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Amygdala structure and the tendency to regard the social system as legitimate and desirable

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Individual variation in preferences to maintain versus change the societal status quo can manifest in the political realm by choosing leaders and policies that reinforce or undermine existing inequalities[1]. We sought to understand which individuals are likely to defend or challenge inequality in society by exploring the neuroanatomical substrates of system justification tendencies. In two independent neuroimaging studies, we observed that larger bilateral amygdala volume was positively correlated with the tendency to believe that the existing social order was legitimate and desirable. These results held for members of advantaged and disadvantaged groups (men and women, respectively). Furthermore, individuals with larger amygdala volume were less likely to participate in subsequent protest movements. We ruled out alternative explanations in terms of attitudinal extremity and political orientation per se. Exploratory whole-brain analyses suggested that system justification effects may extend to structures that are adjacent to the amygdala, including parts of the insula and the orbitofrontal cortex. These findings suggest that the amygdala may provide a neural substrate for maintaining the societal status quo, and opens avenues for further investigation into the association between system justification and other neuroanatomical regions.

Humans commonly live in hierarchical social systems, with members maintaining established inequalities by tolerating and justifying disparities among individuals and groups[1,2]. Although people sometimes object to perceived injustices through collective protest and resistance, social systems with entrenched disparities (such as those based on patriarchy, segregation and caste or class) typically endure very long periods of stability and perceived legitimacy before organized efforts to uproot them are successful[3]. In the current research programme, we examine the neuroanatomical substrates of preferences for maintaining existing social arrangements.

Identifying brain regions that are related to the defence of hierarchical social systems is a crucial step towards a complete understanding of the neurobiological processes that underlie the stability of prevailing social systems and the perpetuation of social inequality. Research on humans and non-human primates has suggested that the amygdala—a small brain region located bilaterally in the medial temporal lobe—is an important brain structure for assessing and navigating hierarchical social systems. For instance, rhesus macaques with amygdala lesions (versus intact amygdalae) became less socially dominant over time in the hierarchy[4,5]. Macaques with bilateral amygdala lesions also exhibit less fear in response to threatening stimuli[6]. Loss of social status may therefore stem from a diminished capacity to assess the social and physical environment.

Humans with amygdala damage exhibit similar behavioural changes. For instance, they are more likely to judge strangers' faces to be approachable and trustworthy[7,8], are less likely to respond punitively to violations of social norms[9] and may exhibit a complete lack of fear when confronted with threatening stimuli such as snakes[10]. Thus, amygdala damage impairs typical social functioning in humans and non-human primates.

Amygdala size and structure in healthy individuals predicts variability in social functioning[11]. Grey matter volume in the amygdala is positively associated with social status in macaques[12], as well as social network size in macaques[13] and humans[14,15]. Studies of amygdala lesions and grey matter volume therefore suggest that this brain region is vital for navigating social systems. These findings support functional neuroimaging work that links the amygdala to the processing of motivationally salient information, whether that information conveys threat[16–18], uncertainty[19,20] or features of social groups[21–24].

Previous work suggests that orientations concerning hierarchy and belief systems regarding society are also rooted in the neuroanatomical structure of the amygdala. For instance, larger bilateral amygdala grey matter volume was associated with learning the status of members of a novel hierarchical social system, but it was not associated with learning a non-social hierarchy[21]. Other studies reveal a positive correlation between political conservatism and right amygdala volume[25]. Thus, amygdala volume may be related to ideology and the formation of knowledge and opinions regarding the legitimacy and desirability of social hierarchy. However, it is not entirely clear why this relationship would exist.

Here, we consider the possibility that associations among amygdala volume, responses to social hierarchy and political conservatism may be due in part to individual variability in the motivation to defend and bolster the existing social system—termed 'system justification'[1,26]. A system-justifying psychological orientation favours the social, economic, and political status quo, and may promote vigilance to social hierarchy and a preference for ideologies that characterize extant inequality as legitimate and necessary[1,27]. Many behavioural studies have shown that system justification accounts for attitudes and behaviours that attribute legitimacy to existing hierarchical social systems, such as stereotyping[28], conservative and meritocratic ideologies[27,29,30], and a reluctance to help those who are disadvantaged[31]. Moreover, system justification is theorized to arise from basic psychological needs to manage threat, uncertainty and social relations[32]—three functions that are linked to the amygdala.

Given the role of system justification in supporting the existing social order and the role of the amygdala in promoting vigilance in social hierarchies, we investigated the possibility that individual differences in system justification would vary with amygdala structure.

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We explored the hypothesis that greater system justification would be associated with larger grey matter volume in the amygdala in study 1 and conducted a confirmatory replication in study 2. We focused on brain structure as an indicator of slow-to-change individual differences in regional computational capacity[11].

