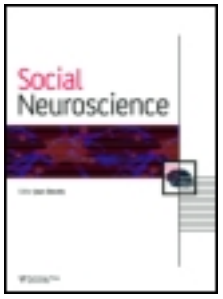

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Individualism, conservatism, and radicalism as criteria for processing political beliefs: A parametric fMRI study

Giovanna Zamboni [a b], Marta Gozzi [a c], Frank Krueger [a], Jean-René Duhamel [d], Angela Sirigu [d] & Jordan Grafman [a]

[a] National Institutes of Health, Bethesda, MD, USA

[b] Università di Modena e Reggio Emilia, Modena, Italy

[c] Università di Milano Bicocca, Milan, Italy

[d] Centre National de la Recherche Scientifique, Bron, France

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Individualism, conservatism, and radicalism as criteria for processing political beliefs: A parametric fMRI study

Giovanna Zamboni
National Institutes of Health, Bethesda, MD, USA, and Università di Modena e Reggio Emilia, Modena, Italy

Marta Gozzi
National Institutes of Health, Bethesda, MD, USA, and Università di Milano Bicocca, Milan, Italy

Frank Krueger
National Institutes of Health, Bethesda, MD, USA

Jean-René Duhamel and Angela Sirigu
Centre National de la Recherche Scientifique, Bron, France

Jordan Grafman
National Institutes of Health, Bethesda, MD, USA

Politics is a manifestation of the uniquely human ability to debate, decide, and reach consensus on decisions affecting large groups over long durations of time. Recent neuroimaging studies on politics have focused on the association between brain regions and specific political behaviors by adopting party or ideological affiliation as a criterion to classify either experimental stimuli or subjects. However, it is unlikely that complex political beliefs (i.e., ''the government should protect freedom of speech'') are evaluated only on a liberal-to-conservative criterion. Here we used multidimensional scaling and parametric functional magnetic resonance imaging to identify which criteria/dimensions people use to structure complex political beliefs and which brain regions are concurrently activated. We found that three independent dimensions explained the variability of a set of statements expressing political beliefs and that each dimension was reflected in a distinctive pattern of neural activation: individualism (medial prefrontal cortex and temporoparietal junction), conservatism (dorsolateral prefrontal cortex), and radicalism (ventral striatum and posterior cingulate). The structures we identified are also known to be important in self–other processing, social decision-making in ambivalent situations, and reward prediction. Our results extend current knowledge on the neural correlates of the structure of political beliefs, a fundamental aspect of the human ability to coalesce into social entities.

Keywords: Politics; Multidimensional scaling; Parametric fMRI; Social cognition; Medial prefrontal cortex; Temporoparietal junction; Ventral striatum.

Correspondence should be addressed to: Jordan Grafman, Cognitive Neuroscience Section, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Building 10, Room 7D43, MSC 1440, Bethesda, MD 20892-1440, USA. E-mail: grafmanj@ninds.nih.gov

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INTRODUCTION

Whenever and wherever people form a community, they are called to make explicit decisions affecting that social group, whether it be a school district or a state government. In its broadest sense, *politics* refers to the set of beliefs, behaviors, and rules through which humans cooperate and debate in order to reach a consensus on action. From a social cognitive neuroscience perspective, understanding how people evaluate and organize their political beliefs (i.e., ''the government should invest more in welfare'') and where in the brain this process is represented can help to better define the functioning of the social brain. Converging evidence from evolutionary psychology and cognitive neuroscience have, in fact, fostered the notion that various brain regions are differently specialized for social cognition (Adolphs, 2003a). Several neuroimaging studies have recently explored the neurobiological correlates of cooperation (Rilling et al., 2002; Sanfey, 2007), moral emotions (Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005), and trust (Krueger et al., 2007a), demonstrating the differential role of mesolimbic structures and prefrontal and temporoparietal cortices in representing different aspects of social cognition. Since politics is a domain where inter-individual relationships are driven to an even higher level of sophistication, we expect the involvement of similar brain networks.

However, only recently has social neuroscience explicitly investigated the neural correlates of politics (Amodio, Jost, Master, & Yee, 2007; Kaplan, Freedman, & Iacoboni, 2007; Knutson, Wood, Spampinato, & Grafman, 2006; Westen, Blagov, Harenski, Kilts, & Hamann, 2006). Some of these neuroimaging studies have explored the patterns of brain activity associated with the presentation of well-known politicians' faces, showing the involvement of dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC) in viewing the opposing candidate (Kaplan et al., 2007), and the involvement of the anterior prefrontal cortex in implicit measures of party membership biases (Knutson et al., 2006). Other studies have shown how candidates' declarations affect subjects' motivated reasoning (Westen et al. 2006) or have focused on neurophysiologic differences between liberals and conservatives associated with the involvement of the dorsal ACC during a cognitive (go/no-go) task (Amodio et al., 2007). All these neuroimaging studies on politics have focused on the neural correlates of political affiliation by examining the distinction between conservatives or liberals, or between the major competing US parties (Democrat and Republican) to classify either experimental stimuli or subjects. However, ideological or party affiliation might not entirely reflect how political beliefs are internally evaluated and can be influenced by other phenomena such as unreflective face judgment (Ballew & Todorov, 2007). In addition, in modern political psychology the assumption that people's political beliefs can be definitively explained by a liberal-to-conservative dimension has not been uniformly accepted (Converse, 1964; Feldman, 2003; McGuire, 1985). There should also be some concern that a one-dimensional approach may not be satisfactory since the definition of any label can change based on cultural and historical context (see Jost, Nosek, & Gosling, 2008). In addition, while a single label (e.g., conservatism) may account for voting patterns under certain conditions, it is unlikely that a unidimensional approach can satisfactorily explain the complexity of deliberative judgments about political issues.

Therefore, the present study differs from previous neuroimaging studies on politics in two ways. First, we attempted to ascertain whether a complete understanding of political beliefs requires a multidimensional approach rather than assuming that it relies only on the liberal-to-conservative dimension. Second, we focused on the characteristics concerning stimuli expressing different political beliefs, rather than on individual differences between subjects. We were particularly interested in studying how political beliefs are organized in terms of their communalities and differences and how this is reflected in brain activations, but less concerned with how people then translate beliefs into judgments of agreement/disagreement and, ultimately, into political behaviors such as voting. Therefore, we used the novel combination of multidimensional scaling (MDS) and parametric functional magnetic resonance imaging (fMRI) to investigate how the psychological architecture of political beliefs is organized and where it is represented in the brain. MDS is a data reduction technique that has been previously employed in political science to study the perception and evaluation of political candidates (Jacoby, 1986; Weisberg & Jerrold, 1970; Zinni, Rhodebeck, & Mattei, 1997). In cognitive neuroscience, it has

recently been used in association with fMRI to establish the psychological dimensions underlying the structure of social event knowledge and to identify their neural correlates (Wood, Knutson, & Grafman, 2005).

