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<https://doi.org/10.1093/scan/nsv107>

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Neuromodulation of Group Prejudice and Religious Belief

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WORD COUNT: 5,048

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## Abstract

People cleave to ideological convictions with greater intensity in the aftermath of threat. The posterior medial frontal cortex (pmMFC) plays a key role in both detecting discrepancies between desired and current conditions and adjusting subsequent behavior to resolve such conflicts. Building on prior literature examining the role of the pmMFC in shifts in relatively low-level decision processes, we demonstrate that the pmMFC mediates adjustments in adherence to political and religious ideologies. We presented participants with a reminder of death and a critique of their in-group ostensibly written by a member of an out-group, then experimentally decreased both avowed belief in God and out-group derogation by down-regulating pmMFC activity via transcranial magnetic stimulation. The results provide the first evidence that group prejudice and religious belief are susceptible to targeted neuromodulation, and point to a shared cognitive mechanism underlying concrete and abstract decision processes. We discuss the implications of these findings for further research characterizing the cognitive and affective mechanisms at play.

*Keywords:* ethnocentrism, religiosity, transcranial magnetic stimulation, posterior medial frontal cortex.

### Neuromodulation of Group Prejudice and Religious Belief

Parochial ideologies motivate numerous aspects of human social life, from art movements to wars. Moralistic ideologies involving group chauvinism and religion are arguably the most socially impactful—and, at times, the most perniciously divisive. The extent of commitment to political and religious ideologies shifts across contexts, with cues of threat eliciting particularly sharp increases in adherence (Jonas et al., 2014; McGregor et al., 2013). Although social scientists have attended for some time to the manner in which threats moderate commitment to political and religious values, only recently have psychologists turned their attention to the neurobiological mechanisms at play (e.g., Inzlicht et al., 2009; Klackl et al., 2014; Luo et al., 2014; Proulx et al., 2012; Tritt et al., 2012). Here, we experimentally demonstrate that a region of the brain previously shown to enable problem-solving with respect to low-level conflicts, such as switching motor behavior to achieve a reward, plays a central role in investment in ideological beliefs.

The posterior medial frontal cortex (pmMFC) is a plausible mediator of shifts in ideological commitment. The pmMFC complex includes the dorsal anterior cingulate cortex (dACC) and the dorsomedial prefrontal area anterior to the supplementary motor cortex (dmPFC), and has been linked to a wide variety of reactions to negative emotional stimuli (Etkin et al., 2011; Maier et al., 2012; Rushworth et al., 2007). The pmMFC plays a key role in detecting discrepancies between desired and current conditions, and adjusting subsequent behavior during decision-making tasks (Bush et al., 2002; Ridderinkhof et al., 2004; Shima and Tanji, 1998). In humans, the dACC component of the pmMFC has been proposed to induce a compensatory increase in moral or cultural values following exposure to threats (e.g., reminders of death, uncertainty, or meaninglessness) (Proulx et al., 2012; Tritt et al., 2012). Reminders of death

trigger activity in the dmPFC (Han, Qin, and Ma, 2010; Shi and Han, 2013), and have been shown to increase ideological investment in a range of topics, including national identification and punishment of norm-violators (see Jonas et al., 2014). Likewise, cues of social isolation both activate the dACC (Eisenberger, 2012) and elicit heightened ethnocentrism (Navarrete et al., 2004). Interestingly, ACC activation elicited by low-level Stroop-like conflicts can be attenuated by priming religious participants with reminders of their religious beliefs (Inzlicht and Tullett, 2010). Conversely, just as reactivity to low-level (e.g., Stroop) conflicts appears susceptible to moderation by high-level (e.g., religious) beliefs, relatively high-level conflicts, such as asking participants to contemplate their future non-existence, can polarize evaluations of low-level target stimuli (e.g., aversive noise blasts; Holbrook et al., 2011). These findings suggest that, because different conflict-response systems efficiently share certain components, activation of one system (e.g., for managing physical pain) can influence the operation of other systems (e.g., for managing social isolation).

Noting the evident degree of shared structure uniting diverse sorts of reactions to diverse sorts of threats, proponents of the Reactive Approach Motivation (RAM) model argue that threatening goal-conflicts (of any kind) are detected within the anterior cingulate cortex, triggering feelings of anxiety which are subsequently palliated by activating approach-motivated states (McGregor et al., 2013; Nash et al., 2011). Consonant with the RAM model, activity in the anterior cingulate region is associated with anxiety, and the act of imagining cherished ideological convictions has been found to activate brain states associated with approach motivation and subsequent reductions in anxiety (Harmon-Jones, 2004; Urry et al., 2004). Importantly, these reactive approach-motivated responses are theorized to include ideological reactions such as out-group derogation and religious extremism. Thus, the RAM theory (and

similar accounts such as “the Meaning Maintenance Model”; Heine et al., 2006) predicts that the dACC is involved in exaggerating ideological responses in the aftermath of any poignant threat. Importantly, according to the RAM and related perspectives, the function of ideological reactions to threat is to reduce intrapsychic threat-anxiety—not to address the eliciting threat itself in any strategic, domain-specific way (Holbrook and Fessler, 2015).

