Alternative mechanisms for regulating racial responses according to internal *vs* external cues

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Personal (internal) and normative (external) impetuses for regulating racially biased behaviour are well-documented, yet the extent to which internally and externally driven regulatory processes arise from the same mechanism is unknown. Whereas the regulation of race bias according to internal cues has been associated with conflict-monitoring processes and activation of the dorsal anterior cingulate cortex (dACC), we proposed that responses regulated according to external cues to respond without prejudice involves mechanisms of error-perception, a process associated with rostral anterior cingulate cortex (rACC) activity. We recruited low-prejudice participants who reported high or low sensitivity to non-prejudiced norms, and participants completed a stereotype inhibition task in private or public while electroencephalography was recorded. Analysis of event-related potentials revealed that the error-related negativity component, linked to dACC activity, predicted behavioural control of bias across conditions, whereas the error-perception component, linked to rACC activity, predicted control only in public among participants sensitive to external pressures to respond without prejudice.

Self-regulation has been a central theme of psychology since the field's inception (James, 1890), and questions of how we orchestrate intentional behaviour in the midst of countervailing impulses continue to drive much theoretical inquiry. Psychological scientists from diverse research traditions have examined mechanisms of behavioural regulation at multiple levels of analysis, ranging from cultural influences to neural transmission. In the social psychological literature, much research on self-regulatory processes has been conducted in the context of prejudice and stereotyping. Stereotypes of African Americans, for example, are pervasive in American culture, and for most Americans, these stereotypes come to mind automatically and may influence their responses towards black people (Devine, 1989). Despite strong automatic associations between African Americans and stereotypic traits, many white Americans are motivated to inhibit expressions of racial bias in the service of their egalitarian beliefs (Allport, 1954; Devine, 1989). Hence, for low-prejudice people, responding without prejudice constitutes a significant regulatory challenge. Laboratory research on regulating one's intergroup responses thus provides a powerful and ecologically valid context for examining mechanisms of self-regulation.

Classic conceptualizations of racial bias have emphasized the role of self-standards, such as one's personal attitudes and beliefs, in driving efforts to respond without prejudice (Devine *et al.*, 1991; Monteith, 1993; Dovidio *et al.*, 1996). These self-standards reflect internalized cues for self-regulation (Monteith and Devine, 1993), which provide chronic impetuses to detect and inhibit unintended stereotypic associations in order to respond in an unbiased manner (Devine, 1989). These cues constitute the chronic internal regulation of one's responses to African Americans that bring behaviour inline with one's beliefs. Because these regulatory cues reflect one's internalized attitudes and beliefs, they are activated across situations and tend to be stable predictors of behaviour (Ryan and Connell, 1989; Devine *et al.*, 2002). Thus, for low-prejudice people, internal cues should predict the regulation of racial responses regardless of the presence or absence of external cues, such as normative pressures to respond without prejudice.

Since the passage of civil rights legislation in the 1950s, researchers have observed a rise in the American's normative standards of egalitarianism that proscribe expressions of intergroup bias, independent of personal beliefs (Crosby *et al.*, 1980). These normative standards provide externally generated cues for response regulation. Because external cues correspond to the presence of peers and authority figures who would disapprove of prejudiced responses, they influence behaviour only in situations when such cues are present, as in public, but not in private, situations (Plant and Devine, 1998). Much of the research has demonstrated that the actual or anticipated presence of a potentially disapproving peer or authority figure leads to reduced expression of race bias in self-reports and behaviour (Blanchard *et al.*,

1991; Monteith *et al.*, 1996; Plant *et al.*, 2003), although some research has also shown that the anxiety associated with such external pressures may interfere with successful inhibition of automatic stereotypes (Lambert *et al.*, 2003).

Importantly, external social cues do not affect the behaviour of all people. Individuals vary considerably in the extent to which they are concerned with social pressures to respond without prejudice (Dunton and Fazio, 1997; Plant and Devine, 1998), and these external cues only affect the behaviour of people who report high sensitivity to normative egalitarian pressures (Plant *et al.*, 2003). It is therefore critical to consider individual differences in sensitivity to normative egalitarian standards while examining the effects of public *vs* private response conditions on the regulation of race-biased behaviour. Taken together, the literature has demonstrated that the presence of social pressure enhances self-regulatory demands to respond without race bias, but only among individuals who are sensitive to such pressures.

Despite much evidence for complementary internal and external motivations to respond without prejudice, research has not addressed whether regulation according to external cues relies on a different underlying mechanism than regulation according to internal cues. The extant literature concerning internal *vs* external cues for regulating race-biased responses is suggestive of different underlying processes, whereby externally driven forms of race-bias regulation likely involve an additional set of mechanisms beyond that of internally driven forms of regulation. Next, we describe a theoretical framework that identifies specific neurocognitive processes associated with response regulation.

NEUROCOGNITIVE MECHANISMS OF RESPONSE CONTROL

Neurocognitive models of response regulation suggest that the anterior cingulate cortex (ACC) plays a central role in monitoring ongoing response tendencies for competition and in signalling the need for enhanced control when such conflict occurs (Botvinick *et al.*, 2001). Neuroimaging research has found that conflict between prepotent *vs* intentional response tendencies, elicited using cognitive control tasks such as the Stroop and Ericksen flankers tasks (Eriksen and Eriksen, 1974), activates dorsal regions of ACC (dACC) (Carter *et al.*, 1998; Botvinick *et al.*, 1999; Barch *et al.*, 2001). As ACC activity increases, it engages regulatory mechanisms by signalling prefrontal cortical (PFC) activity associated with executive functions, such as selection for action, working memory and more deliberative processing (Gehring and Fencsik, 2001; Kerns *et al.*, 2004).

