Red Brain, Blue Brain: Evaluative Processes Differ in Democrats and Republicans

Darren Schreiber[1,2*], Alan N. Simmons[3,4], Christopher T. Dawes[1], Taru Flagan[3,5], James H. Fowler[1], Martin P. Paulus[3,4,5]

[1] *Department of Political Science, University of California San Diego, La Jolla, CA 92103 USA*
[2] *School of Law, University of San Diego, San Diego, CA 92110 USA*
[3] *Department of Psychiatry, University of California San Diego, La Jolla, CA 92093, USA*
[4] *Veterans Affairs San Diego Healthcare System, San Diego, CA 92161, USA*
[5] *Laboratory of Biological Dynamics and Theoretical Medicine, University of California San Diego, La Jolla, CA 92093, USA*

*To whom correspondence should be addressed. Email: dmschreiber@ucsd.edu

We matched public voter records to 54 subjects who performed a risk-taking task during functional imaging. We find that Democrats and Republicans had significantly different patterns of brain activation during processing of risky decisions. Amygdala activations, associated with externally directed reactions to risk, are stronger in Republicans, while insula activations, associated with internally directed reactions to affective perceptions, are stronger in Democrats. These results suggest an internal vs. external difference in evaluative process that illuminates and resolves a discrepancy in the existing literature. This process-based approach to political partisanship is distinct from the policy-based approach that has dominated research for at least the past half century. In fact, a two parameter model of partisanship based on amygdala and insula activations achieves better accuracy in predicting whether someone is a Democrat or a Republican than a well-established model in political science based on parental socialization of party identification.

Ideological differences between political partisans have been attributed to logical, psychological, or social constraints [1]. These differences are thought to be driven by institutional political processes or individual policy preferences, rather than biological differences in evaluative processes. To test a conjecture that ideological differences between partisans reflect distinctive neural processes, we matched publicly available party registration records with the names of participants (28 males, 26 females) who had previously taken part in an experiment designed to examine risk-taking behavior during functional brain imaging.

Individuals completed a simple risk-taking decision-making task [2] during which participants were presented with three numbers in ascending order (20, 40, and 80) for one

second each. While pressing a button during the presentation of the number 20 on the screen always resulted in a gain of 20 cents, waiting to select 40 or 80 was associated with a pre-determined possibility of losing 40 or 80 cents. Therefore, participants chose between a lower "safe" payoff and a higher risky payoff. The probabilities of receiving a negative 40 or 80 were selected such that there was no advantage of choosing 20, 40 or 80 during the task, i.e. the overall pay-off would have been the same for each pure strategy.

Participant groups were composed of 31 Democrats and 23 Republicans who did not differ with regard to age ($F(52,1)=1.73$, $p=0.19$) or gender ($\chi^2=1.31$, $p=0.253$) and gave informed written consent approved by the University of California San Diego Human Research Protection Program. Imaging data was processed using AFNI [3] and extracted for a priori regions of interest within the amygdala, insula, and anterior cingulate. Significantly greater activation was observed in the bilateral amygdala and ventral anterior cingulate for Republicans and in the right anterior insula in Democrats when making winning risky versus winning safe decisions (see SOM).

The amygdala plays a critical role in fear conditioning, however, this structure is also important for other emotional information processing and behavior [4]. Functional neuroimaging studies have shown amygdala activation in fear conditioning [5], reward related processing [6], encoding of emotionally salient information [7], risk-taking [8], processing positively valenced stimuli[9], and appetitive or aversive olfactory learning[10]. In comparison, neuroimaging studies of insular cortex have found critical involvement of this neural structure in pain [11], interoceptive [12], emotion-related [13], cognitive [14], and social processes [15]. In particular, the insular cortex is important for subjective feeling states and interoceptive awareness [12, 16]. Thus, it appears in our experiment that Republican participants, when making a risky choice, are predominantly

externally oriented, reacting to the fear-related processes with a tangible potential external consequence. In comparison, risky decisions made by Democratic participants appear to be associated with monitoring how the selection of a risky response might feel internally.

The association between party identification and ideology is well known, with Republicans typically exhibiting more political conservatism than Democrats [17]. Prior studies have shown that self-reported liberals demonstrate stronger levels of physiological sensitivity to cognitive conflict [17] and that supporters of socially conservative policies have higher skin conductance response levels when exposed to startle stimuli [18]. The present study resolves the apparent conflict in these results. If Republicans are utilizing externally oriented processes in reacting to risks while Democrats are internally directed, then we would expect the one group to be more supportive of socially conservative policies and the other to be more sensitive to internal conflict.