In contrast to the RAM model’s emphasis on the interchangeability of threats and the heightened ideological reactions that they elicit, convergent lines of evidence generated independently of the RAM literature indicate that the dmPFC / dACC complex functions as an interface relating threat-detection with the coordination of targeted solutions relevant to resolving particular threats. The pmPFC has been observed to consistently react to various sorts of discrepancies within the social domain, and pmPFC activity correlates positively with social behavioral shifts that reduce the given discrepancy (Izuma, 2013). For example, pmPFC activity is associated with preference changes to reduce cognitive dissonance (Izuma et al., 2010, 2015; van Veen et al., 2009) and with increases in social conformity upon detecting divergences between one’s stated opinions and group consensus (Izuma and Adolphs, 2013; Klucharev et al., 2009). Klucharev and colleagues (2011) further demonstrated that experimental down-regulation of activity in the pmPFC using transcranial magnetic stimulation (TMS) decreases social conformity. Thus, upon detection of concrete physical problems such as receiving a negative outcome in a motor task (Shima and Tanji, 1998), or relatively abstract problems such as realizing that one is out of step with social consensus, processes associated with pmPFC activity appear to coordinate relevant responses (Izuma and Adolphs, 2013; Rushworth et al., 2004; Ullsperger et al., 2004), such as switching motor behavior to achieve a reward (Shima and Tanji, 1998) or changing one’s opinion to conform with others (Klucharev et al., 2009; 2011).<sup>1</sup> These results indicate that the

pMFC is part of a neurocognitive architecture that is co-opted into distinct, domain-specific networks that manage both concrete and abstract challenges of various types. Note that this problem-solving account of the role of pMFC structures focuses on the production of responses that are relevant to the eliciting problem, whereas approaches such as the RAM model emphasize the reduction of anxiety as a functional benefit which may stem from problem-irrelevant responses (Holbrook, in press).

Building upon these findings, we hypothesize that when problems involve conflicting ideological values, or insoluble dilemmas such as the inevitability of death, pMFC mechanisms may invoke relevant belief systems. Specifically, we predict that participants confronted with their own mortality will “solve the problem” via pMFC mechanisms that facilitate amplifying their belief in God; likewise, participants confronted by an out-group member’s critique of their group’s values will more intensely derogate out-group critics. Participants whose pMFC has been experimentally down-regulated via TMS should therefore display less religiosity following a reminder of their own mortality and less derogation of critical out-group members. Ours is an admittedly ambitious hypothesis, as both the problems and the solutions at issue are more abstract than those previously shown to be addressed by the pMFC. In addition, it is important to note that the RAM model, which highlights the production of *any* anxiolytic approach-motivated response to threat rather than the problem-focused interpretation that we have emphasized, produces the same predictions. Accordingly, the present study should be regarded as an initial investigation of whether ethnocentrism or religiosity can be experimentally neuromodulated by targeting the pMFC—a hypothesis that accords with multiple theoretical perspectives—and not as a test of the problem-specific versus generically palliative nature of the process.

### **Overview of the Study**

To test the causal role of the pMFC in adherence to group and religious ideologies, we applied TMS or sham stimulation followed by a 10-minute filler task to ensure that down-regulation of the pMFC took effect. We then primed all participants with thoughts of death using a brief writing task, followed by a self-report affect schedule to assess potential effects of TMS on conscious emotion. Next, participants were asked to read essays (one critical of the United States, one complimentary) ostensibly written by immigrants to the U.S., then evaluate the authors' personalities and attitudes, a dependent measure frequently used to assess ethnocentrism. Given that the pMFC reacts to aversive cues, including social disagreement (Klucharev et al., 2009) and rejection (Eisenberger, 2012), sharp criticism of participants' national in-group appears likely to elicit a pMFC conflict-response reaction, in addition to that elicited by the prior reminder of death. We therefore predicted that TMS of the pMFC would particularly increase the favorability of ratings of the critical immigrant (as the complimentary immigrant poses no evident challenge aside from outgroup status). Religious belief was then measured using two self-report scales targeting parallel "negative" beliefs in the Devil, demons, and Hell, and "positive" beliefs in God, angels, and Heaven, respectively. We predicted that the TMS manipulation would particularly decrease the endorsement of positive religious beliefs (as the negative beliefs do not offer as appealing an alternative to non-existence following death). Thus, both ethnocentrism and religiosity were assessed using matched positive and negative affective targets, enabling an assessment of whether effects of TMS might be explained by a simple positivity or negativity bias.