In a behavioral experiment, we applied MDS to similarity ratings, from 24 subjects, between pairs of a set of political statements (e.g., ''The government should invest more on welfare'' paired with ''The law should strictly control immigration'') and obtained a spatial distribution that was explained by three orthogonal dimensions. Individual differences such as political orientation, gender, or age did not affect the obtained MDS distribution and the three underlying dimensions. In a subsequent fMRI experiment, we asked a separate sample of 26 subjects to read and judge the same political statements. We then employed a parametric design to identify, across individuals, the brain regions whose neural response was linearly modulated by the salience of each of the three dimensions, independently from subjects' characteristics and judgments.

It has recently been proposed that the medial prefrontal cortex plays a fundamental role in social cognitive processes engaged in perception and judgments about other people (Amodio & Frith, 2006). As long as political thinking requires knowledge about people and society, we expected that the dimension that, compared to the others, discriminates between individual and collective involvement would be associated with activity in medial prefrontal cortex subregions. We further predicted that, in line with previous neuroimaging studies on politics, a dimension representing ideological preferences and party affiliation would instead be associated with activity in other regions of the prefrontal cortex such as the ACC and DLPFC, which have a role in processing political candidates' information (Kaplan et al., 2007; Knutson et al., 2006; Westen et al., 2006). Finally, we hypothesized that a dimension concerning emotional aspects of political beliefs would be associated with activity in mesolimbic structures.

MATERIALS AND METHODS

Pre-study and selection of experimental materials

Before the MDS and fMRI experiments, we conducted a pre-study to identify a set of political statements to be used as stimuli in both the experiments.

We selected items contained in several international and national studies and surveys of political relevance (European Values Study Group/World Values Survey Association, 2006; Robinson, Shaver, & Wrightsman, 1999). We converted them into 620 declarative statements, always using the auxiliary ''should'' prior to the active main verb in order to express an opinion. The political relevance of each statement was established by 12 independent subjects (6 women, mean age 28.1 ± 5.3 years, range 23–36, mean education 16.9 ± 2.7 years, range 16–22) using a seven-point Likert scale (from $1 =$ unrelated to politics, to $7 =$ completely related to politics). Statements receiving a median score lower than 3.5 on the political relatedness scale were excluded from the stimulus set, as well as statements explicitly referring to political parties or including individual names. The remaining statements were categorized by the experimenters into five relevant societal issues: ''welfare and economy'', ''values and religious beliefs'', ''general politics and political involvement'', ''civil rights'', ''crime, security and war''. Conceptually redundant statements were eliminated until an equal number of 16 statements for each of the five political issues were obtained. The final set of stimuli was composed of 80 political statements (see the complete list in the Appendix) with no explicit reference to political parties or single individuals. They were used for both the MDS and fMRI experiments.

Subjects who participated in the pre-study did not take part in the two experiments (MDS and fMRI experiments).

Subjects (MDS and fMRI experiments)

Twenty-four healthy volunteers (12 women, mean age 29.8 ± 5.8 years, range 22–42, mean education 18.3 ± 2.6 years, range 14–24) participated in the MDS experiment and another 26 healthy volunteers (13 women; mean age 30.3 ± 6.2 years, range 22–45; mean education 18.6 ± 2.5 years, range 12–23) in the fMRI experiment. All were US citizens, right-handed, and native English speakers. None of them reported a history of neurological or psychiatric disorders. All participants gave informed consent for a protocol that had been approved by the National Institute of Neurological Disorders and Stroke's Institutional

Review Board and were paid for their participation. They were recruited from the Washington, DC area between December 2006 and June 2007.

After the MDS and fMRI experiments, all participants rated on two different seven-point Likert scales their political orientation (from 1 = extremely liberal to 7 = extremely conservative) (Robinson et al., 1999). In the MDS experiment, 58.3% of subjects ($N = 14$) identified themselves as liberal (1, 2, and 3 on the seven-point scale), 25.0% of subjects ($N = 6$) identified themselves as conservative (5, 6 and 7 on the seven-point scale), and 16.7% of subjects ($N = 4$) identified themselves as moderate (4 on the seven-point scale). In the fMRI experiment, 50.0% of subjects ($N = 13$) defined themselves as liberal, 26.9% of subjects ($N = 7$) as conservative, and the remaining 23.1% ($N = 6$) as moderate.

There were no significant differences in age, $t(48) = -0.33$, $p = .75$, years of education, $t(48) = -0.45$, $p = .66$, and political orientation, $\chi^2 = 0.435$, df = 2, $p = .805$, between the two groups participating in the MDS and fMRI experiments.

MDS experiment

Subjects who participated in the MDS experiment were asked to rate the similarity between two simultaneously presented political statements on a seven-point Likert scale (from 1 = extremely similar, to 7 = not similar at all). Each political statement was individually paired with every other statement and each pair presented in random order for similarity ratings. Participants completed the similarity ratings over five testing sessions of two hours each, during one week. Next, they participated in an additional session where they rated each statement on a variety of seven-point scales, corresponding to external criteria potentially related to the dimensions along which political beliefs are organized. The sequence of statements was randomized for each criterion and for each participant, and the order of criteria was counterbalanced across subjects. The external scales were designed to rate statements as follows: *traditional/stereotypical versus open to change/novel*; *individual related versus society related*; "*I have no experience/knowledge about this issue" versus "I have a great amount of experience/knowledge about this issue"*; "*I am not concerned at all about this issue" versus "I am very concerned about this issue"*; "*society is not concerned at all about this issue" versus "society is very concerned about this issue"*; *moderate versus radical*; *liberal versus conservative*. These external scales were chosen based on theories from social psychology (e.g., the *traditional versus open to change* scale was derived from a theory of values), political psychology (e.g., the *liberal versus conservative* scale), and social neuroscience (e.g., *concern* and *experience* scales).

Individual differences MDS (PROXSCAL, SPSS, version 11.0 for PC) was applied to the similarity ratings. The optimal number of orthogonal dimensions explaining the obtained distribution was determined on the bases of stress (ranging from 0 to 1), which is given as a measure of the goodness-of-fit between the hypothesized structure and the original data (Kruskal & Wish, 1978; Schiffman, Reynolds, & Young, 1981). Multiple regression was used to interpret and label the obtained dimensions. In particular, ratings on the external scales were regressed over the dimensions' coordinates (the three dimensions were included as simultaneous predictors during the regression analyses) and those better explained by the dimensions were individuated on the basis of regression weights, multiple correlation coefficients, and significance of the linear regressions analyses (Kruskal & Wish, 1978).