Recent theoretical reviews suggest that dACC and the rostral subregions of the ACC (rACC) may support alternative aspects of conflict processing (Bush *et al.*, 2000; Eisenberger and Lieberman, 2004). Although both (dACC/rACC) have strong anatomical connections to regions associated with regulating complex behaviours (Masterman

and Cummings, 1997); the dACC has particularly strong connections with motor cortices (Bates and Goldman-Rakic, 1993; Luppino *et al.*, 1993), whereas rACC has strong connections with regions of the orbital frontal cortex associated with outcome monitoring and processing complex external contingencies for reward and punishment (Rolls, 1996). In line with these anatomical distinctions, the dACC has been shown to reflect cognitive conflict independent of conscious awareness (Berns *et al.*, 1997; Nieuwenhuis *et al.*, 2001) and has been implicated in action monitoring processes regardless of whether or not the behaviour is relevant to social cognition. In contrast, the rACC activation has been associated with the perception of response errors, feeling states and the ability to process more complex external goal contingencies (Bush *et al.*, 2000; Ullsperger and von Cramon, 2001; Garavan *et al.*, 2003; Bishop *et al.*, 2004). These findings are consistent with recent theorizing that more dorsal, posterior regions of the medial frontal cortex (MFC) are associated with the behavioural responses arising from internalized, self-monitoring processes, whereas more rostral, anterior regions are involved in the integration of action tendencies with expectancies of punishment or reward (Eisenberger and Lieberman, 2004; Ochsner *et al.*, 2005; Amodio and Frith, 2006). These theoretical distinctions support the idea that dACC activity is involved in internally driven regulation of racial responses, independent of the situational context, whereas rACC activity should become important when successful regulation requires the consideration of external cues, such as when responding in the presence of an observer who would disapprove of one's race-biased behaviour.

Measuring conflict-related dACC and rACC activity using event-related potentials

Rapid changes in ACC activity associated with self-regulatory conflict processing may be measured using event-related potentials (ERPs). ERPs reflect the firing of groups of neurons, measured using scalp electroencephalography (EEG), as an individual responds to a discrete event. By collecting EEG using a high sampling rate (e.g. 2500 Hz), ERPs can track real-time changes in brain activity as regulatory processes unfold. Two components of response-locked ERPs have been linked with conflict-related activity of the ACC: error-related negativity (ERN) and error-positivity (P_e); (Figure 1).

The ERN (also, N_e) has been shown to reflect activity of the caudal dACC (Dehaene *et al.*, 1994; van Veen and Carter, 2002; see Luu *et al.*, 2003 for additional potential sources). The ERN is a negative-polarity voltage deflection observed in scalp-recorded EEG at the frontocentral midline when participants make a response error on a cognitive conflict task (Falkenstein *et al.*, 1991; Gerhing *et al.*, 1993). The ERN typically peaks within 100 ms of an error response and is thought to reflect cognitive conflict between an intended
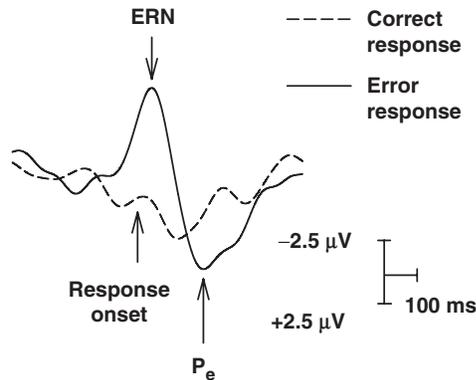
Fig. 1 Illustration of the ERN and P_e components elicited by errors on a behavioural task.

response and the actual (erroneous) response being executed (Yeung *et al.*, 2004). Several studies have demonstrated a relationship between ERN amplitude and behavioural regulation on conflict tasks, such that individuals with larger average ERN responses to errors exhibit patterns of greater response control across the task, as indicated by accuracy, post-error slowing and process-dissociation estimates of control (Gehring *et al.*, 1993; Pailing *et al.*, 2002; Amodio *et al.*, 2004). Given the pattern of these findings, the ERN has been interpreted as serving a self-monitoring function (Luu *et al.*, 2000).

The P_e component of the ERP has been shown to reflect the activity of the rACC (Keihl *et al.*, 2001; van Veen and Carter, 2002; Herrmann *et al.*, 2004). The P_e is a positive-polarity voltage deflection that peaks ∼100–200 ms following a response error, just after the ERN. Like the ERN, the P_e has been associated with behavioural control (Nieuwenhuis *et al.*, 2001). Research by Nieuwenhuis *et al.* (2001) suggests that whereas the ERN reflects pre-conscious conflict processing associated with an impending error, the P_e reflects conscious evaluation of one's response error, that is, the subjective awareness of conflict between one's intended and actual behaviour. In Neiuwenhuis *et al.*'s (2001) study, participants completed an anti-saccade task, in which their eye gaze was tracked while they attempted to inhibit saccades to stimuli presented in different locations on a computer monitor. After each trial, participants reported whether they had made an erroneous saccade. Because saccades may occur automatically when a stimulus appears in the visual field, responses were difficult to inhibit, and participants made more unperceived errors (11.2%) than perceived errors (7.4%) on the task. Importantly, both perceived and unperceived errors resulted in similar ERN responses, but only perceived errors produced a significant P_e response. This finding is consistent with theory and research concerning rACC activity reviewed above and corroborates other research indicating that the P_e wave is an ERP indicator of rACC error-perception processes.

