroup under scarcity. Consistent with this idea, the degree of the N170 impairment due to manipulated scarcity was associated with greater anti-Black/pro-White allocation bias in behavior. Of course, the relationship between a mediator and outcome in the mediation framework is correlational (Bullock, Green, & Ha, 2010; Fiedler, Schott, & Meiser, 2011), and inferences of putative causality further depend on theoretical and methodological consideration. One such consideration is the possibility of alternative pathways. One alternative is that allocation behavior precedes the visual processing of the recipient—an unlikely path given the very rapid timecourse of visual processing. A second possibility is that perceived scarcity caused both the N170 delay and the bias in allocation behavior, with no causal relationship between the N170 and behavior. However, there was no direct effect of scarcity on behavior; only an indirect effect, via N170 delay, was observed. Finally, existing research has demonstrated a causal effect of

configural encoding disruption on social judgments and harm (Fincher & Tetlock, 2016; Hugenberg et al., 2016), which supports the possibility that the relationship between N170 delay and allocation bias observed here is plausible. In light of these considerations, our results are most consistent with the proposal that scarcity effects on face processing may facilitate discriminatory behavior.

Broadly, these results begin to reveal a relationship between very high-level inferences of economic scarcity on the comparatively low-level neural encoding of a face. What explains this relationship? One possibility is that conditions of scarcity guide White decision makers' engagement in the task, leading them to deprioritize Black recipients relative to White recipients, and that this shift in processing strategy leads them to engage a lesser degree of early attentional processing of Black faces (and hence diminished visual encoding). Exploratory post hoc analyses of our data, reported in the online supplemental materials, appear to support this account: Black faces viewed under scarcity elicited reduced P1 ERP amplitude relative to White faces in Study 1, a component that peaks ~ 100 ms after face onset and reflects early attention allocation. This result suggests that participants in the scarcity condition showed greater automatic orienting to White compared with Black faces. This rapid shift in attentional processing would likely stunt the visual input from a Black face and thus diminish its visual encoding, consistent with the observed N170 delay. This analysis suggests a plausible explanation for how a high-level factor like scarcity could influence visual face encoding.

Although Study 1 provided evidence for our core hypothesis, features of the ERP method measurement limited our ability to address some questions. First, although the N170 ERP method used in Study 1 provides an established index of face processing, it could not precisely identify the neural source of this effect in fusiform cortex. Our interpretation of the N170 delay, following prior research (Bentin et al., 1996; Maurer, Le Grand, & Mondloch, 2002; Rossion et al., 2000; Rossion & Gauthier, 2002), is that

it reflects a decrease in configural processing associated with a reduced contribution of fusiform activity and increased contribution of other neural generators (Rossion & Gauthier, 2002). Because the EEG methods used in Study 1 do not afford the spatial resolution to assess the precise neural source of the N170, our inference regarding the specific role of the fusiform would benefit from additional fMRI evidence.

A second question concerns the psychological processes that may link the process of face encoding to allocation decisions in the context of scarcity. The method used in Study 1 provided a rigorous and circumscribed assessment of early face encoding, but it could not address our extended question of whether encoding effects may relate to devaluation of minority recipients. An exploration of these questions would require other methods, such as fMRI, which can simultaneously assess neural activations in the fusiform and regions associated with the computation of value.

Finally, although we observed the predicted impairment in Black face processing under scarcity, this pattern emerged in the context of a marginal main effect of scarcity. Thus, it is possible that scarcity has a general effect on face encoding across race, such that encoding is impeded for any type of face under scarcity. This inference is ambiguous, however, because scarcity was a between-subjects factor in Study 1, and therefore the main effect of scarcity on N170 delay could represent a true effect of scarcity on face processing *or* a chance effect of variability between subjects assigned (randomly) to each condition. This ambiguity could be resolved using a fully within-subjects design. To address these issues, we conducted a second study in which brain activity was recorded using fMRI and scarcity was manipulated as a within-subjects variable.

Study 2

In Study 2, we used fMRI to replicate and extend the findings of Study 1. By using fMRI, we could capitalize on its superior spatial resolution to confirm the selective role of the fusiform cortex, which would further validate our inference regarding configural encoding. By using a within-subjects design, we could also disambiguate the selective effect of scarcity on the encoding of Black faces from a domain-general effect of scarcity on face encoding.

In addition, the use of fMRI in Study 2 permitted us to explore an extension of our hypothesis; that is, whether the effect of scarcity on face encoding and biased decisions is associated with the devaluation of Black recipients, as indicated by decreased activity in the striatum. We were specifically interested in this neural region because of its established role in the encoding of social valuation and the guidance of choice behavior (O'Doherty, 2004; Ruff & Fehr, 2014; Zink et al., 2008). Although the striatum is often implicated in nonsocial valuation, social perception also involves striatal activity, especially when learning or making decisions about social agents (see Báez-Mendoza & Schultz, 2013; Hackel, Doll, & Amodio, 2015). For example, Zink et al. (2008) found that striatal activity tracks the explicit value of others in a competitive game, with less activity to overtly devalued players—an effect accompanied by reduced fusiform activity. In another study, reduced striatal activity was observed among participants induced to feel poor (as opposed to rich) when they witnessed monetary transfers to others instead of themselves (Trombi, Rangel, Camerer, & O'Doherty, 2010). These findings sug-

gest that the striatum supports the encoding of the value of social targets under resource-scarce conditions. In addition, because the striatum is also known to support the translation of value computations into choice decisions (O'Doherty, 2004), its role in scarcity-induced allocation bias would help to explain how early face encoding deficits give rise to discriminatory behavior.

