Coordinated Roles of Motivation and Perception in the Regulation of Intergroup Responses: Frontal Cortical Asymmetry Effects on the P2 Event-related Potential and Behavior

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Abstract

■ Self-regulation is believed to involve changes in motivation and perception that function to promote goal-driven behavior. However, little is known about the way these processes interact during the on-line engagement of self-regulation. The present study examined the coordination of motivation, perception, and action control in White American participants as they regulated responses on a racial stereotyping task. Electroencephalographic indices of approach motivation (left frontal cortical asymmetry) and perceptual attention to Black versus White faces (the P2 event-related potential) were assessed during task per-

formance. Action control was modeled from task behavior using the process-dissociation procedure. A pattern of moderated mediation emerged, such that stronger left frontal activity predicted larger P2 responses to race, which in turn predicted better action control, especially for participants holding positive racial attitudes. Results supported the hypothesis that motivation tunes perception to facilitate goal-directed action. Implications for theoretical models of intergroup response regulation, the P2 component, and the relation between motivation and perception are discussed. ■

INTRODUCTION

Human social interactions can be extremely complex, requiring one to balance personal and interpersonal goals while adhering to the normative standards of one's culture or society. When a social interaction involves someone from another racial group, negative stereotypes about the group can interfere with these goals. Managing such interactions often requires self-regulation—a set of psychological processes that function to promote an intended response despite the presence of distractions or other biasing influences such as social stereotypes (Gollwitzer & Moskowitz, 1996). In the cognitive psychology literature, basic forms of self-regulation may be studied in the context of response control on tasks such as the Stroop color-naming task, in which the meaning of a word interferes with one's goal of naming the ink color. Self-regulatory processes ensure that the task of naming the word's ink color is not influenced by the tendency to read the word's text, which helps one to perform the task accurately. In social contexts, self-regulatory processes often involve more elaborate goals, as well as more potent distractions. For example, in an interracial interaction, regulatory processes may be needed to promote an egalitarian response (i.e., one that is race-irrelevant) despite the automatic activation

of racial stereotypes that threaten to bias responses away from one's goal.

Although the importance of self-regulation in such situations is widely recognized, the mechanism through which successful regulation operates remains a topic of inquiry and some debate. Extant theoretical models of intergroup response regulation emphasize the role of motivation (Fazio, 1990; Devine, 1989), which is thought to engage more controlled (i.e., careful) and intentional patterns of responding (Amodio, Devine, & Harmon-Jones, 2008; Monteith, 1993). Other theorists have noted that self-regulation involves changes in perception and attention to goal-relevant cues, presumably to prepare an individual to implement an intended response (Shah & Kruglanski, 2008; Monteith, Ashburn-Nardo, Voils, & Czopp, 2002). But how do motivational and perceptual processes work together in the context of self-regulation? And how are these processes influenced by personal attitudes? On the basis of research in social psychology and neuroscience, the present research posited that motivation tunes perceptual attention to goal-relevant cues in order to facilitate action control. This hypothesis was tested using measures of brain activity while participants regulated their behavioral responses on a racial stereotyping task. Furthermore, it was hypothesized that the coordination of motivation, perception, and action would be more pronounced among individuals with egalitarian racial attitudes, given their stronger personal interest in performing well on the task.

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Psychological Mechanisms of Self-regulation

Mechanistic accounts of self-regulation suggest that it involves multiple psychological processes working in concert (Carver & Scheier, 1998). Chief among these is motivation (Fazio, 1990; Tolman, 1932), which represents the desire to engage a goal-directed response. Social behavior is characterized by a range of motivations, such as to affiliate, to uphold group norms, and to respond without stereotypes. For example, stronger egalitarian motivation has been shown to facilitate accurate responding on a task, even when implicit racial stereotypes bias one's responses toward an incorrect response (Amodio et al., 2008; Payne, 2005). Hence, motivation clearly plays a key role in engaging control over one's actions.

Less is known about the specific mechanism through which motivation leads to a self-regulated response. In addressing this issue, Monteith (1993) pointed to the effects of motivation on perceptual attention. She proposed that the motivation to respond without prejudice evokes vigilance to racial cues, because such cues signal the potential for making an unintended racially biased response. Monteith showed that, after being alerted to the potential for prejudice, low-prejudice participants engaged greater attentional resources to racial cues and responded more slowly and carefully in subsequent race-related judgments. This analysis is consistent with Bruner and Postman's (1949) view that perception is an active, goal-driven process (see also Van Bavel, Packer, & Cunningham, 2008; Balcetis & Dunning, 2006), and suggests that motivation facilitates action control by modulating perception. Although ample psychological evidence has implicated motivational and perceptual processes in self-regulation, less is known about the way these processes interact to promote intentional behavior.

