

Running head: NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

**Title:** SUPPLEMENTARY MATERIALS: The neurocomputational bases of explore-exploit decision making.

**Author List:**

Jeremy Hogeveen<sup>1-2,9\*</sup>, Teagan S. Mullins<sup>1-2</sup>, John D. Romero<sup>1-2</sup>, Elizabeth Eversole<sup>1-2</sup>, Kimberly Rogge-Obando<sup>3</sup>, Andrew R. Mayer<sup>1,4-6</sup>, & Vincent D. Costa<sup>7-8\*</sup>

**Affiliations:**

1. Department of Psychology, University of New Mexico, Albuquerque NM 87131 USA.
2. Psychology Clinical Neuroscience Center, University of New Mexico, Albuquerque NM 87131 USA.
3. Department of Biomedical Engineering, Vanderbilt University, Nashville TN 37235 USA.
4. Department of Psychiatry & Behavioral Sciences, University of New Mexico School of Medicine, Albuquerque NM 87131 USA.
5. Department of Neurology, University of New Mexico School of Medicine, Albuquerque NM 87131 USA.
6. The Mind Research Network/Lovelace Biomedical Research Institute, Pete & Nancy Domenici Hall, Albuquerque NM 87106 USA
7. Department of Behavioral Neuroscience, Oregon Health and Science University, Portland OR 97239 USA.
8. Division of Neuroscience, Oregon National Primate Research Center, Beaverton OR 97006USA.

\* **Co-Corresponding Authors:** Jeremy Hogeveen, [jhogeveen@unm.edu](mailto:jhogeveen@unm.edu); Vincent D. Costa, [costav@ohsu.edu](mailto:costav@ohsu.edu).

**Footnote:**

9. Lead Contact.

### Inventory of Supplemental Information

#### Page 3. Supplementary Figures

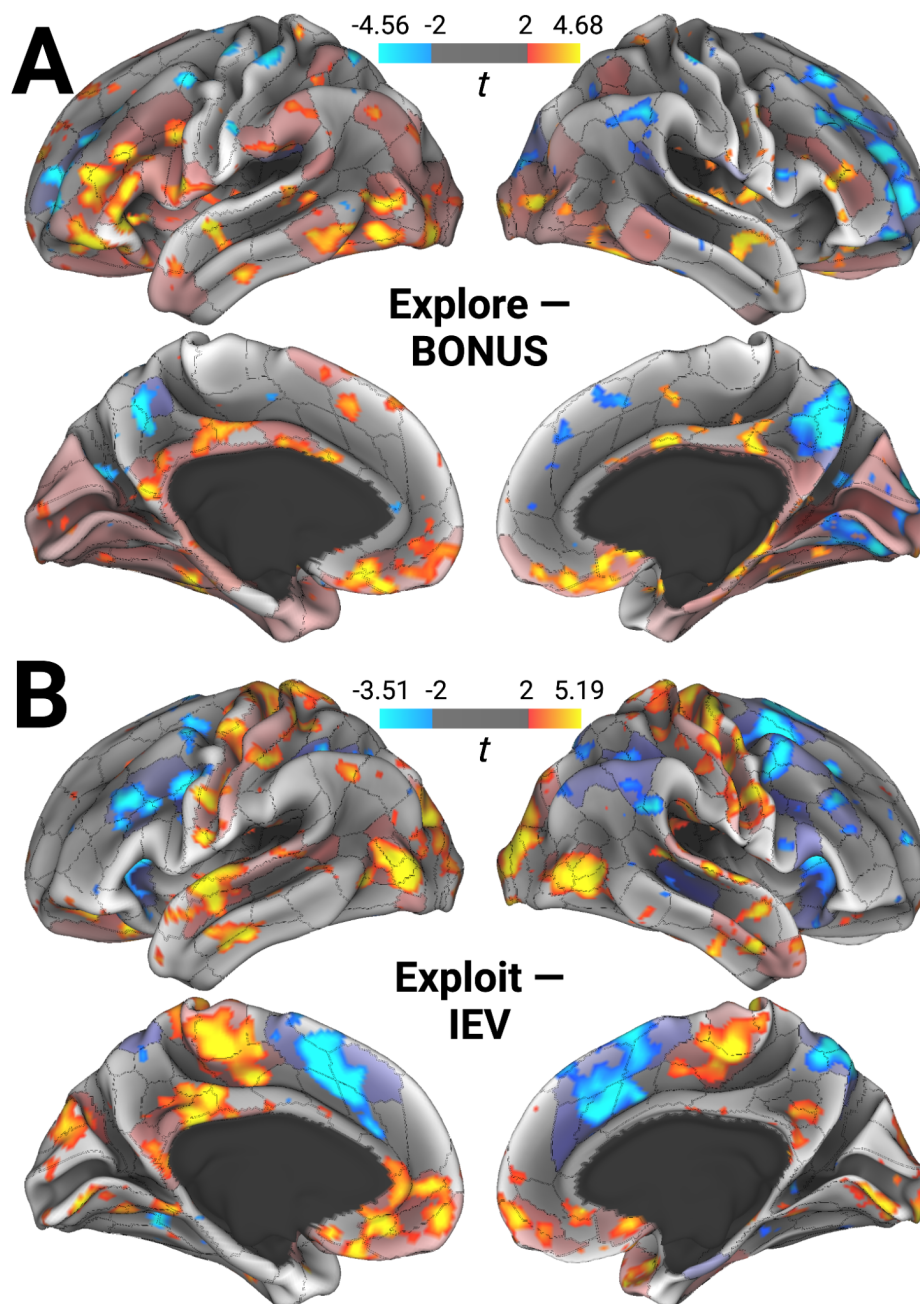
- Page 3. Supplementary Figure 1: Bayesian multilevel modeling versus voxelwise analysis results overlays.
- Page 4. Supplementary Figure 2: Distribution of within-subjects associations between trialwise IEV and BONUS parameters.
- Page 5. Supplementary Figure 3:  $\hat{R}$  values for our IEV Bayesian multilevel models.