Method

Participants. Thirty-five White-identified undergraduate psychology students at New York University participated in return for course credit. Participants were prescreened such that none reported a history of neurological problems, and all had normal or corrected-to-normal vision, were right-handed, and were native English speakers. Participants completed a metal screening checklist and provided written informed consent before neuroimaging. Our goal was to include at least 22 participants to achieve 80% power to detect a medium interaction effect in this fully within-subject design, assuming a conservative .7 correlation between repeated neural measurements (given a .9 correlation in Study 1).

Two participants were excluded from analysis because their imaging data could not be recovered from the servers; two were excluded because they lacked detectable Face > Fixation fusiform activity and thus regions of interest (ROIs) could not be drawn; one was excluded for failing to complete more than 10% of trials. These exclusions yielded 30 participants for analysis (mean age = 19.63, $SD = 1.40$; 16 self-identified as female, 14 as male).

Procedure and materials. As in Study 1, participants were recruited for a study described as an economic game in which they would allocate funds to others based on perceptions of their deservingness, inferred from pictures of peoples' faces. In order to compare effects of scarcity and control conditions within subjects, participants were further told that we were interested in the way that people allocate different amounts of money, and that their task would be divided into two blocks of trials, one with larger and one with smaller dollar amounts. Participants then performed the multi-trial decision task twice, once in the scarcity condition and once in the control condition, in counterbalanced order. During scarcity trials, participants learned they could have up to \$100 to allocate; during control trials, participants learned they could have up to \$10 to allocate. Importantly, all participants believed they would have \$10 to allocate on each trial in both blocks, thereby holding the actual amount constant across trials. To determine the success of this manipulation, participants were thoroughly probed for suspicion prior to debriefing.⁷

On each trial of the allocation task, a fixation cross appeared for 2–8 s (jittered; $M = 3.67$; 50% of trials were 2 s, 25% were 4 s, 16.7% were 6 s, and 8.3% were 8 s), followed by a face for 4 s, during which time participants registered their allocation decision. Again, participants' task was to simply indicate the portion of \$10 they believed the recipient deserved, this time in \$2.50 increments,

⁷ Three participants expressed some suspicion regarding whether the \$10 assignment in each condition was truly random. However, they did not report the hypothesis, role of race, nor role of scarcity. Results are nearly identical if these participants are excluded from analysis. No other participants reported suspicion, and most reported using the same decision strategy in each condition. See online supplemental materials for funneled debriefing questions and participants' responses, and for results excluding suspicious participants.

on a five-button scanner-friendly controller. Participants were assured their choices were confidential in order to avoid reputation or reciprocity concerns. Participants completed a total of 72 trials in each condition. Assignment of individual faces to condition was counterbalanced and their order of appearance within condition was randomized. No face stimulus was repeated throughout the task. Participants were reminded of their allocation allowance every 24 trials. Upon each block completion, participants indicated the extent to which their allocation allowance felt limited, using a scale anchored from 1 (*extremely limited*) to 5 (*not at all limited*), as a manipulation check. When both conditions were complete, participants exited the scanner and completed demographic questionnaires assessing their age, race, and gender.

Scanning parameters and fMRI preprocessing. fMRI data were collected using the 3T Siemens Allegra head-only scanner at the New York University Center for Brain Imaging with the Siemens standard head coil. Anatomical images were acquired using a T1-weighted protocol (256 × 256 matrix, 176 1-mm sagittal slices), along with a field map and short TE EPI scan to improve functional-to-anatomical coregistration. Functional images were acquired using a multiecho EPI sequence (TR time = 2,000 ms; echo time = 15 ms; field of view = 240 mm, flip angle = 82 degrees, bandwidth = 4,166 Hz/Px, and echo spacing = 0.31 ms), obtaining 34 contiguous oblique-axial slices (3 mm × 3 mm × 3 mm voxels) + 20 degrees parallel to the anterior commissure–posterior commissure line. Fixation scans acquired at the start of each run were dropped from analysis to allow for magnet equilibrium. Data were preprocessed and analyzed in SPM8 (Wellcome Department of Cognitive Neurology, London, United Kingdom), coregistered to structural images, corrected for slice acquisition time and motion, transformed to conform to the default EPI Montreal Neurological Institute (MNI) brain interpolated to 3 mm × 3 mm × 3 mm, smoothed using a 6-mm full-width/half-maximum kernel, corrected for artifacts, and detrended.

fMRI data analysis. Individual participants' blood-oxygenation-level-dependent (BOLD) responses to face presentations (4 s) were modeled at the first-level as a function of a canonical hemodynamic response function (HRF) with a 128-s high-pass filter, using a general linear model (GLM) with four predictors (scarcity-Black, scarcity-White, control-Black, control-White). We then submitted these first-level GLM analyses conducted on individual subjects' BOLD signal to a second-level random effects analysis treating subjects as a random factor, to examine the interactive effect of scarcity condition and face race on neural activity.