Neural Mechanisms of Self-regulation

To gain insight into the mechanisms through which self-regulation facilitates goal-driven behavior, it is useful to consider patterns of connectivity associated with controlled processing in the brain. In the cognitive neuroscience literature, controlled processing is primarily associated with prefrontal cortex (PFC; Badre, 2008). Anatomical studies of the macaque brain—a close human homologue—reveal that PFC regions linked to control are extensively interconnected with structures associated with goal-directed action (Fuster, 2001; Passingham, 1993). Major pathways for goal-directed action involve PFC, basal ganglia, and the thalamus (i.e., fronto-striatal loops), operating in conjunction with midbrain processes (Middleton & Strick, 2000). Left PFC, in particular, is involved in the implementation of goal-directed behavioral responses, via a fronto-striatal–pallidal circuit involving supplementary and primary motor cortices (whereas right PFC is often implicated in inhibitory control; Aron, 2007). Hence, the major targets of control-related PFC regions are structures that support behavioral action.

Other research has examined PFC mechanisms that coordinate perception and attention (Kastner & Ungerleider, 2000). For example, major projections from lateral regions of PFC modulate basic sensory inputs via connections to the thalamus (Barbas & Zikopoulos, 2007) and further influence perception through signals to visual and auditory association cortices (Medalla, Lera, Feinberg, & Barbas, 2007). PFC also modulates oculomotor networks, constituting an important interface between perception and action in the context of control (Miller & Cohen, 2001). Through these connections, PFC is thought to select motivationally relevant signals while inhibiting irrelevant signals, in the service of action goals.

Taken together, anatomical studies highlight the effects of PFC—particularly left lateral regions—on both perception and action control. This general pattern has been observed in several human neuroimaging studies. For example, left lateral PFC activity has been associated with the selection of goal-related semantic information into working memory (Badre & Wagner, 2007; Thompson-Schill, 2003), the modulation of perceptual attention (Kastner & Ungerleider, 2000), and goal-directed motivational states and preparation for action (Harmon-Jones, 2003). In the intergroup domain, activity in left PFC has also been associated with goals to engage in egalitarian behavior (Amodio, Devine, & Harmon-Jones, 2007). What remains missing, however, is evidence for the coordination of motivational and perceptual processes to facilitate action control during the on-line engagement of self-regulation. Such evidence would advance our understanding of the mechanisms involved in self-regulation and shed new light on the processes through which expressions of racial prejudice may be reduced.

The Present Research

The goal of this research was to examine the coordination of motivation, perception, and action as they support behavioral regulation in the face of biasing social stereotypes. To this end, on-line indices of approach motivation and perceptual attention were recorded using EEG while participants completed Payne's (2001) weapons identification task. In this sequential priming task, one's goal is to quickly categorize a target stimulus as either a gun or a tool. Prior to each target, the face of a White or Black person is presented. Consistent with the stereotype of African Americans as dangerous, the presentation of a Black face tends to bias White American participants' responses, such that they are quicker to identify guns than tools immediately after viewing a Black face. White participants also tend to incorrectly identify tools as "guns" when these targets follow the presentation of a Black face (Payne, 2001). Hence, in order to respond accurately on this task, regulation is needed to override these stereotype-driven biases. Furthermore, individuals with more positive racial attitudes show greater self-regulation on this task, such that personal attitudes appear

to guide these regulatory processes (Amodio et al., 2008; Payne, 2005).

In the present study, motivation was indexed by EEG alpha asymmetry extracted from intertrial intervals (ITIs) during task completion (similar to the method used by Davidson, Ekman, Saron, Senulis, & Friesen, 1990). The method used here was novel, however, in that it assessed the degree of left-sided PFC asymmetry while participants engaged in a goal-directed behavioral task, and therefore, it provided an on-line index of motivational processes during the course of task completion. Specifically, frontal EEG asymmetry assessed during the ITIs between experimental trials provided an index of motivational orientation just prior to the appearance of a Black or White face prime. Previous research has established that EEG measures of left (vs. right) frontal inverse-alpha power reflect cortical activity located in left dorsolateral PFC (Pizzagalli, Sherwood, Henriques, & Davidson, 2005; see also Berkman & Lieberman, 2009). Frontal asymmetry has been associated with goal-directed motivational states across many studies (e.g., Amodio et al., 2007; see Harmon-Jones, 2003 for a review). Thus, although the measurement of EEG asymmetry during task performance (i.e., during ITIs) was novel, the relationship between left-sided PFC activity and approach-related motivation is well established.