The role of ACC in regulating responses to race

Amodio *et al.* (2004) examined the role of conflict monitoring in the context of prejudice and stereotyping. In this study, participants' EEG was recorded as they completed a sequential priming task designed to measure their ability to inhibit the influence of automatic racial stereotypes on their behaviour. In the task, called the weapons identification task (WIT), target pictures of guns and handtools were classified, via button-press, following brief presentations of black or white face primes on the computer monitor (Payne, 2001). Low-prejudice participants completed this task in private with no external cues to respond without bias. As in past work, black face primes facilitated correct responses to guns but interfered with responses to tools, as predicted given the strong cultural stereotype of African Americans as hostile and dangerous (Devine and Elliot, 1995; Payne, 2001). This pattern suggested that enhanced regulation was required to respond accurately on black–tool trials, whereby the pre-potent stereotype-consistent 'gun' response must be inhibited and replaced with the correct 'tool' response. Indeed, larger ERN amplitudes were observed for responses on black–tool trials, which required stereotype-inhibition, than on black–gun trials, which did not require inhibition. Furthermore, participants who had larger ERN responses on black–tool trials were more effective at inhibiting stereotypes from influencing their behaviour throughout the task, suggesting that people with more sensitive conflict-monitoring systems are generally more effective self-regulators.

Amodio *et al.*'s (2004) findings suggested that the conflict-related dACC activity was associated with internally driven forms of behavioural regulation. However, their study did not address externally driven forms of race-bias control, nor did it examine the extent to which error-perception and the rACC were involved in response control. The present research was designed to extend the theoretical contributions of Amodio *et al.* (2004) and the previous research on error-perception processes to test the hypothesis that racial responses regulated according to external cues involve the unique contribution of rACC activity, as assessed by the P_e.

STUDY OVERVIEW

We hypothesized that conflict monitoring processes are critical for internally motivated regulation, such that ERN amplitudes would be associated with stereotype inhibition in both the presence and absence of external social pressure. In contrast, we proposed that error-perception processes are particularly important for regulating responses according to external cues, such that P_e amplitudes would additionally be associated with stereotype inhibition in the presence of external pressure, specifically among participants reporting high sensitivity to social pressures to respond without prejudice. To test these hypotheses, we measured participants' neural activity while they completed the WIT in the

presence or absence of external social pressure (i.e. in public or private). Past findings that individuals differ in their sensitivity to normative egalitarian pressures suggest that only highly externally motivated participants should perceive the public response condition as an external cue for self-regulation. For this reason, we examined the effects of public *vs* private response condition as a function of participants' self-reported external motivation to respond without prejudice (Plant and Devine, 1998).

Following the past work (Payne, 2001; Amodio *et al.*, 2004), our primary dependant measure was response accuracy on trials requiring inhibition of automatic stereo-types (i.e. black–tool trials), as compared with accuracy on trials not requiring inhibition (i.e. black–gun trials). Whereas much of the previous research has documented enhanced amplitudes of the ERN, and to a lesser extent the P_e, in response to conflict, the present research focused on the association between conflict-related ERN and P_e amplitudes and behavioural regulation in response to internal *vs* external cues. Hence, we predicted that (i) ERN amplitude would predict stereotype inhibition across conditions and participant groups, whereas (ii) P_e amplitude would predict stereotype inhibition only in the public condition among the participants who reported being sensitive to egalitarian normative pressures.

METHOD

Participants

A total of 66 right-handed undergraduate students (32 female and 34 male) participated for extra course credit. The participants were selected from a sample that had completed the Internal and External Motivation to Respond Without Prejudice scales in an earlier mass-testing session (Plant and Devine, 1998). The validity of these scales has been established in several studies (e.g. Plant and Devine, 2001; Devine *et al.*, 2002; Amodio *et al.*, 2003; Plant *et al.*, 2003; see Plant and Devine, 1998, for a description of psychometric properties). The internal motivation scale ($\alpha = 0.81$) includes items such as 'I attempt to act in non-prejudiced ways toward Black people because it is personally important to me'. The external motivation scale ($\alpha = 0.80$), which provided an index of participants' sensitivity to external pressures, includes items such as 'I attempt to appear non-prejudiced toward Black people in order to avoid disapproval from others'. Agreement with each item was rated from 1 (strongly disagree) to 9 (strongly agree). We recruited participants with high internal motivation ($M = 7.15$, significantly above the scale midpoint, $t(65) = 11.26$, $P < 0.001$) who reported external motivations in the upper ($M = 6.54$) or lower ($M = 2.50$) thirds of the sample distribution. Internal motivation scores did not differ as a function of external motivation (high *vs* low) × response condition (private *vs* public), Fs < 1, and scores on the

internal and external motivation scales were uncorrelated, $r(64) = -0.02$, *ns*, consistent with previous findings (Plant and Devine, 1998, 2001; Amodio *et al.*, 2003; Plant *et al.*, 2003).

Procedure

After providing informed consent, participants were pre-pared for physiological recording and given instructions for the WIT. All participants were told that certain responses could reveal an influence of race bias on their responses (i.e. errors in black–tool trials) and that they should pay attention to the types of errors they made. In the private condition, participants were told that their responses would remain confidential such that they should not be concerned with external pressures to appear non-prejudiced. In the public condition, participants were told that the experimenter would be paying attention to their responses to determine whether they showed signs of racial prejudice.

After completing the WIT, participants rated the extent to which various trait attributes described African Americans as a group. Participants in the private condition made these ratings privately on a sheet of paper and then placed the sheet in a confidential envelope. Participants in the public condition reported their ratings aloud to the experimenter, who then wrote the responses on the rating form. This measure served as a check of the public *vs* private manipulation.