Region of interest (ROI) creation. To isolate the effects of face encoding in the fusiform region, we created bilateral fusiform maps based on peak activity in a functional Face > Fixation contrast, collapsing across conditions. Importantly, because this localizer was based on activity to faces across condition and face race, it remained independent from the analysis comparing activity to faces in this region by condition and race (i.e., the sum of the localizer contrast [1 1 1 1] × interaction contrast [1 -1 -1 1] = 0; eliminating concerns about the use of nonindependent data for ROI selection and analysis). Specifically, we defined the bilateral fusiform maps as 10 mm spheres around the location of peak activity in the Face > Fixation contrast for the right and left side (MNI coordinates: 30, -66, -12, and -36, -60, -18), following previous research (Ratner, Kaul, & Van Bavel, 2013; see Supple-

mental Figure S2). Given our interest in right FFA activity and given consistent evidence for right-lateralized FFA effects in right-handed participants such as ours (e.g., Kanwisher, McDermott, & Chun, 1997), we then extracted mean parameter estimates (β values) from the right FFA maps and submitted them to a repeated-measures analysis of variance as a function of scarcity and race conditions.

Because an additional aim of this study was to understand the relationship between diminished face encoding and devaluation under scarcity, and because of the well-established role of the striatum in valuation (Ariely & Berns, 2010; Poldrack, 2011) and the guiding of action in decision tasks (O'Doherty, 2004), we examined functional connectivity between the fusiform ROI and an anatomically defined striatum ROI. The striatum ROI was generated from the caudate and putamen AAL atlas regions (which includes nucleus accumbens). The inference of reward processing from striatum activity is based on extensive prior research in humans and animals (Ariely & Berns, 2010; Poldrack, 2011); moreover, a NeuroSynth analysis revealed that the terms "reward" and "value" had an 89% and 79% probability, respectively, of appearing in published reports of striatal activation (MNI coordinates -12, 4, -10; Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). In the present research, all ROIs were selected prior to any data analysis on the basis of our theoretical hypotheses and prior findings in cognitive neuroscience.⁸

Psychophysiological interactions (PPIs). We examined connectivity between the fusiform and striatum ROI with a psychophysiological interaction model (PPI). This PPI analysis allowed us to test our a priori questions about whether scarcity jointly reduces fusiform and striatum activity, and whether this joint activity gives rise to anti-Black allocation. Whereas a Race × Condition effect on striatum activity only reveals whether fusiform and striatum activity are independently less active on scarce-Black trials (see online supplemental materials), the PPI analysis determined whether fusiform and striatum respond in tandem on scarce-Black trials, perhaps because dampened fusiform activity decreased striatal activity. We used the generalized PPI SPM8 toolbox to manage the repeated-measures nature of the data (McLaren, Ries, Xu, & Johnson, 2012). Participants' data were entered in a second-level random effects model with regressors for (a) each trial type (Scarcity/Control × Black/White faces; i.e., the psychological regressors); (b) the timecourse from the Face > Fixation functionally defined fusiform ROI (i.e., the physiological regressor); and (c) the interaction of this timecourse with each trial type. We then examined the interaction of the four Conditions × Fusiform Timecourse Regressors within the anatomical striatum ROI to identify regions in which the strength of connectivity with the fusiform seed varied by trial type, using a voxel-wise threshold of $p < .001$ and SPM8's small-volume correction procedure, $p_{FWE} < .05$. To interpret interaction patterns, we extracted mean parameter estimates (beta values) from within significant ROIs and submitted them to a 2 (Race: Black Face vs. White Face) × 2 (Condition: Scarcity vs. Control) repeated-measures ANOVA (for

⁸ Though striatum was our a priori hypothesized region of interest given our interest in devaluation, we also performed whole-brain analyses and exploratory ROI analyses to examine secondary hypotheses about additional psychological mechanisms that might support our effects (see online supplemental materials).

descriptive purposes only; significance was determined by the random effects model). See online supplemental materials for whole-brain methods and analysis.

Results

Manipulation check. Participants rated resources in the scarcity condition as more limited ($M = 2.80$, $SD = 1.19$) than resources in the control condition ($M = 3.23$, $SD = 1.14$), $t(29) = -2.09$, $p = .045$, Cohen's $d = 0.38$. Thus, despite the use of a within-subjects manipulation in this experiment, the manipulation of scarcity was validated.

Scarcity and race effects on fusiform activity. Our main hypothesis was that scarcity would impede the encoding of Black faces but not White faces, replicating Study 1. Based on our theorizing and Study 1 results, we expected to observe a selective reduction in right fusiform activity to Black faces viewed under scarcity (e.g., Bentin et al., 1996). This prediction was supported by a Condition \times Race interaction, $F(1, 28) = 7.16$, $p = .012$ (see Figure 3). In the scarcity condition, activity in the right fusiform was significantly reduced to Black faces ($M = 2.85$, $SD = 1.20$) relative to White faces ($M = 3.28$, $SD = 1.21$), $F(1, 28) = 13.05$, $p = .001$, whereas in the control condition, right fusiform activity to Black faces ($M = 3.14$, $SD = 1.20$) and White faces ($M = 3.10$, $SD = 1.25$) did not differ, $F(1, 28) = 0.07$, $p = .798$. Within-race comparisons further revealed that the effect of scarcity involved both a reduction in activity to Black faces, $F(1, 28) = 2.11$, $p = .157$, and enhancement to White faces, $F(1, 28) = 0.96$, $p = .335$ —trends that jointly contributed to the significant effect of scarcity on Black versus White face processing.⁹ This pattern replicated Study 1, further demonstrating Black face encoding impairments under conditions of economic scarcity.