Perceptual attention was indexed by the P2 component of the ERP to Black versus White face primes during the task. The P2 is a positive-polarity stimulus-locked ERP associated with attentional processing of perceptual cues, such as faces (Schutter, de Haan, & van Honk, 2004). Timing of the P2 varies by task, and in studies of intergroup face perception, the P2 to faces typically peaks at approximately 170–180 msec (Ito & Urland, 2003). The P2 is distinct from the face-specific N170 ERP, which is responsive to the structural composition of a face. Although the timing of the P2 and N170 are similar on some tasks, they differ in topography and presumed source, and also in their association with psychological processes. For example, the P2, but not the N170, is sensitive to the emotional and motivational significance of a face, whereas the N170 is uniquely sensitive to structural components and the orientation of a face (Ashley, Vuilleumier, & Swick, 2004).

Several studies of White participants' ingroup/outgroup perception have observed larger P2 amplitudes to Black than White faces, which is interpreted as greater perceptual attention to outgroup members (Bartholow & Dickter, 2007; Ito, Willadsen-Jensen, & Correll, 2007). Because participants in race perception experiments are typically aware that the study concerns race, P2 effects likely reflect attention to a cue that signals the potential for a race-biased response. That is, for a highly prejudiced person in the experiment, a Black face stimulus might represent a cue that one's prejudices may be revealed (e.g., to the experimenter). A Black face may also be perceived as threatening to such individuals. In either case, the stimulus holds emotional and/or motivational significance. For a low-prejudice person, a Black face represents a cue that action control is

needed, and thus, it holds motivational significance associated with an increase in accurate task performance. For high- and low-prejudice participants alike, the presentation of a Black face should elicit a larger P2 than a White face, but this P2 effect is more likely to translate into behavioral regulation for low-prejudice individuals (Monteith, 1993; Fazio, 1990).

The main hypothesis in the present experiment was that stronger task engagement, indexed by greater left frontal cortical activity across trials, would predict larger P2 amplitudes in response to Black versus White face primes, given that Black faces are more relevant to subjects' concern that racial stereotypes might influence their responses. This P2 effect, in turn, should be associated with greater action control, particularly for participants with positive racial attitudes.

METHODS

Participants and Procedure

Forty-six right-handed White Introductory Psychology students participated for extra course credit. Right-handed participants were selected to avoid physiological differences due to brain laterality (e.g., Davidson et al., 1990).

Procedure

Upon arrival at the laboratory, participants provided informed consent and were then fitted with an electrode cap for EEG recording. The experimenter explained that on each trial of the task, a Black or White face would appear briefly on the computer screen, followed by a picture of a handgun or hand tool. Participants were to identify the target as a "gun" or a "tool" by pressing a corresponding key within a 500-msec deadline; a warning to respond more quickly followed responses that exceeded this deadline. To engage participants' motivation to respond without racial bias (i.e., among low-prejudice individuals), they were told that their responses on the task could be influenced by the race of the primes (Amodio et al., 2008). However, they were assured their responses would be private and completely confidential. Past research has shown that this procedure is effective in engaging participants' personal motivations to respond without prejudice while mitigating any normative concerns about appearing racist to others (Amodio et al., 2008; Amodio, Kubota, Harmon-Jones, & Devine, 2006). Hence, this procedure allowed us to examine the effect of personal attitudes on self-regulatory processes in the absence of normative concerns.

Tasks and Materials

Weapons Identification Task

As in Payne (2001), stimuli included two Black and two White male faces, four handguns, and four hand-tools. Stimuli were presented in the center of the computer screen, and trial order was randomized. Each trial began with a

pattern mask (1 sec), followed by the prime (200 msec), the target (200 msec), and then a second pattern mask. The second mask remained on screen until a response was registered or until 2 sec elapsed. ITIs, from which frontal asymmetry scores were derived, ranged from 2 to 4 sec. The task included 26 practice trials and 288 experimental trials. Stimuli and recording triggers were presented using DMDX software (Forster & Forster, 2003).