## **Methods**

### **Participants**

Undergraduates were recruited for a study, ostensibly consisting of a series of unrelated



measures, in exchange for \$25. Participants were pre-screened by telephone for history of neurological disorders and other contraindications to TMS, as well as for political orientation, ethnicity, and U.S. citizenship. As has been done in similar ways in prior studies employing this measure of intergroup bias (Greenberg et al., 2001; Holbrook et al., 2011; McGregor et al., 1998; Navarrete et al., 2004), to ensure that participants would respond aversively to a Latino immigrant's criticisms of the U.S., those who identified as "extremely liberal" or as non-U.S. citizens were excluded from participating, and four individuals who self-identified as "Hispanic/Latino" after participating were dropped prior to analysis.<sup>2</sup> The final sample consisted of 38 participants (58% female,  $M_{\text{age}} = 20.9$  years,  $SD = 2.67$ ). 36.8% of the participants identified as White, 36.8% as East Asian, 13.2% as South Asian, 7.9% as Middle Eastern, and 5.3% as Other. As intended, the sample was politically moderate ( $M = 4.68$ ,  $SD = 1.51$ ; 1 = *Extremely Liberal*; 5 = *Moderate*; 9 = *Extremely Conservative*).

The Magstim Rapid 2 device used for this experiment can only perform the TMS protocol adopted here at up to 44% of the equipment's maximum stimulator output. Four participants, however, had high active motor thresholds that would have exceeded this limit, and hence these four participants were assigned to the sham group. All other participants were randomly assigned to the TMS condition (19 participants) or the sham control condition (19 participants). The sample size was based on Klucharev et al.'s (2011) demonstration of the effects of TMS of the pmFC on a social judgment. The study was approved by the University of California, Los Angeles, Institutional Review Board, and written informed consent was obtained from all participants.

### **TMS Manipulation**

We stimulated the right pMFC: rostral cingulate zone, Brodmann areas 24, 32, 6, and 9; center of mass at MNI coordinates ( $x, y, z$ ) [8, 16, 52] mm (Klucharev et al., 2011). At the beginning of the experiment, we localized the motor cortex using single pulse TMS. As the tibia representation and the pMFC are located at the same depth within the medial cortex, the pMFC location was ascertained by moving the coil anteriorly to the motor cortex. The distance of the pMFC from the motor cortex was calculated for each participant according to the size of their head, using the international 10-20 system (Klem et al., 1999), as has been done in prior TMS studies (Klucharev et al., 2011; Knoch et al., 2009). During stimulation, the TMS coil was placed at an average distance of 3.75 cm to the motor cortex. We used continuous theta-burst stimulation, in which 600 pulses were applied in bursts of three pulses at 50 Hz, repeated at 5 Hz for a total of 40 seconds (see the Supplementary Online Materials [SOM] for details). This technique has been demonstrated to reduce neural activity for at least one hour (Huang et al., 2005). Participants in the TMS condition were stimulated at 80% of their active motor thresholds; those in the sham condition were stimulated at 10% of their active motor thresholds. Following actual or sham stimulation, participants performed the experimental tasks at a computer station in the same room. The entire protocol, following TMS or sham stimulation, required approximately 40 minutes.

## Measures

**Motor and visual distracter tasks.** Immediately following stimulation, participants completed filler motor and visual estimation tasks to ensure that down-regulation of the pMFC took effect (Huang et al., 2005) and to defray suspicion about the target hypothesis regarding ideological affirmation (see the SOM for details).

**Reminder of death.** Next, participants were asked to write brief responses on the subject of their own death, a threat-induction that was selected because of the evident link between the prospect of death and palliative thoughts of God and the afterlife (Rosenblatt et al., 1989; see the SOM).

**Self-reported affect.** Following the death writing task, participants completed the Positive and Negative Affect Schedule—Expanded Form (PANAS-X; Watson and Clark, 1991; see the SOM).

**Group prejudice.** Participants were next asked to read two essays (presented in counterbalanced order) that were ostensibly written by immigrants to the United States from Latin America (see the SOM). The text for these essays was taken directly from previous research in which being reminded of death intensified ethnocentric bias as measured by evaluations of the immigrant authors (Greenberg et al., 1994). After reading each essay, participants rated their agreement with six statements using an 8-point Likert scale (1 = *Strongly Disagree*; 8 = *Strongly Agree*): (a) “I like the person who wrote this,” (b) “I think this person is intelligent,” (c) “This is the kind of person I would like to work with,” (d) “I think this person is honest,” (e) “I agree with this person’s views,” and (f) “I think this person’s opinions of America are true”; (complimentary essay:  $\alpha = .79$ ; critical essay:  $\alpha = .92$ ).