In addition to dimensions' coordinates, the output of the weighted Euclidean MDS model includes weights that portray differences between different individuals. This allowed us to establish whether the resulting dimensions/criteria were homogeneously used across all the participants or whether they were affected by individual differences (Schiffman et al., 1981). We entered normalized weights into one-way ANOVAs to test whether there were differences between subgroups of subjects, based on differences in demographic and political orientation characteristics, in the salience they attached to the stimulus space dimensions.

fMRI experiment

fMRI paradigm

During the fMRI experiment, subjects were presented with the political statements that they saw via a mirror system attached to the head coil. Each political statement was presented under two different conditions (Figure 1). In the political judgment condition, subjects indicated

by pressing a key whether they mostly agreed or disagreed with the statement. This task was chosen to ensure that participants focused on the political meaning of the stimuli whereas their specific answers were not used as a condition in the fMRI analysis. In keeping with this approach, subjects were informed that their answers were not the focus of the experiment and that the task was meant to have them ''thinking politically''. In the font condition, subjects indicated the font in which the statement was written. This condition was included to be able to isolate in the general linear model the parametric effect of the dimensions only during the semantic processing of the statements (namely, the ''political judgment'' condition), and to exclude any potential parametric effect determined by perceptual and lexical processing induced by the ''font'' condition. In addition, there was a baseline condition during which subjects simply looked at a fixation asterisk. Subjects were instructed to press a key by using the index or middle finger of their right hand to judge whether they mostly agreed or disagreed (political judgment task) or to judge if the font was Helvetica or Swiss (font task). The order of runs and the key/finger assignment were counterbalanced across subjects. Before scanning, subjects were given a supervised practice session to familiarize themselves with the two tasks (different political statements were used for this purpose).

Each trial consisted of a slide stating the task (''judgment'', ''font'', or ''fixation'') displayed for 1.6 s, followed by the stimulus (statement or fixation asterisk) displayed for 6 s, followed by a blank screen displayed for a mean of 4 s (jittered from 2 to 6 s in 2-s steps). If the subject answered by pressing a response button within the 6 s, the statement disappeared and a blank screen completed the 6-s period allowed for each statement. There were four runs, each containing 50 trials ($N = 20$ judgment trials, $N = 20$ font trials, $N = 10$ fixation trials) presented in a pseudorandom order. No statements were repeated in the same run in order to minimize any potential retrieval effect. In addition, for each statement, the order of the task was randomly assigned, so that a potential effect of repetition would have equally affected the two experimental conditions. Visual stimulus presentation was controlled by the Experimental Run Time System (Berisoft Cooperation, Germany, www.erts.de).

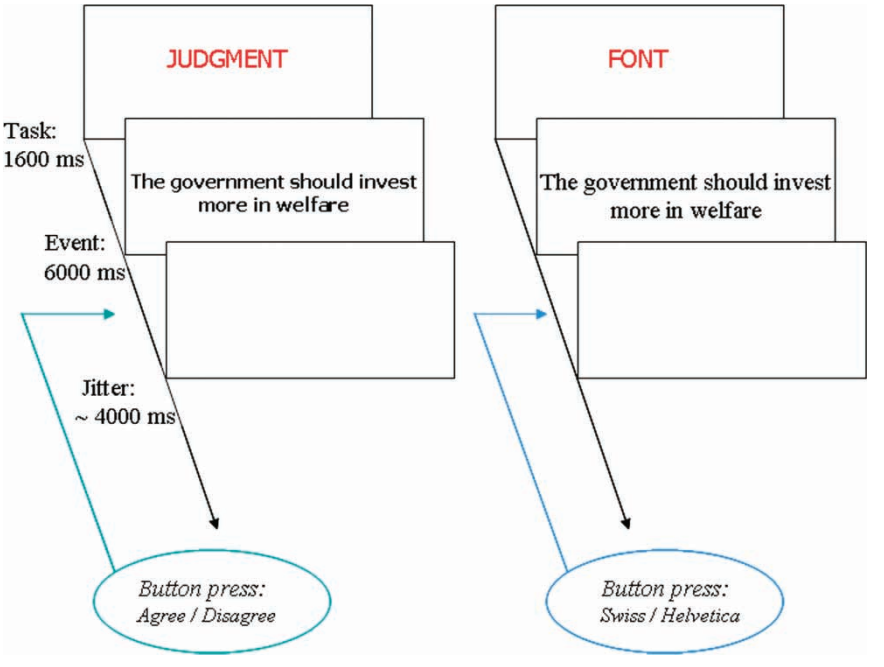

Figure 1. fMRI paradigm. In the fMRI experiment, each political statement was presented under two conditions. Furthermore, there was a baseline condition during which subjects looked at a fixation point (not shown in the figure). After a slide stating the task (displayed for 1.6 s), subjects saw the statement (displayed for a maximum of 6 s) and indicated whether they mostly agreed or disagreed (in the judgment task) or whether the statement was written in Helvetica or Swiss font (in the font task), then a blank screen (displayed for a mean of 4 s) appeared.

Image acquisition

A 3-T GE MRI scanner equipped with an eight-channel receiver head coil was used to acquire single-shot, 2D gradient EPI (echoplanar imaging) T2*-weighted images with blood oxygenation level-dependent (BOLD) contrast (TR = 2 s; TE = 30 ms; flip angle = 90°; FOV = 240 mm; 31 slices, slice thickness 3 mm without gap; matrix size = 64 × 64; voxel size = 3.75 × 3.75 × 3 mm). In each run, 297 functional volumes were obtained with slices acquired along the transverse plane, parallel to the anterior to posterior commissural line. The first five volumes were discarded to allow for T1 equilibration effects. High-resolution T1-weighted 3D MP-RAGE structural images were also acquired (TR = 6.1 ms; TE = min full; flip angle = 12°; FOV = 240 mm; 124 slices, slice thickness 1.5 mm; matrix size = 256 × 192 × 124).