#### Page 6. Supplementary Tables

- Page 6. Supplementary Table 3: Summary table for Bayesian multilevel model results from the exploration BONUS model.
- Page 7. Supplementary Table 4: Summary table for Bayesian multilevel model results from the trials since novel model.
- Page 8. Supplementary Table 5: Summary table for Bayesian multilevel model results from the IEV model.

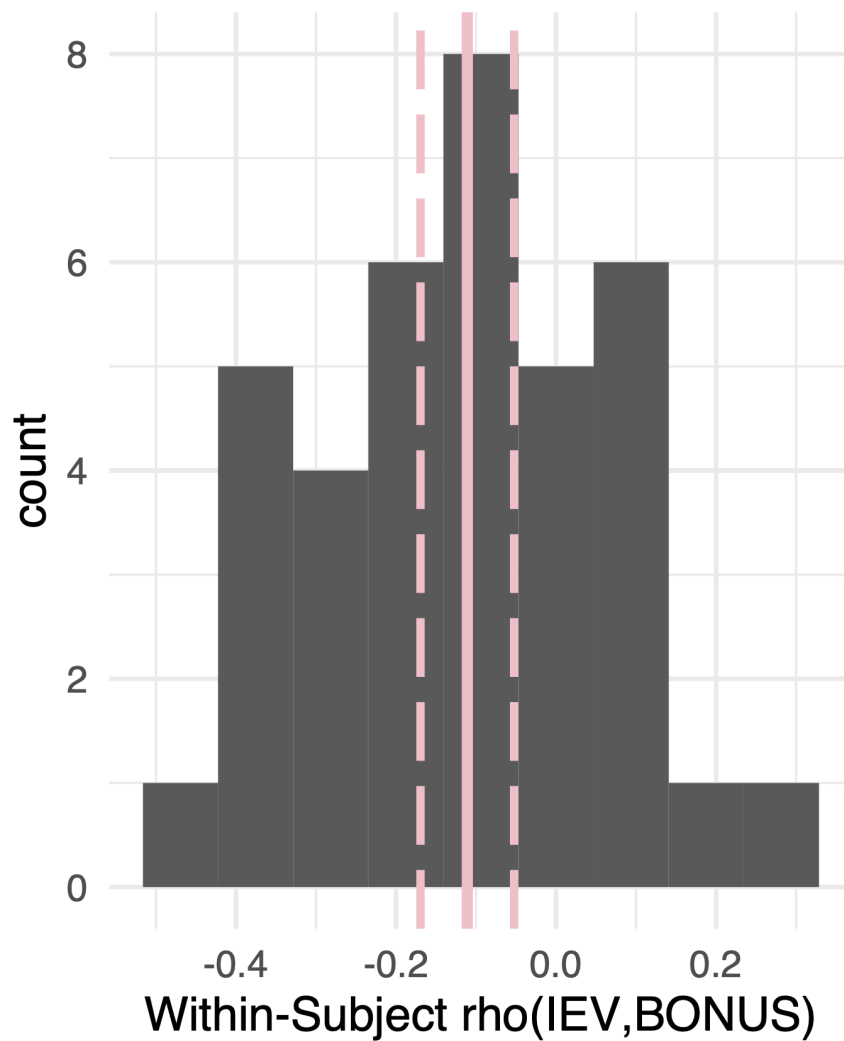
## Supplementary Figures

**Supplementary Figure 1. Overlays illustrating the spatial overlap between Bayesian multilevel modeling results versus conventional voxelwise modeling; Related to Figures 2A-B. (A)** Overlay of the exploration BONUS fMRI results derived from ROI-level Bayesian Multi-Level Modeling (BMLM; semitransparent parcels via **Figure 2A**) and conventional modeling using FSL's FLAME approach (height thresholded,  $|t| \geq 2$ ; warm and cool clusters reflect activation and deactivation, respectively). **(B)** Analogous visualization of the IEV maps (BMLM results via **Figure 2B**). Key findings reported in the main text all show highly similar results using conventional voxelwise modeling.



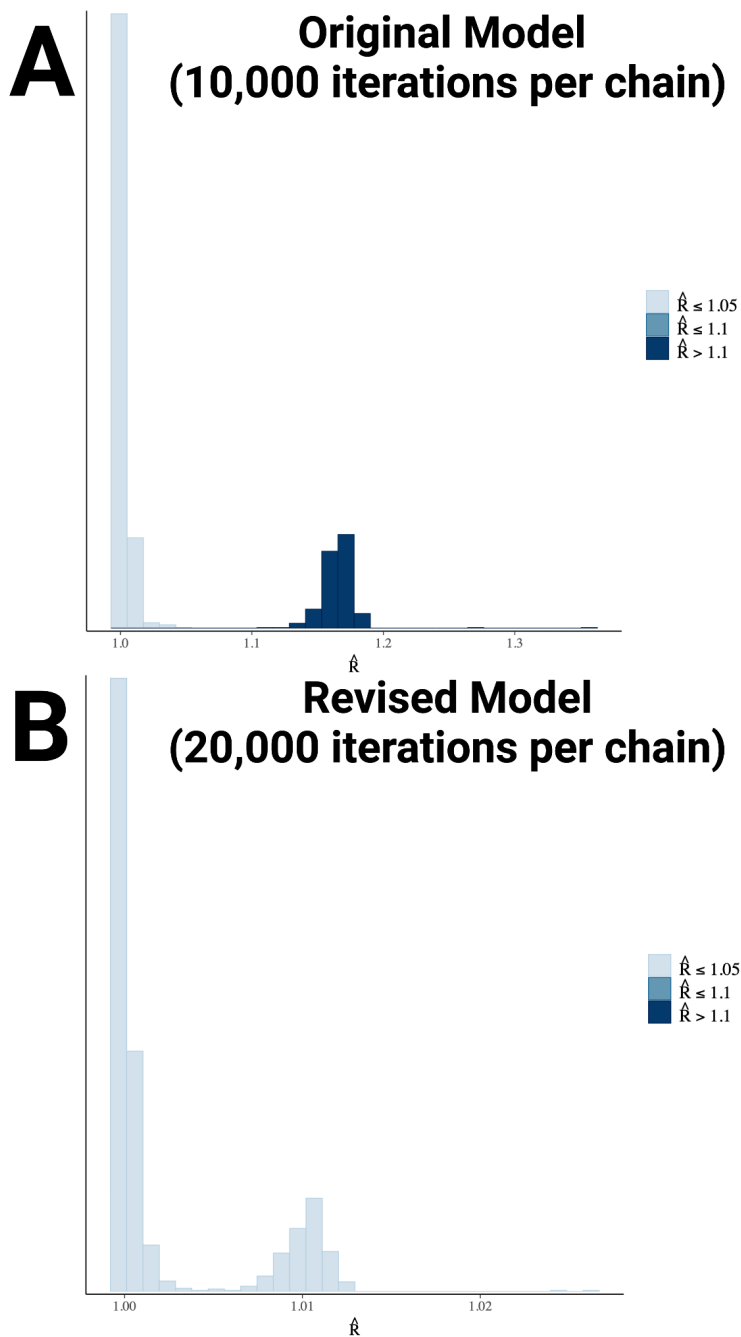
## NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

**Supplementary Figure 2. Distribution of within-subjects associations between trialwise IEV and BONUS parameters; Related to Figure 1J.** Histogram of the rank-ordered correlation between BONUS and IEV parameters within subjects (i.e., trial-level estimates). Overall, there was a small negative effect size for this relationship across the sample (Pink vertical lines:  $M_{\rho} = -0.11$ , 95%-CI = -0.17 to -0.05).



## NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

**Supplementary Figure 3. R values for our IEV Bayesian multilevel models; Related to Figures 2C and 3B.** (A) Original IEV Bayesian multilevel model demonstrated issues with model convergence (i.e., substantial portion of  $\hat{R} > 1.1$ ), but (B) this was resolved by doubling the number of iterations per MCMC chain in the model.



## NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

## Supplementary Tables

Supplementary Table 1. Summary table for Bayesian multilevel model results from the exploration BONUS model; Related to Figures 2A,C,D &amp; 3B-C.

ROI	Mean	10%-HDI	90%-HDI	P+
<b>Glasser Atlas ROIs</b>				
RH_p10p	-0.0282	-0.0444	-0.0126	0.0109
LH_p10p	-0.0273	-0.0436	-0.0112	0.0143
RH_31pd	-0.0128	-0.0290	0.0029	0.1486
LH_31pd	-0.0104	-0.0261	0.0053	0.1937
LH_d32	-0.0046	-0.0204	0.0111	0.3569
RH_d32	-0.0036	-0.0191	0.0120	0.3861
RH_p9-46v	-0.0009	-0.0166	0.0146	0.4834
RH_TE1a	-0.0002	-0.0166	0.0158	0.5012
LH_TE1a	0.0027	-0.0125	0.0181	0.5929
LH_LIPd	0.0036	-0.0122	0.0191	0.6265
RH_s32	0.0118	-0.0044	0.0281	0.8289
RH_LIPd	0.0137	-0.0019	0.0292	0.8719
LH_p9-46v	0.0163	0.0004	0.0317	0.9057
RH_IFSa	0.0163	0.0010	0.0312	0.9143
LH_OFC	0.0170	0.0008	0.0335	0.9088
RH_OFC	0.0185	0.0019	0.0350	0.9254
LH_FFC	0.0246	0.0081	0.0416	0.9716
RH_10v	0.0248	0.0082	0.0411	0.9728
LH_10v	0.0302	0.0136	0.0466	0.9895
LH_s32	0.0318	0.0147	0.0489	0.9892
LH_IFSa	0.0439	0.0274	0.0602	0.9993
RH_FFC	0.0456	0.0282	0.0630	0.9990
<b>Amygdala &amp; Striatal ROIs</b>				
RH_Caudate	0.0135	-0.0023	0.0291	0.8655
RH_Amygdala	0.0162	0.0003	0.0324	0.9043
LH_Caudate	0.0195	0.0037	0.0355	0.9407
RH_Putamen	0.0237	0.0086	0.0389	0.9745
LH_Amygdala	0.0258	0.0083	0.0432	0.9685
LH_Putamen	0.0273	0.0121	0.0424	0.9858
RH_Accumbens	0.0365	0.0197	0.0528	0.9966
LH_Accumbens	0.0377	0.0203	0.0551	0.9962

## NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

**Supplementary Table 2. Summary table for Bayesian multilevel model results from the trials since novel model; Related to Figure 4.**

