The neuroanatomical basis and development of system justification and political beliefs

by

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ABSTRACT

Understanding how people come to justify or challenge existing social systems is critical for many social and political outcomes, such as voting, collective action, and intergroup dynamics, especially when the status quo is marked by injustice or inequality. Across four studies integrating theory and methods from social psychology, political science, and cognitive neuroscience, my dissertation explores the psychological and neuroanatomical factors underlying ideological beliefs and behaviors. It also begins to address the "chicken-and-egg" problem in political neuroscience of whether a potential causal relationship between biology and political beliefs can be understood as dynamic and bidirectional. Specifically, Studies 1 and 2 examine the relationship between amygdala structure and system justification, showing that larger grey matter volume in the bilateral amygdalae is associated with greater system justification tendencies. Study 3 uses a "natural experiment" approach to test a causal link between biology and ideology by examining a lesion patient sample. I find that damage to the amygdala is related to the expression of more liberal political beliefs. Finally, Study 4 is a prospective, longitudinal investigation of structural changes to the brain to understand the relationship between the development of brain structure, system justification, and ideological preferences (including participation in collective action) in a college sample. Using new, more precise techniques for longitudinal brain structure analysis, I find that regional changes to grey matter volume are related not only to changes in ideology but are also a function of the ideological contributions of a college education. Taken together, this research sheds light on the psychological processes that contribute to ideologically motivated protection of the status quo through the use of novel techniques in the study of system justification and political processes.

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INTRODUCTION

I had always considered my thoughts as something abstract, but they weren't; they were as material as the heart beating in my chest. The same was true of the mind, the soul, the personality; all of it was fixed in the cells and originated as a result of the various ways in which these cells reacted with one another. All of our systems, too—communism, capitalism, religion, science—they also originated in electrochemical currents flowing through this three-pound lump of flesh encased in the skull. (Karl Ove Knausgaard)

Human and non-human animals alike commonly live in social and political systems that are characterized by hierarchy. Such formalized inequality is often remarkably stable, with people (and other animals) supporting the maintenance of the established order by tolerating and accepting inequalities (e.g., Bernstein, 1969; Jost, Banaji, & Nosek, 2004). On the other hand, individuals are also capable of objecting to egregious or unjust inequalities through spontaneous protest or organized collective resistance (Boehm et al., 1993; Brosnan & de Waal, 2003). Indeed, a growing literature suggests that in both childhood and adulthood, humans (e.g., Dawes et al., 2007; Tricomi et al., 2010; Warneken et al., 2010)—as well as primates (Brosnan & de Waal, 2003)—prefer outcomes that are equal and equitable. At the same time, across species, individual differences in psychological temperament are an important factor in determining tolerance vs. rejection of inequitable resource distribution, including preferences for social dominance and other personality differences (Brosnan et al., 2015; Pratto, Sidanius, Stallworth, & Malle, 1994).

Despite individual variability in tolerating inequality, the balance of human history may tilt in favor of sustaining hierarchical arrangements, as the historian Zinn observed (1968/2002): "Rebellion is only an occasional reaction to suffering in human history; we have infinitely more instances of forbearance to exploitation, and submission to authority, than we have examples of revolt." Indeed, social systems rooted in deep inequality, such as slavery, segregation, and patriarchy, have typically endured long periods of stability and perceived legitimacy before successful collective efforts to uproot them. In light of these psychological and historical observations, I am interested in understanding the tension between the competing forces of preferences to maintain the status quo vs. preferences to attain egalitarian and just outcomes. My dissertation research therefore focuses on the basic psychological and ideological processes by which people come to accept and maintain existing (characteristically unequal) social systems and to resist social change. To this end, my research uses neuroimaging, brain lesion, and prospective, longitudinal methods to shed light on the basic neurobiological and psychological processes that can lead to ideological acceptance of hierarchical social systems, as well as how the social environment may influence such preferences. Furthermore, I will suggest that for preferences regarding the maintenance or rejection of hierarchical social systems, the relationship between biological, psychological, and environmental processes is dynamic and potentially bidirectional. That is, I argue that not only do basic biological and psychological predispositions influence social and political preferences, but extended exposure to particular social and political environments can also shape even basic neurobiological architecture.

System justification theory

System justification theory posits that to varying degrees individuals are motivated to maintain, defend, and bolster the social systems they are a part of, even when the systems are characterized by social, economic, and political inequalities (Jost, Banaji, & Nosek, 2004; see Jost & van der Toorn, 2012 for a review). It is theorized that system justification motivation arises from basic psychological needs to manage threat, uncertainty, and social connections (Jost, Fitzsimons, & Kay, 2004; Jost, Ledgerwood, & Hardin, 2008; Hennes, Nam, Stern, & Jost, 2012). Moreover, engaging in system justification serves a palliative function with respect to managing such psychological needs—people rationalize social disparities in part because it alleviates distress that could arise from being faced with social ills (Jost & Hunyady, 2002).

In addition to (and sometimes in spite of) self- and group-interested goals, the motivation to justify existing systems typically produces resistance to social change. If the status quo is regarded as familiar and comfortable, then it follows that significant departures from the status quo (such as efforts to eradicate social inequalities) can easily be construed as threatening and therefore resisted. Dozens of behavioral studies have demonstrated that individual differences in system justification predict variability in attitudes, ideologies, and behaviors that affirm existing social structures and inequalities, such as endorsement of group-based stereotypes (Kay & Jost, 2003), politically conservative and meritocratic ideologies (Jost, Glaser, Kruglanski, & Sulloway, 2003; Jost, Nosek, & Gosling, 2008; see also Knowles, Lowery, Hogan, & Chow, 2009), and decreased willingness to support social change, including redistributive policies that aid the disadvantaged (Wakslak, Jost, Tyler, & Chen, 2007).

Even those who are disadvantaged in a hierarchical system sometimes justify the established social arrangements and resist collective efforts in their social and economic interest (Jost, Pelham, Sheldon, & Sullivan, 2003). For instance, women who justify the traditional gender system engage in greater self-objectification and less feminist social activism (Calogero, 2013; see also Yeung, Kay, and Peach, 2014), low-status group members express more outgroup favoritism and ingroup ambivalence compared to high-status group members (Jost & Burgess, 2000), and Māori (a disadvantaged indigenous group in New Zealand) who endorse system-justifying meritocratic beliefs express greater opposition to a reparative policy in their group's interest (Sengupta & Sibley, 2013).

The psychological and neurobiological basis of system-justifying ideologies

Conventional wisdom and the tradition of research in political science has long assumed that individual variation in social and political preferences arises from personal experiences and exposure to "top-down" (e.g., institutional, economic) influences (Fiorina, 2005; Poole & Rosenthal, 1997; Sniderman & Bullock, 2004; Zaller, 1992). However, recent research in political psychology and political science has begun to examine the more "bottom-up" influences of psychology and biology on social and political attitudes and behaviors (Jost, Federico, & Napier, 2009; Jost, Nam, Van Bavel, & Amodio, 2014; Hibbing, Smith, & Alford, 2014). Indeed, emerging research in psychology, genetics, and neuroscience demonstrates that both situational and dispositional differences in cognitive, perceptual, and physiological orientations help to explain differences in political ideology (e.g., Jost, Federico, & Napier, 2009; Oxley et al., 2008; Funk et al., 2013; Oskarsson et al., 2015).

Many recent investigations of the biological bases of political ideologies and behaviors (e.g., Kanai, Feilden, Firth, & Rees, 2011; Smith et al., 2011a; Ahn et al., 2014) have stemmed from an influential theoretical perspective introduced via meta-analysis by Jost, Glaser, Kruglanski, and Sulloway (2003). Integrating studies spanning 88 samples, 12 countries, and over 20,000 cases, Jost and colleagues observed that basic psychological needs to manage anxiety and to avoid uncertainty were consistently related to political conservatism. Given these empirical observations, the authors proposed that adherence to political ideologies, and conservatism in particular, is motivated by heightened psychological needs to manage uncertainty and threat (see also Thorisdottir, Jost, Liviatan, & Shrout, 2007 for another cross-national study linking security needs to right-wing orientation). This psychological account of political ideology paved the way for research integrating biological approaches in understanding people's ideological preferences to maintain vs. challenge the status quo.

Investigating system justification and political beliefs using multiple, mutually informative levels of analysis can contribute to a better understanding of the psychological needs and processes by which people come to justify existing social arrangements. Identifying brain structures that are related to variability in ideological preferences to defend (vs. oppose) hierarchical social systems is a critical first step for understanding the neural (and related psychological) processes that might underlie the protection of prevailing social systems and the perpetuation of social inequality. The application of neuroscience to social and political topics such as this offers a powerful set of research methods that promises to integrate multiple levels of analysis. As the biologist E. O. Wilson (1998) wrote in *Consilience: The Unity of Knowledge*: "the social sciences are intrinsically compatible with the natural sciences. The two great branches of learning will benefit to the extent that their modes of causal explanation are made consistent" (p. 205). Through techniques more commonly used in fields such as neuroscience and behavioral genetics, it may be possible to analyze complex phenomena in terms of underlying constituent processes (Cacioppo & Berntson, 1992).

Examining the structure of specific brain regions may provide a useful index of relatively stable inter-individual differences in psychology or social preferences. Specifically, studies of neural structure assess grey matter volume, which comprises cortical thickness and surface area. Grey matter volume is understood as the computational capacity of a certain brain region, with many studies linking larger grey matter volume with greater efficacy of behaviors supported by that region (Kanai & Rees, 2011). This kind of interpretation is supported by lesion studies that suggest causal involvement of regional brain structures in psychological and behavioral outcomes, in that damage to certain regions can impact related psychological functioning (e.g., Anderson & Phelps, 2001; Harrison, Hurlemann, & Adolphs, 2015).

Brain lesion research on non-human primates has suggested that the amygdala is particularly important for navigating the complex and hierarchical social systems of macaques. For instance, rhesus macaques became less socially dominant and tended to fall in the social hierarchy following amygdala lesioning (Rosvold, Mirsky, & Pribram, 1954; Bauman, Toscano, Mason, Lavenex, & Amaral, 2006). Loss of social dominance after amygdala lesioning may be related to diminished ability to appropriately assess the social and physical environment, as rhesus macaques that received bilateral amygdala lesions not only exhibited lower inhibition in social interactions with novel, potentially adversarial conspecifics, but also less fear in response to normally threatening stimuli like snakes (Amaral, 2003). Similarly, humans with amygdala lesions exhibit lower inhibition in approaching low-information, ambiguous stimuli (Harrison, Hurlemann, & Adolphs, 2015), including one famous patient with complete bilateral amygdala damage who exhibits no inhibition in approaching typically fear-inducing stimuli (Feinstein, Adolphs, Damasio, & Tramel, 2011). The amygdala also plays a role in species-typical social dominance behavior in other non-human animals, including rats (Bunnell, 1966), cats (Fonberg, 1988), and dogs (Fuller, Rosvold, & Pribham, 1957).

Grey matter volume in the amygdala has been shown to be associated with social status in macaques (Noonan et al., 2014). In both macaques (Sallet et al., 2011) and humans (Bickart et al., 2011; Kanai, Bahrami, Roylance, & Rees, 2012), greater grey matter volume in the amygdala is associated with having a larger social network, which may very well entail successfully navigating a more complex and hierarchical social landscape. Together, these amygdala lesion and grey matter volume findings suggest that the amygdala is an important brain structure for navigating social landscapes, providing appropriate motivational orienting toward conspecifics in establishing or successfully maintaining positions in a social hierarchy.

Consistent with research implicating the amygdala in detecting motivationally significant stimuli in a social environment, other recent work on humans has begun to investigate the possibility that specific orientations and beliefs regarding society and hierarchical systems are rooted in the neuroanatomical structure of the amygdala. For instance, Kumaran, Melo, and Duzel (2012) found that larger bilateral grey matter volume in the amygdala was associated with better performance on a task in which participants learned and identified the relative rank of members in a novel hierarchical social system. The specificity of this relationship was bolstered with a contrasting finding that amygdala volume was not predictive of performance on a non-social hierarchy learning task. Moreover, Kanai, Feilden, Firth, and Rees (2011) observed that political conservatism (measured in terms of ideological self-placement) was positively correlated with larger right amygdala volume. It is perhaps unsurprising that similar to other animals, the amygdala is important for humans in navigating their social and political structures, considering evidence indicating the amygdala's central role in processing motivationally salient information, whether it is threatening (e.g., Adolphs et al., 1995; Phelps et al., 2001), uncertain (e.g., Whalen, 2007; Herry et al., 2007), or relevant to social group navigation (e.g., Van Bavel, Packer, & Cunningham, 2008; Kumaran, Melo, & Duzel, 2012; Zink, Tong, Chen, Bassett, Stein, & Meyer-Lindenberg, 2008). These findings present the intriguing possibility that the amygdala is involved in complex social and political learning and belief formation, but it is not yet clear what it is about social hierarchy and conservatism that might be supported by amygdala structure.

I propose that an important psychological link in the relationship between amygdala volume and social hierarchy knowledge and conservatism may lie in individual variability in a system justification motivation to see existing social, political, and economic arrangements as just and legitimate (Jost, Banaji, & Nosek, 2004). In other words, a psychological orientation favoring maintenance of the societal status quo may underlie vigilance to markers of social hierarchy (and potential changes to it), as well as affinity for conservative ideology that allows for greater degrees of hierarchy and inequality (Jost et al., 2003; Jost, Nosek, & Gosling, 2008). Furthermore, evidence suggests that system justification motivation arises from basic psychological needs to manage threat, uncertainty, and social connections (Hennes, Nam, Stern, & Jost, 2012), which may find a common neural basis in the amygdala. I investigate the neuroanatomical basis of system justification in Studies 1 and 2.

The development of system-justifying (vs. system-challenging) beliefs: Tackling the "chicken-and-egg" problem

On the basis of previous research, it cannot be determined whether (a) individual differences in brain structure and function lead to diverging ideological preferences, and/or (b) exposure to and adoption of specific social and political beliefs leads people to think in certain ways, causing our brains to process information differently. The typically held view of such a "chicken-and-egg" problem is that biological and psychological characteristics are heritable and stable, so they must shape political preferences, and not the other way around (e.g., Hibbing et al., 2014; Smith et al., 2011b), which has led some to erroneously conclude that social and political attitudes and behaviors are "hard-wired."

I hypothesize that differences in neurocognitive structure and functioning are *dynamically* linked to social and psychological processes that across time, both reflect and give rise to the expression of political behavior. That is, I favor a dynamic, recursive theoretical framework in which the connection between physiological (and psychological) functioning and political outcomes is conceived of as bidirectional rather than unidirectional (see Figure 1). This perspective is consistent with the notion that ideological beliefs are the product of a potentially mutually reinforcing "elective affinity" between top-down, socially constructed ideological belief systems and bottom-up, biological and psychological predispositions (Jost, Federico, & Napier, 2009). Indeed, I posit that not only can biological and psychological predispositions affect system-justifying (vs. system-challenging) beliefs and political outcomes, but consistently encountered (and embraced) ideological narratives or belief systems can also affect a person's psychological and physiological characteristics.

Ultimately, investigating this hypothesis and beginning to tackle the "chicken-and-egg" problem requires the use of multiple, innovative research methods (including both longitudinal and experimental techniques) that make it feasible to isolate causal processes (Jost, Noorbaloochi, & Van Bavel, 2014). As discussed above, one method that can help tease apart causal direction is experiments with brain lesion patients. To the extent that damage to a certain region of the brain can affect psychological and behavioral functioning believed to be associated with that region, one can infer that there is a causal relationship between a neural structure and subsequent behavior. Previous work with experimental lesioning of amygdala structures in macaques demonstrated that the amygdala is important for avoiding threat and attaining social status (Rosvold, Mirsky, & Pribram, 1954; Amaral, 2003). Humans who have damaged amygdala structures by medical necessity (not by experimental procedure) have similarly exhibited decreases in fear, anxiety, and avoidance of threat (Feinstein, Adolphs, Damasio, & Tramel, 2011), as well as decrements in ability to identify fearful facial expressions (Adolphs et al., 1999). Building upon such brain lesion findings and the previously discussed behavioral links between existential concerns and conservative ideologies, I test a causal relationship between amygdala damage and ideological preferences in Study 3.

Another important method for inferring causality is the longitudinal method. But given the challenges of conducting such protracted investigations, there is little existing research using prospective, longitudinal methods. Yet such methods have much to offer, and two studies connect early personality characteristics to later political tendencies: both Block and Block (2006) and Fraley et al. (2012) observed that childhood temperament at approximately age 4 (as measured by play and other behavior) correlated with political beliefs in adulthood, such that children who tended to be easily upset or afraid of the dark were later more conservative, and children who were more active and restless were later more liberal.

In terms of malleability of neural structure, studies of nonhuman animals have demonstrated that the brain can change quite significantly in response to training and experience (Fu & Zuo, 2011), and increasingly, it would appear that this is true of human animals as well. To date, most studies of change in brain structure have examined change in clinical settings, such as atrophy of brain regions in relation to conditions such as Alzheimer’s disease, dementia, etc.

(e.g., Chan et al., 2003; Pengas et al., 2009; Rohrer et al., 2013). But increasingly researchers are finding that even in healthy subject populations, brain structure change (above and beyond the developmental course) in response to training and experience is quite common. For instance, men who completed a 4-year training program to become London cab drivers exhibited increased grey matter volume in the posterior hippocampus, along with significant changes in memory capacity (Woollett & Maguire, 2011). Although there are limitations to what can be concluded on the basis of existing research (Thomas & Baker, 2013), some changes in brain structure have been observed following training in a variety of domains, including mindfulness training (Hölzel et al., 2010; Hölzel et al., 2011), exercise (Erickson et al., 2011), academic instruction (Ceccarelli et al., 2009), second language acquisition (Mechelli et al., 2004), musical training (Hyde et al., 2009), golfing (Bezzola et al., 2011), and juggling (Draganski et al., 2004; Boyke et al., 2008). Such evidence from cognitive neuroscience suggests that repeated experiences, perhaps including social and political experiences, may be capable of altering the structures of the human brain. I explore this possibility in Study 4.