A critical unresolved problem common to studies of the formation of ideology on both individual and institutional levels is the process through which a high dimensional space of distinct values, preferences, or issues is reduced to a low dimensional ideological space [19]. It is even less clear why voters and their representatives in government should organize political attitudes into apparently constrained bundles that are relatively consistent over time [20]. While it has been suggested that biological factors may lead liberals and conservatives to have different sets of politically relevant *values* [21], the evidence presented here suggests that the *processes* of evaluation themselves are distinct, perhaps leading to differentiable values, as well as differing preferences for issues, candidates, and parties.

Perhaps the strongest finding to come out of the "Michigan school" when the behavioral revolution spread to political science in the 1950s is that parents socialize their children to

identify with the same political parties that they do. In fact, the correlation between parent and child is "so familiar and well established" that it is often taken as one of the few "axioms" of political science [22]. Indeed, a simple model of partisanship that includes mother's and father's party accurately predicts about 69% of self-reported choices between the Democratic and Republican party (see SOM). Yet, a simple two-parameter model of partisanship using activations in the amygdala and the insular cortex during the risk task significantly out-performs this longstanding model, correctly predicting about 79% of the observed choices (see SOM).

A central question unanswerable by this present study is the direction of causality. Although political ideology [21] and strength of partisanship appear to be genetically heritable [23], identification with a particular party does not. Thus, it is possible that neurobiological differences between Republicans and Democrats drive their identification with different parties. And, it is also possible that the mental processes that distinguish the world views of Republicans and Democrats are reflected in the different neural mechanisms they utilize. Further untangling the roles of party, ideology, genes, and neurocognition will be essential for advancing our understanding of political attitudes and behavior. Being able to accurately predict party identification using only neural activity during a risk-taking task suggests that investigating basic neuropsychological differences between partisans may provide us with more powerful insights than have been available using the traditional tools of political science.