**Religious belief.** Next, religious belief was measured using a version of the Supernatural Belief Scale (Jong et al., 2013) modified to create two scales which mirror “positive” and “negative” aspects of Western religious belief, comparable to the “positive” and “negative” immigrant authors in the ethnocentrism measure. The items were presented in random order and rated according to the same scale employed in the immigrant ratings. The positive scale consisted of: (a) “There exists an all-powerful, all-knowing, loving God”; (b) “There exist good

personal spiritual beings, whom we might call angels”; (c) “Some people will go to Heaven when they die”; ( $\alpha = .90$ ). The negative scale consisted of: (a) “There exists an evil personal spiritual being, whom we might call the Devil”; (b) “There exist evil, personal spiritual beings, whom we might call demons”; (c) “Some people will go to Hell when they die” ( $\alpha = .93$ ). An overall religiosity variable combining both scales was calculated by averaging all six items ( $\alpha = .95$ ).

## Results

**Self-reported affect.** A MANOVA revealed no significant effects of condition on any of the subscales comprising the PANAS-X,  $ps .09 - .92$  (see SOM Table 1 for detailed results).

Participants in both conditions reported feeling relatively low levels of negative affect (TMS:  $M = 1.22$ ,  $SD = .27$ ; Sham:  $M = 1.43$ ;  $SD = .51$ ) or fear (TMS:  $M = 1.32$ ,  $SD = .38$ ; Sham:  $M = 1.52$ ;  $SD = .57$ ). Likewise, the participants reported feelings of moderately positive affect (TMS:  $M = 2.44$ ,  $SD = .61$ ; Sham:  $M = 2.37$ ;  $SD = .75$ ). This pattern indicates that participants experienced low levels of conscious anxiety despite having been recently reminded of death.

**Group prejudice.** Preliminary tests detected a significant effect of the order of essay presentation on ratings of the “anti-U.S.” immigrant (presented first:  $M = 2.94$ ,  $SD = 1.46$ ; presented second:  $M = 4.03$ ,  $SD = 1.47$ ),  $F(1, 36) = 5.30$ ,  $p = .027$ ,  $\eta^2_p = .13$ , 95% CI [-2.07, -.13], with no order effect observed for ratings of the “pro-U.S.” immigrant,  $p = .74$ . Essay order was therefore controlled for in subsequent analyses of the effects of condition on ratings of the immigrant who was critical of the United States. As predicted, participants in the TMS condition rated the critical immigrant 28.5% more positively ( $M = 4.10$ ,  $SD = 1.66$ ) than did participants in the sham condition ( $M = 2.93$ ,  $SD = 1.22$ ),  $F(1, 35) = 7.01$ ,  $p = .012$ ,  $\eta^2_p = .17$ , 95% CI [-2.06, -.27]. In contrast, overall ratings of the laudatory, “pro-U.S.” immigrant were an average of 8.2%

higher ( $M = 5.90$ ,  $SD = .87$ ) in the TMS condition than in the sham condition ( $M = 5.42$ ,  $SD = 1.17$ ), and this difference did not attain statistical significance,  $F(1, 36) = 2.09$ ,  $p = .157$ ,  $\eta^2_p = .06$ , 95% CI [-1.16, .20] (see Figure 1). Follow-up tests confirmed that there was no interaction between condition and order of presentation on the ratings of either essay,  $ps > .17$ , and that controlling for essay order does not alter the significance or approximate magnitude of the effects of condition.

**Religious belief.** We next tested the effects of TMS on endorsement of religious beliefs following a reminder of death. In a marginal trend, overall avowed religious belief (including both positive and negative beliefs) was reduced in the TMS condition ( $M = 2.95$ ,  $SD = 1.85$ ) relative to the sham condition ( $M = 4.26$ ,  $SD = 2.32$ ),  $F(1, 36) = 3.74$ ,  $p = .061$ ,  $\eta^2_p = .09$ , 95% CI [-0.06, 2.70]. As predicted, this shift was driven by a significant reduction in expressed belief in “positive” religious ideas. Participants in the TMS condition reported an average of 32.8% less conviction in “positive” religious beliefs ( $M = 3.05$ ,  $SD = 1.92$ ) than did sham participants ( $M = 4.54$ ,  $SD = 2.26$ ),  $F(1, 36) = 4.80$ ,  $p = .035$ ,  $\eta^2_p = .12$ , 95% CI [.11, 2.87]. Participants in the TMS condition also reported less conviction in negative religious beliefs ( $M = 2.84$ ,  $SD = 1.89$ ) relative to sham participants ( $M = 3.98$ ,  $SD = 2.50$ ), but this difference was not statistically significant,  $F(1, 36) = 2.52$ ,  $p = .122$ ,  $\eta^2_p = .07$ , 95% CI [-0.32, 2.60] (see Figure 2).