Overview of the Present Research

The current research provides theoretical and methodological advances to the study of system justification and political processes. To date, system justification and political processes have largely been studied using behavioral measures. Integrating neuroscientific methods such as measures of neural structure has the potential to provide convergent evidence on the basic psychological needs and processes that give rise to system-justifying ideological preferences. System justification theory and theoretical accounts of political ideology also stand to benefit from neuroscientific investigation, as understanding of the component psychological processes can be enhanced by integrating previously overlooked neuroscience literature on psychological functions of brain regions such as the amygdala. Furthermore, as noted above, there is a dearth of longitudinal research on the development of sociopolitical preferences, especially as it pertains to the potential co-development of brain structure and system-justifying (vs. system-challenging) ideological beliefs.

In Studies 1 and 2, I first investigate whether there is a relationship between brain structure and individual differences in system justification motivation, focusing on amygdala structure. In Study 3, I examine ideological differences in people with brain lesions in different neuroanatomical regions (namely the amygdala vs. frontoparietal regions), as well as healthy control subjects. In Study 4, I explore the potential dynamic relationship between brain structure and system-justifying vs. system-challenging political preferences through a prospective, longitudinal study of college students.

STUDIES 1 & 2

The relationship between amygdala structure and individual differences in system justification

Given the implications of system justification for the perpetuation of social hierarchy and the amygdala's role in promoting vigilance in social hierarchies (e.g., Rosvold, Mirsky, & Pribram, 1954; Bauman, Toscano, Mason, Lavenex, & Amaral, 2006; Kumaran, Melo, & Duzel, 2012), I investigated the possibility that system justification motivation itself varies with amygdala structure. I chose to focus on brain structure (vs. function) as a more stable indicator of regional computational capacity that would be particularly useful for shedding light on chronic individual differences (see Kanai & Rees, 2011). Specifically, I hypothesized that greater system justification would be associated with larger grey matter volume in the amygdala in humans.

1.1 Materials and Methods

Participants

Study 1. Forty-nine healthy right-handed participants (mean age = 19; 58% female) were recruited from the Introductory Psychology participant pool at NYU, based on their responses in the battery of questionnaires at the start of the term. The study was approved by University Committee on Activities Involving Human Subjects (UCAIHS), the NYU Institutional Review Board, and all participants provided written informed consent. I deliberately recruited only White participants in order to minimize potential racial and ethnic differences in brain structure. Furthermore, I recruited participants from a previous mass battery testing session to represent the full range of ideological beliefs; I preselected participants in this manner in order to minimize ideological skew in the sample, as well as to be able to explore potential effects of ideological extremity. However, the preselection process was independent from the study session and the experimenter was therefore unaware of participant ideology.[1]

Study 2. Forty-five healthy right-handed participants (mean age = 20; 67% female) were more ethnically diverse than in Study 1, and identified as 27% White, 9% Black, 16% Latino/Hispanic, 44% Asian, and 4% other. The greater ethnic diversity of participants in Study 2 expanded upon the generalizability of Study 1. The study was approved by University

[1] Due to a clerical error, one participant was scanned who did not meet the preselection criteria, and I therefore excluded her from the analyses.

Committee on Activities Involving Human Subjects (UCAIHS), the NYU Institutional Review Board, and all participants provided written informed consent.

Procedure

Participants arrived to the scan center for a study titled “Scanning Social Judgments and Decisions” in Study 1 and “Social Cognition” in Study 2. They underwent a resting state structural MRI scan, and responded to a questionnaire (which included measures of system justification and political ideology; see Tables 1 and 2 for all behavioral measure correlations in Studies 1 and 2, respectively) outside the scanner.

In Study 1, I randomly counterbalanced the order of the scan and the questionnaire in order to determine whether the experience of being inside the MRI scanner affected how participants reported their system justifying and ideological beliefs, such that 25 participants were scanned before taking the questionnaire, and 23 participants responded to the questionnaire before the scan. There were no order effects for system justification, whether it was measured before (M = 4.78, SD = 1.46) or after the scan (M = 4.94, SD = 1.42), $t(46)$ = .39, p = .70. Participants did report being significantly more conservative among those who reported their ideology before the scan (M = 6.13, SD = 2.67) than those who reported after the scan (M = 4.28, SD = 2.25), $t(46)$ = -2.61, p = .01. However, it may be that there were pre-existing ideological differences between the two groups despite random assignment, as we found participants’ ideology scores from the battery (measured before the experimental session and therefore unaffected by the study) were significantly more conservative among those who took the questionnaire first (M = 6.52, SD = 2.64) than those who underwent the scan first (M = 4.56, SD = 2.53), $t(46)$ = -2.62, p = .01, suggesting that group differences were not due to the experience of being inside the scanner. (System justification scores from the battery were not different as a function of scanner-questionnaire order, $t(46) = -1.04$, $p = .30$.)

Given that the scanner experience itself did not appear to significantly affect participants' responding in Study 1, in Study 2, I measured system justification and political ideology for all participants after the scan session.

System justification. Participants were given the 8-item general system justification scale (Kay & Jost, 2003), which measures the extent to which people are motivated to justify, defend, and bolster the extant social, economic, and political systems. The scale assesses agreement with items such as "In general, you find society to be fair" and "American society needs to be radically restructured" (reverse-scored) on a 9-point scale ranging from 1 = *strongly disagree* to 9 = *strongly agree*. In Study 1, the mean system justification score was 4.86 ($SD = 1.43$). In Study 2, the mean system justification score was 4.12 ($SD = 1.18$).

Political ideology. Participants were also asked to indicate their political ideology on an 11-point scale ranging from 1 = *extremely liberal* to 6 = *neither* to 11 = *extremely conservative*. In Study 1, the mean ideology score was 5.17 ($SD = 2.60$). In Study 2, the mean ideology score was 4.09 ($SD = 2.00$).

Consistent with previous work (e.g., Jost et al., 2003), greater system justification was correlated with greater conservatism in both studies: $r(46) = .37$, $p < .01$ (Study 1); $r(43) = .45$, $p = .002$ (Study 3).

MRI data acquisition

I acquired MR images with a 3T Siemens Allegra head-only scanner. T1-weighted high-resolution anatomical images (MPRAGE, repetition time = 2500 ms; echo time = 4.35 ms; field of view = 256 × 256 mm; voxel size = 1 × 1 × 1 mm) were acquired for each subject, with slices collected manually aligned to be parallel to the anterior commissure- posterior commissure line.

MRI data analysis

VBM preprocessing and analysis. I used voxel-based morphometry (VBM) to analyze the structural images (Ashburner & Friston, 2000). I first segmented T1-weighted MR images into grey matter (GM) and white matter (WM) using the segmentation tools in Statistical Parametric Mapping 8 (SPM8; Wellcome Department of Imaging Neuroscience, London UK, http://www.fil.ion.ucl.ac.uk/spm). Then I performed diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL) in SPM8 for intersubject registration of the grey matter images. I smoothed the registered images with a Gaussian kernel of 12 mm full-width half-maximum and then transformed them to Montreal Neurological Institute (MNI) stereotactic space using affine and nonlinear spatial normalization implemented in SPM8. I ensured that the total amount of grey matter was retained before and after spatial transformation by modulating the transformed images by the Jacobian determinants of the deformation field. Therefore, the value of GM volume represented the volume of tissue per unit of spatially normalized image in arbitrary units. Total GM volumes across the whole brain were computed from the segmented images for each participant.

Whole brain analyses. I entered the smoothed, normalized images into a multiple regression analysis across the participants. Following previous work (e.g., Kanai et al., 2011; Campbell-Meiklejohn et al., 2012), I included the regressors of sex, age, and overall brain (GM) volume as covariates of no interest and therefore regressed out any effects of these factors. I entered system justification as a regressor of interest. Voxels positively related to system justification were thresholded at $p < .001$ with a minimum cluster of 10 voxels.

ROI analyses. In addition, I conducted ROI analyses on the bilateral amygdala per the *a priori* hypothesis regarding these structures. I extracted the grey matter volume separately for the left and right amygdala using an ROI mask based on the Harvard-Oxford subcortical structural atlas implemented in the Oxford University Centre for Functional MRI of the Brain Software Library (http://www.fmrib.ox.ac.uk).

I also explored other ROIs, following a previous finding linking GM volume in the anterior cingulate cortex (ACC) and the left insula to political ideology (Kanai et al., 2011). For these regions, I extracted GM volume using procedures in SPM 8. These ROIs were defined as spheres with a radius of 20 mm centered at x = -3, y = 33, z = 22 for the ACC, and x = -38, y = -16, z = -2 for the left insula (Kanai et al., 2011). I did not find significant associations between these brain regions and system justification (or ideology) that replicated across both studies (see Tables 6-7 for summaries of all effects).

1.2 Results

Study 1. Increased grey matter volume in the bilateral amygdalae was significantly associated with greater system justification, $r(46) = 0.29$, $p = .04$ (see Figure 2; all peak clusters are reported in Table 3). Whole brain analyses examining GM volume differences as a function of political ideology as the main regressor of interest did not reveal any significant effects, and the effect of system justification held even after adjusting for ideology (see Table 5 for a summary of regression model comparisons). The analyses held after small volume correction using amygdala masks, indicating greater grey matter volume in both the left and right amygdalae as a function of system justification.

To further probe the data and rule out alternative explanations, I extracted ROI values from the bilateral amygdalae in order to test a range of linear regression models (see Table 5 and further discussion below). Across the various models, I found that the data were most parsimoniously explained by a model that included only system justification as the main independent variable (adjusting for age, sex, and global brain volume, as in the whole brain analysis; $\beta = .14$, $t(43) = 2.05$, $p = .046$), suggesting that a belief that the existing social order is desirable, just, and legitimate is instantiated in amygdala structure. A model that included political ideology in addition to system justification did not explain a significantly greater proportion of the variance of amygdala volume than the model including only system justification ($\Delta R^2 < .001$, $p = .91$), and ideology was not a significant predictor of amygdala volume ($\beta = -.01$, $t(42) = -.12$, $p = .91$), whereas system justification was a marginally significant predictor ($\beta = .15$, $t(42) = 1.92$, $\Delta R^2 = .02$, $p = .06$). Similarly, a model that included only ideology (adjusting for age, sex, and global brain volume) did not explain a significant amount of the variance in amygdala volume, $\beta = .05$, $t(43) = .65$, $\Delta R^2 = .002$, $p = .52$.

Study 2. Again I found that bilateral amygdalae volume was strongly positively associated with system justification, $r(43) = .49$, $p = .001$ (Figure 3; all peak clusters as revealed under whole brain analysis are reported in Table 4). These results also held after small volume correction using amygdala masks for the left and right amygdalae.

I again tested a range of linear regression models (see Table 5), and found that across the various models, system justification was consistently a significant predictor of amygdala volume (all β's > .30, p's < .01). A model that included only ideology (adjusting for age, sex, and global brain volume) did not explain a significant amount of the variance in amygdala volume, β = -.003, $t(40) = -.03$, $\Delta R^2 < .001$, $p = .97$. When political ideology and system justification were both included in the model, system justification (entered at step 1) explained a greater proportion of the variance in amygdala volume ($\beta = .40$, $t(40) = 5.17$, $\Delta R^2 = .08$, $p < .001$), than did ideology (entered at step 2; $\beta = -.15$, $t(39) = -2.13$, $\Delta R^2 = .02$, $p = .04$).[2]

Regression model comparisons on bilateral amygdala volume. Using extracted mean ROI values of grey matter volume within masks for the left and right amygdalae, I tested several regression models on mean bilateral amygdala volume (see Table 5; and see Tables 6 & 7 for summaries of model comparisons for the ACC and left insula, respectively). Across all models, because the range of values for the ROIs was so small, I entered ROI variables (i.e., amygdala, ACC, and left insula variables) that I multiplied by a factor of 100 in order to obtain non-zero unstandardized regression coefficients and standard errors. All models were also adjusted for age, gender, and global brain volume as in the whole brain analyses in SPM. In addition, the residuals from each model (across amygdala volume, ACC, and left insula) were consistently roughly normally distributed and homoscedastic, so I felt comfortable making inferences based on the estimated standard errors.

The various multiple regression models followed the general form of an ordinary least squares (OLS) model in various combinations:

$$\hat{y} = b_0 + b_1 * x_1 + b_2 * x_2 + \ldots + b_n * x_n + \varepsilon$$

[2] When ideology was entered into the model at step 1 and system justification was entered at step 2 of the hierarchical regression model, system justification explained a significant portion of the variance ($\Delta R^2 = .10$, $p < .001$), whereas ideology did not ($\Delta R^2 < .001$, $p = .97$).

where

$\hat{y}_{S1}$ = predicted GM volume in bilateral amygdalae (Study 1)
$\hat{y}_{S2}$ = predicted GM volume in bilateral amygdalae (Study 2)
b_0 = constant (intercept)
b_n = unstandardized regression coefficients (slope)
x_1 = political ideology
x_2 = ideological extremity
x_3 = general system justification
x_4 = economic system justification
x_5 = general system justification extremity
x_6 = economic system justification extremity
ε = error term

I first describe the preferred model (model 3 in Table 5) and then the alternative models:

$$\hat{y}_{S1} = 17 + .365*x_3 + \varepsilon \qquad \text{(model 3)}$$

$$\hat{y}_{S2} = 42 + 1.097*x_3 + \varepsilon.$$

Model 3 indicated that greater system justification was associated with larger grey matter volume in the bilateral amygdalae (adjusting for the effects of age, sex, and global brain volume), for both Study 1 (b = .365, SE = .178, β = .14, t = 2.05, p = .046) and Study 2 (b = 1.097, SE = .243, β = .33, t = 4.51, p < .001).

I examined the potential additional effect of political ideology in Model 3a, adding ideology as a regressor in addition to system justification:

$$\hat{y}_{S1} = 17 - .013*x_1 + .374*x_3 + \varepsilon \qquad \text{(model 3a)}$$

$$\hat{y}_{S2} = 43 - .287*x_1 + 1.317*x_3 + \varepsilon.$$

Model 3a indicated that in Study 1, system justification was a marginally significant predictor of amygdala volume (b = .374, SE = .195, β = .15, t = 1.92, p = .06), but ideology was not (b = -.013, SE = .105, β = -.01, t = 0.12, p = .91). In Study 2, both system justification (b =

1.317, *SE* = .287, β = .40, *t* = 5.17, *p* < .001) and ideology (*b* = -.287, *SE* = .135, β = -.15, *t* = -2.13, *p* = .04) were associated with amygdala volume.

To assess whether political ideology by itself was associated with amygdala volume (as was found in Kanai et al., 2011), I included ideology as the regressor of interest in model 1:

$$\hat{y}_{S1} = 16 + .065 * x_1 + \varepsilon. \qquad \text{(model 1)}$$

$$\hat{y}_{S2} = 43 - .005 * x_1 + \varepsilon.$$

Model 1 indicated that ideology was not significantly associated amygdala volume in Study 1 (*b* = .065, *SE* = .100, β = .05, *t* = .65, *p* = .52), nor in Study 2 (*b* = -.005, *SE* = .158, β = -.003, *t* = -.03, *p* = .97).

To examine the possibility that ideological extremity was a factor in addition to ideology, Model 2 included ideological extremity, which was measured by the absolute value of the distance from the midpoint of the scale:

$$\hat{y}_{S1} = 16 + .069 * x_1 + .023 * x_2 + \varepsilon \qquad \text{(model 2)}$$

$$\hat{y}_{S2} = 43 + .054 * x_1 + .331 * x_2 + \varepsilon.$$

Model 2 revealed that neither political ideology nor ideological extremity were associated with GM volume in the amygdala in Study 1 (ideology: *b* = .069, *SE* = .110, β = .05, *t* = .63, *p* = .53; ideological extremity: *b* = .023, *SE* = .212, β = .009, *t* = .11, *p* = .91), nor in Study 2 (ideology: *b* = .054, *SE* = .166**,** β = .03, *t* = .33, *p* = .73; ideological extremity: *b* = .331, *SE* = .291, β = .09, *t* = 1.14, *p* = .26).

To assess whether specific motivations to justify the economic system would be associated with brain structure, in Models 4 and 4a I tested the potential effect of economic system justification (Jost & Thompson, 2000) in addition to general system justification (model 4) and general system justification and ideology (model 4a):

$$\hat{y}_{S1} = 18 + .512*x_3 - .185*x_4 + \varepsilon \qquad \text{(model 4)}$$

$$\hat{y}_{S2} = 42 + .993*x_3 + .168*x_4 + \varepsilon$$

$$\hat{y}_{S1} = 18 + .001*x_1 + .512*x_3 - .185*x_4 + \varepsilon \qquad \text{(model 4a)}$$

$$\hat{y}_{S2} = 42 - .309*x_1 + 1.156*x_3 + .288*x_4 + \varepsilon.$$

Models 4 and 4a both suggested that general system justification was consistently a significant predictor of amygdala volume across both studies, to a greater extent than economic system justification and political ideology. Model 4 revealed that greater general system justification was associated with larger amygdala volume (Study 1: b = .512, SE = .257, β = .19, t = 2.00, p = .05; Study 2: b = .993, SE = .315, β = .30, t = 3.16, p = .003), whereas economic system justification was not (Study 1: b = -.185, SE = .277, β = -.06, t = -.67, p =. 51; Study 2: b = .168, SE = .320, β = .05, t = .53, p = .60). In Model 4a, the effect of general system justification was again largest (Study 1: b = .512, SE = .261, β = .19, t =1.97, p = .06; Study 2: b = 1.156, SE = .308, β = .35, t = 3.75, p = .001), economic system justification was not associated with amygdala volume (Study 1: b = -.185, SE = .261, β = -.06, t = -.60, p = .55; Study 2: b = .288, SE = .309, β = .08, t = .93, p = .36), and the effect of ideology was inconsistent across studies (Study 1: b = .001, SE = .121, β < .001, t = .005, p = .996; Study 2: b = -.309, SE = .137, β = -.16, t = -2.26, p = .03).