We assessed T1-weighted structural magnetic resonance imaging (MRI) scans from 48 healthy young Caucasian adults (58% female; study 1) and directly replicated the effects in 45 healthy adults (67% female; study 2) of diverse ethnic backgrounds to test the reliability and generalizability of the effect. In addition to the neuroanatomical scan, participants completed the general system justification scale[33], which includes items such as "In general, you find society to be fair," and "Everyone has a fair shot at wealth and happiness". Participants also indicated their political orientation from 1 (extremely liberal) to 11 (extremely conservative)[34]. We then used voxel-based morphometry (VBM)[11,35] analyses to examine the relationship between system justification and grey matter volume (see Methods for further details).

Given previous work suggesting that there could be a relationship between amygdala size and system justification[21,25], we conducted small-volume corrected region of interest (ROI) analyses within anatomically defined masks of the left and right amygdalae. We constrained our analyses to the left and right amygdalae by applying 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). These masks of the left and right amygdalae included voxels that had a ≥20% chance of being classified as the amygdala. Following previous studies[25], we included potential confounding variables of age, sex, and global brain volume as regressors of no interest; thus, any observed effects would not be attributable to these factors. In study 1, system justification was positively associated with grey matter volume (Fig. 1a) in the left amygdala ($t(43)=3.82$, $P=0.013$ family-wise error (FWE) corrected, peak Montreal Neurological Institute (MNI) coordinates: $x=-36$, $y=-9$, $z=-17$) and in the right amygdala ($t(43)=4.58$, $P=0.002$ FWE corrected, peak MNI coordinates: $x=27$, $y=12$, $z=-21$). We then conducted a confirmatory replication in study 2 with a strong a priori hypothesis of a positive relationship between system justification and amygdala volume (Fig. 2a), which was observed bilaterally (left amygdala, $t(40)=3.84$, $P=0.014$ FWE corrected, peak MNI coordinates: $x=-11$, $y=-1$, $z=-26$; right amygdala, $t(40)=4.68$, $P=0.002$ FWE corrected, peak MNI coordinates: $x=20$, $y=8$, $z=-14$). All significant clusters within the amygdala ROIs are reported in Supplementary Tables 1 and 2.

We then extracted mean grey matter volume values of all voxels within these amygdala masks to assess the bivariate correlation with system justification and alternative explanatory models (see Methods). We confirmed with the mean ROI volume analysis that larger grey matter volume in the bilateral amygdalae was strongly associated with greater system justification in study 1 ($r(46)=0.29$, $P=0.04$) (Fig. 1c), and study 2 ($r(43)=0.49$, $P=0.001$) (Fig. 2c), adjusting for age, sex and global brain volume[25].

To assess alternative explanations that variability in amygdala volume may be accounted for by more specific ideological beliefs or by ideological extremity, we tested a range of linear regression models that included political ideology, economic system justification (that is, the tendency to legitimize economic inequality under capitalism[36]) and attitudinal extremity (see Supplementary Methods and Supplementary Table 3 for discussion of each model). Across the various models in study 1, the data were most parsimoniously explained by a model that included system justification as the primary predictor of interest, $\beta=0.14$, $t=2.06$, $P=0.045$. A model that included ideology in addition to system justification did not explain a significantly greater proportion of the variance in amygdala volume than the model that only included system justification