### Discussion

Down-regulating the pMFC via TMS significantly decreased both derogation of an “anti-U.S.” out-group member and avowed belief in God, angels, and Heaven following a reminder of death, supporting the hypothesis that the pMFC plays an important role in ideological responses to threat. These neuromodulated shifts in expressions of group bias and religious belief cannot be taken as indiscriminate positive or negative bias, as ratings of an outgroup member expressing strikingly negative views increased, yet ratings of traditionally positive religious beliefs (e.g., belief in a benevolent God) decreased. Rather, the pMFC seems to mediate changes in abstract

beliefs to address contextually shifting problems, such that, for example, reminders of the inevitability of death bolster beliefs in God and Heaven. However, the present study did not include problem-irrelevant modes of ideological endorsement, leaving open the possibility that, consistent with the RAM model, participants in the sham condition would have expressed more exaggerated ideological responses that were incidental to the problems of death or scathing criticism of one's group values.

Given the prior evidence that down-regulation of the pMFC decreases social conformity (Klucharev et al., 2011), the diminished expressions of group prejudice and religious belief observed here may stem from a mechanism sensitive to affirming consensus attitudes, insofar as outgroup derogation and belief in God are considered normative (Navarrete et al., 2004). However, although some of our results are consistent with this interpretation, a narrow social conformity account would not clearly explain the lack of significant shifts in ratings of the "pro-U.S." immigrant or of negative religious beliefs. Instead, the results are more consistent with a portrait of the pMFC as detecting poignant conflicts (including ideological conflicts), and recruiting responses relevant to addressing those conflicts (including ideological representations). According to this approach, the pro-U.S. immigrant posed no ideological conflict and hence did not elicit a significantly enhanced affirmation of group values, whereas the problem of death is not as effectively ameliorated by negative religious beliefs (i.e., relative to Heaven, continued existence in Hell presents a poor alternative to annihilation), and hence negative religious beliefs were not bolstered following reminders of mortality to the extent that positive beliefs were.

### **Future Directions**

The present study provides a “proof-of-concept” that adherence to high-level, abstract beliefs can be experimentally neuromodulated. However, the present design does not address several key questions that should be pursued in further research. Most notably, in order to create a context in which ideological adherence could be expected to be relatively intense, particularly with regard to religious ideas, we reminded all of our participants of death. Our data therefore do not reveal whether down-regulation of the pMFC via TMS would reduce either group bias or religious belief in the absence of a recent threat prime. Relatedly, we have conceptualized the present design as involving two sorts of problems (i.e., mortality and criticism of group values) that may each be addressed by custom-tailored solutions (i.e., religiosity, and derogation of the critical out-group member, respectively). This framing is consistent with the finding that TMS influenced evaluation of the critical author, but not the complimentary author. However, death primes have been found to exaggerate derogation of individuals who criticize in-group values in numerous studies, such that encountering an attack on group values in the aftermath of a reminder of death may constitute a double-shot threat. Thus, the reduction in out-group derogation observed in the TMS condition may reflect a diminution in the impact of the death prime rather than—or in addition to—a diminution in the response to the challenge posed by the out-group critic. Future research incorporating a non-threat control condition will be essential to ascertain whether down-regulation of the pMFC reduces out-group derogation, or avowed religious belief, in the absence of a background threat.

The present design is also limited inasmuch as it focuses on the threat posed by death, whereas a diverse array of threats have been shown to exacerbate various forms of ideological adherence (Proulx et al., 2012; Holbrook, in press; Holbrook and Fessler, 2015). Future research should assess the relative fit versus interchangeability of threats and subsequent expressions of

forms of ideological investment. For instance, a special relationship likely obtains between the problem of death and the apparent solution afforded by Western concepts of the afterlife (Holbrook and Sousa, 2013), such that reminders of death exert unique effects on the role of the pMFC in adherence to religious beliefs in comparison to threats that are unrelated to the desirability of a pleasant afterlife. Accordingly, more investigation is needed to assess the effects of the neuromodulation of the pMFC on ideological investment following both alternate threats and alternate forms of ideology (e.g., related to environmentalism or human rights). Future research is also required to address the potential role of individual differences in political orientation, personality, emotion, and other potentially relevant dimensions in moderating the relationship between the pMFC and ideological investment.