In Model 5 I more directly examined the association between economic system justification and amygdala volume. Model 5a assessed the effect of both economic system justification and political ideology.

$$\hat{y}_{S1} = 16 + .195{*}x_4 + \varepsilon \qquad \text{(model 5)}$$

$$\hat{y}_{S2} = 43 + .801{*}x_4 + \varepsilon$$

$$\hat{y}_{S1} = 16 + .016{*}x_1 + .176{*}x_4 + \varepsilon \qquad \text{(model 5a)}$$

$$\hat{y}_{S2} = 43 - .188{*}x_1 + .937{*}x_4 + \varepsilon.$$

In Study 1, economic system justification was not significantly associated with amygdala volume in either Model 5 (b = .195, SE = .208, β = .07, t = .93, p = .36) or in Model 5a (b = .176, SE = .256, β = .06, t =.69, p = .50), in which ideology was also not a significant predictor (b = .016, SE = .125, β = .01, t =.13, p = .90). However, in Study 2, economic system justification was positively associated with amygdala volume in both Model 5 (b = .801, SE = .276, β = .23, t = 2.91, p = .006) and Model 5a (b = .937, SE = .296, β = .27, t = 3.17, p = .003), in which ideology continued not to be a significant predictor (b = -.188, SE = .154, β = -.10, t = -1.23, p = .23).

Model 6 tested for the effect of general system justification extremity in addition to general system justification, and Model 6a added ideology.

$$\hat{y}_{S1} = 18 + .302{*}x_3 - .343{*}x_5 + \varepsilon \qquad \text{(model 6)}$$

$$\hat{y}_{S2} = 42 + 1.018{*}x_3 - .133{*}x_5 + \varepsilon$$

$$\hat{y}_{S1} = 18 + .022{*}x_1 + .283{*}x_3 - .361{*}x_5 + \varepsilon \qquad \text{(model 6a)}$$

$$\hat{y}_{S2} = 18 - .287{*}x_1 + 1.239{*}x_3 - .131{*}x_5 + \varepsilon.$$

In Study 1, no effects reached conventional levels of statistical significance, although general system justification approached marginal significance (b = .302, SE = .185, β = .12, t = 1.63, p = .11), whereas system justification extremity did not (b = -.343, SE = .296, β = -.08, t = -1.16, p = .25) in Model 6, as well as in Model 6a (general system justification: b = .283, SE = .209, β = .11, t = 1.35, p = .18; system justification extremity: b = -.361, SE = .312, β = -.09, t = -1.16, p = .25; ideology: b = .022, SE = .109, β = .02, t = .21, p = .84). In Study 2, general system justification emerged as positively associated with amygdala volume (b = 1.018, SE = .360, β = .31, t =2.83, p =.007) to a greater extent than system justification extremity (b = -.133, SE = .441, β = -.03, t = -.30, p =.77) in Model 6 as well as 6a (general system justification: b = 1.239, SE = .361, β = .38, t = 3.44, p = .001; system justification extremity: b = -.131, SE = .423, β = -.03, t = -.31, p = .76; ideology: b = -.287, SE = .136, β = -.15, t = -2.11, p = .04).

Finally, in Model 7 I tested for the effects of economic system justification and economic system justification extremity, and in Model 7a I added ideology.

$$\hat{y}_{S1} = 16 + .230{*}x_4 + .334{*}x_6 + \varepsilon \qquad \text{(model 7)}$$

$$\hat{y}_{S2} = 43 + .811{*}x_4 + .019{*}x_6 + \varepsilon.$$

$$\hat{y}_{S1} = 16 + .006{*}x_1 + .223{*}x_4 + .333{*}x_6 + \varepsilon \qquad \text{(model 7a)}$$

$$\hat{y}_{S2} = 43 - .197{*}x_1 + 1.016\ {*}x_4 + .147{*}x_6 + \varepsilon$$

Study 1 revealed that no effects were significantly associated with amygdala volume in Model 7 (economic system justification: b = .230, SE = .212, β = .08, t = 1.09, p = .28; economic system justification extremity: b = .334, SE = .339, β = .07, t = .99, p =.33), nor in Model 7a (economic system justification: $b = .223$, $SE = .261$, $\beta = .08$, $t = .86$, $p = .40$; economic system justification extremity: $b = .333$, $SE = .345$, $\beta = .07$, $t = .97$, $p = .34$; ideology: $b = .006$, $SE = .125$, $\beta = .004$, $t = .05$, $p = .96$). In Study 2 I found slightly different results, with economic system justification emerging as positively associated with amygdala volume ($b = .811$, $SE = .380$, $\beta = .23$, $t = 2.14$, $p = .04$), although economic system justification extremity was not ($b = .019$, $SE = .518$, $\beta = .004$, $t = .04$, $p = .97$) in Model 7, as in Model 7a (economic system justification: $b = 1.016$, $SE = .412$, $\beta = .29$, $t = 2.47$, $p = .02$; economic system justification extremity: $b = .147$, $SE = .525$, $\beta = .03$, $t = .28$, $p = .78$; ideology: $b = -.197$, $SE = .159$, $\beta = -.10$, $t = -1.24$, $p = .22$).

1.3 Discussion

In two studies, I found that a desire to defend and justify the existing social system as fair and legitimate was associated with larger grey matter volume in the bilateral amygdalae. To my knowledge, these studies provide the first evidence of a relationship between system justification and neuroanatomical structure. The replication of the effect in Study 2 suggests that this finding is a reliable, potentially robust one, although of course further investigation is warranted with other, even more diverse population samples. Examination of a range of regression models further suggests that a relationship between amygdala volume and political preferences may be driven in part by system-justifying preferences that may inform ideological beliefs (such as among British college students as described in Kanai et al., 2011).

Although these findings suggest that beliefs about complex constructs like social systems are reflected in basic brain structure, they do not address the "chicken-and-egg" problem of causality of whether biology precedes social and political beliefs or if social and political environments can influence biology itself (Jost, Nam, Amodio, & Van Bavel, 2014; Jost, Noorbaloochi, & Van Bavel, 2014). For instance, we cannot determine on the basis of these data whether greater volume of amygdala tissue leads one to engage in greater system justification, or whether through the course of years of justifying the existing social structures, one develops greater volume in amygdala tissue. I explore these causal relationships in the following studies.

STUDY 3

The effect of amygdala lesions on political ideology

One approach to examining a potential causal relationship between neurobiology and sociopolitical beliefs is to investigate whether a change in biology can affect ideology. People who have experienced a significant change in their biology through surgical or medical lesioning of focal areas of the brain can thus be good candidates for, in some sense, a "naturally occurring" experiment of related psychological functioning. For instance, case studies of SM, a human patient with rare focal bilateral amygdala lesions due to Urbach-Wiethe disease, have documented her apparent lack of fear responses to typically fear-inducing objects and situations (such as snakes, spiders, haunted houses, and scary movies; Feinstein, Adolphs, Damasio, & Tramel, 2011). Such studies elucidate the causal role of the amygdala in recognizing and reacting to existential threats (Adolphs, Tranel, Damasio, & Damasio, 1994; but see also Feinstein, Buzza, Hurlemann, et al., 2013 for a distinction between external vs. internal threats). Further, across a range of measures assessing general fear, anxiety, phobias, and distress, patient SM reliably reports diminished experiences of these feeling states compared to control populations (Feinstein, Adolphs, Damasio, & Tramel, 2011).

Building upon previously documented links between the amygdala and anxiety (e.g., Amaral, 2002), anxiety and ideology (e.g., Jost et al., 2003), and ideology and the amygdala (Kanai, Feilden, Firth, & Rees, 2011; see also Studies 1 and 2 above), I assessed a lesion patient sample to test the potential causal role of the amygdala in the formation of political beliefs. In this study, I investigated the possibility that patients with amygdala damage would not only exhibit lower levels of anxiety, but also report more liberal political beliefs than matched lesion controls and healthy controls.

3.1 Materials and Methods

Participants

Fifty participants (mean age = 39.9 years; 26 female; 33 White/European-American, 9 Black/African-American, 4 Asian/Asian-American, 4 Latino/Hispanic) were recruited from the Patient Registry for Studies in Perception, Emotion, and Cognition (PROSPEC) at New York University. This patient registry comprises both patients who have brain tissue damage (often from surgical intervention to address a variety of medical conditions such as tumors or epileptic seizures) and healthy control subjects with intact brain tissue. The study was approved by the University Committee on Activities Involving Human Subjects (UCAIHS) at NYU, and all participants provided written informed consent.

Using masks created by trained neuropsychologists, the lesion patients were classified by their primary tissue damage. This procedure classified 15 amygdala lesion (AL) patients and 17 lesion control (LC) patients with frontoparietal damage (but no amygdala damage). Eighteen healthy control (HC) subjects with no brain damage were also recruited from the registry. These three classifications served as "natural" experimental groups, which (following dummy coding) were matched for age (F(2,47) = .74, p = .49), sex (F(2,47) = .68, p = .51), years of education (F(2,47) = .14, p = .87), and overall IQ (F(2,47) = .45, p = .64).

Procedure

As part of a general battery of questionnaires given to all participants in the NYU patient registry, the participants in this study responded to surveys assessing psychological characteristics and political ideology administered by a trained neuropsychologist (see Table 8 for behavioral measure correlations).

Political ideology. Participants reported their political ideology using self-placement items ranging from 1 (*extremely liberal*) to 6 (*neither*) to 11 (*extremely conservative*). They reported ideological self-placement in general ("Where on the following scale of political orientation would you place yourself (overall, in general)?"), as well as on social ("In terms of social and cultural issues, how liberal or conservative are you?") and economic ("In terms of economic issues, how liberal or conservative are you?") dimensions. On average, participants were slightly liberal in general (M = 4.77, SD = 2.24), socially (M = 4.38, SD = 2.57), and economically (M = 5.49, SD = 2.75).

Religiosity. Participants were asked about their religiosity with a single item ("How important are your religious beliefs?") from 1 (*not at all important*) to 7 (*extremely important*). They reported their religious beliefs as being moderately important on average (M = 4.40, SD = 2.08).

Anxiety. Chronic anxiety was assessed with the 21-item Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988; α = .86). Anxiety-related symptoms are assessed with ratings of a variety of physical and psychological symptoms related to fear and panic (e.g., numbness or tingling, feeling hot, wobbliness in legs, heart pounding or racing, terrified, nervous, fear of the worst happening) from 0 (*not at all*) to 3 (*severely, I could barely stand it*) during the preceding week. The average anxiety score was 5.10 (SD = 5.94), which is classified as in the range of low anxiety (i.e., scores between 0 and 21). There was a trend of lower levels of anxiety being associated with greater general conservatism, which was not significant, $r(48) = -.12$, $p = .39$, but was consistent with a wider range of negative (vs. positive) effects, 95% CI(r) = {-.39, .16}.

3.2 Results

In order to compare psychological and political outcomes between people with different types of brain lesions or no lesions within a regression framework, I created dummy codes for each of the lesion type groups to flexibly assign a reference group in different analyses for targeted pairwise comparisons. Specifically, the dummy variable for the amygdala lesion group coded AL patients as 1 and the LC and HC groups both as 0; the dummy variable for the lesion control group coded LC patients as 1 and the AL and HC groups both as 0; and the dummy variable for the healthy control group coded HC subjects as 1 and the AL and LC groups both as 0.

Previous findings on amygdala lesion patients have not only demonstrated that damage to the amygdala alters affective responding to uncertainty and threat, but patient SM has also been found to report much lower levels of anxiety (as measured by the Beck Anxiety Inventory) compared to controls (Feinstein, Adolphs, Damasio, & Tramel, 2011). Therefore I first tested for differences between amygdala lesion patients and controls on anxiety. With the LC group as the reference group (i.e., coded 0), I entered the dummy-coded AL and HC groups into a regression predicting anxiety levels (i.e., BAI scores). There was a significant difference between groups ($F(2,47) = 10.67$, $p < .001$), and lesion classification (i.e., AL, LC, HC) accounted for 31.2% of the variance in anxiety ($R^2 = .312$, $p < .001$). Specifically, amygdala lesion patients ($M = 3.27$) reported significantly less anxiety than lesion control patients ($M = 9.65$), $b = -6.38$, $SE = 1.78$, $t(47) = -3.58$, $p = .001$, 95% CI = {-9.97, -2.80}. Healthy control subjects ($M = 2.33$) also reported less anxiety than lesion control patients, $b = -7.31$, $SE = 1.70$, $t(47) = -4.30$, $p < .001$, 95% CI = {-10.74, -3.89}. However, healthy controls and amygdala lesion patients did not differ on anxiety levels, $b = .93$, $SE = 1.76$, $t(47) = .53$, $p = .60$, 95% CI = {-2.60, 4.47}(with the HC group as the reference group for this comparison).

Next, I tested whether lesion type had an effect on political ideology. I entered the dummy coded AL and HC groups (with LC as the reference group) into a regression model predicting general political ideology. Lesion type explained 5.6% of the variance in political ideology ($R^2 = .056$), but the effect was not significant, $F(2,47) = 1.40$, $p = .26$. Likewise, although pairwise comparisons were not significant, I did observe that the direction of mean differences suggested that amygdala lesion patients tended to be more liberal ($M = 4.47$) than lesion control patients ($M = 5.5$), $b = -1.03$, $SE = .79$, $t(47) = -1.31$, $p = .20$, which was supported by the 95% confidence interval (-2.62, .55) indicating that the range of differences supported by the data skewed in the more liberal (i.e., more negative) direction for amygdala lesion patients. Similarly, the political orientation of healthy control subjects ($M = 4.33$) trended (albeit not significantly) toward greater liberalism than lesion control patients, $b = -1.17$, $SE = .75$, $t(47) = -1.55$, $p = .13$, 95% CI = {-2.68, .35}. And amygdala lesion patients and healthy controls exhibited similar levels of liberalism, $b = .13$, $SE = .78$, $t(47) = .17$, $p = .87$, 95% CI = {-1.43, 1.70}.[3,4]

In order to account for the differences in anxiety between lesion type groups (as well as the negative, albeit non-significant, relationship between anxiety and conservatism in this sample), I next assessed the effect of lesion type on political ideology after adjusting for the effects of anxiety. To this end, I entered anxiety scores (centered at the mean) and lesion type (dummy coded AL and HC, reference group LC) into a hierarchical regression model predicting general political ideology. As noted previously, anxiety (entered at step 1) did not have a significant overall effect on political ideology, $R^2 = .015$, $b = -.05$, $SE = .05$, $t(48) = -.87$, $p = .39$, 95% CI = {-.16, .06}. However, lesion type (entered at step 2) had a significant effect on political ideology ($F(3,46) = 2.74$, $p = .054$; see Figure 4) and explained significantly more variance in ideology above and beyond anxiety ($\Delta R^2 = .15$, $F(2,46) = 3.70$, $p = .03$). Specifically, at mean levels of anxiety amygdala lesion patients were significantly more liberal (*adjusted M* = 4.21) than lesion control patients (*adjusted M* = 6.14; $b = -1.93$, $SE = .85$, $t(46) = -2.27$, $p = .03$), but not compared to healthy control subjects (*adjusted M* = 3.94; $b = .27$, $SE = .75$, $t(46) = .35$, p

[3] Parallel tests of the effect lesion type on social ($F(2,47) = .18$, $R^2 = .008$, $p = .83$) and economic political orientation ($F(2,47) = 1.26$, $R^2 = .051$, $p = .29$) yielded similar results to general political orientation. Because I did not have specific hypotheses regarding domain-specific political ideology departing from general political ideology, I did not assess these effects further.

[4] Although not a focus of my investigation, I also explored whether lesion type had an effect on the importance of another type of belief system—religion. I found no effect of lesion type on religiosity, $F(2,47) = .57$, $R^2 = .024$, $p = .57$. For the researcher particularly interested in religious beliefs, this null effect may not be necessarily discouraging, however. The way participants were asked about their religious beliefs (“How important are your religious beliefs?”) did not directly assess the nature of their religious beliefs (e.g., Christian, Jewish, Muslim, Buddhist, perhaps even atheist, etc.) or the degree to which subjects participated in organized religion. Future tests more directly probing religiosity would certainly be preferable.

= .73). Lesion control patients were significantly more conservative than both the amygdala lesion patients and the healthy controls (b = 2.20, SE = .85, $t(46)$ = 2.58, p = .01) at mean levels of anxiety.[5]

3.3 Discussion

In this "natural" experiment, I found that amygdala lesion patients reported greater liberalism compared to frontoparietal (control) lesion patients at equivalent levels of anxiety. Amygdala lesion patients were equally as liberal as healthy control subjects who had no history of brain damage. These findings suggest that the amygdala plays a potentially important role in the formation of political beliefs insofar as damage to this brain structure seems to alter political beliefs compared to the effect of damage to other areas of the brain.

If it is indeed the amygdala that modulates anxiety and subsequent ideology, given that neither healthy control subjects nor lesion control patients have amygdala damage, one might expect that amygdala lesion patients should not only exhibit lower levels of anxiety but also express greater liberalism than *both* other groups. Indeed, with total bilateral amygdala damage, patient SM exhibited notably lower levels of anxiety compared to healthy control subjects (Feinstein, Adolphs, Damasio, & Tramel, 2011). However, unlike patient SM, all the amygdala lesion patients in this sample had only partial amygdala damage, so some amygdala tissue (and presumably function) was preserved. Moreover, a category of experience that the amygdala lesion and frontoparietal lesion patients share (but that the healthy controls do not) is a

[5] There was no interaction effect of lesion type and anxiety (Anxiety × AL dummy variable: b = .09, SE = .30, $t(44)$ = .29, p = .78; Anxiety × LC dummy variable: b = .01, SE = .21, $t(44)$ = .05, p = .96). I therefore did not explore potential pairwise effects further.

presumably stressful or even traumatic medical diagnosis accompanied by brain damage (either from a medical event or surgical intervention). Such events related to brain damage and experiences following the tissue damage (such as potential changes to self-perceptions or feelings of self-efficacy) could have a global amplifying effect on an individual's anxiety levels. (It should be noted that in this sample participants were matched on education level and general intelligence, although that doesn't preclude varying self-perceptions.) That is, one might reasonably expect brain damage patients to have heightened levels of anxiety compared to healthy people in general. If that is the case, then perhaps some degree of amygdala damage provides, in some sense, a "buffering" effect against heightened anxiety from brain trauma that makes amygdala lesion patients look like healthy individuals in terms of anxiety levels and ideology.