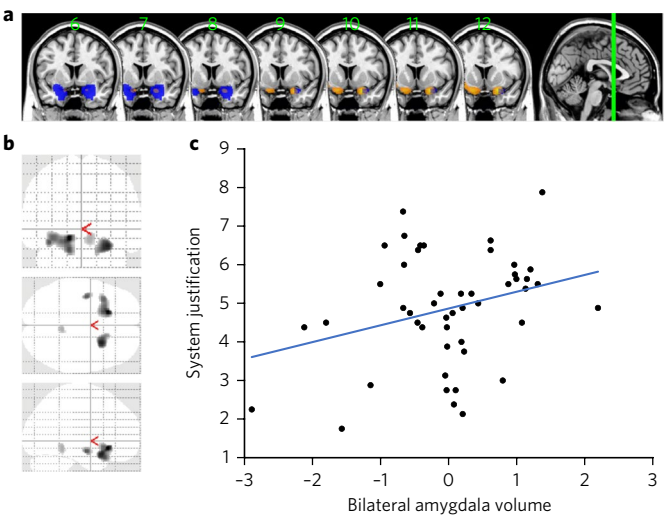

Fig. 1 | The relationship between grey matter volume in the bilateral amygdalae and system justification in study 1. a, Multi-slice coronal heat maps (at MNI $y=6$, 7, 8, 9, 10, 11, 12; slice positions are also indicated by green lines in sagittal cross-section displayed on the right) show that grey matter volume differences in the bilateral amygdalae are associated with system justification ($t>3.0$, $P<0.05$ FWE corrected). Amygdala effect is observed in the overlapping region between bilateral amygdala masks (in blue) and the system justification statistical map (in orange). **b**, Glass brain images of whole-brain analysis (coronal, axial, and sagittal cross-sections from top to bottom) suggest specificity of system justification effect in regions including the bilateral amygdalae ($P<0.001$, minimum cluster of 20 voxels). The red arrowheads mark the origin in the coordinate space. **c**, Higher tendencies to assess the existing social system as fair and legitimate (that is, system justification) were positively correlated with larger grey matter volume in the bilateral amygdalae ($r(46)=0.29$, $P=0.04$). Here, amygdala volume is computed as the average of the left and right amygdala volumes, adjusted for age, sex, and overall brain volume, and standardized such that 0 indicates the average volume with changes in 1 s.d. increments. In study 1, $N=48$.

($\Delta R^2<0.001$, $P=0.88$), and ideology was not a significant predictor of amygdala volume ($\beta=-0.01$, $t=-0.16$, $P=0.88$), whereas system justification remained a marginally significant predictor ($\beta=0.14$, $t=1.94$, $\Delta R^2=0.02$, $P=0.059$; see also Supplementary Methods). Additional models that examined differences in amygdala volume as a function of economic system justification and attitudinal extremity (across ideology, general system justification, and economic system justification) did not yield consistently significant effects. Tests of the same models for study 2 supported the observation that system justification (more than other factors) was a significant and robust predictor of amygdala volume (all βs >0.29, Ps <0.01 for system justification effects across models).

We also conducted an exploratory whole-brain analysis (following a previous study[25]) such that voxels that were positively related to system justification were thresholded at $P<0.001$ with a minimum cluster of 20 voxels (Figs. 1b and 2b). All peak clusters for both studies are reported in Supplementary Tables 1 and 2. In addition to confirming the bilateral amygdala effect, the whole-brain analysis of both studies revealed clusters in additional regions, such as the orbitofrontal cortex, which has rich connections with the amygdala and has also been identified as a crucial neural component in socioemotional behaviour. It has been suggested that the orbitofrontal cortex uses the motivational information detected by the amygdala to guide and adjust goal-directed behaviours in social environments, such as hierarchical contexts[37]. We also observed system justification

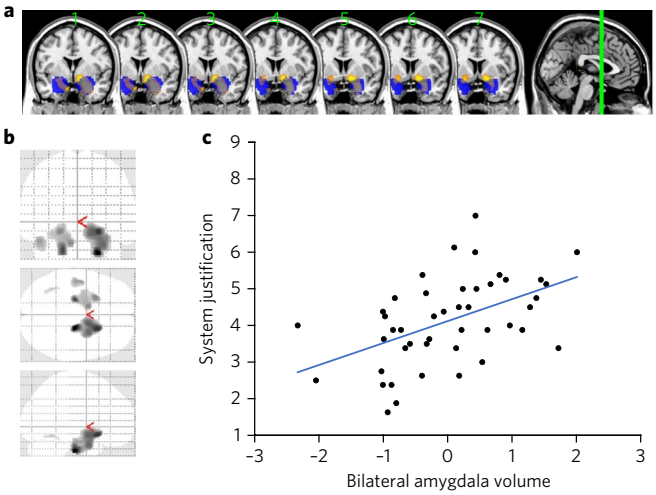

Fig. 2 | Confirmatory replication in study 2 of a positive correlation between bilateral amygdala volume and system justification. All computations and statistical adjustments are the same as in study 1. **a**, Multi-slice coronal heat maps (at MNI $y = 1, 2, 3, 4, 5, 6, 7$; slice positions are also indicated by green lines in sagittal cross-section displayed on the right) show that grey matter volume differences in the bilateral amygdalae are associated with system justification ($t > 3.0$, $P < 0.05$ FWE corrected). Amygdala effect is observed in the overlapping region between bilateral amygdala masks (in blue) and the system justification statistical map (in orange). **b**, Glass brain images of whole-brain analysis (coronal, axial, and sagittal cross-sections from top to bottom) suggest specificity of system justification effect in regions including the bilateral amygdalae ($P < 0.001$, minimum cluster of 20 voxels). Red arrowheads mark the origin in the coordinate space. **c**, Higher tendencies to assess the existing social system as fair and legitimate (that is, system justification) were positively correlated with larger grey matter volume in the bilateral amygdalae ($r(43) = 0.49$, $P = 0.001$). In study 2, $N = 45$.

effects in the insula in both studies, which is consistent with previous (incidental) findings that link the structure of the insula with conservatism[25]. As the insular cortex is a region linked to a diverse array of functions, such as disgust[38], interoceptive awareness[39], pain detection[40], and empathy[41], we did not have strong predictions regarding its relationship with system justification. Thus, although we did not predict structural variation in the orbitofrontal cortex and the insula (among other regions; see Supplementary Tables 1 and 2) as a function of system justification, future work that more directly examines such a relationship could reveal the regulatory processes necessary for functioning in and perhaps justifying a hierarchical social system.