Scarcity and race effects on fusiform-striatum connectivity. A secondary hypothesis was that the scarcity-decreased fusiform activity to Black faces would be related to a reduction in valuation-related activity in the striatum; that is, to the extent that participants' encoding of Black faces was impaired, they should also "devalue" those faces. To explore devaluation effects associated with the reduction in fusiform response to Black faces, we conducted an a priori psychophysiological interaction (PPI) analysis (O'Reilly, Woolrich, Behrens, Smith, & Johansen-Berg, 2012) with the right fusiform ROI as the seed region, searching for coactivation in the predetermined striatum ROI. That is, we examined the strength of connectivity between the fusiform and striatum ROI as a function of trial type (Condition \times Race), in order to determine whether decreased fusiform response corresponded most strongly with decreased valuation-related striatum activity on scarcity-Black trials.

This contrast revealed a significant positive relationship between the fusiform and striatum ROI, which was strongest on scarce-Black trials, $p < .001$ (uncorrected), small-volume correction within striatum anatomical mask, $P_{FWE} < .0001$, $k = 70$ (Figure 4A–B).^{10,11} This finding suggests that neural activity related to face encoding and valuation was most tightly coupled on scarce-Black trials, such that diminished face encoding was associated with diminished valuation.

Scarcity and race effects on discrimination. As in Study 1, and based on previous research (Krosch & Amodio, 2014; Krosch, Tyler, & Amodio, 2017), we did not expect a direct effect of

scarcity and race on behavior. Using a mixed-measure ANOVA, we confirmed this was the case: The critical Scarcity \times Race interaction on allocation bias was not significant, $F(1, 28) = 0.27$, $p = .62$.

Scarcity and race effects on discrimination mediated by fusiform-striatum connectivity. We did however predict that the strength of the relationship between diminished face processing and devaluation would be associated with behavioral discrimination, such that participants who showed the greatest scarcity-driven connectivity between decreased fusiform and decreased striatum activations would show the largest anti-Black bias. That is, scarcity would induce greater anti-Black allocation through the combination of reduced fusiform and striatum response to Black faces. To test this prediction, we created an index of anti-Black allocation bias on scarcity trials (a contrast comparing the average amount allocated on Scarce-Black trials to all other trial types) and fusiform-striatum connectivity (a contrast comparing the strength of fusiform-striatum connectivity on Scarce-Black trials to other trial types). As expected, a within-subjects mediation analysis (Judd, Kenny, & McClelland, 2001) revealed a significant indirect effect of scarcity, such that it increased anti-Black allocation through enhanced functional connectivity between the fusiform and striatum on scarce-Black trials, $B = 0.43$, $SE = 0.17$, $\beta = 0.56$, $t = 2.64$, $p = .014$ (Figure 4C; see online supplemental materials for details of the full mediation model and additional analyses).

Discussion

Study 2 provided additional evidence for the reduced encoding of Black faces under scarcity, as indicated by fusiform cortex activity—a conceptual replication of Study 1 using a different method of neuroimaging. This result again revealed a selective effect, such that fusiform activity was lower in response to Black than White faces in the scarcity condition but did not differ in the control condition. This pattern was consistent with our inference, in Study 1, that N170 results reflected a reduction in configural encoding of Black faces under scarcity, underpinned by activity in the fusiform cortex. Again, our results suggest that under conditions of scarcity, White perceivers exhibit a reduced visual encoding of Black faces as human faces.

Importantly, by utilizing a within-subjects design, we were able to clarify the pattern observed in Study 1 and more definitively determine that scarcity-related processing deficits were race-specific. In Study 2, participants experienced both scarcity and control conditions in a within-subject design. This design controlled for individual differences and thus permitted a more precise

⁹ The fusiform ROI contrast (Faces > Fixation) was orthogonal to the Condition \times Race contrast. However, to ensure our results were robust to the ROI selection method, we replicated them using a right fusiform anatomical ROI which yielded a significant cluster of 28 voxels at $p < .005$ (uncorrected), which survived small-volume correction (SVC), $P_{FWE} < 0.03$ (see online supplemental materials).

¹⁰ An additional analysis using an 8-mm sphere around the nucleus accumbens yielded similar results with a cluster of 17 voxels at $p < .001$ (uncorrected), SVC, $P_{FWE} < .03$, suggesting our results are robust to the method of defining the striatum (see online supplemental materials).

¹¹ This pattern of fusiform-striatum connectivity was unique; additional PPI analyses involving a set of exploratory ROIs were not significant (see online supplemental materials).

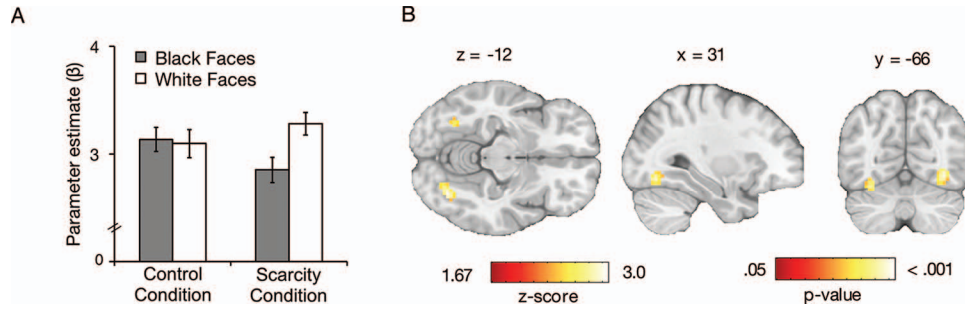


Figure 3. Scarcity effects on race in fusiform gyrus ROI ($N = 30$). (A) Average parameter estimates of each trial type across the right fusiform ROI compared to fixation. Error bars represent within-subject ± 1 SE. (B) Activity within the fusiform gyrus as a result of a second-level 2 (Race: Black vs. White) \times 2 (Condition: Scarcity vs. Control) repeated-measures ANOVA, which treated subjects as a random factor (the image is shown at a voxel-wise threshold of $p < .05$). See the online article for the color version of this figure.