Another puzzling aspect of these results—given previous theorizing regarding the relationship between existential concerns (such as anxiety) and ideology (Jost et al., 2003)—lies in the absence of a clear relationship between anxiety and conservatism. In fact, although it was non-significant, the trending direction of the relationship between anxiety and ideology in the current sample was heightened anxiety accompanying more liberal orientation ($r(48) = -.12$, $p = .39$), which stands in contrast to other findings linking heightened anxiety to conservatism (e.g., Jost et al., 2003; Oxley et al., 2008). I speculate that this somewhat surprising (null) effect may have obscured an otherwise straightforward relationship between lesion type, anxiety, and political ideology. At the same time, I am open to the possibility that this null effect belies a potentially more interesting, dynamic relationship between anxiety and ideology. Heightened existential needs to manage anxiety may attract people to system-justifying, conservative ideology in part because it serves a palliative function by legitimizing the familiar status quo, which in turn helps to diminish anxiety and distress (Jost & Hunyady, 2002; Jost & Hunyady, 2005; Napier & Jost, 2008; Napier, Thorisdottir, & Jost, 2010). That is, perhaps the experience of brain trauma increases general anxiety, which is alleviated in part among frontoparietal lesion patients through subscribing to (relatively) more conservative beliefs. In contrast, in amygdala lesion patients the reduction in amygdala tissue itself exerts a diminishing effect on anxiety, which obviates a heightened need for ideological coping. Because in this study both anxiety and political ideology were measured at the same time (and after lesion onset), it is difficult to disentangle the potential dynamic relationship between these factors. Future work could focus on this dynamic component more directly, potentially by examining a) whether situationally induced anxiety leads to more conservative beliefs in healthy people and lesion control patients but not in amygdala lesion patients, and b) whether presenting (conservative) rationalizations of the status quo alleviates anxiety in healthy people and lesion control patients, but not in amygdala lesion patients.

Finally, although this study represents one approach to examining causal relationships between biology and political preferences, it only tests the nature of the relationship in one direction: brain to ideology. Therefore, in the final study, I explored the potential influence of social and political environments on brain structure.

STUDY 4

A longitudinal investigation of the development and relationship of ideological beliefs, system justification, and brain structure

The Bennington College study was a landmark study examining the development of social and political attitudes during an important period of attitudinal change and influence in late adolescence. Newcomb (1943) measured college students' political attitudes when they were incoming freshmen at Bennington College and again when they were outgoing seniors. Because the students came from largely conservative families and Bennington College was characterized by largely liberal faculty, the setting provided an opportunity to examine social influence on attitudes in young adults. At the end of their four years in college, the students generally reported more liberal attitudes than at the beginning, particularly for those who had been very active in the college community and desired independence from their families. Notably, the political attitudes that the students developed during their years in college were stable even 20 and 50 years later, suggesting that early adulthood (and perhaps particularly the college experience) is a critical period of influence, development, and crystallization of important social and political attitudes for the adult lifespan (Newcomb, Koenig, Flacks, & Warwick, 1967; Alwin, Cohen, & Newcomb, 1991).

Following in the tradition of the Bennington College study, Study 4 followed NYU students from their freshman to senior years of college to examine the psychological and neurobiological processes and structures that undergird ideological preference formation. Specifically, I conducted a prospective, longitudinal study of young adults designed to examine the interplay between brain structure and the expression of political ideology and system justification tendencies. There are several reasons to focus on this time period: a) individuals in late adolescence and early adulthood are especially "impressionable" when it comes to political attitudes (Alwin & Krosnick, 1991), b) many ideological preferences are crystallized during the first election in which individuals vote, which is often shortly after turning 18 (Sears & Valentino, 1997), c) college students tend to possess cognitive abilities and motivational resources that facilitate "ideological" reasoning (Highton, 2009), and d) this age range includes a critical biological period of neural plasticity in which the prefrontal cortex is still developing (Gogtay et al., 2004). To my knowledge, this is the first investigation of its kind in examining the (bi)directional relationship of biology and ideology in adults in a timeframe particularly important for ideological and neurobiological development.

The college experience can in many ways serve as a training exercise in not only developing critical thinking faculties but also in acquiring knowledge and contact with ideologically relevant content. Depending on the types of exposure a student has to courses and social activities, their ideological preferences and perhaps even brain structure may be shaped importantly for the course of their lives (Newcomb, 1943; Alwin, Cohen, & Newcomb, 1991; Lottes & Kuriloff, 1994). For instance, Guimond (1999) found that at a military college, students overall expressed more conservative views at the end of their educational experience than at the start. But there was a moderation by college major such that students who majored in engineering became significantly more conservative than those who had majored in the humanities or social sciences. Similarly, I expected that majoring in disciplines typically characterized by relatively more liberal faculty, such as the social sciences or humanities (Hamilton & Hargens, 1993; Guimond, 1999; Zipp & Fenwick, 2006), would not only lead students to espouse more liberal, less system-justifying beliefs at the end of their college years, but also potentially exhibit decreases in grey matter volume in the amygdala. In contrast, I expected that students majoring in fields characterized by relatively more conservative faculty, such as business or economics (Hamilton & Hargens, 1993; Zipp & Fenwick, 2006) will lead students to espouse relatively more conservative, system-justifying beliefs at the end of their college years alongside potential increases in grey matter volume in the amygdala.

To address these questions, I designed a neuroimaging study with longitudinal measurements of both brain structure and social and political beliefs. I followed up with a cohort of participants from Study 1 (whose brains were scanned in their freshman year) in their senior year to assess potential changes in their brain structure and ideological, system-justifying preferences. I hypothesized that changes in ideological beliefs (presumably as a function of experiences in college) would be accompanied by changes in neuroanatomical structure (focusing on the amygdala but also exploring other focal brain regions such as the ACC and insula following Kanai et al., 2011), suggesting that ideological socialization can affect basic biological processes in young adults.

4.1 Materials and Methods

Participants

I recruited 21 participants (all right-handed, 12 female[6]) from the previous sample of New York University undergraduates whose data I initially collected when they were freshmen between fall 2011 and spring 2012 (Time 1; Study 1). These participants had previously

[6] One participant identified as male at Time 1 and identified as transgender female at Time 2. I chose to categorize this participant's sex as male for the MRI processing and analyses for two primary reasons: 1) I did not have access to information about her transition status or other biological and medical history, and 2) there is a dearth of empirical research on potential differences in the brain structure of transgender vs. cisgender individuals. Therefore I decided that a participant's biologically assigned sex (i.e., Time 1 identification) was a reasonable designation for the purposes of adjusting for the effects of sex on brain structure.

indicated in Study 1 that they would be interested in participating in follow-up studies. For the current component of the project, the participants were mostly college seniors shortly before or after graduation (mean age = 21.95 years), with data collection occurring in the spring and summer of 2015 (Time 2). The average time difference between the two scans was 3.02 years (SD = .28). Participants were pre-screened to exclude those who reported a history of neurological problems or were not English speakers, and to ensure that all participants had normal or corrected-to-normal vision. The study was approved by the University Committee on Activities Involving Human Subjects (UCAIHS), the NYU Institutional Review Board, and all participants completed a metal screening checklist and provided written informed consent prior to participation. Payment for participation in this study was $60.

Because not all participants from Time 1 came back for the Time 2 study, I compared those who had only participated at Time 1 with those who participated at Time 2 to assess whether the two subsamples differed substantially. I found that the two subsamples did not differ in age ($t(47) = .97$, $p = .34$), gender ($t(47) = .25$, $p = .81$), or political orientation ($t(47) = -.31$, $p = .76$). It should be noted that at Time 1, participants were preselected to represent the full spectrum of ideology (and minimize the typically observed liberal skew in college participants). Despite the fact that I obtained a smaller sample size at Time 2 than at Time 1, the lack of ideological difference between the two groups indicates that the ideological balance was maintained at Time 2.

Procedure

Participants arrived to the scan center for a study titled "Scanning Social Judgments and Decisions 2". I administered a resting state structural MRI scan to each individual participant and they responded to a questionnaire following the scan session.

I collected individual difference measures outside of the scanner. Some were measures of ideology and psychology/personality that were also collected from participants at Time 1, which helps to assess changes across the college term, but I also administered some new measures that address more recent political activity, as well as the students' college majors to assess whether potential changes are related to the ideological leanings of their academic experiences. Correlations between the Time 2 individual difference measures are reported in Table 9.

The following measures were collected at both Time 1 and Time 2:

System justification. Participants responded to the 8-item general system justification scale (Kay & Jost, 2003; $\alpha = .90$) assessing their confidence in and desire to justify and defend the existing social, economic, and political arrangements on a numeric scale ranging from 1 (*strongly disagree*) to 9 (*strongly agree*; see Study 1 for example statements). At Time 2, participants' mean system justification score was 4.21 ($SD = 1.38$).

Political ideology. General political orientation was measured by self-placement on an 11-point scale ranging from 1 (*extremely liberal*) to 11 (*extremely conservative*). At Time 2, participants reported being very slightly liberal overall, with an average score just below the midpoint (i.e., *neither liberal nor conservative*) of 5.24 ($SD = 2.51$).

Need for cognition. I also administered the 18-item *Need for Cognition* scale (Cacioppo et al., 1984; $\alpha = .88$), which assesses a person's tendency to engage in and enjoy effortful cognitive activity. Participants indicated how much they agreed on a 5-point scale ranging from 1 (*extremely uncharacteristic*) to 5 (*extremely characteristic*) on statements such as “I really enjoy a task that involves coming up with new solutions to problems,” and “I only think as hard as I have to” (reverse-scored). At Time 2, the average need for cognition score was 3.69 (SD = .60). (Note that I obtained Time 1 need for cognition measures from a larger battery of questionnaires in which all participants at that time had taken.)

Personality. I assessed participants’ personality traits using a 10-item scale of the Big Five personality domains (Gosling, Rentfrow, & Swann, 2003). This measure assesses each of the “Big Five” personality dimensions with two items rated from 1 (*disagree strongly*) to 7 (*agree strongly*): extraversion (e.g., “I see myself as extraverted, enthusiastic”; M = 4.45, SD = 1.60; α = .84,), agreeableness (e.g., “I see myself as critical, quarrelsome” (reverse-scored); M = 4.60, SD = 1.23; α = -.17[7]), conscientiousness (e.g., “I see myself as dependable, self-disciplined”; M = 4.52, SD = 1.54; α = .64), emotional stability (e.g., “I see myself as anxious, easily upset” (reverse-scored); M = 4.19, SD = 1.36; α = .61), and openness to experience (e.g., “I see myself as open to new experiences, complex”; M = 6.05, SD = 1.01; α = .84).

The following are new measures that I collected only at Time 2:

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[7] The negative reliability score (i.e., Cronbach’s α) is likely due to the small sample size (N = 21) and small number of items (N = 2) included in the score computation, under which conditions sampling error can produce a negative average covariance—that is, the sum of the individual item variances is greater than the scale variance—that leads to a negative α (Lord & Novick, 1968). The reader may also be concerned with the low alphas of the conscientiousness and emotional stability measures, but the authors of the short Big Five scale (Gosling, Rentfrow, & Swann, Jr., 2003) note that this brief measure was created to optimize validity but not ensure high alphas, and that researchers who do not have a primary theoretical interest (as is the case here) should be comfortable using this brief scale.

Social and political policy attitudes. I assessed participants' attitudes toward a number of public policy issues and social movements, focusing on issues that were of particular contemporary relevance (some items adapted from Hennes, Nam, Stern, & Jost, 2012). Participants indicated their agreement or disagreement with each statement on a scales ranging from 1 to 7 (and these endpoints were labelled according to each statement) for the following topics:

- Tea Party: "The Tea Party movement is a populist movement that endorses reduced government spending, opposition to taxation in varying degrees, reduction of the national debt and federal budget deficit, and which tries to adhere to the original meaning and intent of the Constitution. Do you generally approve or disapprove of the Tea Party political movement?" (1 = *strongly disapprove* to 7 = *strongly approve*; *M* = 2.95, *SD* = 1.91)
- Occupy Wall Street: "Occupy Wall Street is a protest movement against social and economic inequality, greed, corruption, and the undue influence of corporation on government—particularly from the financial services sector. Do you generally approve or disapprove of Occupy Wall Street and occupy movements in other cities?" (1 = *strongly disapprove* to 7 = *strongly approve*; *M* = 5.24, *SD* = 1.73)
- Health care policy ("Obamacare"): "As you may know, in 2010 Barack Obama and Congress passed a law that restructures the nation's healthcare system, which requires nearly all Americans to have health insurance. Under this law, people who cannot afford insurance receive financial help from the government while people who do not

buy insurance pay a penalty. All in all, do you approve or disapprove of this law?" (1 = *strongly disapprove* to 7 = *strongly approve*; *M* = 5.19, *SD* = 1.83)

- Governmental regulation: "In general, do you think there is too much, too little, or about the right amount of government regulation of business and industry?" (1 = *too little*, 4 = *right amount*, 7 = *too much*; *M* = 2.95, *SD* = 1.80)
- Abortion: "With respect to abortion policy, would you consider yourself to be pro-choice or pro-life?" (1 = *definitely pro-choice* to 7 = *definitely pro-life*; *M* = 1.81, *SD* = 1.60)
- Same-sex marriage: "Do you think marriages between same-sex couples should or should not be recognized by the law as valid, with the same rights as traditional marriages?" (1 = *definitely should not be valid* to 7 = *definitely should be valid*; *M* = 6.29, *SD* = 1.65)
- Immigration: "In your view, should immigration be kept at its present level, increased, or decreased?" (1 = *greatly decreased*; 4 = *kept at its present level*; 7 = *greatly increased*; *M* = 4.86, *SD* = 1.39)
- Climate change was assessed by averaging responses to three items: "Do you believe that climate change is occurring?"; "Do you believe that climate change is anthropogenic (caused by human behavior)?"; "Do you believe that there is strong scientific evidence that climate change is occurring and man-made?" (1 = *definitely not* to 7 = *definitely*; *M* = 6.30, *SD* = 1.12; α = .88)

Participation in protests. As an index of political behavior in the form of collective action, I asked students about their participation in protests since entering college ("Have you engaged in protest activities while in college?") to which their response was binary (i.e., *Yes* or *No*). If participants indicated that they had engaged in protest activities, I also asked them to specify the type of protest. Nine participants indicated participating in a protest during college and 12 indicated that they had not. Of those who reported participating in a protest, they indicated that they had participated protests on Occupy Wall Street ($N = 4$), Black Lives Matter ($N = 3$), the Climate Change March ($N = 3$), and against rape and sexual violence ($N = 1$). Notably, no participants indicated engaging in collective action for explicitly conservative causes, such as the Tea Party movement.

Academic experience. Finally, in order to assess the effect of students' college academic experiences on potential subsequent changes to their ideology and brain structure, I asked participants to report their college major. The purpose of this measure was to examine how students' academic experiences can serve a socialization role in ideological development. To that end, I obtained ratings of the perceived political orientation of each stated major from an independent sample ($N = 200$) through Amazon Mechanical Turk. These independent raters indicated how liberal or conservative in content they perceived each college major to be on a scale from 1 (*extremely liberal*) to 11 (*extremely conservative*). On average, the students' college majors were rated as somewhat liberal ($M = 4.63$, $SD = 1.29$; see Table 10 for list of all college majors and ideological ratings). These independent ratings also generally mapped onto previous work categorizing different fields of study in terms of ideology (Hamilton & Hargens, 1993; Guimond, 1999; Zipp & Fenwick, 2006). For example, subjects such as literature ($M = 4.17$) and psychology ($M = 5.03$) were rated as relatively more liberal than subjects such as economics ($M = 8.15$) and computer science ($M = 6.82$). If students reported majoring in more than one subject (i.e., double majors), I computed the average of the two subjects' ideological ratings to assign them a college major ideological score.

MRI Data Acquisition

For their second MRI scan, participants were again run on the 3T Siemens Allegra head-only scanner at the NYU Center for Brain Imaging using the Siemens standard head coil. To reduce measurement error in assessing structural change, the same imaging parameters were used as in Time 1 (Study 1). Anatomical images were acquired using a T1-weighted protocol (MPRAGE sequence, 256 × 256 matrix, 176 1-mm sagittal slices). I obtained oblique-axial slices parallel to the anterior commissure–posterior commissure line.

MRI Analysis Procedures

I used voxel-based morphometry (VBM) to analyze structural change of grey matter (Ashburner & Friston, 2000).

MRI pre-processing. An important requirement for longitudinal studies of brain structure is that within-subject, a voxel in one location at time 1 should be aligned with the same location imaged at time 2 (in addition to the requirement that between subjects, each brain also needs to be aligned with the others included in the analysis). In previous work assessing structural changes of grey matter (e.g., Draganski et al., 2004; Hölzel et al., 2010; Hölzel et al., 2011), the typical approach has been to align time 2 scans to time 1 scans. However, this approach has been criticized for introducing different levels of interpolation-related changes that can manifest as confounded effects, as results for longitudinal structural differences can depend even on which time point scan is used as the reference (Thomas & Baker, 2013). It has therefore been suggested that aligning the two time point scans to their within-subject midpoint removes asymmetries in the alignment algorithm, making it a preferable approach for assessing structural change (Thomas et al., 2009; Thomas & Baker, 2013; Rohrer et al., 2013).