Attitudes toward Blacks (ATB) Scale

Participants completed Brigham's (1993) ATB scale privately, as part of a questionnaire battery administered in a mass testing session held several weeks before the experiment. The ATB is a 20-item questionnaire that assesses attitudes toward Black people on a 1–7 scale, with higher scores indicating more positive attitudes. For each item, participants rated their endorsement of statements such as "I would rather not have blacks live in the same apartment building I live in" (reverse-coded) and "Black and white people are inherently equal". Cronbach's alpha coefficient indicated that the scale was highly reliable, α = .87, and the mean score was 5.72 (SD = 0.89). It is notable that although the average score was above the midpoint, the midpoint represents a highly negative attitude toward Black people (i.e., ambivalence about living in the proximity of a Black person). As such, ATB scores typically span the upper end of the scale in American college samples.

Behavioral Data Processing

Error rates and correct response latencies were calculated as a function of trial type. In addition, separate indices of controlled versus automatic patterns of responding were modeled from task behavior using Jacoby's (1991) process-dissociation (PD) procedure (see also Payne, 2001). In tasks such as the weapons identification task used here, *control* is defined as the extent to which a subject's behavior accurately matches the explicit goal of categorizing target objects (guns or tools), regardless of the race of the prime face (Payne, 2005). Following Payne's (2001) formula, the control estimates were quantified as the following: Control = P(correct response on congruent trials) − P(incorrect response on incongruent trials), where congruent refers to stereotype-consistent trials (e.g., Black–gun trials) and incongruent refers to stereotype-inconsistent trials (e.g., Black–tool trials). This index is equivalent to general response accuracy, but rescaled for the PD framework to range from −1 to 1. PD control estimates were calculated for Black and White trial types. As in past studies (e.g., Amodio et al., 2008; Payne, 2005), the control estimates for Black- and White prime trials were highly correlated and considered collinear [$r(44)$ = .87, p < .001], consistent with the conceptual definition of "control" as the successful implementation of a task goal, which was to correctly categorize targets regardless of the prime race

(Mendoza, Gollwitzer, & Amodio, 2010). Therefore, the main behavioral index of control was the average PD control estimate, collapsed across race, as in previous studies (e.g., Mendoza et al., 2010; Amodio, 2009; Amodio et al., 2008).

Estimates of automatic race-biased responding were also computed for comparison. Whereas the control estimate reflects participants' success in performing the task correctly without the influence of race, the PD estimate of automatic stereotyping reflects the degree to which, when an error is made (i.e., when control fails), the error reflects a stereotype-driven response bias. In the case of Black trials, the index of automatic stereotyping was quantified as the probability of making an error on Black–tool trials, controlling for the probability of control [i.e., Black–tool errors/(1 − control)], as described by Payne (2001). A White-automatic estimate was also computed, but because White Americans are not typically associated with either guns or tools, this estimate served as a baseline, included here as an additional comparison.

EEG Recording and Processing

EEG was recorded from 27 tin electrodes embedded in a stretch-lycra cap, with a left earlobe reference and forehead ground. Frequencies from DC to 100 Hz were digitized at 2500 Hz. Off-line, EEG was re-referenced to average earlobes and scored for movement artifact.

P2 Processing

For P2 scoring, EEG data were submitted to a regression-based blink-correction procedure, and frequencies below 1 Hz and above 15 Hz were digitally filtered. A 1000-msec stimulus-locked epoch of EEG, beginning 300 msec prior to prime onset, was selected for each artifact-free trial. A 100-msec prestimulus baseline average was subtracted from each epoch to normalize signals within trials. ERPs associated with White and Black face primes were averaged, and P2 amplitudes were scored as the average voltage between 150 and 250 msec postprime (avoiding convolution with ERPs to target stimuli, which emerge approximately 50 msec after target onset).[1]

Frontal Cortical Asymmetry

Following artifact rejection, EEG from baseline and task ITIs were spline-fitted to 1000 Hz. Artifact-free 1024-point epochs were submitted to a fast-Fourier transformation using a 75%-overlapping Hamming window. Alpha power (8–13 Hz) was extracted and submitted to a natural-log transformation. Following past work, alpha asymmetry was computed by subtracting left- from right-sided alpha power at homologous sites, such that higher values represent stronger left-sided cortical activity. Analyses focused on activity at lateral frontal regions (F8–F7), which reflected the activity of dorsolateral PFC (Pizzagalli et al., 2005).

Asymmetry scores from medial frontal (F4–F3) and parietal (P4–P3) sites were also examined for comparison. Preliminary analyses revealed that EEG asymmetry did not vary by trial type, consistent with the idea that left PFC activity should reflect general task engagement. Therefore, asymmetry scores were averaged across trial types.

RESULTS

Analyses were conducted in two steps. First, task-related effects were examined separately for behavioral control, frontal asymmetry, and P2 amplitudes. Next, the main hypothesis regarding relations among these variables was tested.