Ideological responses are abstract in that they invoke ideas regarding intangibles such as group values or religious convictions rather than the concretely physical. This distinction between “abstract” and “concrete” should not be conflated with the distinction employed in Construal Level Theory research on abstract (i.e., broad, superordinate, decontextualized) versus concrete (i.e., specific, subordinate, contextualized) modes of representation with which one may construe the same stimulus (Liberman and Trope, 2008). Note, for example, that participants might conceptualize the ideologically relevant stimuli utilized in our study (e.g., God, or the out-group critic) at varying levels of hazy generality or vivid detail. However, although these senses of abstractness are conceptually distinct, there are grounds to speculate that ideological responses—particularly those related to group bias—sometimes involve shifts toward a more superordinate, schematic mode of categorization (Fiske and Neuberg, 1990). For example, manipulating participants to engage a superordinate mode of categorization via unrelated tasks has been reported to increase stereotype-based attributions of qualities both to other people and



to the self (McCrea, Wieber, and Myers, 2012). It is therefore possible that down-regulating the pMFC in the present study increased ratings of the critical out-group author in part because participants placed into a less ideological mindset conceptualized the target as a unique individual rather than as a homogeneous out-group member invested with negative stereotypical traits. Future research might explore whether pMFC increases use of group stereotypes and related superordinate modes of categorization in contexts of threat, and, if so, whether this shift toward abstraction mediates some ideological responses.

Interestingly, the pMFC appears to marshal ideological shifts in the absence of increased conscious anxiety. We observed no significant differences between the TMS and sham conditions in any of the 13 subscales comprising our self-report affect measure, and the participants reported feeling low levels of negative affect and moderate levels of positive affect. This pattern of apparent sanguinity despite being reminded of death is consistent with prior research showing that implicit, but not explicit, anxiety increases following the death writing task used here (for a review, see Jonas et al., 2014). Accordingly, our TMS manipulation may have reduced ideological responses by a) reducing the extent to which the threatening stimuli were cognitively categorized as threats, b) reducing the implicit anxiety typically associated with the detection of threats, c) reducing the capacity to coordinate enhanced ideological adherence following threat-detection, or d) some combination of the above. Follow-up investigations might employ measures targeting implicit anxiety to clarify which of the above possibilities applies.

We utilized a sham control (TMS at 10% of the maximum stimulator output) rather than equivalently intense TMS of a neural control region. Although we acknowledge that follow-up research should include tests of neural control regions, it does not appear likely that TMS of any brain region would equivalently neuromodulate ideological cognition. In addition to the

considerable evidence for a special relationship between ideological reactions and pMFC, Klucharev and colleagues (2011) observed comparable judgment shifts in both sham TMS and control TMS (of the medial parietal cortex) relative to TMS of the same pMFC area manipulated here. In addition, because the present design did not include an active TMS control condition, we cannot rule out the possibility that the experience of TMS in general is responsible for the observed effects. For example, TMS is associated with mild discomfort, whereas sham TMS is not, and this difference in experience might account for our findings. However, for multiple reasons, we think this unlikely. First, the equivalence of self-reported affective states between conditions makes it unlikely that the observed effects owe to differences in the subjective experience of receiving TMS versus sham TMS. Second, religious belief has a demonstrable analgesic effect (Wiech et al., 2008), hence we might expect that any physical discomfort associated with TMS would enhance, rather than diminish, endorsement of positive religious ideas. Nonetheless, future designs incorporating TMS of neural control areas could importantly confirm the unique contribution of the pMFC and experimentally circumscribe the precise component(s) of the pMFC complex that direct ideological responses to threat. Neuroimaging would also be particularly valuable in clarifying the effect of the TMS manipulation used here on the subregions of the pMFC, as, at present, it is unclear whether the effects that we obtained are due to down-regulation of the dmPFC, down-regulation of the underlying dACC, or down-regulation of both.

Crucially, the brain areas mediating shifts in ideological adherence should not be construed as modularly confined to the pMFC, as TMS may be expected to affect regions that are interconnected with the target region (Driver et al., 2009), and as the pMFC is itself a large complex directing diverse aspects of cognition and behavior (Amodio and Frith, 2006;

Ridderinkhof et al., 2004). Perhaps the greatest challenge for future research will be mapping the precise neural mechanisms that undergird threat-related uptakes in ideological modes of processing.

### **Conclusion**

History teaches that investment in cherished group and religious values can bring forth acts of both heroic valor and horrific injustice. Understanding the psychological and biological determinants of increases in ideological commitment may ultimately help us to identify the situational triggers of, and individuals most susceptible to, this phenomenon, and thereby gain some leverage over the zealous acts that follow. The present findings suggest that the pMFC integrates processing distributed across interconnected brain regions to augment adherence to high-level ideals upon detection of relevant conflicts (e.g., criticisms of group values trigger strengthening of investment in group values; reminders of death motivate enhanced belief in a pleasant afterlife). The results provide evidence that relatively abstract personal and social attitudes are susceptible to targeted neuromodulation, opening the way for researchers to not only describe the biological mechanisms undergirding high-level attitudes and beliefs, but to establish causality via experimental intervention. Lastly, these findings illustrate the economical manner with which the brain utilizes common conflict-resolution mechanisms to achieve shifts in both concrete behavior and adherence to abstract beliefs.