test of the hypothesis—that is, whether scarcity alone can influence face processing or whether the effect of scarcity is truly selective for Black faces. Consistent with our hypothesis, the decrease in fusiform activity was selective for Black faces. A main effect of scarcity on fusiform activity did not emerge, suggesting the main effect on latency in Study 1 was likely driven by random

between-subjects variation rather than by a general effect of scarcity.

In addition, Study 2 examined the role of valuation in the effect of scarcity-altered face encoding on decision making. Results of the PPI analysis revealed that the scarcity effect on fusiform activity to Black faces related to valuation-related activity in the

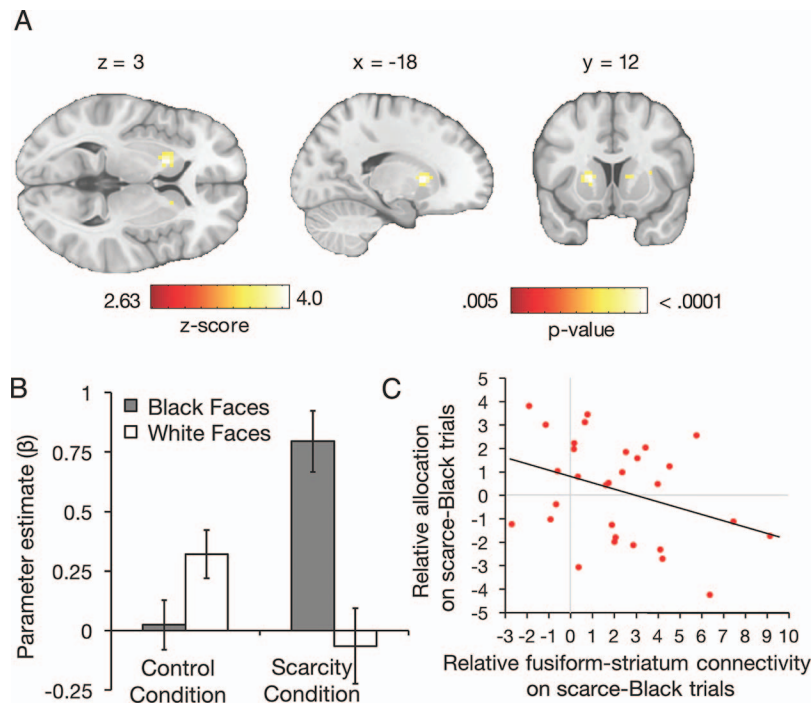


Figure 4. Results of functional connectivity analysis ($N = 30$). We examined functional connectivity between the right fusiform seed region and the striatum ROI by trial type (Scarcity \times Race). (A) The Scarcity \times Race contrast revealed significant fusiform-striatum connectivity as a function of trial type, $p < .001$ (uncorr.), small-volume corrected, $P_{FWE} < .0001$ (activation illustrated at $p < .005$ uncorrected). (B) Average parameter estimates of connectivity between the striatum and fusiform ROIs for each trial type (for descriptive purposes). Error bars represent within-subject ± 1 SE. Decreased fusiform activity on Scarce-Black trials was most strongly coupled with decreased striatum activity. (C) Subjects who exhibited the strongest fusiform-striatum connectivity on scarce-Black trials (compared with other trial types) allocated fewer resources on scarce-Black trials (compared with other trial types). See the online article for the color version of this figure.

striatum. In other words, the disruption in face encoding was associated with a reduction in valuation of Black faces under scarcity. Furthermore, a novel contribution of Study 2 was to identify devaluation as a possible mechanism through which face encoding deficits give rise to discriminatory behavior. Specifically, our fMRI results suggested complementary roles of visual processing (associated with fusiform activity) and reward processing (associated with striatal activity) in intergroup social perception. Striatal activity has long been implicated in valuation (Ariely & Berns, 2010; Poldrack, 2011) and supports goal-directed action (O'Doherty, 2004), and our results appear to link perceptual biases with neural signatures of devaluation in the prediction of biased economic decision making.

Because PPI analysis is correlational, and given the slow time-course of BOLD signal, the sequence of these effects cannot be directly inferred; hence, it is possible that striatum activity preceded fusiform activity or, alternatively, that their responses are parallel and complementary, but not causally related. However, we know from Study 1 that the effects of scarcity on face processing occurs as early as 170 ms following presentation of a face—a timeframe that likely precedes valuation-related activity in the striatum. Although contemporary noninvasive neuroimaging methods cannot provide a clear test of causality, our results are consistent with such a pathway. More broadly, Study 2 provided further evidence that impeded visual encoding of Black faces under scarcity relates to discriminatory behavior.