Task-related Effects

Behavior

Performance on the weapons identification task revealed a pattern of automatic stereotyping and efforts at regulation. As in past studies, a 2 (prime: Black vs. White face) × 2 (target: gun vs. tool) analysis of variance (ANOVA) on log-transformed response latencies produced the expected interaction [$F(1, 45) = 22.41, p < .001$; raw latencies are illustrated in Figure 1A]. Simple effect analyses indicated that, compared with White faces, Black faces facilitated "gun" responses [$t(45) = 4.33, p < .001$], and interfered with "tool" responses [$t(45) = 3.76, p < .001$]. A 2 (prime) × 2 (target) ANOVA for error rates revealed a similar interaction [$F(1, 45) = 22.87, p < .001$; Figure 1B]. Simple effect analyses indicated that guns were categorized more accurately when they followed Black than White faces [$t(45) = 4.48$, $p < .001$], whereas tools were categorized less accurately following Black than White faces [$t(45) = 4.27, p < .001$]. This pattern established that the task successfully elicited stereotyping tendencies and the need for regulation.

Analyses of PD estimates indicated that, as expected, automatic effects were larger for Black trials ($M = .59, SD = 0.14$) than White trials ($M = .44, SD = 0.15$) [$t(45) = 4.67$, $p < .001$], and these estimates were not correlated [$r(44) = −.18, p = .23$]. This pattern established that the task elicited a response bias driven specifically by African

American stereotypes. Although the main index of control was collapsed across race, a comparison of PD control estimates for Black ($M = .49, SD = 0.21$) and White ($M = .47, SD = 0.20$) trials indicated that they did not differ [$t(45) = 1.14, p = .26$]. The lack of difference, combined with the collinearity of the control estimates for Black and White trials, supported the point that control on this task reflects a domain-general process that promotes accurate performance independent of race (Amodio et al., 2008; Payne, 2005).

PFC Activity

The EEG measure of frontal cortical asymmetry served as the index of task motivation. As in past research, greater left-sided lateral frontal activity was taken to reflect stronger action-oriented motivation (Harmon-Jones, Amodio, & Harmon-Jones, 2009). A one-way ANOVA comparing asymmetry scores between the sites (lateral frontal, medial frontal, and parietal) was significant [$F(2, 90) = 300.37, p < .001$]. This analysis indicated that left asymmetry was stronger at lateral frontal sites ($M = 0.41, SD = 0.10$) than medial frontal sites ($M = 0.13, SD = 0.06$) [$t(45) = 20.15, p < .001$] and parietal sites ($M = 0.09, SD = 0.07$) [$t(45) = 20.51, p < .001$]. Asymmetry scores at the medial frontal and parietal sites did not differ [$t(45) = 0.82, p = .42$]. The strong activity of left lateral PFC during the task was consistent with its theorized role in goal-directed motivation and action (Harmon-Jones, 2003). Importantly, left frontal cortical activity did not differ as a function of trial type ($Fs < 1$), further suggesting that this pattern of brain activity was associated with the general engagement of task motivation. Lateral–frontal asymmetry scores therefore served as the index of task motivation in subsequent analyses.

P2

The P2 ERP component is typically pronounced at midline scalp sites. A 2 (prime: Black vs. White) × 3 (site: fronto-central vs. central vs. parietal) ANOVA tested differences in P2 amplitudes to Black versus White faces at fronto-central (FCz), central (Cz), and parietal (Pz) midline sites. The expected main effect for race was significant [$F(1, 45) = 62.24, p < .001$]. At each site, the P2 was larger in response to Black faces than White faces [$t(45)s > 5.80, ps < .001$], consistent with previous work (Bartholow & Dickter, 2007; Ito & Urland, 2003). The interaction was also significant [$F(2, 90) = 5.24, p < .01$], suggesting that the P2 effect was most pronounced at FCz, where amplitudes were greater to Black faces ($M = 2.57, SD = 2.21$) than to White faces ($M = 0.97, SD = 2.69$) [$t(45) = 8.54, p < .001$; Figure 2]. The P2 waveform peaked at 174 msec, replicating previous findings (Ito & Urland, 2003), such that a differential response to race occurred just 174 msec after face onset.[2] The difference in P2 amplitudes to Black versus White faces at FCz was therefore used as the main index of perceptual attention to race in the subsequent analyses.
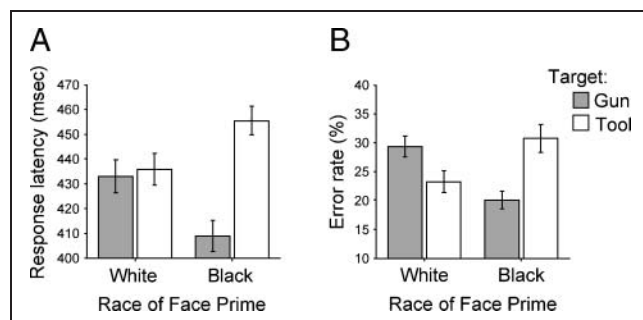

Figure 1. Response latencies (A) and error rates (B) on the weapons identification task, as a function of prime race and target.