### Funding

This work was supported by a UCLA Clinical and Translational Science Institute grant to D.M.T.F, M.I., C.H., and K.I. (UL1TR000124). This research was also supported by the Brain Mapping Medical Research Organization, Brain Mapping Support Foundation, Pierson-Lovelace Foundation, The Ahmanson Foundation, William M. and Linda R. Dietel Philanthropic Fund at the Northern Piedmont Community Foundation, Tamkin Foundation, Jennifer Jones-Simon Foundation, Capital Group Companies Charitable Foundation, Robson Family and Northstar Fund.

Acknowledgments

We thank A. Daniello, S. Needham, J. Nam and the research assistants of Fessler Lab.

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## Footnotes

<sup>1</sup> Following others (e.g., Binder et al., 2005; Jonas et al., 2014; Jost and Amodio, 2012), we use the terms “concrete” and “abstract” in the straightforward sense of poles defining a spectrum from the immediately physical (e.g., hand movements in a motor task) to the intangibly conceptual (e.g., shifting one’s views on welfare to accord with a newly adopted moral schema).

<sup>2</sup> Follow-up analyses were later conducted including these four excluded individuals. Consistent with the theoretically-grounded methodological concerns regarding the inclusion of self-identified Hispanic/Latino participants in a study assessing ideological responses to Latino immigrant targets intended to be regarded as out-group members, the effect of TMS on ratings of the anti-U.S. immigrant author was no longer significant, (sham:  $M = 3.11$ ,  $SD = 1.34$ ; TMS:  $M = 3.94$ ,  $SD = 1.64$ ),  $F(1, 39) = 3.67$ ,  $p = .063$ ,  $\eta^2_p = .09$ , 95% CI [-1.71, .05]. The effect of the TMS manipulation on ratings of the pro-U.S. author also remained nonsignificant (sham:  $M = 5.44$ ,  $SD = 1.35$ ; TMS:  $M = 5.98$ ,  $SD = .87$ ).  $F(1, 39) = 3.03$ ,  $p = .09$ ,  $\eta^2_p = .07$ , 95% CI [-1.18, .09]. The effect of the TMS manipulation on religiosity was unchanged. Avowed conviction in “positive” religious beliefs remained significantly lower in the TMS condition, (sham:  $M = 4.68$ ,  $SD = 2.21$ ; TMS:  $M = 3.29$ ,  $SD = 1.96$ ).  $F(1, 39) = 4.67$ ,  $p = .037$ ,  $\eta^2_p = .11$ , 95% CI [.09, 2.71], with no effect on “negative” religious beliefs (sham:  $M = 3.91$ ,  $SD = 2.38$ ; TMS:  $M = 2.92$ ,  $SD = 1.89$ ).  $F(1, 39) = 2.18$ ,  $p = .147$ ,  $\eta^2_p = .05$ , 95% CI [-.36, 2.33].

**Supplementary Online Material****to accompany****Neuromodulation of Group Prejudice and Religious Belief****Colin Holbrook, Keise Izuma, Choi Deblieck, Daniel M. T. Fessler, and Marco Iacoboni****Stimulation Parameters**

We used continuous theta-burst stimulation, in which 600 pulses were applied in bursts of three pulses at 50 Hz, repeated at 5 Hz for a total of 40 seconds. A 110 mm double cone coil (Magstim Company) was connected to the magnetic stimulator (Magstim Rapid2). Differential parallel-bar EMG Sensor recording electrodes (1 cm in length; 1 mm in girth; interelectrode distance of 1 cm) (Delsys, Natick MA, USA) were centered over the tibialis anterior muscle. Active motor thresholds were established as the minimum stimulus intensity that produced an objectively detectable EMG response of >100 microvolts in 5 of 10 trials during isometric contraction of the tibialis anterior muscle. The stimulation intensity in the TMS condition was set at 80% of this active motor threshold ( $M = 40.5\%$  of the stimulator's maximum output,  $SD = 6.42$ ). The coil was held radially to the participant's head.

**Measures**

**Motor and visual distracter tasks.** Immediately following stimulation, participants completed a filler task involving motor coordination (Bush and Shin, 2006) to ensure that down-regulation of the pMFC took effect (Huang et al., 2005) and to defray suspicion about the target hypothesis regarding ideological affirmation. After this initial filler task, participants began what was described as a set of unrelated measures, the first two of which were also distracters involving visual estimation. In these tasks, participants were asked to estimate the number of

colors present in images of jellybeans and seashells prior to their conversion to greyscale. Exploratory tests revealed no effects of condition on any of these three distracter measures,  $ps > .50$ .