Image analysis

Image preprocessing and statistical analyses were performed using SPM5 (www.fil.ion.ucl.ac.uk/spm/software/spm5). Preprocessing steps included realignment and unwarping, slice timing correction, normalization ($3 \times 3 \times 3$ mm^3 voxel size), and smoothing (full width at half maximum = 6 mm). Anatomical structural images were normalized and coregistered to the functional images. Estimated translation and rotation parameters were inspected and all subjects showed < 3 mm of motion. At the single-subject first-level analysis, statistical maps were constructed using a general linear model (Friston, Frith, Turner, & Frackowiak, 1995) which included as regressor functions the three trial types (''Political Judgment'', ''Font'', and ''Fixation''), plus three parametric regressors (corresponding to the three dimensions' coordinates) for the ''political judgment'' events and three parametric regressors for the ''font'' events. Those parametric regressors linearly modulated the hemodynamic responses as a function of the three dimensions for the ''political judgment'' and ''font'' events. Trials were modelled as events assuming a canonical hemodynamic response function (HRF) with time and dispersion derivatives. Linear contrasts were computed to assess the parametric effect of each dimension during the ''political judgment'' condition, controlling for the effect of the remaining regressors, including the effect of the same dimensions during the ''font'' condition. Note that we only considered the parametric effect of the dimensions while subjects were explicitly concentrating on the political meaning of the statements, controlling for the parametric effect of the same dimension when they were discriminating fonts.

The resulting contrast images were then entered in second-level random effect analyses, each estimating the parametric effect of a certain dimension. Subjects' self-ratings on the seven-point Likert political orientation scale were included as a nuisance covariate in all second-level analyses. This allowed us to control for its effect, and therefore to be sure that we were identifying those regions parametrically modulated by the dimensions independently from subjects' ideological preferences. *F* statistics were estimated to identify brain regions where the BOLD signal was linearly associated with each dimension, testing for both positive (activations) and negative (deactivations) relationships. Next, *t*-tests were estimated to detect whether the linear relationship was positive or negative in the identified regions (see Table 1). Statistical maps were thresholded at $p < .001$ uncorrected on the whole brain analyses (minimum cluster size = 5 voxels, corresponding to 135 mm^3). Small volume FWE-corrections at $p \leq .05$ were applied to predefined regions of interest (ROIs) for which we had an *a priori* hypothesis on the basis of previous studies on social cognition: prefrontal cortex (four subregions: ventromedial, dorsomedial, dorsolateral, and ventrolateral PFC) (Amodio & Frith, 2006; Kringelbach, 2005; Lotze, Veit, Anders, & Birbaumer, 2007), temporoparietal junction (TPJ) (Allison, Puce, & McCarthy, 2000; Puce & Perrett, 2003), striatum (including nucleus accumbens, putamen, and caudate) (Moll et al., 2006; Rilling et al., 2002), insula (Phan, Wager, Taylor, & Liberzon, 2004; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003), and amygdala (Phan et al., 2004; Phelps, 2006). The ROIs were created using the Automatic Anatomical Labeling (AAL) atlas (Tzourio-Mazoyer et al., 2002) as implemented in the WFU Pickatlas (Maldjian, Laurienti, & Burdette, 2004; Maldjian, Laurienti, Kraft, & Burdette, 2003) integrated in SPM5. Identification of brain regions was determined by using an anatomical atlas and looking at activations in original MNI space projected onto a standard MNI template. In addition, Talairach transformed coordinates (using Matthew Brett's formula, www.mrc-cbu.cam.ac.uk/imaging/common/mnispace.shtml) were used to identify corresponding Brodmann areas on the Talairach atlas. In Figures 4, 5, and 6 statistical

TABLE 1
Parametric effects of dimensions underlying political beliefs

Dimension	*Side*	*Area*	*x*	*y*	*z*	*Z score*	*Linear relationship*
Individualism	R	Anterior ventromedial prefrontal cortex (BA10)	3	43	−12	3.44*†	Positive
	R	Dorsomedial prefrontal Cortex (BA 9/32)	6	45	34	3.33*	Negative
	L	TPJ, Supramarginal Gyrus (BA40)	−50	−54	28	3.78*	Negative
	L	Lateral Orbitofrontal (BA47)	−48	34	−12	3.22	Negative
Conservatism	R	Dorsolateral Prefrontal Cortex (BA46)	48	39	15	3.89*	Positive
Radicalism	L & R	Posterior cingulate/precuneus (BA31)	−1	−60	28	3.68	Positive
	R	Anteroventral Striatum (caudate head)	6	18	2	3.64*†	Negative
	L	Posterior medial, Lingual (BA18)	−15	−90	2	4.03	Negative

Notes: All areas surviving $p < .001$ uncorrected threshold (cluster size of five or more voxels, corresponding to 135 mm^3) in the whole brain analysis are reported. *Areas surviving $p \leq .05$ small volume correction (FWE) over *a priori* ROIs. †Cluster size <135 mm^3. Coordinates are in Talairach space. ''Linear relationship'' column reports the sign of the parametric linear relationship: ''Positive'' denotes areas showing a positive linear relationship between the BOLD signal and a dimension's coordinates (namely, activation while the dimension increases, or deactivation while the dimension decreases); ''negative'' indicates a negative linear relationship (namely, activation with a dimension's decrease, or deactivation with a dimension's increase). BA, Brodmann's areas.

maps are displayed on a MRIcron template (Rorden & Brett, 2000) and thresholded at $p < .005$ (uncorrected) for illustrative purposes. Regional responses also survived FWE-corrected $p \leq .05$ over *a priori* ROIs.

RESULTS

MDS experiment

The MDS analysis, applied to the similarity ratings of political statements, allowed us to obtain a spatial distribution of the statements and to derive the number of orthogonal dimensions required to preserve their reciprocal distances (Figure 2). A three-dimensional solution was chosen on the basis of stress (normalized raw stress = 0.08). The 80 statements were normally distributed among the three dimensions (Kolmogorov-Smirnov tests $p > .3$, two-tailed, *ns*).

Participants' gender, age, and political orientation did not affect the importance of each dimension in the MDS model. In fact, there were no significant differences between younger (< 30 years old) and older participants (≥ 30 years old), $F(1, 22) < 1$, *ns*, between males and females, $F(1, 22) < 1.5$, *ns*, and between individuals who rated themselves as liberal, moderate, and conservative, $F(2, 21) < 3$, *ns*. Therefore, linear regression analyses were performed for the combined sample of 24 participants.