Given these concerns, I used newly available tools in SPM12 (Wellcome Department of Cognitive Neurology, London, United Kingdom; www.fil.ion.ucl.ac.uk/spm/software/; Ashburner & Ridgway, 2013) that incorporates the improved alignment procedure to pre-process the anatomical data. I followed guidelines in the SPM12 Manual (p. 199, Chapter 27 "Longitudinal Registration") as well as discussions on the SPM user mailing list (https://www.jiscmail.ac.uk/cgi-bin/webadmin?S1=spm) addressed by the developer of VBM techniques and SPM12, John Ashburner (Ashburner & Friston, 2000; Ashburner & Ridgway, 2013). Specifically, I entered Time 1 and Time 2 T1-weighted MR images for each subject into a pairwise longitudinal registration procedure, which is based on inverse-consistent alignment between first and second scans and incorporates a bias field correction and rigid-body transform. This procedure accounts for the time difference between scans in the alignment, so I entered a vector of time differences in years computed for each subject. I designated noise estimates based on fitting two Rician distributions to the intensity histogram of each of the images, which assumes that the residuals (after fitting the registration model) are i.i.d. Gaussian. I set the warping regularization to its default setting (0 0 100 25 100) and the bias regularization parameter to its default (1000000). This registration process produced mid-point average images (between Time 1 and Time 2), as well as maps of the differences between Jacobian determinants (divided by the time interval) of the deformation field. The Jacobian difference maps indicate the rate of contraction (values less than 0) and expansion (values greater than 0).

I then segmented the mid-point average images into white and grey matter images. Using images generated from the segmentation process, I computed a product of the grey matter average image and their corresponding Jacobian maps (from the longitudinal registration) to generate an image mapping the amount of contraction and expansion in grey matter across each individual's brain (using the ImCalc function in SPM12).

Next, I aligned the average grey matter images (multiplied by their corresponding Jacobian difference maps) across subjects using diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL). I smoothed the registered images with Gaussian kernel of 10 mm full-width half-maximum. I chose a smaller kernel for the longitudinally registered images than the single time-point data in Study 1 (12 mm) because intrasubject registration over time is much more accurate than intersubject normalization and the amount of smoothing can be decreased for more accurately aligned images. I then transformed the smoothed images to the Montreal Neurological Institute (MNI) stereotactic space using affine and nonlinear spatial normalization. The value of grey matter volume therefore represented the volume of tissue expansion or contraction per unit of spatially normalized image (in arbitrary units)—that is, a "difference" image between the two time points. Total volume changes across the whole brain were computed from the segmented images for each participant.

Whole brain analyses. I entered the smoothed, normalized difference images into a multiple regression model across the participants. I fit separate models for change in ideology (Time 2 – Time 1 political ideology), change in system justification (Time 2 – Time 1 system justification), and ideological orientation of college major to estimate a relationship between these variables and change in grey matter volume. Across these models, I included the regressors of sex, age, and overall brain volume change as covariates of no interest following guidelines in previous work (Barnes et al., 2010). In the SPM regression model framework, a mask is typically applied to determine a threshold at which voxels should be included in the analysis (to help correct for the multiple comparison problem). With single time-point VBM analysis, the masking threshold is usually set at an absolute value of 0.1 or 0.2. However, for analyses of structural change, thresholds such as these may be overly restrictive masks (and can lead to false negatives), as potentially interesting voxels may be excluded from statistical analysis. Therefore, using the SPM Masking Toolbox (http://www0.cs.ucl.ac.uk/staff/g.ridgway/masking/), I created and applied an explicit mask that "objectively selects a threshold for the average image which optimizes an intuitively reasonable objective function" in which the threshold maximizes the correlation between the average image and the voxels exceeding the threshold (Ridgway et al., 2009). Voxels positively related to the variables of interest were thresholded at a statistical criterion of $p < .001$ (uncorrected) with a minimum cluster of 10 voxels.

ROI analyses. In addition to whole brain analyses, I also examined volume difference values in targeted regions of interest using tools within SPM12. I examined grey matter volume change separately for the left and right amygdala using ROI masks based on the Harvard-Oxford subcortical structural atlas implemented in the Oxford University Centre for Functional MRI of the Brain Software Library (http://www.fmrib.ox.ac.uk). Other ROIs that I explored were defined as spheres with a radius of 20 mm centered at x = -3, y = 33, z = 22 for the ACC, x = -38, y = -16, z = -2 for the left insula, and x = 38, y = -16, z = -2 for the right insula (Kanai et al., 2011).

4.2 Results

Ideological and psychological change. I first assessed changes in the individual difference measures administered to participants at both time points. To this end, I ran paired t-tests (two-tailed) to compare Time 1 and Time 2 measures within subjects.

Participants were significantly more liberal at the end of college (Time 2; M = 4.43, SD = 2.34) than at the beginning of college (Time 1; M = 5.24, SD = 2.51), $t(20) = -2.16$, $p = .04$. There was also a slight trend toward lower system justification tendencies at the end of college (M = 4.01, SD = 1.40) than at the beginning (M = 4.21, SD = 1.38), although the change was not statistically significant, $t(20) = -.98$, $p = .34$.

The only personality trait on which students reported change over the college term was conscientiousness, which decreased from their freshman year (M = 5.10, SD = 1.26) to their senior year (M = 4.52, SD = 1.54), $t(20) = -2.27$, $p = .04$.[8] Students did not report changes in other dimensions of their personality, across the domains of extraversion ($t(20) = -1.10$, $p = .29$), agreeableness ($t(20) = -.98$, $p = .34$), emotional stability ($t(20) = -.17$, $p = .87$), and openness to experience ($t(20) = .36$, $p = .72$).

Students also reported similar degrees of need for cognition across time, $t(20) = -.56$, p = .58.

Time 1 brain structure predicting Time 2 political attitudes and behavior. Next I sought to understand if the causal direction tested initially in Study 3 (i.e., brain to political preferences)

[8] Although a decrease in conscientiousness (along with decreased conservatism) is consistent with previous findings linking greater conscientiousness to conservatism (Carney, Jost, Gosling, & Potter, 2008), it seems plausible that students were also exhibiting classic signs of "senioritis" (i.e., decrements in general performance motivation) by their final year of college.

could be supported by predicting political attitudes and behaviors at the end of college from students' brain structure at the beginning of college. To assess this relationship, I entered Time 1 average amygdala grey matter volume (adjusting for age, gender, and global brain volume) in a range of multiple regression models predicting various political outcomes detailed below. It should be noted that the Time 1 brain images for the longitudinal sample were preprocessed using the same parameters as in Study 1 (in SPM8), a process that was separate from the within-subject longitudinal processing described for this study. I also rescaled the amygdala volume values by a factor of 100 to reduce their inflated impact (due to the extremely narrow range of values before rescaling) on the regression coefficient estimates. This does not change the outcome of the statistical tests.

Amygdala volume at the beginning of college was not related to political ideology at the end of college (adjusting for Time 1 political ideology, in addition to the adjustment variables mentioned above), $b = .28$, $SE = .41$, $t(15) = .69$, $p = .50$. On the other hand, students' freshman year amygdala size did marginally predict their system justification tendencies at the end of college, such that larger amygdala volume at Time 1 was related to somewhat higher system justification tendencies at Time 2 (adjusting for Time 1 system justification in addition to the other adjustment variables), $b = .32$, $SE = .17$, $t(15) = 1.89$, $p = .08$.

Larger amygdala volume at Time 1 predicted greater support for the Tea Party at Time 2 ($b = .69$, $SE = .28$, $t(16) = 2.43$, $p = .03$), but was not significantly related to (slightly more negative) attitudes toward Occupy Wall Street at Time 2 ($b = -.34$, $SE = .31$, $t(16) = -1.13$, $p = .28$). Time 1 amygdala volume was also not significantly related to Time 2 attitudes about the new health care policy (Obamacare), although the trend was negative, $b = -.46$, $SE = .32$, $t(16) =$

-1.45, p = .17. Judging the levels of governmental regulation in business and industry as too high (at Time 2), however, was predicted by larger amygdala volume at Time 1, b = .60, SE = .28, $t(16) = 2.13$, p = .049. The remaining public policy attitudes at Time 2 were not significantly predicted by Time 1 amygdala volume, although the non-significant estimated relationships were in the predicted directions: same-sex marriage attitudes (b = -.41, SE = .27, $t(16) = -.15$, p = .88), immigration attitudes (b = -.35, SE = .23, $t(16) = -1.53$, p = .15), and climate change (b = -.19, SE = .20, $t(16) = -.94$, p = .36), but not abortion attitudes (b = -.10, SE = .31, $t(16) = -.33$, p = .74).

To estimate the effect of amygdala volume at the start of college on subsequent political activity, I entered amygdala volume (Time 1, adjusted for age, gender, and global volume) into a binary logistic regression predicting the likelihood that students participated in protests. Strikingly, students who had larger amygdala volumes as freshmen were less likely to participate in protests in later years, b = -1.27, SE = .66, Wald $X^2(1)$= 3.69, p = .055, 95% CI (e^b): {.076, 1.026} (see Figure 5).

Changes to brain structure. Finally, I investigated whether changes in brain structure (in terms of grey matter volume) over the course of a college education corresponded with changes in political ideology, changes in system justification, and the ideological orientation of the focus of their studies—their college major.

Under whole brain analysis, there were no regions in which grey matter expansion was associated with increased conservatism (at Time 2 vs. Time 1) at a threshold of 10 voxels, $p < .001$ (uncorrected). Likewise, even with small volume correction in targeted ROIs (defined above: left and right amygdalae, ACC, left and right insulae), no structural change related to greater conservatism was evident. However, under whole brain analysis (as well as under small volume correction), increased liberalism (at Time 2 vs. Time 1) was associated with grey matter expansion in the ACC (peak voxel coordinates: x = 2, y = 18, z = 27; see Figure 6). Using extracted ROI values from the ACC (adjusted for age, sex, and global brain volume change), the relationship between change in the ACC and change in ideology was trending in a negative direction $r(19) = -.31$, $p = .17$, *95% CI* = {-.65, .14}. Intriguingly and against prediction, increased liberalism was also associated with grey matter expansion in the left amygdala under both whole brain and small volume corrected analyses (peak voxel coordinates: x = -27, y = 6, z = -26). However, examination of this relationship using extracted ROI values from the left amygdala (adjusted for age, sex, and global brain volume change) revealed that the relationship between change in the amygdala and change in ideology was negative but not significant, $r(19) = -.16$, $p = .49$, *95% CI* = {-.55, .29}. No other *a priori* ROIs tested under small volume correction were associated with increased liberalism, and all peak voxels under whole brain analyses are reported in Table 11.

Increased system justification (at Time 2 vs. Time 1) was not associated with changes in grey matter volume across the whole brain (including under small volume corrected analyses with *a priori* ROIs). Whole brain analysis of decreased system justification (at Time 2 vs. Time 1) revealed expanded volume in the left posterior cingulate (peak voxel: x = -6, y = -39, z = 24) at $p < .001$ (uncorrected; all peak voxels are reported in Table 12). No regions for which I had *a priori* hypotheses demonstrated change that corresponded to decreased system justification, even under small volume correction. Given that I did not have predictions about the posterior cingulate with respect to change in system justification, I consider this finding an exploratory one useful for future investigation. For example, activity in the posterior cingulate has previously been related to judgment of moral transgressions (Parkinson et al., 2011), evaluation of emotionally evocative stimuli (Maddock, 1999), and increases in this region have been associated with mindfulness practice in stress reduction (Hölzel et al., 2011).

And finally, I examined the potential effect of the ideological orientation of students' college majors on changes to regional grey matter volume over the course of their college education. Under whole brain analysis (and small volume correction), college majors that were rated as more conservative were positively associated with expansion in the right insula (peak voxel: x = 45, y = -8, z = 8) at $p < .001$ (uncorr.; see Table 13). Using extracted ROI values from the right insula (adjusted for age, sex, and global brain volume change), the relationship between insula volume and college major ideology was trending in the positive direction, $r(19) = .34$, $p = .13$, *95% CI* = {-.11, .67}. This result is largely consistent with the findings of Kanai et al. (2011), who discovered a link between greater left insula volume and conservatism. They speculated that because conservatives are more sensitive to disgust (e.g., Inbar, Pizarro, & Bloom, 2009) and the insula is involved in feeling disgust (e.g., Wicker et al., 2003), people with larger insula volume may be inclined toward conservative views. The current results suggest that right insula volume can increase with more conservatively-oriented coursework in college. No other ROIs of interest were associated with conservative majors, even under small volume correction. On the other hand, whole brain analysis, I found an unexpected relationship between college majors that were rated as more liberal and expansion in the right medial orbitofrontal cortex (peak voxel: x = 17, y = 38, z = -26) at $p < .001$ (uncorr.; see Table 14). Again, in the absence of a clear prediction with respect to this relationship and given the pitfalls of reverse inference, I submit this finding for more targeted future studies.

4.3 Discussion

In this longitudinal study, I continued my exploration of the “chicken-and-egg” problem of social and political neuroscience. Overall, I found that present day NYU students (similar to the Bennington College students in the 1930s and 1940s) tended to become more liberal over the course of their college years. In addition, the volume of their amygdalae at the start of college was not only related to later system justification tendencies, but it could also predict students’ participation in protest activities down the line. I also observed preliminary evidence that changes in brain structure can correspond to ideological socialization via a student’s college education. Specifically, majoring in fields rated as more conservative-leaning led to a trend toward increased grey matter volume in the right insula. Furthermore, changes in the volume of the ACC were moderately associated with increased liberalism among students across time, suggesting that a brain region important for managing uncertainty and conflict (e.g., Botvinick et al., 1999; Amodio, Jost, Master, & Yee, 2007) can exhibit plasticity that corresponds with ideological plasticity.

All the results here (including the hypothesized but null results) should be interpreted with caution for a variety of reasons. Of course, as with other typical studies of neural function and structure, there were a number of regional associations in the brain that were not predicted. I present those regions here (without excessive speculative reverse inference) to inform future studies probing these potential relationships further. It is the case that longitudinal samples are better equipped (due to increased within-subject power and greater precision of neuroanatomical alignment) than cross-sectional samples to detect small differences in brain structure (Mills & Tamnes, 2014), and my sample size is similar to other studies of structural change (e.g., Hölzel et al., 2011; Chételat et al., 2005). Nevertheless, the fact remains that N = 21 is a small sample especially for detecting what are likely small changes in brain structure. The small sample size may be a primary reason that the residuals are roughly but not very normally distributed and display some heteroscedasticity when extracted ROI values are regressed on ideology change and college major ideology in separate OLS models. Given the small sample, these violations of the model assumptions are particular reason to interpret the results cautiously. Furthermore, the resolution of structural MRI is not high enough to be able to determine what microscopic changes (e.g., axonal myelination, neuronal genesis vs. death, glial cell proliferation, etc.) might be driving the observed macroscopic, volumetric changes in neural structure, so it is still difficult to interpret the *function* of such changes (Thomas & Baker, 2013; Kanai & Rees, 2011). Although I consider this study an important first step in assessing a dynamic relationship between basic neuroanatomical structure and complex political beliefs, further work is certainly warranted.

An extension of this study might take place, for example, in a college setting that is considerably more conservative in overall orientation (such as a religious college or a military academy), which would help to better assess the structural changes in the brain that may correspond with strengthened conservative, more system-justifying beliefs. Also, many studies of brain structure change use more targeted interventions over shorter periods of time (than the typical 3-4 years of college) to compare the training intervention's effects between controls and intervention groups (e.g., Draganski et al., 2004, Hölzel et al., 2011). In the present study I used continuous individual difference measures to assess changes, but a more targeted experimental approach could potentially yield clearer and stronger results.

Despite these limitations and broad directions for future research, the current study benefited from improved techniques of image alignment and normalization, as well as examination of a sample during a critical time of ideological socialization and continuing brain plasticity. Moreover, Newcomb's Bennington College study (1943) suggests that the effect of ideological socialization of the college experience can persist over the lifetime (Alwin, Cohen, & Newcomb, 1991), and it may even be the case that the development of neural structure that corresponds to college-induced ideological change likewise has lasting effects over the lifespan. Given such potential long-term consequences, increased attention to college students' ideological formation and change during their undergraduate years appears particularly critical—and not simply to be dismissed as a convenience sample (Sears, 1986). Eagly and Chaiken (1993) rightly note that an area especially lacking in social psychological study of attitudes is a developmental perspective, and they argue that naturalistic studies such as the Bennington study (and this one, I submit) "carried out in settings in which people develop strong attitudes are badly needed to understand how attitudes crystallize and become strong" (p. 681). Overall, I suggest that these data, although preliminary, support previous findings on the ideological development brought about during college, and further indicate that the relationship between brain structure and political preferences is dynamic and mutually malleable.

GENERAL DISCUSSION

Through four studies in my dissertation research, I have sought to advance two main hypotheses. The first is that system-justifying ideological preferences share a common neural structure with basic psychological needs to manage threat, uncertainty, and social relationships. The second is that basic neural structure and higher-level social and political constructs can be mutually reinforcing in a dynamic, bidirectional causal relationship. Taken together, I believe that the studies comprising this dissertation research represent theoretical and methodological advances to understanding system justification and political processes by drawing upon neuroscientific theories and longitudinal methods that thus far have been underrepresented in the relevant literature.

In Studies 1 and 2, I found that individual differences in system justification tendencies were related to grey matter volume in the bilateral amygdalae. Specifically, increased amygdala volume was associated with more system-justifying preferences. In Study 3, I found that patients with amygdala damage reported more liberal political orientation than those with damage in other regions of the brain (i.e., frontoparietal areas) at the same levels of anxiety. Amygdala lesion patients were not different from healthy control subjects in their political ideology. And finally in Study 4, I found that trending evidence that increased liberalism in students at the end of their college years (vs. at the start) was associated with expanded grey matter volume in the ACC as well as the right amygdala. Students who had majored in fields that were rated as more conservative exhibited increases in grey matter within the right insula.