At the conclusion of the session, the experimenter probed participants for suspicion and then explained the hypotheses. No participant expressed suspicion about the response condition manipulation or guessed the experimental hypotheses. Each session took ∼2.5 h.

Materials

Weapons identification task. The stimuli and instructions used in the WIT were identical to those used by Amodio *et al.* (2004), originally adapted from Payne (2001). Each trial began with a pattern mask (1 s), followed by a black or white male face prime (200 ms), a gun or tool target (200 ms) and then a second pattern mask, which remained on the screen until a response was made (Figure 2). Stimuli included pictures of two white faces and two black faces, cropped to show only facial features, four handguns and four handtools. The participants were encouraged to classify targets as guns or tools via button-press within 500 ms of the target presentation. A 'Too Slow!' message appeared following responses that exceeded this deadline. Intertrial intervals ranged from 2.5 to 4 s. Prime-target pairs were equally probable and randomly ordered. Stimuli and physiological event markers were presented using DMDX software (Forster and Forster, 2003). The task included 26 practice trials and two blocks of 144 critical trials. Accuracy feedback was given during practice trials but not during
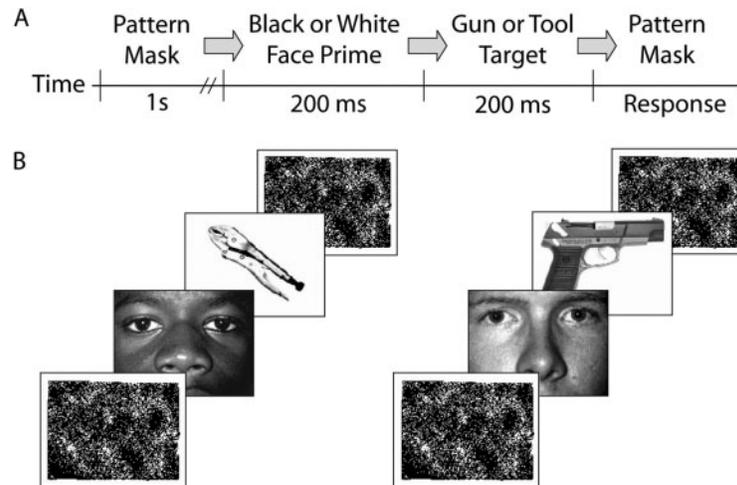
Fig. 2 Schematic of weapons identification task, adapted from Payne (2001), illustrating the timecourse of events (A) and example trial stimuli (B).

critical trials. However, as in other response inhibition tasks, participants could easily detect when they made an error.[1]

Correct response latencies occurring between 250 and 1500 ms were natural-log transformed and averaged within trial type for analysis (mean latencies are presented in raw millisecond). Error rates were computed by dividing total errors by total trials within each trial type.

EEG recording and processing

EEG was recorded from eight tin electrodes embedded in a stretch-lycra cap (ElectroCap, Eaton, OH, USA) corresponding to frontal (F3, F4), parietal (P3, P4) and midline (Fz, Fcz, Cz, Pz) scalp regions, based on the 10–20 international system (Jasper, 1958). EEG was referenced to the left earlobe (signal was also collected from the right earlobe for offline average-ears re-referencing), with a ground electrode placed on the forehead. All electrode impedances were below 5000 Ω. EEG signal was collected from a DC coupling, low-pass filtered at 100 Hz and digitized at 2500 Hz (Neuroscan Synamps, Sterling, VA), and stored to a computer hard drive.

ERN and P_e derivation.   Offline, EEG signal was visually scored for artifact, submitted to a regression-based blink correction procedure (Semlitsch *et al.*, 1986), and passed through a 1–15 Hz band-pass digital filter. An 800 ms epoch of EEG signal, centred on response, was selected for each artifact-free trial. Epochs associated with response latencies below 250 ms and above 1500 ms were excluded because they likely reflected impulsive errors or inattentiveness to the task

(Amodio *et al.*, 2004). Baseline correction procedures subtracted the average voltage occurring from 400 to 50 ms pre-response within each epoch from the entire epoch (because the average ERN began to rise at ∼50 ms prior to response). Waveforms derived from correct and incorrect trials were then averaged for each trial type. Preliminary analyses showed that, on average, the ERN wave peaked at 40 ms post-response, and the P_e peaked at 158 ms post-response. ERN amplitude was scored as the peak negative voltage obtained from the frontocentral (Fcz) electrode occurring between 50 ms pre- and 150 ms post-response (Amodio *et al.*, 2004). The P_e amplitude was scored as the peak positive voltage between 100 and 200 ms post-response at Fcz.[2] The average number of individual EEG epochs comprising each ERN/P_e score was as follows: 14.92 (black–tool), 11.59 (black–gun), 13.15 (white–tool) and 16.55 (white–gun), and the minimum number of epochs for any ERN or P_e score was 5.

Stereotype questionnaire.   Participants rated the extent to which each of 35 trait words described African Americans on a scale ranging from 1 (uncharacteristic) to 7 (characteristic). This list included a subset of words most strongly associated with the African American stereotype (Devine and Elliot, 1995): *lazy, poor, athletic, promiscuous, intelligent (reverse-scored)*, and ratings of these words were averaged to form a stereotype index ($\alpha = 0.60$). Ratings for a subset of words not typically associated with the African American stereotype (*kind, loyal, healthy, straightforward*) were averaged to form a filler index ($\alpha = 0.63$). A 2 (response condition: private *vs* public) × 2 (external motivation: high *vs* low) analysis of variance (ANOVA) produced a marginal

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[1]   As with most behavioural tasks used to elicit ERNs, participants are typically aware of their errors on the WIT despite the absence of feedback. However, the awareness of an error does not mean that the ERN is produced by error perception. Indeed, research designed to address this issue found no association between awareness of errors and ERN (Neiuwenhuis et al., 2001). Rather, conscious awareness of an error likely occurs after the ERN and during the time frame of the P_e wave. The present task was not designed to dissociate awareness from the ERN. Although we are not in a position to make strong claims regarding the role of awareness, it is unlikely that awareness of errors would drive ERN amplitudes.