The first dimension ranged from statements such as ''Citizens should vote based on collective interest'' to statements such as ''Everybody should prioritize his or her own interest over society's''. It was significantly correlated with the external scale ''*individual versus society related*'' $R = .57$, $F(3, 76) = 12.40$, $p < .0005$, indicating that the higher the coordinate, the more individual-centered the statement. It represented the degree to which a political statement affects the single individual or the society, therefore we labeled it as *individualism.*

The second dimension ranged from statements such as ''Gays and lesbians should be able to get legally married'' to statements such as ''Everybody should oppose teaching evolutionary theory''. It strongly predicted the external scales ''*conservative versus liberal*'', $R = .94$, $F(3, 76) = 215.48$, $p < .0005$ and ''*stereotypical versus open to change*'', $R = .82$, $F(3, 76) = 51.74$, $p < .0005$, indicating that the higher the dimension's coordinate, the more conservative and stereotypical the statement. We labeled it as *conservatism.*

Finally, the third dimension ranged from statements such as ''The government should protect freedom of speech'' to statements such as ''People should use violence to pursue political goals''. This dimension predicted the scale ''*moderate versus radical*'', $R = .59$, $F(3, 76) = 13.85$, $p < .0005$, indicating that the higher the dimension's coordinate, the more radical the statement. It characterized political beliefs with respect to moderate or radical content, therefore we labeled it as *radicalism.* The radicalism dimension was distinct from the conservatism dimension. For example, statements that were located at the opposite ends on the conservatism dimension (e.g., ''The law should regulate sexual conduct'' and ''Terminal patients should

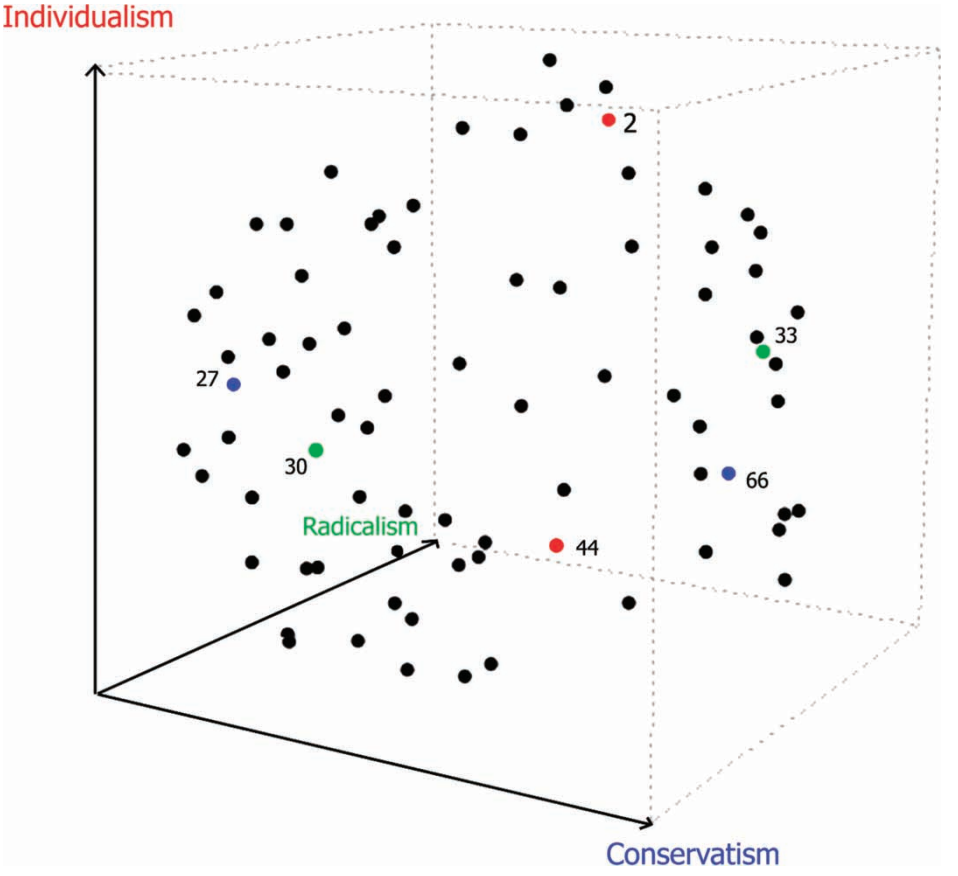

Figure 2. Spatial multidimensional scaling (MDS) distribution. Using MDS, subjects' similarity ratings were transformed into a three-dimensional spatial distribution in which each political statement can be described by three coordinates (Y = individualism, X = conservatism/traditionalism, Z = radicalism). Statements perceived as similar are close and statements perceived as dissimilar are distant. In red are shown examples of statements situated on the opposite ends of individualism (44 = "Citizens should vote based on collective interest"; 2 = "Everybody should prioritize his or her own interest over society's"); in blue, examples of statements situated on the opposite ends of conservatism (27 = "Gays and lesbians should be able to get legally married"; 66 = "The U.S. should use military force in Iran"); and in green, examples of statements situated on the opposite ends of radicalism (30 = "The government should protect freedom of speech"; 33 = "People should use violence to pursue political goals").

have the right to die") were located at the same end on the radicalism dimension, indicating that subjects judged them ideologically opposed but equally radical (Figure 3).

Since the MDS distribution was not affected by individual characteristics such as political orientation, gender, or age, we felt justified in our attempt to focus the fMRI experiment on activations related to characteristics of the political statements rather than on individual differences.

fMRI experiment

Behavioral results

Subjects who participated in the fMRI experiment accurately performed the control task that required them to discriminate between the fonts (mean error rates = 4.95%). They were significantly faster in the font task (mean response time 1452 ms $\pm$ 581) compared to the judgment task (mean response time 3239 ms $\pm$ 512), where they indicated whether they mostly agreed or disagreed with the statement, $t_{(25)} = -19$, $P < 0.0005$. However, correlations between the mean response times and the three dimensions' coordinates were not significant ($r_{(80)} < .1$, *ns*), ruling out task difficulty as a potential confound.

fMRI results

The *individualism* dimension was linearly associated with activation in the ventromedial prefrontal cortex (VMPFC; BA 10; Talairach coordinates of peak voxel: 3, 43, -12; Figure 4;