An important implication of system justification is that even those who are disadvantaged by the existing social arrangements can be motivated to maintain such arrangements, thereby internalizing aspects of their own state of disadvantage[1]. For instance, women often exhibit attitudes and behaviours that support existing gender inequalities, such as believing they deserve less money for their work than men[42–44] and viewing themselves in sexually objectifying ways[45]. We explored the possibility that disadvantaged groups may be as likely as advantaged groups to exhibit a strong connection between amygdala structure and system-justifying tendencies by comparing women and men in our data. By combining both samples, we observed that the relationship between system justification and amygdala volume (adjusting for the effects of age, global brain volume, and sample) was not significantly different in women ($r(56) = 0.38$, $P = 0.004$) compared with men ($r(33) = 0.19$, $P = 0.28$): $z = 0.92$, $P = 0.36$ (two-tailed; see Methods and Supplementary Fig. 1). The positive relationship between amygdala volume and system justification was not significantly stronger for women than for men. This result suggests that the correlation is not driven simply by the members of an advantaged social group (men); rather, the same basic neurobiological processes seem to underlie system-justifying preferences in relatively advantaged and disadvantaged groups.

Finally, we investigated whether amygdala volume predicted subsequent political activity aimed at challenging the status quo. We followed up with 20 participants from study 1 who indicated whether they had participated in any protest movements over the (approximately) 3-year period following their initial brain scan (see Methods for details). We observed that larger amygdala volume (at time 1) was associated with a decreased likelihood of participating in a protest ($b = -4.03$, s.e. $= 1.81$, Wald $\chi^2(1) = 4.93$, $P = 0.03$, 95% confidence interval (CI) (e^b): {0.001, 0.624}) (Fig. 3). Although the sample size was small, this link between amygdala volume and protest behaviour provides initial evidence that the amygdala may not only be related to beliefs about society but also willingness to take action to change certain aspects of the social system.

Together, these findings provide evidence that links larger amygdala volume to (1) the tendency to justify the existing social system as legitimate and desirable, and (2) a reluctance to participate in social protest aimed at changing the status quo. These results were quite robust, having emerged in exploratory and confirmatory studies using relatively conservative amygdala ROI definitions and persisting after adjusting for other social and psychological variables.

Justifying existing hierarchical social structures most often benefits those who are in socially dominant positions, and for high-status individuals, basic motivations to positively regard oneself, one's group, and the larger social system are in alignment[1,2,46]. For those in low-status positions, this motivational intersection is fraught with difficulty, insofar as basic preferences to positively regard oneself and one's group often conflict with the individuals' location at (or near) the bottom of the hierarchical system[1]. Nevertheless, examples abound of low-status individuals who favour the dominant out-group over their subordinate in-group in a wide range of intergroup contexts, including those based on race, sex, and socioeconomic status[45,47,48]. However, the question remains whether it is occupying a dominant social position itself—or justifying the social structure that maintains power disparities—that is related to amygdala structure in humans. Although our comparison of men and women in the present studies suggests the possibility that members of relatively advantaged and disadvantaged groups share the same neural signature that underlies system justification, our sample was collected from a relatively high-status population (students at a highly ranked university). Still, our findings are consistent with the speculation that "the amygdala seems to be involved in the formation and maintenance of a social hierarchy as well as the perception and learning of social dominance"[49]. This analysis opens the door to further examinations of the pattern of relations involving the amygdala, social dominance, and system justification in advantaged and disadvantaged groups (see also Supplementary Discussion).

The healthy functioning of a democratic society is aided by a sophisticated understanding of the basic processes that motivate consequential political behaviours, such as taking collective action to subvert existing inequalities or supporting policies to maintain them. Our results suggest that a common neuroanatomical structure may support system-justifying preferences to maintain inequality, possibly among members of disadvantaged and advantaged social groups. This work contributes to a growing literature demonstrating that individual differences in social and political beliefs are not simply the product of deliberate considerations but are also deeply rooted in biological processes[50]. Continued investigations into the neurobiological and psychological processes that underlie social and political preferences are crucial for understanding when humans are expected to criticize or defend inequality in their social environments.