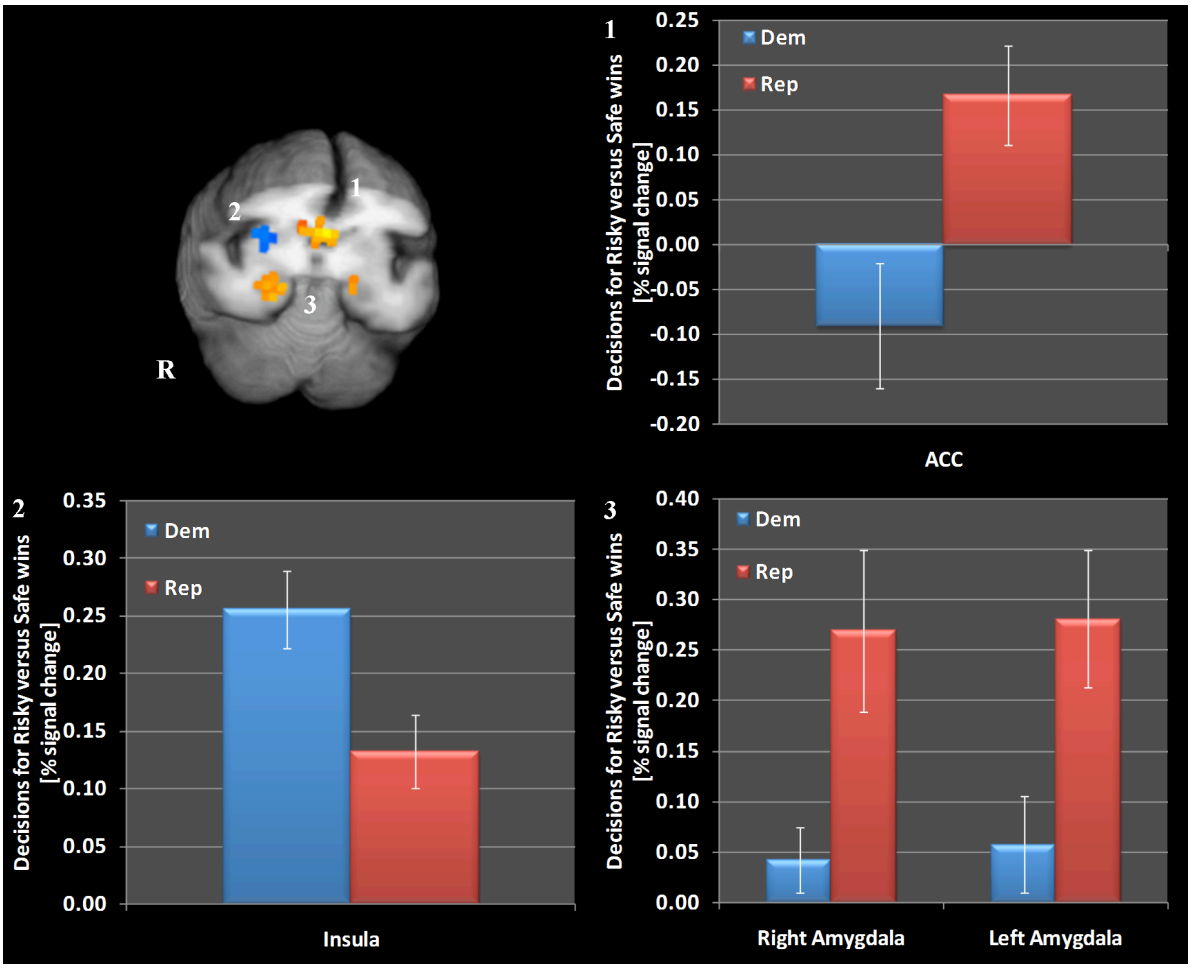

Figure 1. Republicans and Democrats differ in the neural mechanisms activated while performing a risk-taking task. Republicans more strongly activate their ventral anterior cingulate (Region of Interest 1 in the brain image and bar graphs above) and bilateral amgydala (3 above), associated with a more externally oriented reaction to risk. Democrats have higher activity in their right insula (2 above), associated with internally directed reactions to affective perceptions.

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Supporting Online Material
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*To whom correspondence should be addressed. Email: dmschreiber@ucsd.edu

Participants

The UCSD Institutional Review Board approved study procedures. All participants provided written informed consent and were paid for their participation. Fifty-four individuals were studied, including 31 Democrats and 24 Republicans. We acquired voter registration records from San Diego County in March 2008 that included party of registration and electoral turnout history, and names, addresses, and phone numbers to ensure exact matches to subjects who participated in the functional brain imaging study. The groups of Democrats and Republicans did not differ in age (Dem= 27.5, SD=10.1; Rep=31.4, SD=11.7; $F(52,1)=1.73$, $p=0.19$) and gender (Dem: 17 females and 14 males; Rep: 9 females and 14 males; $\chi^2=1.31$, $p=0.25$). Functional imaging data was collected across 1.5T (n=12) and 3T (n=42) scanners. There was no difference between Democrats and Republicans on which scanner the data was acquired on ($\chi^2=0.47$, $p=0.50$).

Task

For the Risky-Gains task [1], participants were presented with three numbers in ascending order (20, 40, and 80). Each number was presented on the screen for one second and if the participant pressed a button when the number was shown on the screen, he/she received the number of points shown on the screen. The participants were informed that for both 40 and 80 points there was a chance that a 40 or 80 in red color might appear on the computer screen which signaled that the participant lost 40 or 80 points, respectively. Thus, although the participant may have gained more points per trial by waiting until a 40 or 80 appears on the screen, there was also a risk of losing 40 or 80 points. The probabilities of presenting a negative 40 or 80 are such that a participant's final score would be identical were they to consistently select 20, 40, or 80. Thus, there was no inherent advantage to select the risky response (40 or 80) over the safe response (20). Each trial lasted 3.5 s irrespective of the participant's choice and the participant received rewarding feedback (stimulus on the screen and auditory sound) immediately after selecting a response.

Image acquisition

For 42 participants, during the task a BOLD-fMRI run was collected for each participant using a Signa EXCITE (GE Healthcare, Milwaukee) 3.0T scanner (T2 * weighted echo planar imaging, TR=2000ms, TE=32ms, FOV=250x250 mm3, 64×64 matrix, 30 2.6mm axial slices with a 1.4mm gap, 290 scans). Functional MRI acquisitions were time-locked to the onset of functional run. During the same experimental session, a high resolution T1-weighted image (SPGR, TI=450ms, TR=8ms, TE=4ms, flip angle=12°, FOV=250x250, ~1 mm3 voxels) was obtained for anatomical reference. For 12 participants, during the task a BOLD-fMRI run was collected for each participant using a 1.5-T Siemens (Erlangen, Germany) scanner (T2*-

weighted echo planar imaging, TR=2,000 ms, TE=40 ms, 64×64 matrix, 20 4-mm axial slices, 256 repetitions). During the same experimental session, a T1-weighted image (MPRAGE, TR=11.4 ms, TE=4.4 ms, flip angle=10°, FOV=256×256, 1 mm^3 voxels) was obtained for anatomical reference.