[2]   The electrical dipoles produced by the rACC and dACC have different orientations (dependent on the orientation of their respective dendritic columns, which in turn varies as a function of cortical topography), and the negative poles of each have been shown to orient toward the same scalp region (e.g. van Veen and Carter, 2002). It is for this reason that the ERN and P_e are typically maximal at the same frontocentral scalp location.

interaction, $F(1, 61) = 3.12$, $P = 0.08$. Simple effects revealed that high external motivation participants reported less endorsement of stereotypes in public ($M = 3.18$, s.d. $= 0.66$) than in private ($M = 3.77$, s.d. $= 0.96$), $t(37) = 2.43$, $P = 0.03$. In contrast, low-external-motivation subjects' reported endorsement did not vary as a function of response condition, $t < 1$. No effects were obtained for filler ratings. These analyses suggested that the manipulation was successful.

RESULTS

Behavioural analyses

A 2 (prime: black *vs* white face) × 2 (target: gun *vs* tool) ANOVA of response latencies produced the expected interaction (Figure 3, panel A), $F(1, 65) = 28.70$, $P < 0.001$, such that black faces facilitated responses to guns and interfered with responses to tools, relative to white faces, ts > 3.47, Ps < 0.001. This effect was not moderated by response condition or level of external motivation. A 2 (prime: black *vs* white face) × 2 (target: gun *vs* tool) ANOVA of error rates produced a significant interaction, $F(1, 65) = 20.01$, $P < 0.001$ (Figure 3, panel B), indicating more erroneous classifications of tools than guns when they followed black face primes, $t(65) = 4.93$, $P < 0.001$. Conversely, participants misclassified guns more than tools when they followed white faces, $t(65) = 2.39$, $P = 0.02$. This interaction was not moderated by response condition or external motivation.[3]

This set of behavioural results demonstrated that (i) black face primes activated a pre-potent stereotype-consistent response tendency and (ii) correctly responding 'tool' following a black face presented a greater regulatory challenge than responding 'gun' following a black face, presumably due to the automatic stereotypic association between African Americans and weapons. This pattern replicated previous findings (e.g. Payne, 2001; Amodio *et al.*, 2004).

Task-related ERN and P_e effects

An initial analysis confirmed that ERN amplitudes on error trials were larger (more negative; $M = -9.07$, s.d. $= 3.88$) than amplitudes on correct trials ($M = -0.18$, s.d. $= 2.37$), $t(65) = 18.65$, $P < 0.001$. A 2 (prime: black *vs* white face) × 2 (target: gun *vs* tool) × 2 (response condition: public *vs* private) × 2 (external motivation: high *vs* low) ANOVA of ERN amplitudes on error trials produced significant main

Fig. 3 Reaction times for correct responses (A) and error rates (B) on the weapons identification task as a function of trial type.

effects for prime, $F(1, 62) = 7.46$, $P < 0.01$, and target $F(1, 62) = 8.36$, $P < 0.01$. These effects were qualified by a prime × target interaction, $F(1, 62) = 15.03$, $P < 0.001$, such that ERN amplitude for black–tool trials was larger than that of any other trial type, ts > 4.0, Ps $< .001$ (Figure 4). This pattern of ERN results replicated Amodio *et al.* (2004). Moreover, this pattern was not moderated by response condition, external motivation, or their interaction.

The average P_e amplitude on error trials ($M = 8.63$, s.d. $= 3.61$) was marginally larger than on correct trials ($M = 7.77$, s.d. $= 3.32$), $t(65) = 1.70$, $P = 0.09$. We did not expect the P_e amplitude to vary as a function of condition, however, because (i) our task was designed so that participants could be aware of their errors (as opposed to Neuiwenhuis *et al.*, 2001) and (ii) all participants were internally motivated to respond without prejudice and thus were expected to monitor their responses. Indeed, a 2 (prime: black *vs* white face) × 2 (target: gun *vs* tool) × 2 (response condition: public *vs* private) × 2 (external motivation: high *vs* low) ANOVA indicated that P_e amplitudes did not vary as a function of response condition, external motivation or their interaction.

Differential contributions of ERN and P_e to response regulation

Our primary theoretical question is concerned with the contributions of conflict-monitoring and error-perception processes to response regulation in private *vs* public