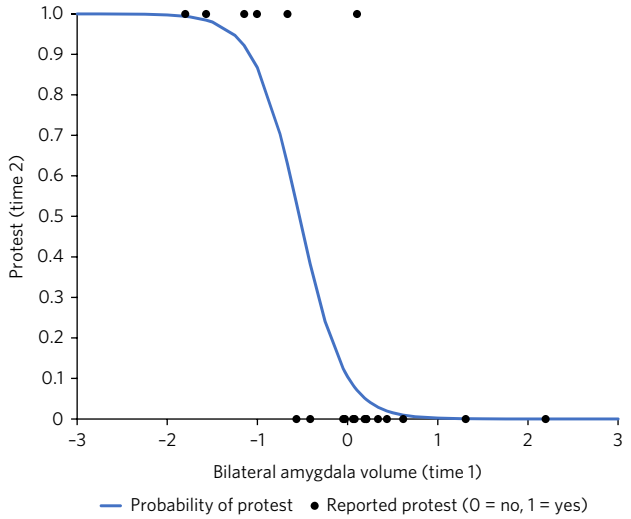

Fig. 3 | Participants' likelihood of participating in a protest during college. The likelihood of and reported participation in a protest during college were assessed at time 2 ($N=20$) and were predicted by bilateral amygdala grey matter volume (standardized and adjusted for age, sex, and global brain volume) at the start of college (time 1): $b=-4.03$, s.e. = 1.81, Wald $\chi^2(1)=4.93$, $P=0.03$, 95% CI (e^b): {0.001, 0.624}.

Methods

Participants. *Study 1.* We scanned 49 healthy right-handed participants (mean age = 19 yr; 58% female) who were recruited from the student participant pool at New York University (NYU), based on their participation in a mass questionnaire at the start of the term. The study was approved by the University Committee on Activities Involving Human Subjects, which is the NYU Institutional Review Board, and all participants provided written informed consent. The data for study 1 were collected from 2011 to 2012. We intentionally recruited an ethnically homogeneous, Caucasian sample from the NYU student participant pool to minimize potential racial/ethnic differences, and sampled evenly across the ideological spectrum. Owing to a clerical error, one participant was scanned who did not meet the pre-selection criteria; thus, we excluded this participant from the analyses, leaving 48 participants for the reported analyses.

Study 2. We scanned 45 healthy right-handed participants (mean age = 20 yr; 67% female) who were more ethnically diverse than in study 1 and who identified as 27% white, 9% black, 16% Latino/Hispanic, 44% Asian, and 4% other. The greater ethnic diversity of participants in study 2 expanded on the generalizability of study 1. The data for study 2 were collected from 2013 to 2014. The study was approved by the University Committee on Activities Involving Human Subjects, which is the NYU Institutional Review Board, and all participants provided written informed consent.

Procedure. Participants arrived to the scan centre 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) outside the scanner. The experimenter was unaware of the participants' ideology, and the ideological pre-selection process was independent of the scanning session.

In study 1, we randomly counterbalanced the order of the scan and the questionnaire to determine whether the experience of being inside the MRI scanner affected how participants reported their system-justifying and ideological beliefs: 25 participants were scanned before taking the questionnaire, and 23 participants were scanned after taking the questionnaire. There were no order effects for system justification, whether it was measured before (mean = 4.78, s.d. = 1.46) or after the scan (mean = 4.94, s.d. = 1.42) ($t(46)=0.39$, $P=0.70$). Participants who reported their ideology before the scan were significantly more conservative (mean = 6.13, s.d. = 2.67) than those who reported their ideology after the scan (mean = 4.28, s.d. = 2.25) ($t(46)=-2.61$, $P=0.01$). However, it may be that there were pre-existing ideological differences between the two groups despite random assignment, as we found that participants' ideology scores from a larger battery of questionnaires that were used for participant recruitment (measured before the experimental session and, therefore, unaffected by the study) were significantly more conservative among those who took the questionnaire first (mean = 6.52, s.d. = 2.64) than those who underwent the scan first (mean = 4.56, s.d. = 2.53) ($t(46)=-2.62$, $P=0.01$), 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: $t(46)=-1.04$, $P=0.30$.)

Given that the scanner experience did not seem to significantly affect participants' responding in study 1, in study 2, we 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[33], 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 "Society is set up so that people usually get what they deserve" 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 (s.d. = 1.43; $\alpha=0.88$). In study 2, the mean system justification score was 4.12 (s.d. = 1.18; $\alpha=0.73$).

Political ideology. Participants were also asked to indicate their political ideology[34] 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 (s.d. = 2.60). In study 2, the mean ideology score was 4.09 (s.d. = 2.00).

Consistent with previous work[27], greater system justification was correlated with greater conservatism in both studies (as administered in the scan session questionnaires): $r(46)=0.37$, $P=0.01$ (study 1); $r(43)=0.45$, $P=0.002$ (study 2).

MRI data acquisition. For both studies, we acquired MRI images with a 3T Siemens Allegra head-only scanner. T1-weighted high-resolution anatomical images (MPRAGE; repetition time = 2,500 ms, echo time = 4.35 ms, field of view = 256 mm × 256 mm, voxel size = 1 mm × 1 mm × 1 mm) were acquired for each subject, with slices collected manually aligned to be parallel to the anterior–posterior commissure line.