Primary Analysis: Relation between Frontal Asymmetry, P2 Effect, and Action Control

The primary hypothesis was that motivation and perception work in concert to promote action control, particularly among low-prejudice individuals. This hypothesis characterizes a statistical pattern of *moderated mediation*; that is, motivational processes influence perceptual attention to race for all participants, but changes in perceptual attention contribute to greater action control only for low-prejudice participants. To test this pattern, multiple-regression procedures recommended by Baron and Kenny (1986) were followed using mean-centered predictors. The first regression revealed that stronger left-sided PFC activity predicted higher PD control estimates across participants [$\beta = .28$, $t(44) = 1.96$, $p = .05$], consistent with the idea that greater task motivation should predict better performance. The second regression indicated that stronger left PFC activity predicted a larger P2 race effect (the proposed mediator) [$\beta = .35$, $t(44) = 2.44$, $p < .02$], supporting the hypothesis that stronger task motivation would be related to greater perceptual attention to Black versus White faces. However, the direct path between the P2 race effect and behavioral control (across subjects) did not reach significance [$\beta = .24$, $t(44) = 1.66$, $p = .10$].

To test for the predicted pattern of moderated mediation—that is, that the effect of perceptual attention on behavior would differ as a function of prejudice level—a third regression was conducted in which PFC asymmetry, P2 effect, prejudice level (ATB scores), and the P2 × Prejudice level interaction were included as predictors, and PD control was the outcome. This regression produced a significant effect for prejudice level [$\beta = .28$, $t(42) = 2.09$, $p = .04$], indicating greater response control among participants with lower prejudice levels. More importantly, the P2 × Prejudice level interaction was significant [$\beta = .36$, $t(42) = 2.29$, $p < .03$], suggesting the predicted pattern of moderated mediation (Figure 3). To test the predicted pattern directly, the
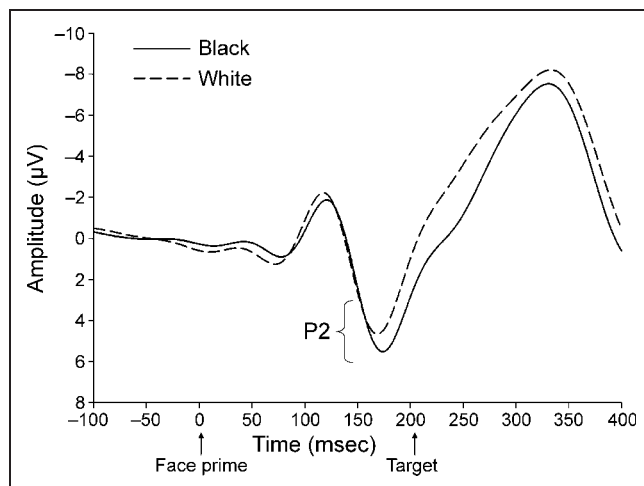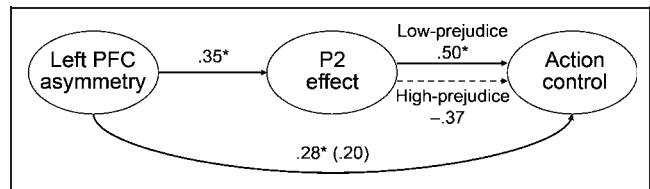
Figure 3. Moderated mediation model illustrating the coordination of motivation (left lateral PFC activity), perception (P2 race effect), and action control (process-dissociation estimate) as a function of low- versus high-prejudice attitudes. Coefficients represent beta-weights from the regression equations. *$p < .05$.