General Discussion

Minorities are often derogated and disenfranchised when resources become scarce—a pattern that leads to heightened discrimination and perpetuated disparities (Bianchi et al., 2018; Esses et al., 1998; Hovland & Sears, 1940; Lauritsen & Heimer, 2010; Riek et al., 2006). We asked whether this pattern of devaluation under scarcity is reflected in the visual perception of faces, such that minority group member faces are less readily encoded under scarcity, and whether this tendency is associated with economic discrimination. This research yielded three major findings.

First, our main hypothesis that scarcity impedes processing of Black faces was supported in two studies with converging evidence from complementary approaches. Specifically, we found that when economic resources were perceived to be scarce (vs. neutral), decision makers showed marked deficits in the encoding of Black recipients' faces, as indicated by a delay in the face-sensitive N170 ERP component in Study 1 and by reduced neural activity in face-sensitive fusiform gyrus revealed by fMRI in Study 2. The combination of these effects provides particularly strong support for our hypothesis: The N170 index revealed that the effect occurs very rapidly, at approximately 170 ms after face onset. Furthermore, based on the extensive N170 face processing literature, the observed N170 delay effect specifically suggests a decrement in configural face processing—a pattern previously observed for inverted human faces and allospecific (e.g., ape) faces. By using fMRI, in Study 2, we were able to locate the effect in the participants' face-selective regions of the fusiform (i.e., their fusiform face areas), consistent with the putative neural source of the N170. Together, these findings provide strong evidence that economic scarcity influences the early visual processing of minority group member faces. Importantly, these findings move beyond

prior work that examined how scarcity influences judgments of racial group membership (e.g., Krosch & Amodio, 2014; Rodeheffer et al., 2012) to demonstrate its effect on the degree to which a Black face is initially registered in the mind as a representing a conspecific (i.e., human) face.

Second, we found that perceptual encoding deficits for Black faces under scarcity were related to a decrease in neural activity associated with valuation. That is, to the extent that participants exhibited diminished Black face encoding under scarcity (compared with other conditions), they showed a complementary reduction in valuation-related striatum activity. These findings suggest that, as proposed, faces seen as less face-like are also viewed as less valuable under resource scarcity.

Finally, these studies collectively demonstrated that the degree of Black face encoding impairment under scarcity was associated, directly or through devaluation, with discrimination in monetary allocations. In Study 1, the extent to which participants showed delays in the N170 to Black (compared with White) faces was related to the extent to which they favored White (compared with Black) recipients in allocation decisions. Study 2 expanded on this proposed pathway to identify a potential mechanism through which a bias in perception can lead to bias in behavior. Specifically, we showed that behavioral discrimination under scarcity was related to the degree of coupling between face encoding deficits and neural signatures of devaluation; that is, participants who showed the tightest link between face encoding deficits and devaluation under scarcity showed the strongest behavioral bias. Together these results support a perceptual account of scarcity effects on discrimination: When resources are scarce, decision makers perceptually devalue Black recipients, which in turn is associated with discriminatory allocation decisions.

Scarcity Effects on Racial Bias

It is well-documented that minorities suffer disproportionately when resources are scarce (Bianchi et al., 2018; Esses et al., 1998; Hovland & Sears, 1940; Lauritsen & Heimer, 2010; Quillian, 1995; Riek et al., 2006; Taylor et al., 2011), yet the sociocognitive mechanisms through which scarcity gives rise to behavioral discrimination have remained obscure. To this end, recent research has identified processes such as biased race categorization (e.g., of mixed-race faces as Black) and representation (of faces as darker and more Afrocentric), as well as moderating factors (e.g., egalitarian motivations, social dominance orientation), that begin to explain the psychology of scarcity-induced discrimination (Ho, Sidanius, Cuddy, & Banaji, 2013; Krosch & Amodio, 2014; Krosch et al., 2017; Rodeheffer et al., 2012). However, these effects do not fully capture the mechanisms that drive discrimination under conditions of scarcity. By linking economic scarcity to early and automatic visual face encoding processes, the present research represents an advance toward understanding *why* scarcity gives rise to discrimination in individual social exchanges and *how* we might mitigate these effects (see Implications for Interventions section below).

These experimental findings also offer new insights into how scarcity may contribute to a broader—and more extreme—range of racial disparities. Although we focused on the effects of scarcity-induced encoding deficits on small monetary allocations, it is possible that the same pathway may also produce more serious

forms of minority group oppression associated with devaluation, such as upticks in physical violence that emerge during economic recession (e.g., Hovland & Sears, 1940; Lauritsen & Heimer, 2010; but see Green, Glaser, & Rich, 1998). Such extreme forms of harm are not easily predicted from cognitive explanations that emphasize biased racial categorization or representation. Yet the perceptual mechanisms of devaluation proposed here may provide an important link between these cognitive explanations and real-world racial injustices.

Our findings also raise new questions regarding the roles of status, race, and group membership in the observed effects of scarcity. Our focus on White Americans' perceptions of Black recipients was guided by historical and contemporary social issues of racial prejudice and discrimination in the United States. However, it is notable that, in this American context, Black recipients in our task are simultaneously racial minorities, members of a low status social group, and members of White participants' outgroup (e.g., Axt, Ebersole, & Nosek, 2014; Sidanius & Pratto, 1999). Although these experiments were not designed to distinguish between these factors, we can speculate on their likely contributions. In light of our study designs, findings, and prior research, our results appear most consistent with an effect of status, which may have been exacerbated by race. In our studies, the participant was a member of a higher-status racial group, placed in a position of power (as allocator), making allocations to same-group and lower-status group members in a nonthreatening context. In addition, differences in appearance associated with race may have exacerbated the visual encoding effects, given that these particular groups—Black and White Americans—are often distinguishable by skin tone and facial features.