MRI data analysis. *VBM preprocessing and analysis.* We used VBM to analyse the structural images[35]. We first segmented T1-weighted magnetic resonance images into grey matter and white matter using the segmentation tools in Statistical Parametric Mapping 8 (SPM8; Wellcome Department of Imaging Neuroscience, http://www.fil.ion.ucl.ac.uk/spm). Next, we performed diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL) in SPM8 for intersubject registration of the grey matter images. We smoothed the registered images with a Gaussian kernel of 12 mm full-width half-maximum and then transformed them to MNI stereotactic space using affine and non-linear spatial normalization implemented in SPM8. We 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. Thus, the value of grey matter volume represented the volume of tissue per unit of spatially normalized image in arbitrary units. Total grey matter volumes across the whole brain were computed from the segmented images for each participant.

Small-volume analyses. We first conducted small-volume corrected ROI analyses on the smoothed, normalized images within anatomical masks of the left and right amygdalae. For these ROI-constrained analyses, we applied 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). These masks of the left and right amygdalae included voxels that had a ≥20% chance of being classified as the amygdala. (A parallel analysis using more inclusive amygdala masks—that is, masks that included voxels with a ≥0.5% chance of being classified as the amygdala—yielded nearly identical results.) We entered system justification scores as the primary contrast of interest in the model, as well as potential confounding variables of age, sex, and global brain volume as regressors of no interest in the SPM8 model, following previous literature[25].

Mean ROI value analyses. To assess a range of regression models, we applied the anatomical masks (a ≥20% chance of being classified as the amygdala) that were used for the small-volume analyses, and extracted the mean grey matter volume separately from all the voxels of the left and right amygdalae within these masks. We averaged the mean extracted volume of the left amygdala and the right amygdala to compute a single bilateral amygdala volume score for each participant. We then assessed the relationship between bilateral amygdala volume (using the extracted ROI values) and system justification, as well as political ideology, economic system justification[36], and ideological extremity across various regression models, again adjusting for the effects of age, sex, and global brain volume (see Supplementary Methods and Supplementary Table 3 for reports of all models tested that assessed the effects on amygdala volume).

We also explored other ROIs, following a previous finding that linked grey matter volume in the anterior cingulate cortex and the left insula to political ideology[25]. For these regions, we extracted grey matter volume using procedures in SPM8. These ROIs were defined as spheres with a radius of 20 mm centred at MNI coordinates $x=-3$, $y=33$, $z=22$ for the anterior cingulate cortex, and $x=-38$, $y=-16$, $z=-2$ for the left insula[25]. We did not find significant associations between these brain regions and system justification or ideology that replicated across both studies (see Supplementary Tables 4 and 5 for reports of all effects).

Whole-brain analyses. In addition, we explored whether there were other regions that varied with system justification across the whole brain. We entered the smoothed, normalized images into a multiple regression analysis across the participants. Following previous work[25,51,52], we included the regressors of sex, age, and overall brain volume as covariates of no interest and, therefore, regressed out any effects of these factors. We entered system justification as a regressor of interest. Voxels that were positively related to system justification were thresholded at $P<0.001$ with a minimum cluster of 20 voxels. See Supplementary Tables 1 and 2 for all peak clusters in study 1 and study 2, respectively.

Sex comparison. To explore the possibility that lower-status groups may be as likely as higher-status groups to exhibit a positive relationship between amygdala structure and system justification, we compared women and men in our data. We combined the samples of study 1 and study 2 to increase our statistical power for this analysis, and we used the extracted mean ROI values from the amygdala volume masks, adjusted for the effects of age, global brain volume, and sample. We found that the relationship between system justification and amygdala volume was not significantly different among women ($r(56)=0.38$, $P=0.004$) compared with men ($r(33)=0.19$, $P=0.28$): $z=0.92$, $P=0.36$ (two-tailed; see Supplementary Fig. 1).

Follow-up survey of protest participation. We recruited 20 participants (12 female) from study 1 whose data were initially collected when they were first year college students (time 1). These participants had previously indicated in study 1 that they would be interested in participating in follow-up studies, and we attempted to recruit the full sample of study 1, offering US$60 for follow-up participation. The follow-up survey (time 2) was conducted shortly before or after participants' college graduation (mean age = 21.95 yr). The average time difference between study 1 and the follow-up survey was 3.04 yr (s.d. = 0.28).

Because not all participants from study 1 (at time 1) came back at time 2, we compared those who had only participated at time 1 with those who participated at time 2 to assess whether the two subsamples differed substantially. We found that the two subsamples did not differ in age ($t(46)=0.95$, $P=0.35$), sex ($t(46)=0.39$, $P=0.70$), or political orientation ($t(46)=-0.52$, $P=0.61$). It should be noted that, at time 1, participants were pre-selected to represent the full spectrum of ideology (and to minimize the typically observed liberal skew in college participants). Despite the fact that we 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.