moderated path between the P2 and PD control scores was tested separately, as simple slopes, at low versus high levels of prejudice (i.e., continuous ATB scores centered at −1 or +1 *SD* relative to the mean, respectively). Predictors included PFC activity, P2, prejudice level, and the P2 × Prejudice level interaction, and the outcome was PD control. At low levels of prejudice, the critical effect of P2 was significant [$\beta = .50$, $SE = 0.036$, $t(42) = 2.99$, $p < .01$]. By contrast, at high levels of prejudice, the critical P2 effect was not significant [$\beta = -.36$, $t(42) = -1.23$, $p = .23$]. With the mediator included in the equation, the effect of PFC activity was no longer significant [$\beta = .20$, $t(41) = 1.40$, $p = .17$], and a Sobel test indicated the a priori predicted pattern of mediation ($z = 1.63$, $p < .05$; one-tailed). That is, the effect of left PFC activity on controlled behavioral responses on the weapons identification task was mediated by the P2 response to Black versus White faces, for low-prejudice participants but not for high-prejudice participants. More broadly, these analyses supported the general hypothesis that motivation tunes perceptual attention, and that these coordinated changes translate into greater action control.

DISCUSSION

Motivation and perception have long factored into theories of action control, yet the on-line coordination of these processes has not previously been demonstrated. The present results showed that motivation to respond accurately on a stereotype-control task appeared to tune perceptual attention to racial cues, which in turn promoted better action control, particularly for individuals with more positive racial attitudes (i.e., in a moderated-mediation pattern). This model of self-regulation is consistent with neuroanatomical connectivity of PFC, and also with classic theories of self-regulation and motivation that emphasize effects on perception and action (Bruner & Postman, 1949; Tolman, 1932). This model differs somewhat from other social psychological theories that focus on the direct, intrapsychic control of biased cognitions and emotions. Rather, it views cognitive and emotional processes as key mechanisms of self-regulation, working in concert to guide goal-driven perception and action. In addition, these findings illustrate the effects of personal attitudes on basic mechanisms of self-regulation. When participants were personally motivated to perform the weapons identification task accurately and

Figure 2. P2 effect for race, showing a larger response to Black than White faces.

without prejudice, motivational and perceptual processes were tightly coordinated with action control. Among participants with more highly prejudiced attitudes, these self-regulatory processes did not cohere, yielding a lower degree of action control. Hence, the inclusion of individual differences in this study provided a way to further validate the results as evidence for the hypothesized self-regulatory effects.

Implications for the Regulation of Intergroup Responses

The present findings advance our understanding of how intergroup responses may be regulated. Many previous approaches to the regulation of intergroup bias have focused on the control of stereotypic thoughts and negative emotional reactions, but this view is complicated by research showing that people are generally unable to control their thoughts or emotions directly (Wegner, 1994; Gross & Levenson, 1993). The current research suggests that control involves motivational processes that modulate the perception of race and promote the implementation of goal-directed behavior, overriding any influence of stereotypes (see also, Mendoza et al., 2010). In the present study, the main goal of participants was to correctly categorize the target as a gun or a tool—a task that should be race-irrelevant. Similarly, real-life interracial interactions usually occur in the context of a general goal, such as asking for directions, discussing a business plan, or resolving a disagreement. In such cases, the main goal of the interaction is irrelevant to race, and bias only emerges to the extent that it influences one's progress on the main goal. Therefore, successful control of intergroup responses involves attention to cues for potential bias, which may then prompt an increase in effort toward the main task goal. Because participants in this study were aware that the experiment concerned the effects of race, successful task performance depended on enhanced attention to cues for potential bias, combined with the promotion of accurate, goal-consistent behavior (which would preclude the influence of underlying biases on behavior). This finding suggests that a successful strategy for reducing racial bias is to train an individual to be more vigilant to racial cues and to respond to such cues by redoubling efforts toward one's (race-irrelevant) task goal (Mendoza et al., 2010; Amodio et al., 2008; Monteith, 1993).

The P2 as Motivated Perception

The present research also has implications for interpretations of the P2 ERP component. The P2 is a widely studied ERP component that is typically interpreted as reflecting bottom–up perceptual processing of a stimulus. However, my findings suggest that the P2 reflects a motivated perception process that reflects top–down goal effects, in line with Bruner and Postman's (1949) proposal that perception and attention generally operate within the context of a goal. This "motivated perception" interpretation acknowledges

that, in virtually any experimental situation, participants are motivated to engage in the central task, and thus, to prepare for the expected presentation of stimuli. For instance, when participants in a psychological experiment begin to see pictures of Black and White faces during the task, they are usually quick to assume that the study examines some aspect of racial prejudice. As a result, they may engage in a top–down process of expectancy at the start of each trial, looking out for cues that may be diagnostic of their prejudice (e.g., Black faces) or that otherwise signal the need to respond more carefully.