fMRI analysis pathway

The data were preprocessed and analyzed with the software AFNI [2]. The echo-planar images were realigned to the temporal center of the longest stable head position and time-corrected for slice acquisition order. To exclude the voxels showing an artifact related to signal drop, a combined threshold/cluster-growing algorithm was applied to the mean of the functional images to compute a region of interest brain mask. This screened out non-brain voxels and voxels falling within the artifact region. A randomized, fast-event related design was used with six resting trials interspersed between the 96 risky-gains trials. The preprocessed time series data for each individual were analyzed using a multiple regression model where five regressors of interest were constructed from the behavioral data obtained from each participant during the task. Specifically, response regressors were defined from the onset of the trial until the individual selected an option and, for punished trials, until the appearance of negative 40 or 80. These five regressors are referred to as (1) selecting 20 (safe response), (2) selecting 40 (risky response), (3) selecting 80 (risky response), (4) punished with -40, and (5) punished with -80. The subsequent time period, which included outcome and intertrial interval, as well as the null trials, served as the baseline condition for this analysis. The regressors of interest were convolved with a modified gamma variate function modeling a prototypical hemodynamic response [3] before inclusion in the regression model. In addition, three regressors were used to account for residual

motion (in the roll, pitch, and yaw direction). Regressors for baseline and linear trends were used to eliminate slow signal drifts. The AFNI program 3dDeconvolve was used to calculate the estimated voxel-wise response amplitude. Finally, a participant-specific voxel-based linear contrast was used to identify brain activation associated with selecting a winning risky response (40 or 80) vs a safe response (20). A Gaussian filter with FWHM 6 mm was applied to the voxel-wise percent signal change data to account for individual variations of the anatomical landmarks. Data of each participant were normalized to Talairach coordinates.

Statistical analyses

A priori regions of interest (defined by the Talairach Daemon atlas [4]) in the bilateral amygdala, bilateral insula, and anterior cingulate (Brodmann Areas 24 and 32) were used as masks for a between groups win risky versus safe decisions (contrasting regressors 2 and 3 with regressor 1 in the list of regressors given above). On the basis of these areas of interest, a voxel-wise a priori probability of 0.05 was determined via simulations, which would result in a corrected cluster-wise activation probability of 0.05 if a minimum volume of 128 μl and two connected voxels (in the amygdala) or 512 μl and eight connected voxels (in all other regions of interest) was considered. Using the thresholding and clustering techniques described above, the corrected voxel-wise probabilities are as follows: amygdala $p<0.012$, insular cortex $p<0.000069$, and anterior cingulate cortex $p<0.00014$. The areas of interest were superimposed on each individual's voxel-wise percent signal change brain image. Only activations within the areas of interest, which also satisfied the volume and voxel connection criteria, were extracted and used for further analysis. Significance values reported in the cluster table were corrected for age and gender. Behavioral analyses were carried out with SPSS 12.0 (Chicago, Il).

Several analyses were carried out to determine the degree to which brain activation predicted partisanship. First, receiver-operator characteristic (ROC) curves were determined for each functional region of interest as well as for the combination of the two most predictive areas. Second, a step-wise linear discriminant function analysis (F_{enter}: $p < 0.05$) was computed with partisanship as the dependent measure and the activation patterns in the areas that differed across democrats and republicans as independent measures. A cross-validation procedure using a leave-one-out classification method (predictions were generated by resampling with one subject removed) was used to determine sensitivity and specificity of the activation patterns to predict partisanship.

Results

Significant greater activation was seen in the bilateral amygdala and ventral anterior cingulate for Republicans and in the right anterior insula in Democrats when making winning risky versus winning safe decisions.

Table S1

Volume	x	y	z	Side	Area	BA	F	p
Dem>Rep								
512	30	17	-2	Right	Insula		6.886	0.011
Rep>Dem								
960	6	32	-7	Right	Anterior Cingulate	32/24	8.320	0.006
768	23	-3	-19	Right	Amygdala		6.081	0.017
256	-18	-5	-14	Left	Amygdala		6.347	0.015

Parents and Party Identification

We acquired dataset 4037 from the Inter-Consortium for Political and Social Research [5] about subjects who self-identified either as a Democrat or a Republican in 1997 (v5750), and the partisanship of the parents during the subjects' adolescence, reported by the subjects during early adulthood in 1973 (v584,v590). We conducted a logistic regression and used this to predict the partisanship of the subjects as shown in the following Table. The model correctly predicts the party 69.45% (S.E. 0.55%) of the subjects.