As an index of political behaviour in the form of collective action, we asked participants about their participation in protests since entering college ("Have you engaged in protest activities while in college?"), to which their response was binary (that is, yes or no). If participants indicated that they had engaged in protest activities, we also asked them to specify the type of protest. Six participants indicated that they had participated in a protest during college and 14 indicated that they had not. Of those who reported participating in a protest, they indicated that they had participated in protests on Occupy Wall Street ($N=4$), Black Lives Matter ($N=3$), the Climate Change March ($N=2$), 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.

To assess whether amygdala volume at the start of college could predict subsequent political activity, we entered amygdala volume (at time 1, adjusted for age, sex, and global brain volume) into a binary logistic regression that predicted 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: $b=-4.03$, s.e. = 1.81, Wald $\chi^2(1)=4.93$, $P=0.03$, 95% CI (e^b): {0.001, 0.624} (Fig. 3).

Life Sciences Reporting Summary. Further information on experimental design is available in the Life Sciences Reporting Summary.

Code availability. All syntax codes used for the analyses are available at https://osf.io/p7vmw/.

Data availability. All data and materials for these studies are available at https://osf.io/p7vmw/.

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Author contributions

H.H.N., J.T.J., and J.J.V.B. designed the research. H.H.N. and L.K. collected the data. H.H.N., L.K., and D.C.-M. analysed the data with input from J.T.J. and J.J.V.B. H.H.N. wrote the manuscript with input from all other authors.

Competing interests

The authors declare no competing interests.

Additional information

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☐ Initial submission ☐ Revised version ☒ Final submission

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Experimental design

1. Sample size

Describe how sample size was determined.

Sample sizes were determined by available funding and subject recruitment response. In Study 1, subjects were pre-selected from a larger battery of questionnaires to increase ideological representativeness and therefore the sample size was 49. A post hoc power analysis for Study 1's effect size of r=.29 reveals achieved power of .54. Study 2 was conducted as a replication and a post hoc power analysis for effect size of r=.49 for N=45 reveal achieved power of .96, suggesting that together, the samples obtained were sufficient.

2. Data exclusions

Describe any data exclusions.

We pre-selected Study 1 subjects from a larger battery of questionnaires to establish ideological representativeness, and we also deliberately used an ethnically homogeneous sample of White/European-American subjects to minimize potential group differences (following a similar example from Kanai, Feilden, Firth, & Rees, 2011*). One subject did not meet these pre-established criteria and was therefore excluded from Study 1's analysis. Study 2 included a more ethnically diverse sample in order to increase representativeness and did not exclude subjects from analysis.

* Kanai, R., Feilden, T., Firth, C. & Rees, G. Political orientations are correlated with brain structure in young adults. Curr. Biol. 21, 677-680 (2011).

3. Replication

Describe whether the experimental findings were reliably reproduced.

Study 2 was a confirmatory replication study of Study 1 and the experimental findings were reproduced.

4. Randomization

Describe how samples/organisms/participants were allocated into experimental groups.

The primary analyses in both studies did not involve assignment into experimental groups. In Study 1, we explored whether the experience of being in the MRI scanner would affect self-reports of political ideology and system justification. For this analysis, we randomly assigned subjects to fill out the questionnaire before or after the MRI scan.

5. Blinding

Describe whether the investigators were blinded to group allocation during data collection and/or analysis.

In both Studies 1 and 2, the experimenter was blinded to subjects' political ideology and system justification.

Note: all studies involving animals and/or human research participants must disclose whether blinding and randomization were used.

6. Statistical parameters

For all figures and tables that use statistical methods, confirm that the following items are present in relevant figure legends (or in the Methods section if additional space is needed).

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement (animals, litters, cultures, etc.)
☐	☒ A description of how samples were collected, noting whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ A statement indicating how many times each experiment was replicated
☐	☒ The statistical test(s) used and whether they are one- or two-sided (note: only common tests should be described solely by name; more complex techniques should be described in the Methods section)
☐	☒ A description of any assumptions or corrections, such as an adjustment for multiple comparisons
☐	☒ The test results (e.g. *P* values) given as exact values whenever possible and with confidence intervals noted
☐	☒ A clear description of statistics including central tendency (e.g. median, mean) and variation (e.g. standard deviation, interquartile range)
☒	☐ Clearly defined error bars

See the web collection on statistics for biologists for further resources and guidance.

Software

Policy information about availability of computer code

7. Software

Describe the software used to analyze the data in this study.	For structural MRI data processing and regression modeling, we used SPM8 as implemented in Matlab. For multiple regression modeling using extracted ROI values, we used SPSS statistical software. We did not use custom algorithms for analyses.