This theoretical analysis suggests that the frequent observation of larger P2 amplitudes to outgroup (vs. ingroup) faces in past research may be due to participants' personal and/or normative concerns about responding without prejudice (e.g., Bartholow & Dickter, 2007; Ito & Urland, 2003), and is further consistent with recent work showing that low-level neural processing of Black versus White faces is driven by top–down motivational effects (Van Bavel et al., 2008; Amodio, Harmon-Jones, & Devine, 2003). This analysis is also consistent with a recent study by van Peer, Spinhoven, Dijk, and Roelofs (2009), in which cortisol administration increased the P2 response to both angry and neutral faces among socially anxious participants, suggesting that the P2 reflected the motivated perception of social threat. More broadly, because the P2 response to faces occurs within the context of experimental tasks that inherently involve motivation and expectancy (i.e., motivation to complete the task and preparation to view stimuli), it may prove useful to interpret past and future P2 effects in terms of motivated perception.

PFC Activity and the Control of Prejudice

It is notable that a similar degree of lateral PFC activity was observed during task completion for both high- and low-prejudice subjects, suggesting that both groups of subjects were strongly motivated to engage in the task. Similarly, greater left PFC activity predicted larger P2 responses to Black (vs. White) faces, regardless of prejudice level. Interestingly, high- and low-prejudice participants differed only in their behavior, such that stronger PFC activity and P2 effects facilitated behavioral control only for low-prejudice participants. This finding is consistent with the idea that controlled processing may arise from different underlying motivations and may apply to different psychological and behavioral targets (Amodio et al., 2003, 2006).

As demonstrated here, the observation of activity in PFC alone does not provide much information about why controlled processes may be engaged or what the intended target of control might be. The inference that PFC activity among low-prejudice participants was associated with controlled processing aimed at responding without prejudice was made possible by the use of a behavioral task designed specifically to elicit response control in combination with behavioral indices of controlled processing. For high-prejudice participants, PFC activity levels were similar, but

they were not associated with the control of a prejudiced response. Without the use of a response-control task or appropriate behavioral assessments, the meaning of PFC activations to Black (vs. White) would be very ambiguous. Indeed, it is difficult to interpret PFC activity observed in response to the passive viewing of Black versus White faces as "prejudice control," because PFC activity could reflect any number of processes (Gilbert et al., 2006). The present findings are among the first to clearly link PFC activity in response to racial outgroups to controlled processes aimed at reducing expressions of prejudice (see also Amodio et al., 2007). Further research will be needed to elucidate the relationship between PFC activity and controlled processing in the context of self-regulation and intergroup responses.

Conclusion

Psychologists have long noted the important associations between motivation, perception, and action (e.g., Bruner & Postman, 1949). However, questions regarding the dynamic interplay of these processes and their links to underlying neural mechanisms had not been addressed directly. The present work examined these relationships in the context of intergroup responses, using on-line neural indices of motivation and perceptual attention to test associations between these processes and behavioral control. The results suggest a model of self-regulation in which motivation functions to tune perception to goal-relevant cues, which in turn enhances goal-directed action—a model consistent with classic theories of motivation as well as recent research on PFC function and connectivity. These findings promise to inform strategies for enhancing self-regulation, particularly in the context of intergroup relations.

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Notes

1. The P2 component was also scored as the peak amplitude occurring between 150 and 250 msec post face onset. Peak amplitude scores showed the same, but slightly weaker, pattern of results as reported in the text. Importantly, the peak P2 amplitude was larger for Black faces ($M = 6.88$, $SD = 2.52$) than White faces ($M = 5.95$, $SD = 2.84$) [$t(45) = 4.19$, $p < .001$], and the P2 difference score interacted with ATB scores to predict PD control in the manner described in the text [$\beta = .35$, $t(45) = 2.50$, $p < .02$].
2. It is notable that the timing of the frontal P2 was similar to that of the temporo-occipital N170, which is linked specifically to face perception. Furthermore, the fact that the P2 and N170 are

opposite in polarity raises the question of whether the observed frontal P2 reflects the opposite dipole of an N170 arising from the same underlying source. To test this possibility, the N170 ERP component was scored at the right (T6) and left (T5) temporo-occipital sites (equivalent to P8 and P7). A 2 (race: Black vs. White) × 2 (hemisphere: left vs. right) ANOVA replicated the typical finding that the N170 amplitude was larger on the right side [$F(1, 45) = 27.26$, $p < .001$]. There was also a nonsignificant trend for the N170 to be larger in response to Black than White faces ($p = .18$). However, N170 amplitudes were not significantly correlated with P2 amplitudes (scored as either peak or average). Thus, the P2 effects described in the text appear to be independent of the N170.

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