ROI	Mean	10%-HDI	90%-HDI	P+
<b>Glasser Atlas ROIs</b>				
RH_FFC	-0.2077017	-0.2409486	-0.1752499	0
LH_FFC	-0.1308604	-0.1643157	-0.0979604	0
RH_LIPd	-0.0902538	-0.1218036	-0.0591218	0.0002
LH_p9-46v	-0.083345	-0.115126	-0.0520216	0.0003
RH_p9-46v	-0.0798982	-0.112082	-0.0475908	0.0009
LH_LIPd	-0.0744357	-0.1049187	-0.0433879	0.0012
LH_OFC	-0.0590778	-0.0932317	-0.0251948	0.0152
RH_OFC	-0.0469398	-0.0790796	-0.0151061	0.0326
LH_d32	-0.0432189	-0.072217	-0.0140809	0.0301
LH_IFSa	-0.0392896	-0.0705753	-0.0085442	0.0509
RH_d32	-0.0376679	-0.0674375	-0.0083286	0.0507
RH_31pd	-0.0351319	-0.0669937	-0.0041429	0.0737
RH_p10p	-0.0321051	-0.0625455	-0.0018652	0.0878
LH_TE1a	-0.0305596	-0.0615345	0.0004637	0.1037
LH_10v	-0.0207196	-0.051067	0.01007264	0.1935
RH_10v	-0.0189319	-0.0489691	0.01119919	0.2103
RH_TE1a	-0.0129331	-0.0441046	0.01811886	0.2994
RH_IFSa	-0.0118654	-0.0428153	0.01868909	0.3118
LH_p10p	-0.0109189	-0.0417486	0.01973512	0.3215
LH_s32	-0.0067546	-0.0379082	0.02418382	0.3916
RH_s32	-0.0036957	-0.0349114	0.026797	0.4396
LH_31pd	0.00389361	-0.0279889	0.03491998	0.5664
<b>Amygdala &amp; Striatal ROIs</b>				
LH_Caudate	-0.0451	-0.0757	-0.0151	0.0272
RH_Caudate	-0.0449	-0.0753	-0.0146	0.0273
LH_Putamen	-0.0443	-0.0741	-0.0144	0.0326
RH_Amygdala	-0.0427	-0.0743	-0.0110	0.0422
RH_Putamen	-0.0386	-0.0684	-0.0097	0.0459
LH_Amygdala	-0.0351	-0.0667	-0.0039	0.0739
LH_Accumbens	-0.0273	-0.0595	0.0051	0.1371
RH_Accumbens	-0.0234	-0.0546	0.0076	0.1633

## NEURAL CORRELATES OF EXPLORE-EXPLOIT SUPPLEMENT

**Supplementary Table 3. Summary table for Bayesian multilevel model results from the immediate expected value (IEV) model; Related to Figures 2B,C,E & 3B,D.**

ROI	Mean	10%-HDI	90%-HDI	P+
<b>Glasser Atlas ROIs</b>				
LH_p9-46v	-0.0322014	-0.0577246	-0.0066319	0.052775
RH_LIPd	-0.0229397	-0.047948	0.00191723	0.117875
RH_a32pr	-0.0227131	-0.0473636	0.00193336	0.11885
RH_p9-46v	-0.0226248	-0.0475684	0.0022954	0.1221
LH_LIPd	-0.0197795	-0.0455936	0.00583524	0.160175
LH_a32pr	-0.0129686	-0.0374135	0.0113734	0.244075
RH_FFC	-0.0112948	-0.0357405	0.0129453	0.2781
LH_IFSa	-0.0108276	-0.0349651	0.0133167	0.2793
RH_p10p	-0.0077168	-0.0321858	0.01687802	0.3407
LH_p10p	-0.005662	-0.0303823	0.01919736	0.381175
RH_IFSa	-0.0037181	-0.0278281	0.0202894	0.418175
LH_FFC	0.00078033	-0.0237762	0.02547304	0.513575
RH_31pd	0.0108444	-0.0135932	0.03514682	0.714225
RH_OFC	0.01156084	-0.0139042	0.03690653	0.720025
LH_31pd	0.01222642	-0.0121791	0.03665595	0.7375
LH_TE1a	0.01255394	-0.0115319	0.03664159	0.746075
RH_s32	0.01322229	-0.0113345	0.03789295	0.756325
RH_TE1a	0.01622889	-0.0085492	0.04120961	0.7971
LH_10v	0.01852123	-0.0066186	0.04387368	0.825325
LH_s32	0.02011563	-0.0046937	0.04513944	0.849625
RH_10v	0.02023952	-0.0048466	0.04550662	0.848175
LH_OFC	0.02448317	-0.0012374	0.05070502	0.8887
<b>Amygdala &amp; Striatal ROIs</b>				
RH_Caudate	-0.0136458	-0.0382062	0.0110644	0.235325
LH_Caudate	-0.0041888	-0.028463	0.02004988	0.4083
LH_Putamen	0.00420839	-0.0198342	0.02834883	0.59065
RH_Putamen	0.00473697	-0.0192038	0.02878338	0.5976
LH_Accumbens	0.01665481	-0.0090525	0.04248281	0.797025
LH_Amygdala	0.01683057	-0.0083277	0.04257793	0.79995
RH_Amygdala	0.02229619	-0.0032859	0.04807117	0.8666
RH_Accumbens	0.03376267	0.00746134	0.06054344	0.950575