For manuscripts utilizing custom algorithms or software that are central to the paper but not yet described in the published literature, software must be made available to editors and reviewers upon request. We strongly encourage code deposition in a community repository (e.g. GitHub). *Nature Methods* guidance for providing algorithms and software for publication provides further information on this topic.

Materials and reagents

Policy information about availability of materials

8. Materials availability

Indicate whether there are restrictions on availability of unique materials or if these materials are only available for distribution by a for-profit company.	All behavioural questionnaire materials used were drawn from previous literature and are publicly available at https://osf.io/p7vmw/

9. Antibodies

Describe the antibodies used and how they were validated for use in the system under study (i.e. assay and species).	No antibodies were used.

10. Eukaryotic cell lines

a. State the source of each eukaryotic cell line used.	No eukaryotic cell lines were used.
b. Describe the method of cell line authentication used.	No eukaryotic cell lines were used.
c. Report whether the cell lines were tested for mycoplasma contamination.	No eukaryotic cell lines were used.
d. If any of the cell lines used are listed in the database of commonly misidentified cell lines maintained by ICLAC, provide a scientific rationale for their use.	No commonly misidentified cell lines were used.

Animals and human research participants

Policy information about studies involving animals; when reporting animal research, follow the ARRIVE guidelines

11. Description of research animals

Provide details on animals and/or animal-derived materials used in the study.

No animals were used.

Policy information about studies involving human research participants

12. Description of human research participants

Describe the covariate-relevant population characteristics of the human research participants.

In both Studies 1 and 2, human subjects were healthy (with no history of neurological disorders) and right-handed. In Study 1, the mean age was 19 years (SD = 1.16), comprised 28 female and 20 male subjects, and all subjects identified their race/ethnic background as White. In Study 2, mean age was 20 (SD = 1.66), comprised 30 females and 15 males, and the sample identified their race/ethnic background as 27% White, 9% Black, 16% Latino/Hispanic, 44% Asian, and 4% other.

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Date: 2017/09/30

Reporting Summary for MRI studies

Form fields will expand as needed. Please do not leave fields blank.

Experimental design

1. Describe the experimental design.	Resting state scan
2. Specify the number of blocks, trials or experimental units per session and/or subject, and specify the length of each trial or block (if trials are blocked) and interval between trials.	1 structural scan (MPRAGE)
3. Describe how behavioral performance was measured.	No task was administered in the scanner.

Acquisition

4. Imaging	
a. Specify the type(s) of imaging.	Structural
b. Specify the field strength (in Tesla).	3T
c. Provide the essential sequence imaging parameters.	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.
d. For diffusion MRI, provide full detail on imaging parameters.	n/a
5. State area of acquisition	Whole brain scan

Preprocessing

6. Describe the software used for preprocessing.	We segmented T1-weighted MR images into grey matter and white matter 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 we performed diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL) in SPM8 for intersubject registration of the grey matter images. We 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. We 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.
7. Normalization	
a. If data were normalized/standardized, describe the approach(es).	Affine and nonlinear spatial normalization (as implemented in SPM8) were applied to the grey matter images. We 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.
b. Describe the template used for normalization/transformation.	MNI stereotactic space as implemented in SPM8

8. Describe your procedure for artifact and structured noise removal.	n/a
9. Define your software and/or method and criteria for volume censoring and state the extent of such censoring.	n/a

Statistical modeling & inference

10. Define your model type and settings.	Multivariate regression group analysis including covariates of age, sex, global volume, and focal predictor of system justification.
11. Specify the precise effect tested.	We specified a t-contrast for the continuous variable of self-reported measure of system justification (within the factorial design of multiple regression), such that significant voxels would be positively related to system justification scores.
12. Analysis	
a. Specify whether analysis is whole brain or ROI-based.	The focal analyses are ROI-based. We also report more exploratory whole brain analyses.
b. If ROI-based, describe how anatomical locations were determined.	We specified the amygdala ROI within left and right amygdala masks based on the Harvard-Oxford subcortical structural atlas implemented in the Oxford University Centre for Functional MRI of the Brain Software Library (www.fmrib.ox.ac.uk), such that voxels within the mask had a 20% or greater chance of being classified as the amygdala.
13. State the statistic type for inference. (See Eklund et al. 2016.)	We report peak voxel statistics (as well as the cluster size in Supplementary Tables 1-2).
14. Describe the type of correction and how it is obtained for multiple comparisons.	Exploratory whole brain analyses were thresholded at $p < .001$ and minimum cluster of 20 voxels. For small volume corrected analyses we report FWE-corrected statistics.
15. Connectivity	
a. For functional and/or effective connectivity, report the measures of dependence used and the model details.	n/a
b. For graph analysis, report the dependent variable and functional connectivity measure.	n/a
16. For multivariate modeling and predictive analysis, specify independent variables, features extraction and dimension reduction, model, training and evaluation metrics.	Multivariate regression model included the independent variables of age, sex, global brain volume, and system justification.