It appears less likely that these findings could reflect group membership effects (i.e., ingroup vs. outgroup effects). Research on minimal group effects typically observed ingroup favoritism in the absence of outgroup derogation (e.g., Brewer, 1999). In the present studies, allocation decisions were non-zero-sum, and thus a mere group effect should produce enhanced processing of ingroup members under scarcity but no changes in the processing of outgroup members. We did not observe this pattern, however. Rather, we observed decrements in face processing specific to outgroup members—a pattern consistent with selective anti-Black allocation biases under scarcity reported by Krosch et al. (2017). These findings suggest that our findings more likely reflect effects of status and race than of group membership. Future research on this issue may disentangle these accounts by manipulating these factors independently.

Scarcity Effects on Early Visual Processing: Potential Mechanisms

Our findings raise new questions regarding the psychological experience of scarcity and how it may produce the visual changes observed in the present research. One possibility is that scarcity increases sensitivity to outgroup cues (e.g., darker skin tone), which facilitates the categorical processing of a face (e.g., as Black) and, as a consequence, shifts attention away from configural cues—an effect that known to produce the *own race bias* (Hugenberg, Young, Bernstein, & Sacco, 2010; Sporer, 2001). That is, according to this account, faces are typically processed according to a “default route,” involving configural encoding that

supports individual identification. However, if an outgroup membership cue is detected, the face is processed more categorically according to that cue (e.g., skin tone) and less configurally (Sporer, 2001). Hence, scarcity might interfere with configural encoding by increasing sensitivity to outgroup cues and enhancing categorical processing—a process connected to behavioral biases (e.g., Fincher & Tetlock, 2016). Although the present studies did not assess race categorization, prior evidence that scarcity affects race categorization is consistent with this account (e.g., Krosch & Amodio, 2014; Rodeheffer et al., 2012).

Other research suggests that scarcity enhances the experience of intergroup competition (e.g., Sherif & Sherif, 1953), which may lead White perceivers to discount the value of Black individuals in economic contexts. That is, scarcity may have implicitly reduced attention to, and thus visual processing of, Black faces relative to White faces. As noted above, Study 1 provided data consistent with this account, such that Black faces viewed under scarcity elicited reduced P1 ERP amplitude relative to White faces (reflecting early attentional preferences for White faces). This automatic orienting and shift in covert attentional processing of White compared with Black faces would, in theory, cascade into Black face visual encoding deficits consistent with the observed N170 delay. These additional results provide clues about the mechanisms through which high-level socioeconomic factors (i.e., scarcity-driven sensitivity to outgroup cues or feelings of intergroup competition) can influence relatively low-level, rapidly unfolding visual processes involved in social cognition.

Impaired Face Processing, Discrimination, and Dehumanization

The deficits in face processing observed in this research, which were specific to Black faces viewed under conditions of scarcity, may represent a very literal form of dehumanization. In prior research, “perceptual dehumanization”—defined as disruption to configural processing—has been shown using face inversion manipulations known to impair configural face encoding (e.g., Cassidy et al., 2017; Fincher & Tetlock, 2016; Hugenberg et al., 2016; Wilson et al., 2018). However, viewing upside-down faces can be ecologically peculiar, as we rarely encounter them in the real world. The N170 delay used here offers an alternative assessment of configural face encoding in response to upright faces. N170 latency has long been implicated in face encoding deficits, and a large body of research demonstrates longer N170 latencies to a variety of “less human” faces, including misaligned, scrambled, eyeless, inverted, and animal faces (Balas & Koldewyn, 2013; Carmel & Bentin, 2002; de Haan, Pascalis, & Johnson, 2002; Eimer, 2000a; George et al., 1996; Itier et al., 2007; Itier, Latinus, & Taylor, 2006; Letourneau & Mitchell, 2008; Rousselet, Macé, & Fabre-Thorpe, 2004; Stahl, Wiese, & Schweinberger, 2008). Importantly, this N170 delay has been observed in response to great ape faces (with clear human-like facial features) relative to human faces, illustrating its sensitivity to perceived *humanity* (Carmel & Bentin, 2002; de Haan et al., 2002; Eimer, 2000b; Gajewski & Stoerig, 2011; George et al., 1996; Letourneau & Mitchell, 2008). These findings suggest that the N170 delay effect observed in Study 1 may represent a literal form of “perceptual dehumanization”—a deficit in encoding a face percept as a human face.

By *measuring* configural processing deficits in response to scarcity, as opposed to manipulating it, we provide evidence of perceptual dehumanization in an ecologically valid face-to-face decision task. Future research on perceptual dehumanization effects and downstream behavioral implications could implement this method to allow for more naturalistic tasks and less demand susceptible tasks (given the N170 occurs at a very early stage of visual perception, ~170 ms after seeing a target face). In addition, future research could further validate the interpretation of N170 delays as a perceptual component of dehumanization by examining its relationship to higher-level constructions of dehumanization (e.g., trait impressions of targeted individuals that minimize their degree of human experience and agency, their ability to feel secondary emotions, and their connection with humanity; Gray et al., 2007; Harris & Fiske, 2006; Kteily et al., 2015; Leyens et al., 2000), as previous researchers have done with manipulated forms of encoding disruption (e.g., inversion; Hugenberg et al., 2016; Wilson et al., 2018). If we accept encoding deficits as “perceptual dehumanization,” as have previous authors (Cassidy et al., 2017; Fincher & Tetlock, 2016; Hugenberg et al., 2016; Wilson et al., 2018), our results suggest that racial minorities may not be seen as fully human when resources are scarce and are consequently perceived as less deserving of resources.