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[3] It is notable that the public *vs* private response manipulation affected participants' self-reported stereotype endorsement but not their accuracy on the weapons-identification task. On the surface, our results appear inconsistent with the findings of Lambert *et al.* (2003). However, the participants in the present study completed the task while being observed by a non-prejudiced experimenter, whereas participants in the Lambert *et al.* (2003) completed the task prior to an upcoming inter-racial interaction. The difference between an actual *vs* anticipated public response condition may be critical, as past research suggests that stress and anxiety associated with a particular task or event is more likely to impair behavioural regulation before or after an acute stressor rather than during its onset (Selye, 1956; McEwen and Seeman, 1999; Aston-Jones and Cohen, 2005). Thus, it is unclear whether our results directly contradict the findings of Lambert *et al.* (2003).
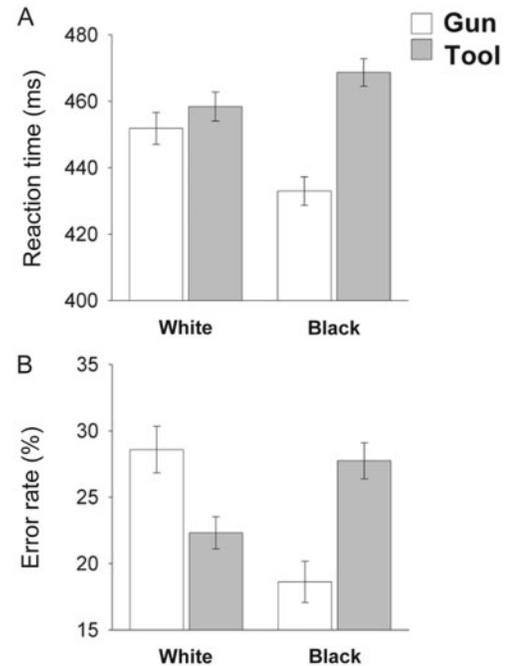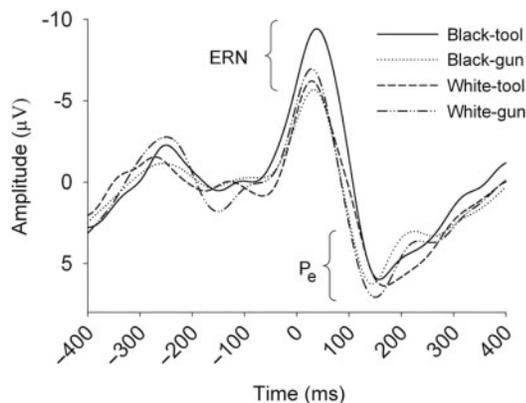
Fig. 4 Error-related negativity (ERN) and error-positivity (P$_e$) waveforms associated with each trial type of the weapons identification task. Zero represents the time of response.

conditions, as a function of participants' degree of external motivation. ERN and P$_e$ amplitudes associated with black–tool trials represented our indices of conflict-monitoring and error-perception, respectively. The primary outcome variable was response accuracy on black–tool trials, which required the inhibition of automatic stereotypes and thus constituted high-conflict trials. Additional analyses examined effects on response accuracy for black–gun responses, which did not require the inhibition of stereotypes and thus constituted low-conflict trials.[4]

ERN effects. We predicted that the ERN amplitude would predict response accuracy on black–tool trials, regardless of response condition or external motivation. In line with this prediction, the correlation between the ERN amplitude and accuracy for black–tool trials was significant, $r(64) = -0.35$, $P < 0.005$. ERN amplitude was not associated with accuracy on black–gun trials, $r(64) = 0.01$, $P = 0.91$. When black–gun accuracy was covaried in a partial correlation analysis, ERN continued to predict black–tool errors, $r(63) = -0.35$, $P < 0.005$. Finally, an exploratory ERN × response condition × external motivation regression

analysis produced only the ERN main effect. This pattern of results is consistent with our hypothesis that the conflict-monitoring process is associated with regulation according to internal cues and should be evident across conditions and participants.

P$_e$ effects. We predicted that the P$_e$ amplitude would predict response accuracy on black–tool trials only among high-external-motivation participants who responded in public. We tested this specific prediction in a set of regression analyses in which P$_e$ amplitude was the primary predictor and the interactions of response condition and external motivation were examined using dummy codes. The first regression tested whether (i) the P$_e$ amplitude predicted black–tool accuracy for the public response/high-external-motivation group and (ii) this effect was different from the effect of P$_e$ on accuracy for the combination of remaining groups (e.g. a 1 *vs* 3 comparison). This analysis revealed a strong effect for P$_e$ amplitude among the public response/high-external-motivation group, $\beta = 0.70$, $t(62) = 3.09$, $P < 0.005$, whereas this effect was not significant for the combined group, $\beta = 0.09$, $t(62) = 0.65$, $P = 0.52$ (Figure 5). Moreover, the effect of P$_e$ on accuracy was significantly larger for the public response/high-external motivation group than for the combination of remaining groups, $\beta = -0.52$, $t(62) = -2.29$, $P < 0.03$ and larger than each of the groups individually, Ps < 0.07. The P$_e$ amplitude continued to predict accuracy on black–tool trials among the high-external-motivation or public response group when the ERN amplitude was covaried, $\beta = 0.61$, $t(61) = 3.07$, $P = 0.007$.

Additional analyses showed that P$_e$ amplitude did not predict accuracy on black–gun trials for any of the four groups, Ps > 0.30, and the effect of the P$_e$ amplitude on black–tool trial accuracy in the public response/high-external-motivation condition remained unchanged when accuracy on black–gun trials was covaried, $\beta = 0.69$, $t(61) = 3.06$, $P < 0.005$. Finally, an exploratory P$_e$ × response condition × external motivation regression analysis predicting accuracy on black–tool trials produced only a significant main effect for P$_e$, $\beta = 0.26$, $t(62) = -2.14$, $P < 0.04$, which was qualified by the planned comparisons reported earlier. This pattern of results was consistent with our hypothesis that the error-perception process is associated with regulation according to external cues and should predict behaviour only in public among individuals sensitive to normative pressures.