A wealth of neuroscientific evidence points to the amygdala as a brain structure whose primary function is judging the motivational relevance (often on dimensions of threat and uncertainty) of environmental targets, perhaps especially in social contexts (see Adolphs, 2010 for a review).[9] On the social psychological side, evidence points to greater motivation to reduce threat and uncertainty giving rise to political preferences that tend to be system-justifying (Jost et al, 2003; Hennes, Nam, Stern, & Jost, 2012). These general observations across disciplines suggest a natural relationship between the amygdala and system-justifying ideologies. I further suggest that system justification motivation may provide a critical link in helping to explain previous studies linking amygdala structure to social and political constructs, such as ideology and knowledge of social hierarchy. I speculate that in both Studies 1 and 2, as well as in some previous work (e.g., Kanai et al., 2011; Kumaran, Melo, & Duzel, 2012), it may be system justification motivation that is a psychologically "active ingredient" linking motivational orienting directed at reducing threat and uncertainty in the environment—as processed in the amygdala—to much higher level social constructs like ideological beliefs. On the basis of these results, including several comparisons of various multiple regression models (see Tables 5-7), it certainly appears that a system-justifying motivation to maintain and bolster existing social structures may be an important psychological factor above and beyond ideology (or even ideological extremity) in understanding the role of the amygdala in social and political beliefs.

It may be that the neurobiology underlying greater motivational orienting to salient aspects of sociopolitical arrangements (e.g., markers of social hierarchy and status) enables

[9] It should be noted that although the amygdala is a small (bilateral) brain structure, in primates it is composed of 13 subnuclei with extensive connections to many other cortical and subcortical structures. It is a matter of some debate whether the amygdala should even be considered a singular entity because of its complexity (Swanson & Petrovich, 1998), and its subcomponents are often distinguished in non-human animal research. However, because the much less invasive techniques usually used to examine the amygdala in humans (such as MRI) have limited spatial resolution, most human studies consider the amygdala as a whole, which may be part of the reason for the diversity of findings on the structure's function (Adolphs, 2010).

proficient comprehension and navigation of such arrangements (e.g., attaining high social status or acquiring a large social network) *via* greater acceptance and legitimation of the hierarchical system itself. After all, attainment of high rank is theoretically possible only if the ranking system is maintained (vs. abolished), especially if people want to avoid increases in uncertainty and threat usually inherent in fundamental system change. Such a perspective would be consistent with the Spinozan hypothesis that (at least temporary) acceptance of an idea is *necessary* for its comprehension (Gilbert, 1991; but see also Hasson, Simmons, & Todorov, 2005). In this view, rejection of an idea can only follow its (simultaneous) comprehension and acceptance, which suggests the intriguing possibility that rejection of a system may only be possible after initial acceptance of a system. Indeed, beliefs tend to be persistent even in the face of disconfirmation (e.g., Ross, Lepper, & Hubbard, 1975; Wegner, Coulton, & Wenzlaff, 1985), and the societal status quo may enjoy similar mental privileges that lend them legitimacy even in the face of contrary evidence such as egregious inequality.

In this vein, although I did not find a significant relationship between political ideology and amygdala volume as reported by Kanai and colleagues (2011), I offer the possibility that system justification could be a common, underlying psychological basis for a relationship between ideology and brain structure. It should be noted that the 95% confidence intervals of the correlation coefficients between amygdala volume and conservatism included the coefficient of $r(88) = .23$ reported in Kanai et al. (2011), in Study 1 ($r(46) = .098$, $p = .51$, 95% CI: {-.19, .37}) and Study 2 $r(43) = -.005$, $p = .97$, 95% CI: {-.30, .29}), suggesting that these findings are at least not inconsistent with one another. It is of course conceivable that political conservatism is construed somewhat differently in the UK than in the USA—for example, British conservatism could be more tightly linked to system-justifying preferences. Situationally, a contributing factor to the stronger relationship between political conservatism and amygdala volume in the previous work than in the current data might be that Kanai and colleagues collected their data in the UK when the prime minister in power, David Cameron, belonged to the Conservative Party (R. Kanai, personal communication, November 22, 2015), which may be a time in which the relationship between system justification and reported political ideology was strengthened given their aligned motivational properties. In contrast, our data were collected when the president in office, Barack Obama, belonged to the more liberal Democratic Party in the US, during which time system justification may, in some sense, reflect a broader attachment to the status quo (with a progressive, liberal representative at the time) in addition to principles of tradition (represented generally by conservatism). Indeed, previous work suggests that people's system justification motivation often supports conservative ideology (Jost & Hunyady, 2005), but can also support the way things are currently (Kay, Gaucher, Peach, Laurin, Friesen, Zanna, & Spencer, 2009). Further investigations across cultures and different political systems could specify other moderators of the relationship between ideology, system justification, and brain structure.

When the amygdala is impaired (through experimental lesioning or medically caused damage), we observe that its related functions—vigilance to threat, avoidance of unknowns (pending further downstream evaluation)—are likewise impaired. The case of patient SM is particularly illustrative of the amygdala's role in identifying threat as motivationally relevant, since in the absence of amygdala structure, SM not only fails to find typically threatening targets as motivationally relevant (through avoidance), but also exhibits lesser general anxiety levels than controls (Feinstein et al., 2011). I would speculate that SM also holds relatively less system-justifying, more liberal political beliefs than matched comparison populations. Of course, the relationship between amygdala damage and complex sociopolitical beliefs is surely context-dependent and difficult to interpret. The wrong characterization of the results from Study 3 would be to infer that holding more liberal political beliefs is indicative of some malfunction or damage to the amygdala. Even if we ignore the fact that brain lesions are a rare occurrence in the general population (and that both healthy and brain damaged individuals hold a range of political beliefs, including liberal as well as conservative beliefs), we can rule out such a faulty conclusion simply by noting that healthy control subjects expressed equally liberal beliefs as the amygdala-damaged patients in Study 3. Instead, I would interpret the results of Study 3 as an illustration of the role of motivational orienting to fear and anxiety in the formation of political ideologies, consistent with the theory of conservatism as social cognition motivated by managing threat and uncertainty (Jost et al., 2003). When the biological basis for attending to threats is manipulated, we see that ideological positioning likewise changes.

At the same time, I also wonder whether a lack of apprehension about spiders and snakes (due to amygdala damage) might translate more broadly in the social domain to lesser apprehension toward novel or stereotypically threatening social groups. It certainly seems to be no coincidence that Nazi propaganda leading up to WWII preyed on people's basic fear of spiders by portraying Jews in stereotypical depictions as spiders taking over Europe (United States Holocaust Memorial Museum, http://collections.ushmm.org/search/catalog/pa1141708). In addition to a lack of fear toward spiders, patient SM exhibits a lack of discomfort with violations of personal space by strangers (that is, standing in extremely close face-to-face proximity) compared to matched controls (Kennedy, Gläscher, Tyszka, & Adolphs, 2009).

Although Kennedy and colleagues (2009) did not specifically vary the social group category (e.g., along racial or social class divisions) of the personal space target in their study, one might expect that SM would prefer smaller personal distances between people of any background compared to controls. It would certainly be a striking finding if SM's personal space preferences were not at all moderated by her counterpart's identity (whereas control subjects' preferences are moderated). Future studies could more directly test this hypothesis by examining whether amygdala lesion patients not only exhibit lower general anxiety, but also judge "threatening" social groups (e.g., immigrants) or policy changes (e.g., increases to immigration caps) as non-threatening and worthy of embracing. Whereas perceptions of outgroups as threats make them seem uncomfortably close (Xiao & Van Bavel, 2012), one might expect that decrements to threat perceptions as mediated by amygdala damage would make the same distance from an outgroup feel comfortable, eliminating preferences for policies that "keep them out" like building physical walls along international borders. Such a finding would be supported by previous work connecting greater physiological reactivity (assumed to index amygdala activity) to more conservative political attitudes (Oxley et al., 2008).

In the first three studies of this dissertation research, the story has primarily been one about the amygdala. Accordingly, I examined potential changes in the amygdala in Study 4, and I observed that counter to my hypothesis there was a small (and non-significant) effect of increases in right amygdala volume corresponding to more liberal changes to political orientation. Future work should seek to observe whether such a change can be replicated, which would help to determine whether this is a spurious finding or one worthy of greater theoretical elaboration.

However, the longitudinal exploration in Study 4 also expanded our purview to other regions of interest. Of (cautiously) greater interest is the finding that a trend toward expansion in the ACC is associated with more liberal changes to political orientation. Previous work links activity originating in the ACC from conflict detection to liberalism (Amodio, Jost, Master, & Yee, 2007). In general, the ACC plays an important role in detecting breaks in habitual patterns (in some sense, deviations from the status quo) and in facilitating flexible responding to these "breaks"—that is, successful execution of cognitive control in response to conflict (Botvinick et al., 2001; Yeung, Botvinick, & Cohen, 2004). Additionally, smaller grey matter volume in the ACC has recently been associated with decreased cognitive control (among high media multitaskers; Loh & Kanai, 2014), suggesting that ACC grey matter plays a useful role in flexible integration of changes to habitual patterns. The current finding that longitudinal increases in ACC volume correspond to increases in liberalism is consistent with this previous work. Perhaps the general movement toward greater liberalism from the beginning to end of college among students can be explained in part by an education that exposes and trains students in greater flexibility of thinking and responding to different, sometimes non-normative perspectives.

The degree to which a field of study integrates relatively more system-accepting or system-challenging perspectives may correspond to perceptions (and even reality) of how conservative or liberal the influence of an education is. Indeed, previous work finds that students' political ideologies change not only in response to the political climate of their college (Newcomb, 1943), but also in response to the ideological bent of their major (Guimond, 1999). In Study 4 I found that students whose college majors were rated as more conservative exhibited small increases in grey matter in the right insula compared to those whose majors were rated as more liberal. Such a change is consistent with previous cross-sectional work showing that larger insula volume is associated with greater conservatism (Kanai et al., 2011). Indeed, although examinations of insula volume in Studies 1 and 2 (see Table 7) were less consistent than those of amygdala volume, I did observe that in some models, larger grey matter volume in the left insula was associated with more conservative, system-justifying preferences (i.e., primarily Models 3a, 4, and 4a) across both studies. The insular cortex is a complex structure that has been associated with a variety of functions, including disgust sensitivity (Wicker et al., 2003), interoceptive awareness of one's bodily responses (Critchley et al., 2004), and empathy (see Bernhardt & Singer, 2012 for a review). Greater insular capacity may facilitate greater general awareness of one's internal states, as well as (at least in some cases) awareness of others' states. However, perceptions of another person's "worthiness" of receiving empathy (such as perceptions of whether the other person is a fair player) may certainly be a moderating influence on the impact of the insula on empathic behavior (Singer et al., 2006). Fruitful avenues of future work could interrogate the potential moderators of the current finding (such as disgust or empathic sensitivity) connecting increased insula volume to more conservative academic studies.

In sum, I have strived to demonstrate across four studies in this dissertation that some of our most complex social beliefs—such as those ideologies about how societies should be organized, how much equality is desirable, when seeking change is worth it—are rooted in basic neural structure and psychological motives. Moreover, I submit preliminary evidence that the relationship between neurobiology and political beliefs is not unidirectional but rather dynamic, bidirectional, and mutually reinforcing. I would expand on the Norwegian writer Karl Ove

Knausgaard's observation that all of our thoughts, beliefs, and even political systems are rooted in our biological systems to argue that our biological systems are likewise rooted in and influenced by the social systems in which we are embedded. Together, the studies in my dissertation research represent just the start of burgeoning investigations into the dynamic neural basis of system-justifying and system-challenging preferences.

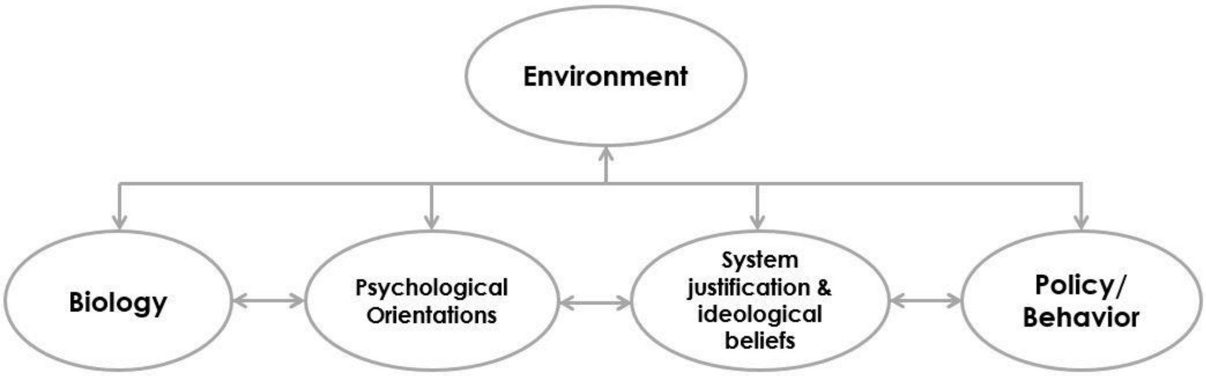

Fig. 1 – Theoretical model of dynamic, bidirectional relationship between biology and political outcomes.

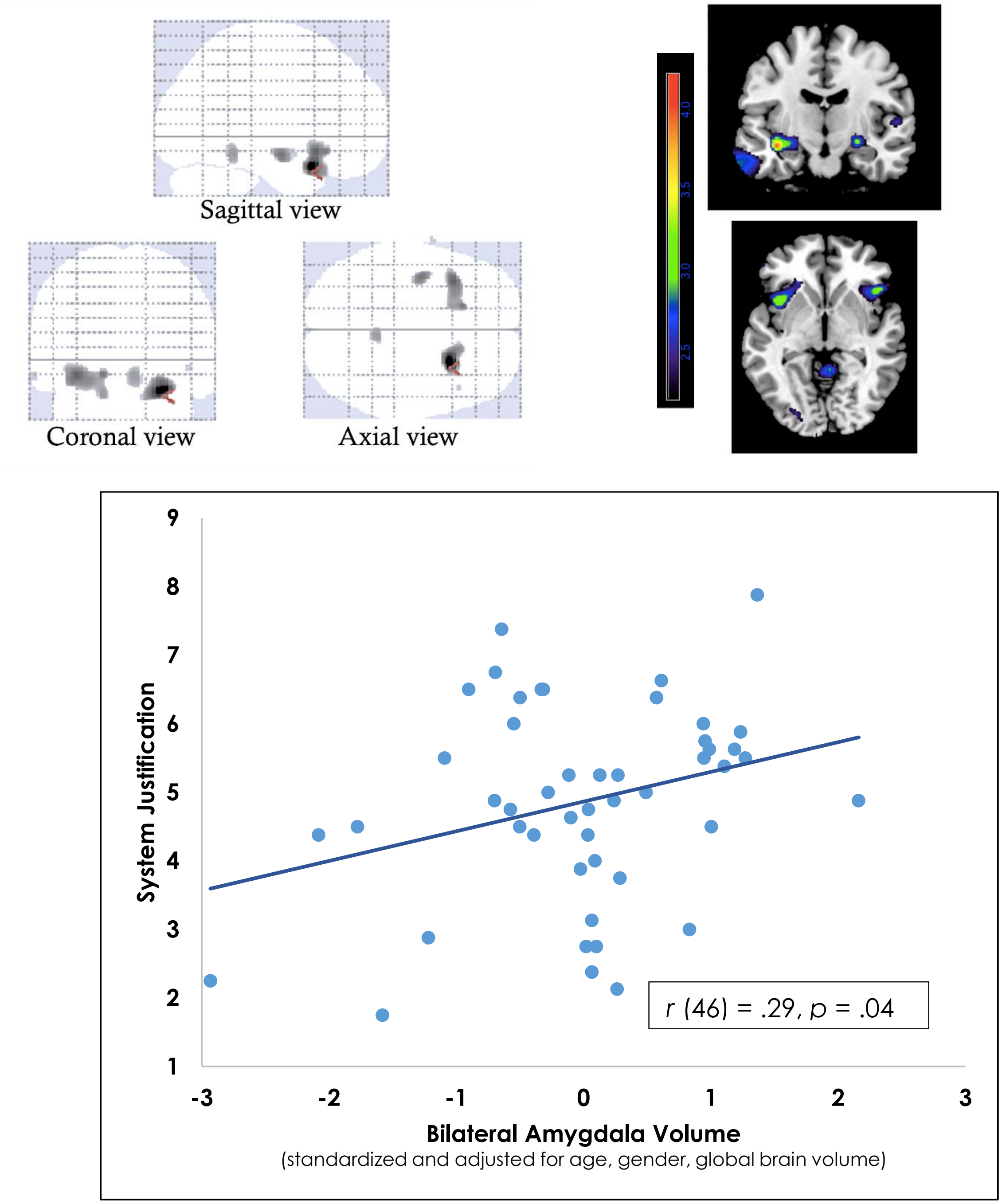

Fig. 2 – Grey matter volume in the bilateral amygdalae is associated with greater system justification (Study 1).