Table S2

	Dependent Variable: Subject party (1=Dem, 0=Rep)		
Independent Variables	*Coefficient*	*Standard Error*	*p*
Mother's Partisanship	0.80	0.17	<0.001
Father's Partisanship	0.27	0.17	0.12
Constant	0.00	0.12	0.99
Percent Correctly Predicted	69.45%	0.55%	
Deviance	414.66		
Null Deviance	479.77		
N	347		

Discriminant Analysis using Amgydala and Insula Activations to Predict Partisanship

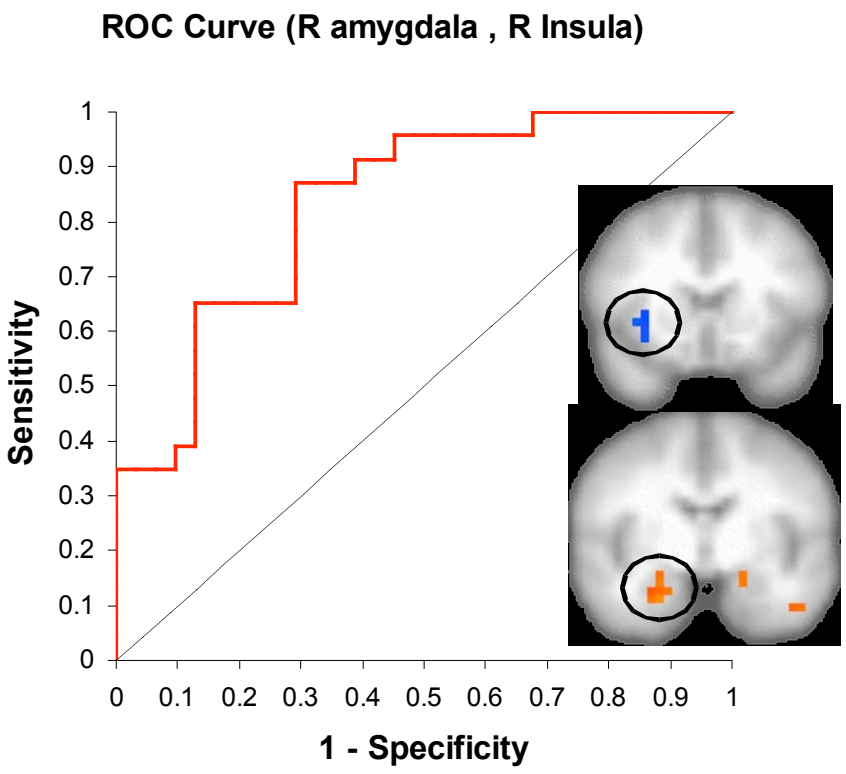
54 individuals completed a risk-taking decision-making task, which was previously found to relate to risk-taking, harm avoidance and neuroticism [1]. Of these individuals, we identified using the San Diego County Voter Registry 31 (17 females) registered Democrats and 23 (9 females) registered Republicans with an average age of 27.5 (10.5 SD) years for Democrats and 31.4 (11.7 SD) years for Republicans. These individuals did not differ on age, education, or any performance measures (number of risky responses) during the risk-taking task. However, when examining brain-related activation differences comparing the processing of risky responses relative to safe responses, we observed that, among other non a-priori hypothesized regions, Republicans showed significantly greater activation in bilateral amygdala whereas Democrats

showed relatively greater activation in right anterior insular cortex. In a subsequent step-wise discriminant function analysis to determine whether brain activation patterns related to risk-taking would be useful to predict party affiliation, we found that using a cross-validation method, brain activation in right amygdala and insula correctly predicted the party affiliation of 79% of the study participants (for further test details see **Table S3**). A Receiver Operator Curve revealed that we achieved significantly greater predictive accuracy (AUC = 0.804 +/- 0.06) than chance.

Table S3

Crossvalidation Results				
Group	Democrat	Republican		
Democrat	70.97%	29.03%	Positive Predictive Value	0.71
Republican	13.04%	86.96%	Negative Predictive Value	0.87
	Sensitivity	Specificity	Correct Prediction	
	0.845	0.750	78.96% (S.E. 0.74%)	

Figure S3



Supporting Online Material References

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