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[4] We were careful in this research to focus our analyses on theoretically relevant waveforms that were interpretable in the context of the behavioural task. Our hypotheses and analyses pertained to responses to black–gun *vs* black–tool trials because these trials provided theoretically clear manipulations of high *vs* low conflict. White faces are included in the task to provide a response alternative, and because white faces are not known to be associated with either tools or guns, they provide an important 'filler' condition. As in the past research (Amodio *et al.*, 2004), successful stereotype inhibition behaviour (i.e. accuracy on black–tool trials) was not predicted by ERNs from white–gun trials, but was associated with ERN amplitudes from white–tool trials ($\beta = 0.30$, $t = 2.49$, $P = 0.02$). This effect is believed to be driven by participants' vigilance for tool targets, because an error in tool trials could indicate race bias (if preceded by a black face). Because faces were presented very quickly (200 ms), a heightened vigilance to tools is an advantageous strategy. In support of this interpretation, black–tool ERNs continued to predict stereotype inhibition accuracy when the effect of white–tool ERNs was covaried in a partial correlation, $r(63) = -0.23$, $P = 0.06$, whereas the effect of white–tool ERNs on accuracy was not significant when black–tool ERNs were covaried, $r(63) = -0.18$, $P = 0.14$. Similarly, the P$_e$ associated with the white–tool trials predicted accuracy among high external motivation participants responding in public, $r(18) = 0.48$, $P = 0.03$, yet black–tool P$_e$ amplitudes continued to predict accuracy when white–tool P$_e$ scores were covaried in a partial correlation, $r(17) = 0.58$, $P < 0.01$. It is likely that the ERN and P$_e$ waves from black–tool and white–tool trials both reflect a degree of vigilance for tool targets, but that the black–tool ERPs represent additional processing of the conflict between a stereotyping tendency and the desire to respond without bias.

DISCUSSION

The complementary roles of internal and external impetuses for self-regulation have been well-documented in the literature on intergroup behaviour (Crosby *et al.*, 1980; Plant and Devine, 1998). Yet previous work has not addressed whether they reflect a single mechanism or
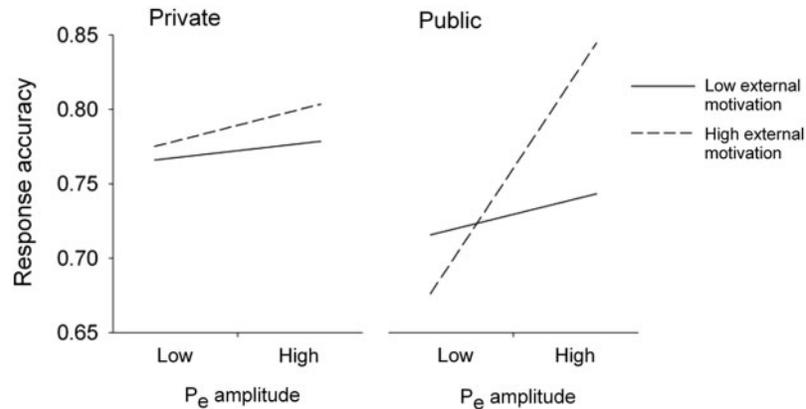
Fig. 5 Predicted values for response accuracy on trials requiring stereotype inhibition (black-tool trials), illustrating the interaction of error-positivity (P$_e$) amplitude and sensitivity to normative pressure in Private *vs.* Public response conditions, computed at one standard deviation below and above each mean.

alternative underlying mechanisms. On the basis of social psychological and neuroscientific theorizing, we proposed that externally driven regulation of race-biased behaviour should involve a distinct mechanism for processing external cues, beyond a mechanism for monitoring response conflicts associated with internalized cues. In support of this proposal, response regulation according to internal cues was associated with the ERN index of dACC activity, representing conflict monitoring, regardless of situational cues. In contrast, response regulation according to external cues was associated with the P$_e$, an ERP component previously associated with an rACC generator, and believed to represent error perception only among participants who were worried about social disapproval and whose responses were observed by an ostensibly non-prejudiced experimenter. Although our conclusions regarding the cortical sources of our ERP findings must be tempered by the fact that we did not collect EEG from a dense array and were therefore unable to conduct source localization analyses, these conclusions are consistent with previous research localizing the ERN and P$_e$ waves to the dACC and rACC, respectively (e.g. Dehaene *et al.*, 1994; van Veen and Carter, 2002), and with theories regarding the functions of dACC and rACC activations (e.g. Bush *et al.*, 2000; Botvinick *et al.*, 2001).

By examining the interaction of social situations and individual differences, we were able to isolate the effect of error perception on behaviour in order to obtain support for our hypothesis. This research is significant because it demonstrates that the function of the P$_e$, and its likely source in the rACC may be clarified by considering its role in social situations in which attitudes and goals are relevant. The present study is one of the few to examine neural activity associated with social pressures (see also, Berns *et al.*, 2005) and is the first to examine explicit social pressure on neural responses in the context of race bias.

Role of rACC in self-regulation in social situations

Currently, the function of rACC activity is of much interest and some debate. One view of rACC activity (and, more broadly, medial frontal cortical activity) is that it reflects a unique neural module for the self and/or social cognition. An alternative view is that regions in frontal cortex provide a general function for integrating endogenous and exogenous information for orchestrating human behaviour. This generalist view argues that the extremely high associational connections within this region make it uniquely suited for computations of complex human social cognition and social behaviour (e.g. Amodio and Frith, 2006). Although our data are suggestive of an important role of rACC when regulating behaviour on the basis of social cues, they do not indicate that the rACC performs a uniquely social function or that other neural regions are not also involved. Hence, our findings are consistent with theorizing that the rACC is part of a general mechanism for complex forms of behavioural regulation. We speculate that this process is especially relevant to social interactions, owing to their complexity and the eminent significance of social relationships for human survival.