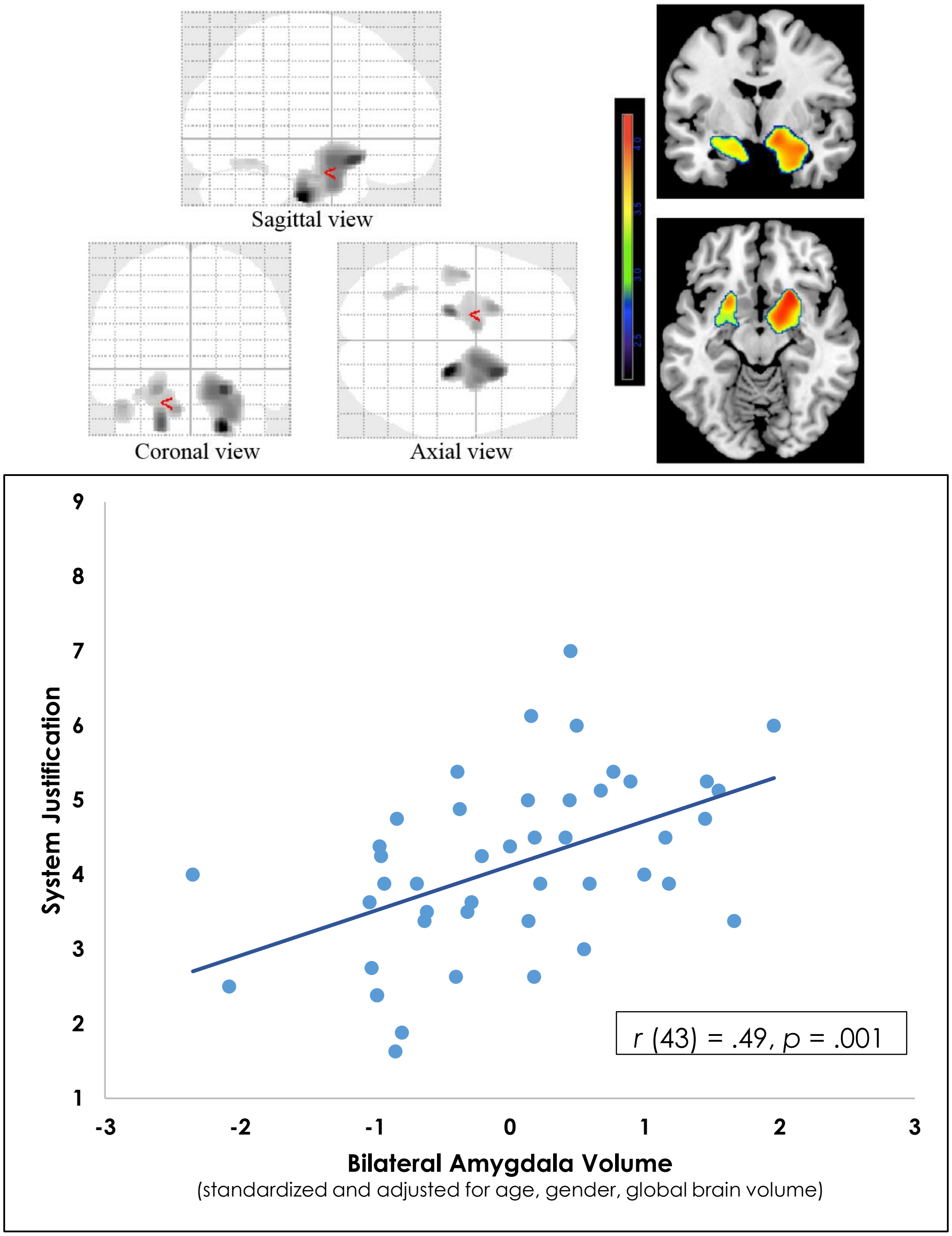

Fig. 3 – Grey matter volume in the bilateral amygdalae is associated with greater system justification (Study 2).

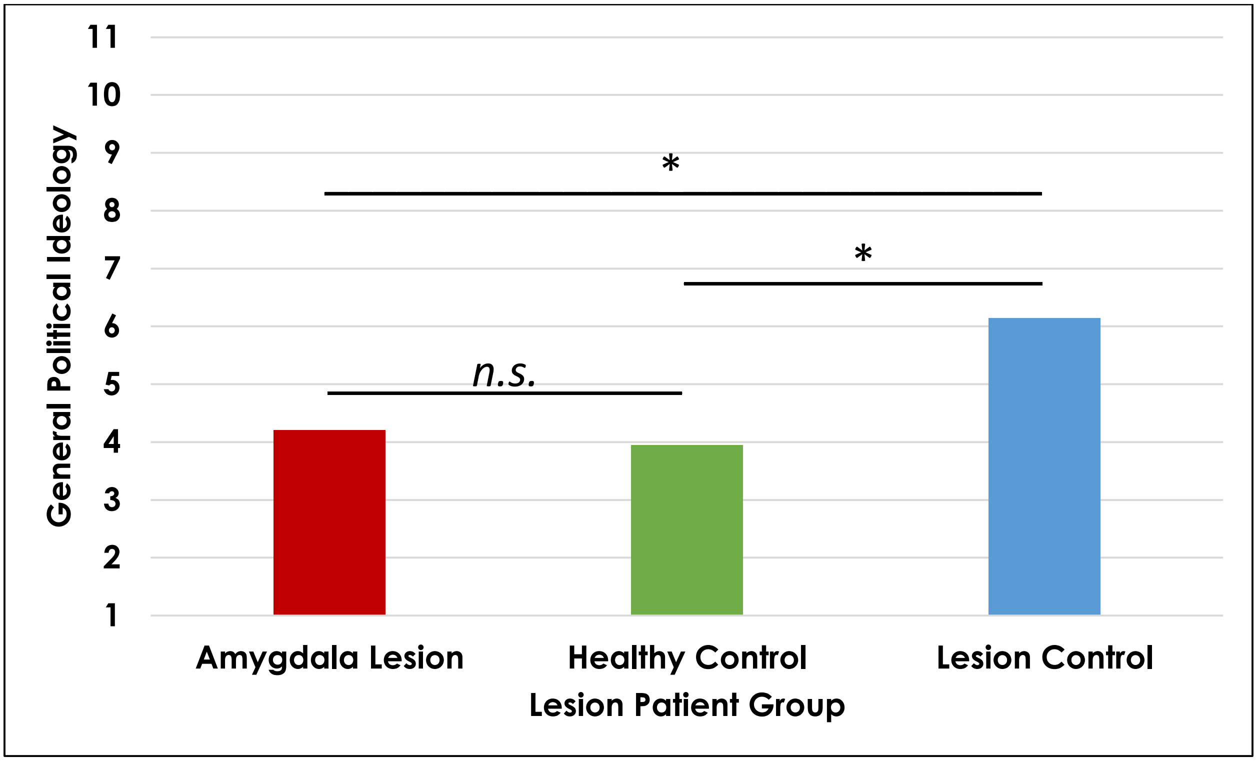

Fig. 4 – Differences in political ideology between amygdala lesion patients, lesion control patients, and healthy control subjects at mean levels of anxiety (Study 3). Higher scores on political ideology indicate conservatism. Pairwise comparisons are significant at *p < .05.

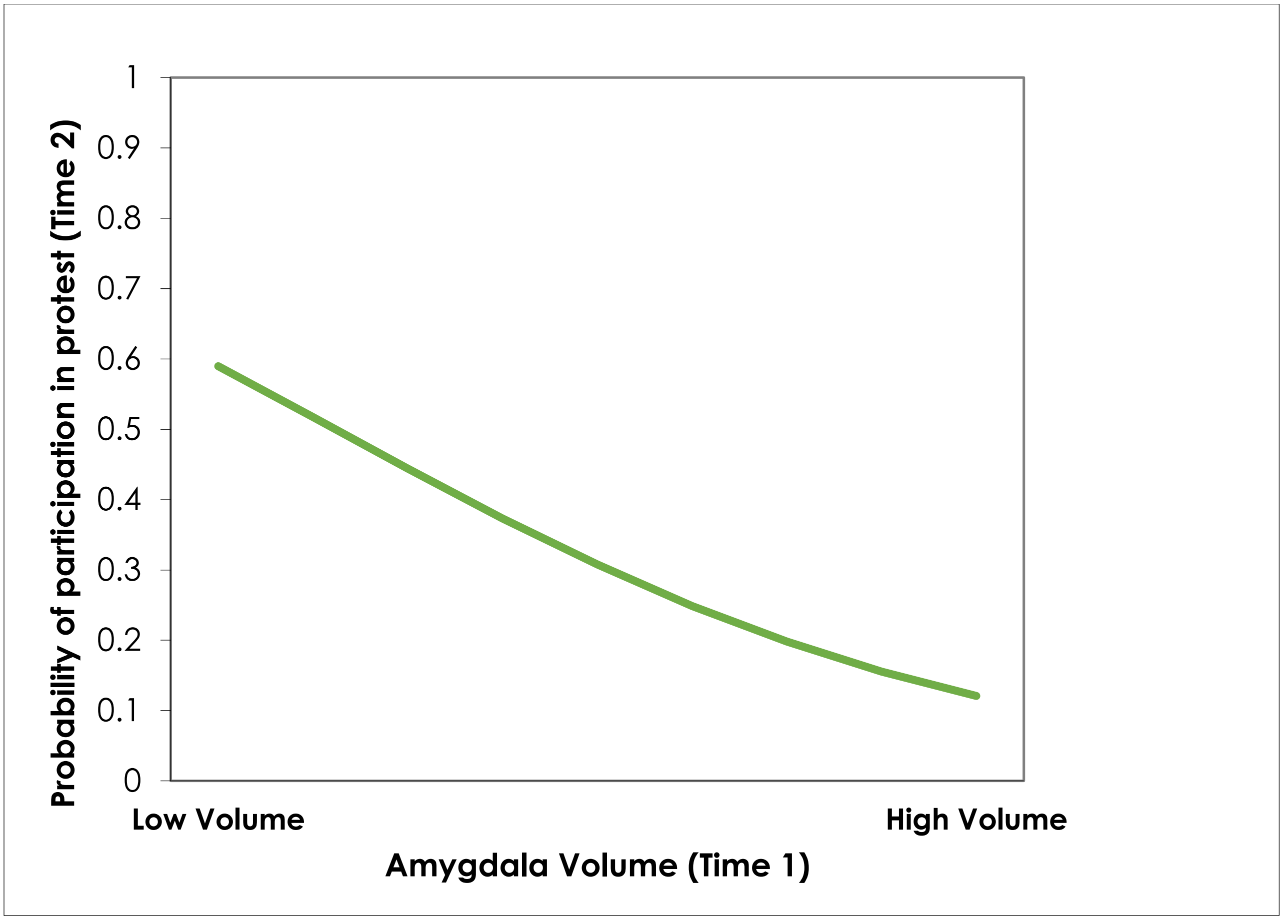

Fig. 5 – Students' likelihood of participating in a protest during college as predicted by amygdala grey matter volume (standardized and adjusted for age, sex, global brain volume) at the start of college (Study 4).

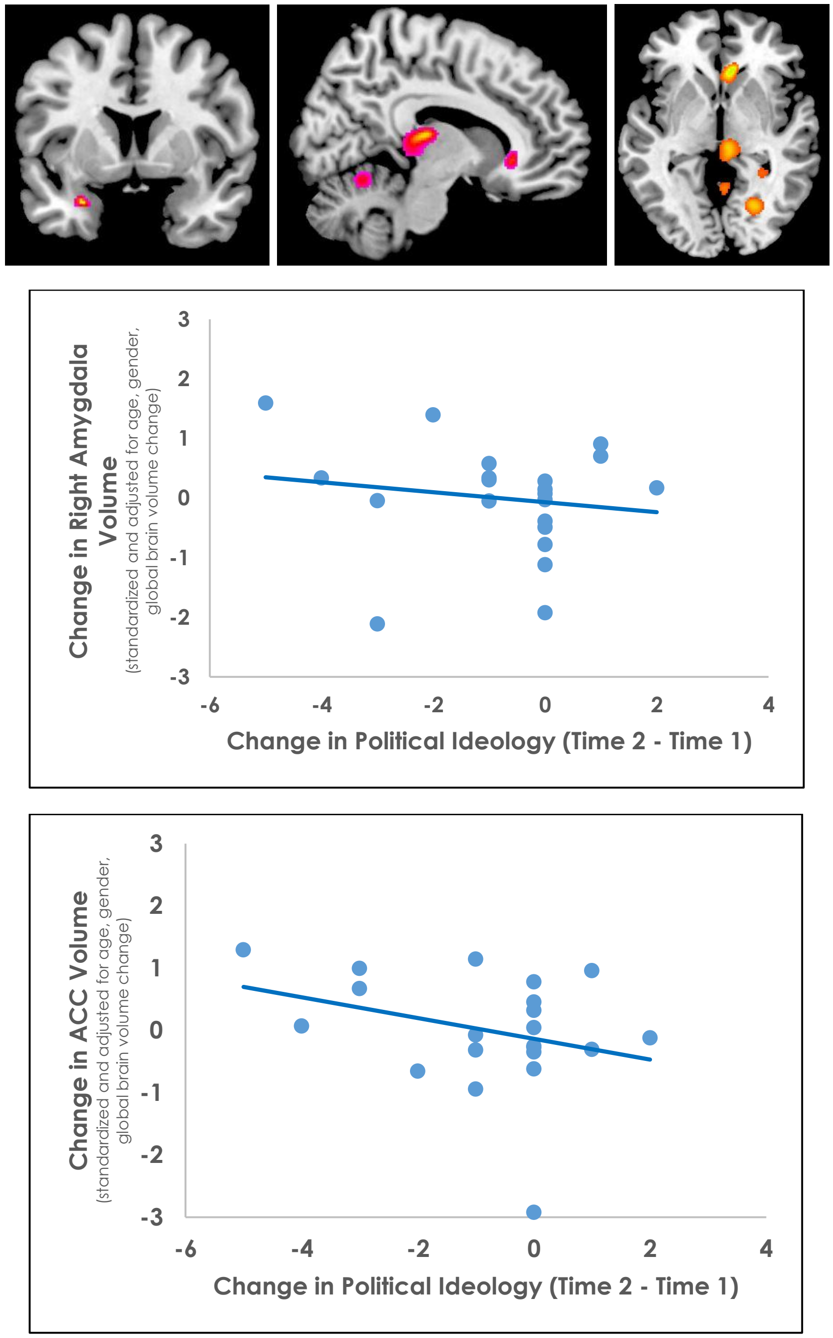

Fig. 6 – Changes to grey matter volume as a function of more liberal ideology change (i.e., inverse ideology contrast; Study 4). Note that values less than zero on the x-axis indicate more liberal change and values greater than zero indicate more conservative change. Top left panel (coronal view) shows left amygdala change. Top middle panel (sagittal view) shows ACC change.

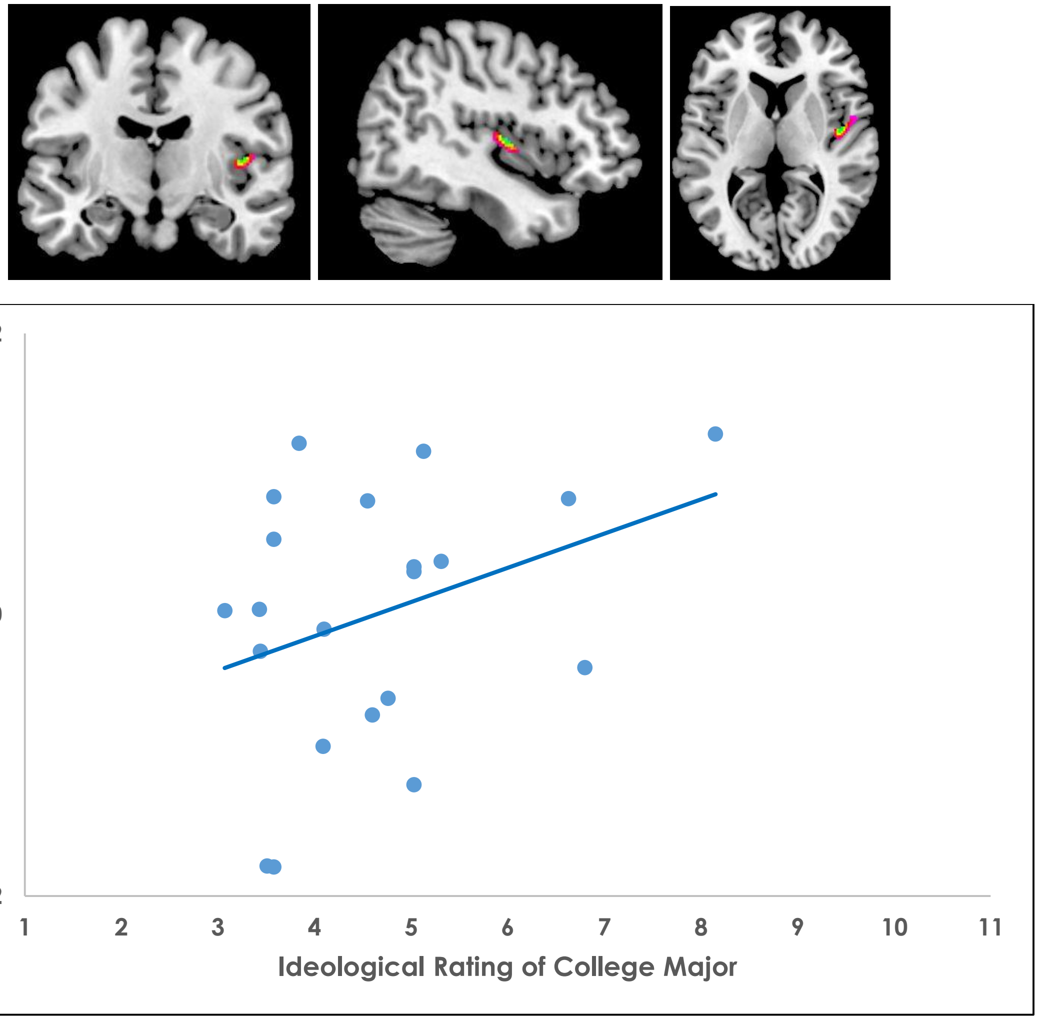

Fig. 7 – Changes to grey matter volume as a function of more conservative college major ideological rating (Study 4). All top panel views showing change in right insula.

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1.	System justification (general)	--													
2.	System justification extremity	-.31*	--												
3.	Political ideology (general)$^{\Delta}$	.37**	.13	--											
4.	Political ideology extremity	.04	.08	-.39**	--										
5.	Political ideology (social)$^{\Delta}$	.20	.27†	.72**	-.26†	--									
6.	Political ideology (economic)$^{\Delta}$	.38**	.16	.81**	-.26†	.38**	--								
7.	Economic system justification (ESJ)	.67**	-.05	.57**	-.10	.38**	.55**	--							
8.	ESJ extremity	-.11	.53**	-.20	.24	.07	.10	-.17	--						
9.	Need for Cognition	-.28†	.23	-.33*	.04	-.31*	-.14	-.31*	.25†	--					
10.	Extraversion	.002	.22	.23	-.13	.08	.27†	.04	.05	-.10	--				
11.	Agreeableness	-.09	.06	.09	-.29*	.06	-.04	-.16	-.25†	.23	.30*	--			
12.	Conscientiousness	.04	.13	.19	.13	.09	-.04	.08	.15	.04	.06	.12	--		
13.	Emotional Stability	.13	-.12	.26†	-.33*	.21	.11	.03	-.13	.22	.04	.45**	.23	--	
14.	Openness to Experience	-.60**	.18	-.22	-.23	-.24	-.12	-.37*	-.06	.32*	.23	.10	.28†	-.02	--

*†p <.10, *p ≤ .05, **p <.01*

Table 1 – Correlations of behavioral study variables (Study 1).
$^{\Delta}$ Note: higher values on political ideology are more conservative.