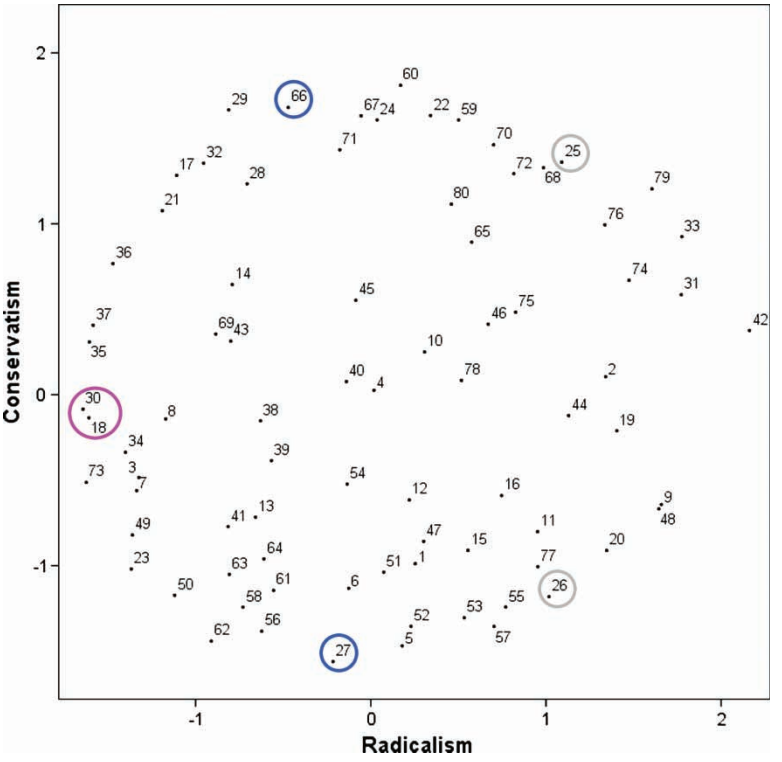

Figure 3. Spatial MDS distribution: plot of conservatism and radicalism. The 80 political statements are represented by numbered points. For clarity, only two of the three obtained dimensions are plotted. Circled in violet are examples of statements perceived as similar and thus spatially close in the MDS distribution (18 = "The government should protect religious freedom"; 30 = "The government should protect freedom of speech"). Circled in gray are examples of statements considered ideologically opposed, but similarly radical: statement 25 ("The law should regulate sexual conduct") showed a high score (1.3) on *conservatism*, whereas statement 26 ("Terminal patients should have the right to die") received a lower score on the same dimension (−1.1). The same statements obtained a similar high score on *radicalism* (∼1.0) in the MDS configuration. Circled in blue are other examples of statements (the same visualized in the same colour in Figure 2), considered even more ideologically opposed, similarly radical, but less radical as compared to the two previous examples: statement 66 ("The U.S. should use military force in Iran") showed a high score (1.7) on *conservatism*, whereas statement 27 ("Gays and lesbians should be able to get legally married") received a lower score on the same dimension (−1.5). The two statements obtained a similar score on radicalism (respectively, −0.5 and −0.2).

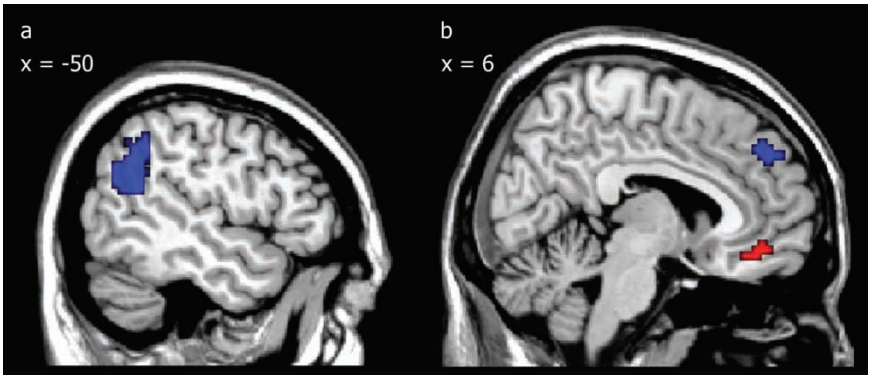

Figure 4. Parametric effect of individualism. Statistical maps are overlaid on a MRIcron template. (a) Coordinates of the individualism dimension showed a negative linear relationship with BOLD response (shown in blue) in the left TPJ, indicating that this region was increasingly activated by more society-related statements. (b) The same coordinates showed a positive linear relationship with BOLD responses (shown in red) in the ventromedial PFC, and a negative linear relationship with BOLD signal in the dorsomedial PFC, indicating that the two medial regions were increasingly activated by more individual-related and more society-related statements, respectively.

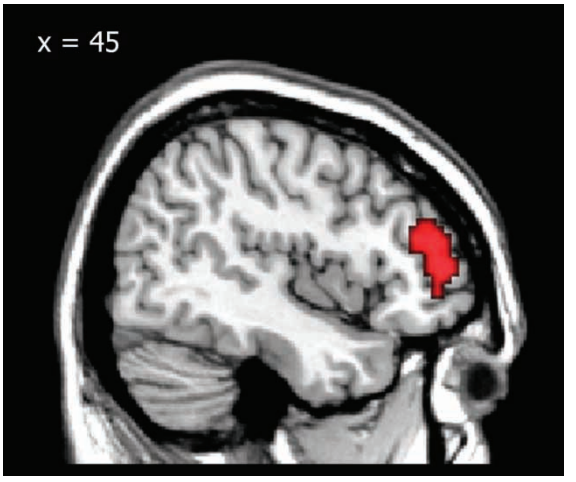

Figure 5. Parametric effect of conservatism. Coordinates of the conservatism dimension showed a positive linear relationship with BOLD responses (shown in red) in the right dorsolateral prefrontal cortex, indicating that this region was increasingly activated by more conservative and stereotypical statements.

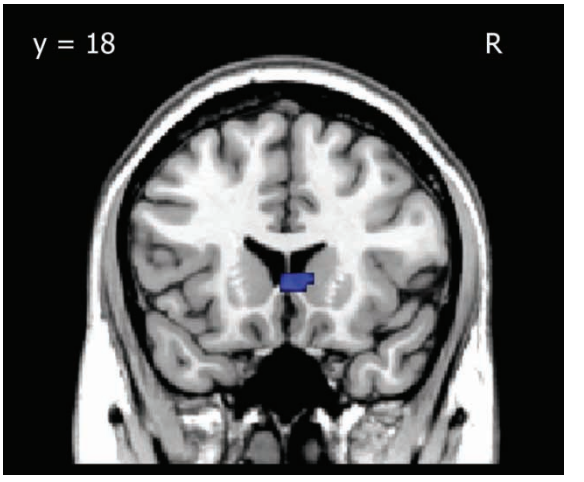

Figure 6. Parametric effect of radicalism. Coordinates of the radicalism dimension showed a negative linear relationship with BOLD responses (shown in blue) in the anteroventral striatum, indicating that this region was increasingly activated by more moderate statements.

Table 1), dorsomedial prefrontal cortex (DMPFC; BA 9/32; Talairach coordinates: 6, 45, 34), and left temporoparietal junction (TPJ; BA 40; Talairach coordinates: $-50, -54, 28$). More individual-related statements (e.g., ''Everybody should prioritize his or her own interest over society's'') were associated with increasing activation in the VMPFC. More society-related statements (e.g., ''Citizens should vote based on collective interest'') were associated with increasing activation in the right DMPFC and left TPJ.