**Reminder of death.** Next, participants were asked to write brief responses on the subject of their own death: (a) “Please briefly describe the emotions that the thought of your own death arouses in you” and (b) “Please jot down, as specifically as you can, what you think will happen to your body as you physically die and once you are physically dead.” This particular threat-induction was selected because of the evident link between the prospect of death and palliative thoughts of God and the afterlife, and also because this induction has been shown to reliably heighten both intergroup prejudice and religiosity in prior studies (Rosenblatt et al., 1989; Jonas et al., 2014; McGregor et al., 2013).

**Self-reported affect.** Following the death writing task, participants completed the Positive and Negative Affect Schedule—Expanded Form (PANAS-X; Watson and Clark, 1991). The PANAS-X measures consciously accessible affect by asking participants to rate the extent to which they feel 60 affective states, with subscales assessing general Positive ( $\alpha = .89$ ) and Negative ( $\alpha = .86$ ) affect, as well as specific negative emotions (Fear [ $\alpha = .78$ ], Hostility [ $\alpha = .58$ ], Guilt [ $\alpha = .89$ ], Sadness [ $\alpha = .86$ ]), positive emotions (Joviality [ $\alpha = .87$ ], Self-assurance [ $\alpha = .79$ ], Attentiveness [ $\alpha = .78$ ]), and other affective states (Shyness [ $\alpha = .77$ ], Fatigue [ $\alpha = .90$ ], Serenity [ $\alpha = .75$ ], and Surprise [ $\alpha = .55$ ]). Participants rated their current affective states using a 5-point Likert scale (1 = *Not at all*; 2 = *A little*; 3 = *Moderately*; 4 = *Quite a bit*; 5 = *Extremely*).

**Group prejudice.** Participants responded to two essays (presented in counterbalanced order) that were ostensibly written by immigrants to the United States from Latin America (Greenberg et al., 1994).

*Pro-U.S. essay:*

The first thing that hit me when I came to this country, was the incredible freedom people had. Freedom to go to school, freedom to work any job you want. In this country people can go to school and train for the job they want. Here anyone who works hard can make their own success. In my country most people live in poverty with no chance of escape. In this country people have more opportunity for success than any other and success does not depend on the group belong to. While there are problems in any country, America truly is a great nation and I don't regret my decision to come here at all.

*Anti-U.S. essay:*

When I first came to this country I believed it was the "land of opportunity" but I soon realized this was only true for the rich. The system here is set up for the rich against the poor. All people care about here is money and trying to have more than other people. This no sympathy for people. It's all one group putting down others and nobody cares about the foreigners. The people only let foreigners have jobs like pick fruit or wash dishes because no American would do it. Americans are spoiled and lazy and want everything handed to them. America is a cold country that is unsensitive to needs and problems of foreigners. It thinks it's a great country but its not.

**Religious belief.** Next, religious belief was measured using a version of the Supernatural Belief Scale (Jong et al., 2013) modified to create two scales which mirror "positive" and "negative" aspects of Western religious belief, comparable to the "positive" and "negative" immigrant authors in the ethnocentrism measure. The items were presented in random order and



rated according to the same scale employed in the immigrant ratings. The positive scale consisted of: (a) “There exists an all-powerful, all-knowing, loving God”; (b) “There exist good personal spiritual beings, whom we might call angels”; (c) “Some people will go to Heaven when they die”; ( $\alpha = .90$ ). The negative scale consisted of: (a) “There exists an evil personal spiritual being, whom we might call the Devil”; (b) “There exist evil, personal spiritual beings, whom we might call demons”; (c) “Some people will go to Hell when they die” ( $\alpha = .93$ ). An overall religiosity variable combining both scales was calculated by averaging all six items ( $\alpha = .95$ ).

Supplementary Table 1. Null effects of TMS condition on self-reported affect

	Sham ( <i>N</i> = 19)		TMS ( <i>N</i> = 19)		<i>F</i>	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Positive Affect	2.37	.75	2.44	.61	.10	.759
Negative Affect	1.43	.51	1.22	.27	2.41	.130
Fear	1.52	.57	1.32	.38	1.65	.207
Hostility	1.25	.36	1.12	.20	1.68	.203
Guilt	1.25	.54	1.24	.35	.01	.906
Sadness	1.68	.76	1.34	.41	3.08	.088
Joviality	2.24	.75	2.42	.60	.70	.408
Self-Assurance	2.22	.73	2.26	.67	.04	.848
Attentiveness	2.86	.86	2.86	.69	.01	.999
Shyness	1.64	.68	1.49	.66	.53	.473
Fatigue	2.82	1.09	2.39	.81	1.84	.184
Serenity	3.47	.84	3.65	.71	.48	.491
Surprise	1.66	.63	1.70	.72	.05	.834

Note. Subjective affect was measured using the Positive and Negative Affect Schedule—Expanded Form (Watson & Clark, 1991)

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