		1	2	3	4	5	6	7	8
1.	System justification (general)	--							
2.	System justification extremity	-.75**	--						
3.	Political ideology (general) $^{\Delta}$	.45**	-.36*	--					
4.	Political ideology extremity	-.20	.22	-.33*	--				
5.	Political ideology (social) $^{\Delta}$	.27†	-.17	.64**	-.15	--			
6.	Political ideology (economic) $^{\Delta}$	.29†	-.21	.73**	.15	.44**	--		
7.	Economic system justification (ESJ)	.67**	-.43**	.46**	-.08	.39**	.25†	--	
8.	ESJ extremity	-.41**	.45**	-.16	.21	-.14	-.03	-.66**	--

†$p < .10$, *$p \leq .05$, **$p < .01$

Table 2 – Correlations of behavioral study variables (Study 2)

$^{\Delta}$ **Note: higher values on political ideology are more conservative.**

Contrast	**Hemisphere**	**Cluster size (k_E)**	**MNI peak coordinates (mm) (x,y,z)**	**Brain region**	**Maximum *t* value**
System justification	L	1297	-17, 23, -12	Gyrus rectus	4.88
	R	699	27, 14, -21	Posterior orbito-frontal cortex, Amygdala	4.61
	L	142	-39, -7, -17	Superior temporal gyrus, Amygdala	4.32
	R	177	8, -43, -12	Cerebellum	3.64

Table 3 – All significant results for a system justification contrast in Study 1. All regions thresholded at $p < .001$, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

Contrast	Hemisphere	Cluster size (k_E)	MNI peak coordinates (mm) (x,y,z)	Brain region	Maximum *t* value
System justification	R	3895	21, -19, -38	Amygdala	5.65
	L	1907	-20, -19, -35	Amygdala	4.84
	L	418	-45, -9, -24	Middle temporal gyrus	3.96
	L	98	-34, -55, -14	Fusiform gyrus	3.63

Table 4 – All significant results for a system justification contrast in Study 2. All regions thresholded at p < .001, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

		Study 1					Study 2				
Model	Regressor	*b*	*SE (b)*	*β*	*t*	*p*	*b*	*SE (b)*	*β*	*t*	*p*
1	Ideology	.065	.100	.046	.646	.521	-.005	.158	-.003	-.033	.974
2	Ideology	.069	.110	.049	.631	.532	.054	.166	.028	.328	.744
	Ideological extremity	.023	.212	.009	.109	.914	.331	.291	.093	1.137	.263
3	General system justification (GSJ)	.365	.178	.141	2.051	.046*	1.097	.243	.334	4.513	< .001***
3a	GSJ	.374	.195	.145	1.919	.062†	1.317	.287	.401	5.168	< .001***
	Ideology	-.013	.105	-.009	-.12	.905	-.287	.135	-.148	-2.130	.040*
4	GSJ	.512	.257	.192	1.995	.053†	.993	.315	.303	3.155	.003**
	Economic system justification (ESJ)	-.185	.277	-.063	-.667	.508	.168	.320	.048	.525	.603
4a	GSJ	.512	.261	.192	1.965	.056†	1.156	.308	.352	3.751	.001**
	ESJ	-.185	.261	-.064	-.602	.551	.288	.309	.082	.930	.358
	Ideology	.001	.121	< .001	.005	.996	-.309	.137	-.159	-2.255	.030*
5	ESJ	.195	.208	.067	.934	.356	.801	.276	.227	2.905	.006**
5a	ESJ	.176	.256	.060	.685	.497	.937	.296	.266	3.169	.003**
	Ideology	.016	.125	.011	.131	.896	-.188	.154	-.097	-1.225	.228
6	GSJ	.302	.185	.117	1.629	.111	1.018	.360	.310	2.829	.007**
	GSJ extremity	-.343	.296	-.083	-1.159	.253	-.133	.441	-.030	-.301	.765
6a	GSJ	.283	.209	.110	1.350	.184	1.239	.361	.377	3.436	.001**

	GSJ extremity	-.361	.312	-.087	-1.158	.254	-.131	.423	-.030	-.309	.759
	Ideology	.022	.109	.016	.205	.839	-.287	.136	-.148	-2.105	.042*
7	ESJ	.230	.212	.079	1.089	.282	.811	.380	.230	2.135	.039*
	ESJ extremity	.334	.339	.074	.985	.330	.019	.518	.004	.037	.971
7a	ESJ	.223	.261	.077	.856	.397	1.016	.412	.288	2.468	.018*
	ESJ extremity	.333	.345	.074	.966	.340	.147	.525	.028	.279	.782
	Ideology	.006	.125	.004	.047	.963	-.197	.159	-.102	-1.242	.222

*†p <.10, *p ≤ .05, **p <.01, ***p < .001*

Table 5 – Model comparisons on amygdala volume (Studies 1 & 2). (Regressor variables were mean-centered, and extremity variables were the absolute value distance from the midpoint of the scale.)

		Study 1					Study 2				
Model	Regressor	*b*	*SE (b)*	*β*	*t*	*p*	*b*	*SE (b)*	*β*	*t*	*p*
1	Ideology	-.105	.152	-.055	-.689	.494	-.142	.167	-.090	-.850	.400
2	Ideology	-.131	.166	-.069	-.790	.434	-.132	.178	-.084	-.742	.462
	Ideological extremity	-.132	.321	-.037	-.413	.682	.054	.313	.019	.172	.864
3	General system justification (GSJ)	-.208	.281	-.060	-.742	.462	-.615	.304	-.230	-2.023	.050*
3a	GSJ	-.157	.307	-.045	-.512	.611	-.605	.337	-.227	-1.798	.080†
	Ideology	-.072	.166	-.038	-.435	.666	-.013	.178	-.008	-.071	.943
4	GSJ	-.761	.388	-.213	-1.960	.057†	-.534	.395	-.200	-1.353	.184
	Economic system justification (ESJ)	.716	.419	.183	1.709	.095†	-.131	.401	-.046	-.326	.746
4a	GSJ	-.737	.390	-.206	-1.890	.066†	-.533	.411	-.200	-1.295	.203
	ESJ	.896	.461	.229	1.944	.059†	-.130	.412	-.045	-.315	.755
	Ideology	-.170	.180	-.089	-.941	.352	-.003	.183	-.002	-.016	.988
5	ESJ	.152	.315	.039	.484	.631	-.471	.316	-.164	-1.493	.143
5a	ESJ	.377	.382	.096	.988	.329	-.429	.345	-.150	-1.246	.220
	Ideology	-.192	.186	-.101	-1.037	.306	-.058	.179	-.037	-.325	.747
6	GSJ	-.276	.295	-.079	-.936	.355	-.272	.444	-.102	-.611	.545
	GSJ extremity	-.369	.471	-.066	-.782	.439	.577	.545	.161	1.059	.296

6a	GSJ	-.243	.333	-.070	-.727	.471	-.261	.470	-.098	-.556	.581
	GSJ extremity	-.337	.496	-.061	-.680	.500	.577	.552	.161	1.045	.302
	Ideology	-.039	.174	-.021	-.227	.822	-.013	.178	-.008	-.074	.942
7	ESJ	.052	.310	.013	.167	.868	-.361	.434	-.126	-.831	.411
	ESJ extremity	-.936	.497	-.154	-1.881	.067†	.223	.592	.052	.377	.709
7a	ESJ	.248	.379	.063	.654	.517	-.283	.479	-.099	-.591	.558
	ESJ extremity	-.897	.500	-.148	-1.792	.081†	.271	.611	.063	.444	.660
	Ideology	-.164	.181	-.086	-.905	.371	-.074	.185	-.047	-.402	.690

†*p* <.10, **p* ≤ .05, ***p* <.01, ****p* < .001

Table 6 – Model comparisons on ACC volume (Studies 1 & 2). (Regressor variables were mean-centered, and extremity variables were the absolute value distance from the midpoint of the scale.)

		Study 1					Study 2				
Model	Regressor	*b*	*SE (b)*	*β*	*t*	*p*	*b*	*SE (b)*	*β*	*t*	*p*
1	Ideology	-.073	.101	-.054	-.722	.474	-.131	.122	-.066	-1.072	.290
2	Ideology	-.087	.110	-.065	-.785	.437	-.088	.128	-.045	-.688	.496
	Ideological extremity	-.069	.213	-.028	-.325	.746	.236	.226	.065	1.046	.302
3	General system justification (GSJ)	.268	.183	.109	1.463	.151	.410	.225	.122	1.822	.076†
3a	GSJ	.374	.196	.153	1.912	.063†	.610	.236	.182	2.581	.014*
	Ideology	-.150	.106	-.112	-1.420	.163	-.261	.125	-.132	-2.092	.043*
4	GSJ	.326	.266	.129	1.228	.226	.675	.285	.201	2.371	.023*
	Economic system justification (ESJ)	-.043	.287	-.016	-.150	.881	-.430	.289	-.119	-1.485	.146
4a	GSJ	.355	.260	.140	1.364	.180	.799	.284	.238	2.815	.008**
	ESJ	.173	.308	.062	.562	.577	-.338	.285	-.094	-1.189	.242
	Ideology	-.204	.121	-.151	-1.690	.099†	-.236	.126	-.119	-1.868	.069†
5	ESJ	.198	.210	.072	.947	.349	.001	.238	< .000	.002	.998
5a	ESJ	.424	.250	.153	1.694	.098†	.111	.256	.031	.433	.667
	Ideology	-.193	.122	-.143	-1.586	.120	-.153	.133	-.077	-1.146	.259
6	GSJ	.155	.184	.064	.843	.404	.387	.334	.116	1.161	.253
	GSJ extremity	-.612	.295	-.156	-2.076	.044*	-.038	.409	-.008	-.093	.926
6a	GSJ	.240	.206	.098	1.161	.252	.588	.335	.175	1.757	.087†

	GSJ extremity	-.534	.307	-.136	-1.737	.090†	-.036	.393	-.008	-.093	.926
	Ideology	-.098	.107	-.073	-.916	.365	-.261	.127	-.132	-2.065	.046*
7	ESJ	.201	.215	.073	.935	.355	-.068	.327	-.019	-.209	.835
	ESJ extremity	.026	.345	.006	.075	.941	-.139	.447	-.026	-.311	.757
7a	ESJ	.434	.258	.157	1.684	.100	.088	.357	.024	.247	.806
	ESJ extremity	.072	.341	.017	.213	.833	-.042	.455	-.008	-.093	.927
	Ideology	-.195	.123	-.145	-1.580	.122	-.150	.137	-.076	-1.092	.282

†$p < .10$, *$p \leq .05$, **$p < .01$, ***$p < .001$

Table 7 – Model comparisons on left insula volume (Studies 1 & 2). (Regressor variables were mean-centered, and extremity variables were the absolute value distance from the midpoint of the scale.)

		1.	2.	3.	4.	5.
1.	Political ideology (general) $^{\Delta}$	--				
2.	Political ideology (social) $^{\Delta}$	.79**	--			
3.	Political ideology (economic) $^{\Delta}$	.69**	.56**	--		
4.	Religiosity	.41**	.35*	.33*	--	
5.	Beck Anxiety Inventory	-.12	-.29*	.02	.15	--

† $p < .10$, * $p < .05$, ** $p < .01$

Table 8 – Correlations of behavioral study variables (Study 3)
$^{\Delta}$ **Note: higher values on political ideology are more conservative.**

		1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	System justification	--								
2.	Political ideology (general) $^{\Delta}$	.35	--							
3.	Political ideology (social) $^{\Delta}$	.55*	.40†	--						
4.	Political ideology (economic) $^{\Delta}$	.41†	.88**	.23	--					
5.	Need for Cognition	-.44*	-.17	-.61**	-.06	--				
6.	Extraversion	.38†	.11	-.06	.14	.23	--			
7.	Agreeableness	-.19	-.28	.11	-.24	-.09	-.12	--		
8.	Conscientiousness	.06	.18	.28	.17	-.20	-.26	-.01	--	
9.	Emotional Stability	.12	-.10	.38†	-.04	-.17	-.17	.17	.55*	--
10.	Openness to Experience	-.41†	-.10	-.76**	.01	.63**	.16	-.37	-.12	-.41†
11.	Tea Party	.40†	.78**	.33	.71**	-.01	.10	-.23	.36	.14
12.	OWS	-.47*	-.50*	-.42†	-.58**	.43†	-.02	.26	-.15	-.11
13.	Obamacare	-.49*	-.48*	-.37†	-.53*	.38†	-.22	.36	< -.01	.15
14.	Regulation	.60**	.42†	.49*	.49*	-.40†	.09	-.24	.14	.36
15.	Abortion	.24	.33	.65**	.17	-.59**	.13	.23	.09	.06
16.	Same-sex marriage	-.07	-.01	-.13	-.04	.10	.16	.37	-.14	-.18
17.	Immigration	-.53*	-.38†	-.47*	-.28	.32	-.13	.26	.06	.27
18.	Climate Change	-.18	-.54*	-.36	-.46*	.02	-.05	.38†	.23	.26
19.	Protest Participation (*No = 0*)	-.24	-.44*	-.17	-.38†	.04	-.20	-.10	-.21	-.10
20.	College major ideological rating $^{\Delta}$	.35	.08	.19	.14	-.05	.20	.21	-.17	.31

† $p < .10$, * $p < .05$, ** $p < .01$

		10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1.	System justification											
2.	Political ideology (general) $^{\Delta}$											
3.	Political ideology (social) $^{\Delta}$											
4.	Political ideology (economic) $^{\Delta}$											
5.	Need for Cognition											
6.	Extraversion											
7.	Agreeableness											
8.	Conscientiousness											
9.	Emotional Stability											
10.	Openness to Experience	--										
11.	Tea Party	-.05	--									
12.	OWS	.41†	-.38†	--								
13.	Obamacare	.17	-.27	.74**	--							
14.	Regulation	-.27	.52*	-.54*	-.47*	--						
15.	Abortion	-.55**	.10	-.29	-.41†	.22	--					
16.	Same-sex marriage	.08	.10	.19	.35	.09	-.09	--				
17.	Immigration	.31	-.06	.52*	.64**	-.26	-.26	.19	--			
18.	Climate Change	.06	-.30	.51*	.67**	-.30	-.25	.28	.57**	--		
19.	Protest Participation (*No = 0*)	.12	-.42†	.20	.04	-.33	-.11	-.31	.22	.17	--	
20.	College major ideological rating $^{\Delta}$	-.39†	.22	-.14	.22	.21	.15	.21	.28	.13	-.13	--

† $p < .10$, * $p < .05$, ** $p < .01$

Table 9 – Correlations of behavioral study variables at Time 2 (Study 4). $^{\Delta}$ **Note: higher ideology values = more conservative.**

Major	Mean (SD)
Anthropology	4.76 (2.20)
Biochemistry	6.80 (2.36)
Comparative Literature	4.17 (2.19)
Computer Science	6.82 (2.32)
Dramatic Writing	3.44 (2.41)
Economics	8.15 (2.36)
Education	5.11 (2.44)
Film and Television	3.58 (2.33)
Media, Culture, Communication	3.84 (2.19)
Music	3.43 (2.22)
Nursing	6.63 (2.26)
Philosophy	4.10 (2.54)
Psychology	5.03 (2.51)
Social Work	4.55 (2.79)
Theatre	3.07 (2.23)
"Subject constitution and the deployment of narrative, from neuroscience to the arts" (Individualized Study Topic)	5.31 (2.16)

Table 10 – College majors and ideological ratings (Study 4). Note that higher values are more conservative.

Contrast	**Hemisphere**	**Cluster size (k_E)**	**MNI peak coordinates (mm) (x,y,z)**	**Brain region**	**Maximum *t* value**
Inverse ideology change (i.e., more liberal)	R	373	17, -54, -20	Cerebellum	5.29
	L	353	-20, -45, -17	Fusiform	4.87
	R	213	6, -23, 12	Thalamus	4.47
	R	38	2, 18, 27	ACC	4.39
	L	14	-27, 6, -26	Superior temporal pole; Amygdala (4.15mm)	4.38
	L	50	-27, -30, -21	Fusiform	4.33

Table 11 – All significant results for an inverse ideology change contrast in Study 4. All regions thresholded at p < .001, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

Contrast	Hemisphere	Cluster size (k_E)	MNI peak coordinates (mm) (x,y,z)	Brain region	Maximum *t* value
Inverse system justification change (i.e., less system-justifying)	L	52	-6, -39, 24	Posterior cingulate	5.21
	L	95	-6, 68, -5	Middle fronto-orbital gyrus	4.67
	L	61	-50, 35, 15	Inferior frontal gyrus	4.27

Table 12 – All significant results for an inverse system justification change contrast in Study 4. All regions thresholded at p < .001, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

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Contrast	**Hemisphere**	**Cluster size (k_E)**	**MNI peak coordinates (mm) (x,y,z)**	**Brain region**	**Maximum *t* value**
College major ideology (i.e., more conservative)	R	33	45, -8, 8	Insula	4.74

Table 13 – All significant results for a college major ideology contrast in Study 4. All regions thresholded at p < .001, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

Contrast	Hemisphere	Cluster size (k_E)	MNI peak coordinates (mm) (x,y,z)	Brain region	Maximum *t* value
Inverse college major ideology (i.e., more liberal)	R	96	17, 38, -26	Medial orbito-frontal cortex	4.97

Table 14 – All significant results for an inverse college major ideology contrast in Study 4. All regions thresholded at p < .001, 10 voxels for whole-brain comparison. Brain region labels at 0 mm from coordinates unless otherwise indicated (distance from coordinates in mm).

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