In identifying a perceptual component of dehumanization, our findings suggest a unique perceptual mechanism to explain how human aversion to violence (e.g., Crockett, Kurth-Nelson, Siegel, Dayan, & Dolan, 2014) has been overcome in historical and present-day brutality against Black Americans. Black people were historically considered less than human via the “3/5ths Compromise” in America and still face dehumanizing representations, often with harmful and violent consequences (e.g., Goff et al., 2008; Hoffman et al., 2016; Waytz, Hoffman, & Trawalter, 2015; Wilson, Hugenberg, & Rule, 2017). The present research suggests one way through which Black Americans may be treated as less than a person—by literally being *seen* that way.

Finally, although much recent research has established that intergroup goals and motivations influence early face processing (e.g., Freeman, Penner, Saperstein, Scheutz, & Ambady, 2011; Hugenberg & Corneille, 2009; Ofan et al., 2011, 2014; Ratner & Amodio, 2013; Van Bavel, Packer, & Cunningham, 2011; Young et al., 2010; Young & Hugenberg, 2010), to our knowledge this study is the first to link situationally induced encoding deficits to behavioral discrimination. Furthermore, while research has shown that artificially disrupting configural face processing (i.e., through inversion) can give rise to blunted ascriptions of humanity (e.g., Cassidy et al., 2017; Hugenberg et al., 2016; Wilson et al., 2018) and lead to greater punishment behaviors (e.g., Fincher & Tetlock, 2016), the current study assessed naturally occurring disruptions in individuals’ configural face processing, as a function of their task goals during the course of decision making, and linked those differences to bias in allocation behaviors.

Stimulus and Sample Diversity

The current research was inspired by real-world observations that racial minorities suffer the greatest consequences of economic downturns, and thus we chose to focus on racial discrimination

perpetrated by non-Black decision makers. However, future research may consider whether similar results would be found with other groups. For example, use of a minimal group paradigm, “model” minority group recipients, or Black perceivers could illuminate whether our findings hinge on the status of recipient groups, broad anti-Black perceptions, or more general intergroup mechanisms that promote discrimination. Previous research suggests that scarcity effects on attitudes are strongest for low status minority groups, yet they exist for other groups as well (Riek et al., 2006). The current investigation may have been a particularly strong test of our hypothesis (given the relatively low status of Black Americans and their historical discrimination), but other groups might still be susceptible. Indeed, we propose perceptual dehumanization as a general mechanism that may apply in any case where perceivers are motivated to see outgroup members as less deserving, regardless of their race. Future research should probe this speculation.

Due to the relatively difficult and immobile nature of EEG and fMRI data collection, our samples were limited to undergraduate psychology student participants at a large private university in a major metropolitan area. Given this population, we cannot gauge the degree to which our effects generalize to less educated people, those from rural areas, or those from nonindustrialized, poor, and nondemocratic societies. Indeed, such samples may differ even on “low-level” processes such as visual perception (Henrich, Heine, & Norenzayan, 2010; Miyamoto, Yoshikawa, & Kitayama, 2011). Future research should capitalize on the growing push toward interlab replication (e.g., StudySwap) to investigate the generalizability of these effects.

Implications for Interventions

By identifying the sociocognitive processes through which economic scarcity operates on behavioral discrimination, our results help to identify points of intervention as well as potential limitations. For example, our results suggest that interventions designed to improve encoding, “rehumanize,” and individuate minority outgroup members, originally developed to alter trait impressions (Harris & Fiske, 2009), may also enhance perceptual encoding of outgroup faces (e.g., Hugenberg et al., 2010), thus buffering the harmful effects of economic scarcity on racial disparities.

At the same time, the implicit nature of encoding deficits suggests a potential limitation to some intervention approaches. An implication is that the effects of impaired encoding on judgment and behavior may be especially difficult to detect and respond to, making them impervious to control. Indeed, the visual process identified in the present research may represent a very durable, resistant pathway through which system-level inequalities perpetuate themselves in individual-level judgments and behaviors. Thus, they may not be easily changed by current interventions and present a challenge for new approaches. For example, *proactive* intervention strategies that do not rely on the detection of biased perception (see Amodio & Swencionis, 2018) may prove more effective at reducing biasing effects in visual perception. If interventions can be developed to reduce these perceptual biases in individual decision makers, they may lessen the impact of institutional forces that drive disparities and facilitate progress to more egalitarian systems.

Data Availability

We report all data exclusions, manipulations, conditions, and measures in both experiments. Neither experiment was formally preregistered, but the hypotheses, method, and analysis plan for Study 1 was described in the initial grant proposal submitted to NSF, which was awarded to support this work. The hypotheses, method, and analysis plan for Study 2 were outlined in Amy R. Krosch's dissertation proposal before data were collected. Deidentified summary data, analysis code, and materials will be made available at osf.io/jkdw5 upon reasonable request and according to IRB restrictions regarding participant privacy/consent.

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