In speculating on the function of the rACC in social behaviour, it may be useful to consider its location relative to other regions of the MFC associated with self-processing and social processing. Extant source localization studies have identified P$_e$ generators in somewhat different regions of the rACC. For example, van Veen and Carter (2002) localized P$_e$ to an area just superior to the genu of the corpus collosum, whereas Hermann *et al.* (2004) localized P$_e$ to a more posterior area of the rACC (but still anterior to the dACC source for the ERN). In both studies, localization was performed for error-related responses on the Eriksen flankers task (Eriksen and Eriksen, 1974). Discrepancies in localization may be due to several factors, such as variation between tasks, variation in electrode arrays, the use of

different localization techniques and patterns of error variance in the data. Nevertheless, a consideration of the P_e source's proximity to areas implicated in mentalizing and theory of mind (e.g. para-ACC region bordering dorsal area of BA 32 and BA 9; see, for example, Frith and Frith, 1999) and self-knowledge and self-focused attention (most anterior para-ACC area bordering on BAs 32 and 10; see, for example, Gusnard *et al.*, 2001) may inform our understanding of its function. For example, does the P_e wave reflect a form of conflict processing that elicits greater self-focused attention, mentalizing or other forms of social cognition? Further research is needed to address these questions.

Dissociable functions of dACC and rACC

Our analyses suggest that the functions of dACC and rACC may be conceptually dissociable, in that they perform different but complementary functions. In practice, however, the functions of the dACC and rACC may be thought of as hierarchically related. That is, theory and research indicate that the dACC is virtually always involved in the regulation of behavioural responses, particularly when the desired response competes with a pre-potent response. Indeed, dACC activity is commonly observed in tasks involving either an actual or implied response. On the other hand, rACC activity appears to be important for further guiding controlled response in accordance with more complex response contingencies, whereas it is not typically activated during simple behavioural responses that depend only on internalized task goals. Therefore, we speculate that the dACC may be required for the regulation of any type of behavioural response, and the rACC may be recruited to the extent that one's behaviour must be guided by more complex response contingencies (such as external social cues or task complexities). It is also possible that the rACC is important for stimulus processing in the absence of behaviour. However, it is difficult to design psychological tasks that are devoid of an implied behaviour, as much of the previous research has shown that simple exposure to a stimulus without a response requirement nevertheless activates a behavioural tendency (e.g. automotives; James, 1890; Bargh *et al.*, 2001). Broadly speaking, our findings and interpretations are consistent with the view that the primary function of the frontal cortex is to orchestrate behaviour, and inferences regarding the function of observed neural activity may be best understood in this context.

It is notable that our use of individual differences in the present study was not designed to dissociate dACC and rACC functions. That is, we included participants who were, on average, internally motivated to respond without prejudice. We expected that the dACC would be activated across conditions, given that all participants had the goal of responding accurately (i.e. in an unbiased manner) on the task. Our hypothesis pertained to the emergence of the rACC

as a predictor of behavioural control in the condition in which responses were regulated according to external social cues. Thus, we did not attempt to examine individuals for whom only the rACC would predict response regulation because, as outlined above, it is unlikely that the rACC would be involved in the absence of dACC activation during behaviours involving response conflict.

Theoretical implications for models of self-regulation

Although extant theorizing has emphasized the significance of both internal and external factors in self-regulation (see, for example, Baumeister and Vohs, 2004), few theories have examined their interplay (cf. Deci and Ryan, 2000). A limitation in this line of inquiry is the lack of a theoretical model outlining the mechanisms underlying internal *vs* external forms of self-regulation. Having associated internally and externally motivated regulation with previously identified ERP indices of dACC and rACC activity, respectively, we can bring findings from the cognitive neuroscience literature to bear on the interplay between internal and external impetuses for self-regulation. On the one hand, our theoretical analysis suggests a mechanistic explanation for some previous findings. For example, the findings that individual differences in internal and external motivations to respond without prejudice are generally uncorrelated (Plant and Devine, 1998; Amodio *et al.*, 2003), and that externally motivated regulation tends to be less stable and less consistent than internally motivated regulation (e.g. Ryan and Connell, 1989), can be explained by our evidence for alternative neurocognitive substrates associated with conflict monitoring and error perception.

On the other hand, our findings suggest new hypotheses regarding self-regulation and intergroup behaviour. For example, given the stronger anatomical connections of the dACC to motor areas in the brain, one might expect that internally driven regulation would be more evident in behavioural responses than would externally driven regulation. In contrast, externally driven regulation may have more significant effects in responses involving more cognitively complex forms of judgement and decision-making. As another example, previous evidence that conflict monitoring operates independently of conscious awareness, whereas error-perception processes are associated with conscious awareness, suggests that attentional load would be more detrimental to regulation according to external cues than to internal cues. By the same token, individuals may be more attentive to regulatory failures when responding on the basis of external compared with internal cues, and failures to regulate according to external cues may lead to more elaborate and potentially more substantial reparatory processing in service of future prejudice reduction.

Finally, it is notable that the social neuroscience approach was critical to the present research. Our conclusion that error perception predicts self-regulatory processes

specifically in response to external cues required the integration of social psychology and neuroscience at all levels of research (theory, method, measurement, analysis and interpretation). This research, and other work evidencing neural processes especially relevant to social behaviour (e.g. Eisenberger *et al.*, 2003; Richeson *et al.*, 2003), suggests that a consideration of social psychological factors will enhance the design of neuroscientific research and the interpretation of neural activation patterns.

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