The *conservatism* dimension was linearly associated with activation in the right DLPFC (BA 46; Talairach coordinates of peak voxel: 48, 39, 15; Figure 5). This region was increasingly activated for more conservative and stereotypical statements (''Everybody should oppose teaching evolutionary theory'').

The *radicalism* dimension was associated with activation in the anteroventral striatum (Talairach coordinates of peak voxel: 6, 18, 2; Figure 6) and posterior cingulate/precuneus (PC/P; BA 31; Talairach coordinates: $-1, -60, 28$). The linear relationship between neural response in anteroventral striatum and radicalism coordinates was negative, indicating that this region was more activated for more moderate and non-radical statements (''The government should protect freedom of speech''). Instead, the linear relationship between neural response in PC/P and dimension's coordinates was positive, indicating that this region was more activated for more radical statements (''People should use violence to pursue political goals'').

DISCUSSION

This study identified the neuroanatomical correlates of criteria used to evaluate political beliefs. The findings of the MDS experiment indicate that three independent and equally important criteria/dimensions (individualism, conservatism, and radicalism) can explain the variability of the political beliefs that we used as stimuli. These results are consistent with previous behavioral research in the field of social and political psychology that used data reduction techniques to identify factors or criteria organizing political attitudes. For example, *Individualism* and *Conservatism* appear similar to two dimensions identified by Schwartz in his work about human values (Schwartz, 1992). Using an MDS algorithm, he proposed that people's values could be arrayed along the ''*Self-transcendence versus self-enhancement''* dimension and the ''*Openness to change versus conservation''* dimension. When translated into the political domain, the first dimension would reflect the contraposition between collectivistic and individualistic political beliefs (in the present study, *Individualism*); the second dimension might reflect concerns about whether politics should focus on promoting civil rights or protecting societal *status quo* (in the present study, *Conservatism*). Other authors have

used multidimensional scaling techniques in the field of political psychology to study the perception of political candidates (Jacoby, 1986; Weisberg & Jerrold, 1970). They found that the differences between candidates can be explained by the ideological dimension (corresponding to *Conservatism*) usually associated to a more affective dimension regarding candidates' personality or appeal. The differences between our MDS results and previous political psychology studies that used MDS may be explained in terms of the type and number of political stimuli that we used (complex political statements instead of names or pictures of single individuals and a larger number of political stimuli). This was necessary in order to employ the MDS results in a parametric fMRI experiment. Note that the combination of MDS and fMRI has not only been advocated (Adolphs, 2003b) but also already applied (Wood et al., 2005) in the field of social neuroscience. However, further research applying data reduction techniques to stimuli with a political content is needed to replicate the behavioral results of the current study.

Having suggested a psychological architecture of political beliefs, parametric fMRI was then used to identify the brain regions whose neural activity is modulated by the salience of the identified criteria/dimensions when people "think politically", independently from their agreement with, or preferences for, a specific political statement.

The *individualism* dimension, expressing whether a political belief is individual- or society-centered, was linearly associated with activation in VMPFC, DMPFC, and TPJ. It has been demonstrated that the medial prefrontal cortex has a prominent role in self-referential processing (Amodio & Frith, 2006; Northoff et al., 2006) and in tasks implying the distinction of self or others' attributes (Ochsner et al., 2004). Our results revealed an opposite pattern of activation of the VMPFC and DMPFC, suggesting that distinct medial prefrontal cortical regions are associated with the processing of different features of social knowledge. In line with this functional distinction, it has been shown that the VMPFC is activated when inferring the mental state of similar others whereas the DMPFC is activated when inferring the mental state of dissimilar others (Mitchell, Macrae, & Banaji, 2006). This has suggested that the VMPFC is primarily involved in self-referential processing and is also engaged when others-referential processing implies a self-referential evaluation, whereas the DMPFC is associated with more universally applicable social-cognitive processes independent from the self (Mitchell et al., 2006). In the context of the present experiment, more individual-centered political statements were associated with greater activity in the VMPFC because they may have induced self-referential processing. Conversely, more society-centered statements were associated with greater activity in the DMPFC because they may have required others-related social processing. Further studies are needed to explore this association between individualism and self-referential processing and between collectivism and others/societal-processing.

There is evidence that the TPJ in humans is involved in the representation of perspectives that help distinguish self and others (Decety & Sommerville, 2003; Sirigu, Daprati, Pradat-Diehl, Franck, & Jeannerod, 1999) and in the interpretation of the intentions of others' goal-directed movements (Blakemore & Decety, 2001). Therefore, it has been argued that this region has a role in decoding socially relevant information (Adolphs, 2003a). The involvement of the TPJ in processing society-related statements is probably related to its importance for detecting socially relevant attributes and taking the perspective of others.

The *conservatism* dimension, which corresponds to the liberal-to-conservative criterion, was associated with activity in the right DLPFC. There is a large literature on DLPFC function in cognitive neuroscience, with many studies associating this region with working memory (D'Esposito, Postle, Ballard, & Lease, 1999; Owen et al., 1998; Petrides, 2000), response inhibition (Mitchell, Rhodes, Pine, & Blair, 2008), emotion (Hooley, Gruber, Scott, Hiller, & Yurgelun-Todd, 2005), and moral judgment (Moll et al., 2005). In this study, we speculate that activity in the DLPFC may reflect a role of this region in deliberative decision-making in complex social evaluations. This interpretation is supported by previous studies demonstrating DLPFC activation when subjects were faced with good/bad decisions and had to reflect about their initial response (Cunningham & Zelazo, 2007), and when subjects decided whether to accept or reject unfair monetary offers in the Ultimatum Game (Sanfey et al., 2003). A recent transcranial magnetic stimulation (TMS) study demonstrated that only the right, and not the left, DLPFC has

a role in implementing fairness motives when self-interest (represented by the impulse to earn money) and fairness (represented by costly punishment of unfair offers) are in conflict (Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006). The observation that this region was increasingly activated by conservative beliefs could be explained by claiming that conservative statements require more complex social judgments marked by greater cognitive dissonance between self-interest and sense of fairness.

Alternatively, greater DLPFC activation for more conservative statements may have more to do with the liberally minded participants' reaction against such statements. Although participants' ideological affiliation was added in the analysis as a nuisance covariate allowing us to control for between-subjects differences, it is still true that, as a group, subjects participating in our study were more liberal than conservative (see Methods). Therefore, the activity in the DLPFC in response to more conservative statements may reflect cognitive control mechanisms elicited by other-party opinions. This interpretation is supported by previous research showing that the DLPFC was bilaterally engaged when viewing a political candidate from the opposing political party compared with viewing one's own candidate (Kaplan et al., 2007) and when viewing one's own candidate in association with unpleasant words in a political Implicit Association Test (Knutson et al., 2006). Activity in this area was also found for faces of racial outgroups (Cunningham, Raye, & Johnson, 2004; Richeson et al., 2003). These previous studies, coupled with the current results, suggest that activation of cognitive control networks in the DLPFC may reflect the active inhibition of, and deliberation over, unwanted biases. It is possible that subjects were trying to mitigate their negative feelings toward the opposing party in order to decide whether they agreed or disagreed with the specific position expressed in the statement. While the current results demonstrate the involment of the DLPFC in processing information when a liberal-to-conservative criterion is involved, future studies will be needed to clarify its role in the mediation of complex judgments versus the implementation of cognitive control mechanisms.

The *radicalism* dimension, expressing the degree to which a political statement is radical or moderate, was linearly associated with activation in the anteroventral striatum and PC/P. Neuroimaging and electrophysiological evidence have suggested that the ventral striatum regulates reward reinforcement and prediction and is activated by a number of stimuli, including food and money (O'Doherty, 2004; Schultz, Tremblay, & Hollerman, 1998; Walter, Abler, Ciaramidaro, & Erk, 2005). In addition, in a neuroimaging study on iterative competitive games (the Prisoner's Dilemma game), a similar activation of the right anteroventral striatum has been found when subjects were cooperating, but not when they were defecting (Rilling et al., 2002). Based on this finding, the authors suggested that the striatum is also involved in more abstract rewards such as the feeling of being engaged in a mutually cooperative social interaction. Accordingly, our results demonstrated that this region was increasingly activated by moderate and non-radical statements (e.g., ''The government should protect freedom of speech'', ''The U.N. should keep the world in peace''). We argue that since moderation—as opposed to radicalism and fundamentalism—is a largely accepted and shared social value, activation of the anteroventral striatum reflects the rewarding effect of moderate and non-radical political beliefs. Instead, the neural response in PC/P increased for more radical statements. The involvement of this region may reflect its role in the encoding of emotion-laden autobiographical memories regarding the recent past (Fink et al., 1996; Piefke & Fink, 2005), in episodic retrieval (Wagner, Shannon, Kahn, & Buckner, 2005), and in emotional salience processing (Maddock, 1999; Maddock, Garrett, & Buonocore, 2003).

In summary, we showed that the representation of complex political beliefs relies on three fundamental dimensions, each reflected in distinctive patterns of neural activation: The degree of *individualism* of political beliefs was linearly associated with activation in the medial PFC and TPJ, the degree of *conservatism* with activation in the DLPFC, and the degree of *radicalism* with activation in the ventral striatum and PC/P. Our findings support the interpretation that the political belief system depends on a set of social cognitive processes including those that enable a person to judge themselves and other people, make decisions in ambivalent social situations, and comprehend motivational and emotional states. It is likely that the importance of these processes, each associated to a dimension, would rise or fall depending on the context of the specific

political task a person is engaged in. Future research is needed to clarify their interactions.

The multidimensionality of this system and the engagement of an extended neural network demonstrate the complexity of the organizational structure of explicit political beliefs and undermine the plausibility of using a one-dimensional approach to understand all forms of political thought. How this multidimensional political belief system evolved from more basic social phenomena and how it influences people's political behaviors such as voting remain open to empirical investigation.

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APPENDIX

Set of the 80 statements used in the MDS and fMRI experiments

The government should invest more in foreign aid.
Everybody should prioritize his or her own interest over society's.
The U.S. should encourage utility companies to sell clean energy.
Everybody should pay high taxes for extensive social welfare.
Everybody should reduce water consumption for environmental reasons.
The government should invest more in welfare.
The government should invest more in research.
The government should invest more in education.
The U.S. should increase taxes for rich people.
People without talents should live in need.
The government should provide jobs for everyone.
The government should provide housing for everyone.
The U.S. should support social equality.
Everybody should accept his or her place within society.
The government should provide health care for everyone.
Everybody should receive free health care.
Religious leaders should influence people's votes.
The government should protect religious freedom.
Society should get priority over individual interests.
Everybody should support anti-nuclear energy movements.
Politicians should prohibit euthanasia.
Politicians should speak out against homosexuality.
Everybody should freely decide about abortion.
The law should prohibit abortion.
The law should regulate sexual conduct.
Terminal patients should have the right to die.
Gays and lesbians should be able to get legally married.
The law should limit experiments with human embryos.
Everybody should oppose teaching evolutionary theory.
The government should protect freedom of speech.
The government should control the press.
Politicians should believe in God.
People should use violence to pursue political goals.
The U.S. should advance human rights in other countries.
The U.S. should bring democracy to other nations.
The U.S. should support dissidents in dictatorial countries.
The U.S. should support the pro-democracy movement in China.
The U.N. should help all developing countries.
Young people should care about politics.
Everybody should attend lawful demonstrations.
People should have the right to participate in strikes.
People should support dictators.
Citizens should vote based on self-interest.
Citizens should vote based on collective interest.
Citizens should support candidates of the same race.
Politicians should care only about their campaign contributors.
Everybody should have the right to sign petitions.
Young people should protest against capitalism.
Everybody should support anti-racist movements.
African American children should get more scholarships.
Jews should have more influence on American politics.
African Americans should have more influence on American politics.
Hispanic Americans should get jobs without discrimination.
African Americans should get housing without discrimination.
The U.S. should elect an African-American president.
The U.S. should elect a woman president.
Women should have more influence on American politics.
Politicians should limit gender discrimination.
The country should fear homosexuals.
The country should fear Muslims.

Homosexuals should hold public demonstrations.
Muslims should teach in schools.
Politicians should limit racial discrimination.
Immigrants should freely enter U.S. borders.
All U.S. citizens should fight for the country.
The U.S. should use military force in Iran.
The U.S. should use nuclear weapons again.
The government should invest more in defense.
Politicians should oppose nuclear proliferation.
The U.S. should maintain strong military forces.
The U.S. should intervene militarily in other countries.
The U.S. should use military force against Palestinians.
The U.N. should keep the world in peace.
Everybody should sacrifice his or her own life for the country if necessary.
People should have the right to kill in self-defense.
Every nation should have the death penalty.
The U.S. should prohibit the death penalty.
The law should control gun selling to reduce crime.
The government should use torture with terror suspects.
The law should strictly control immigration.