Neuron, Volume *71*

Supplemental Information

Perceptual Classification

in a Rapidly Changing Environment

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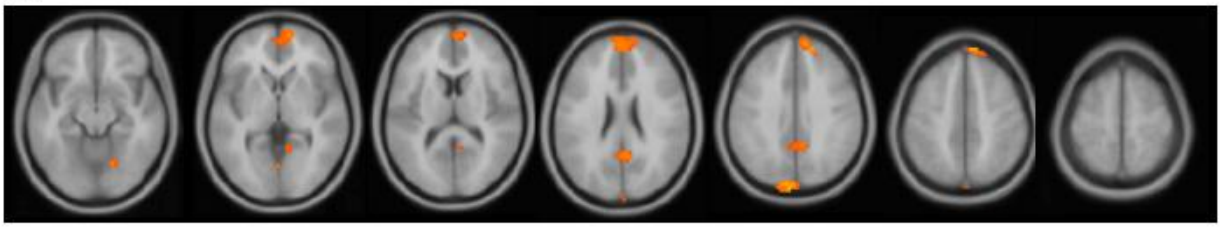
A



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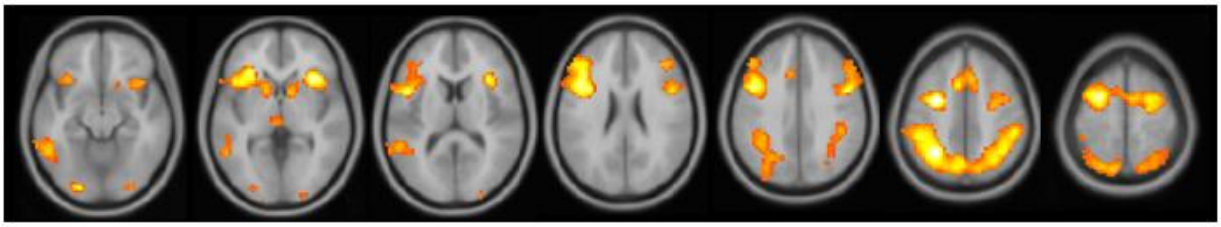

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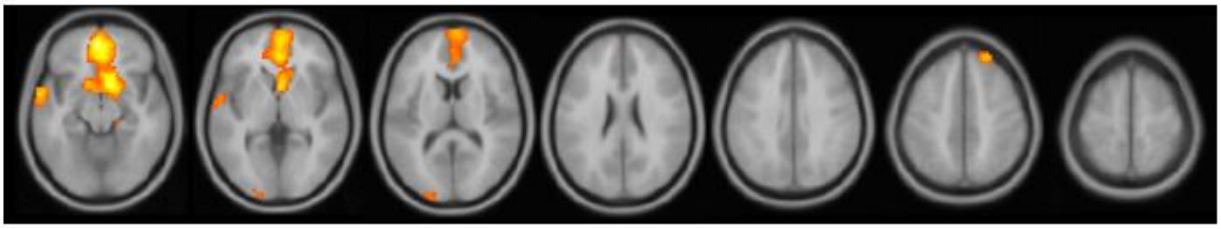

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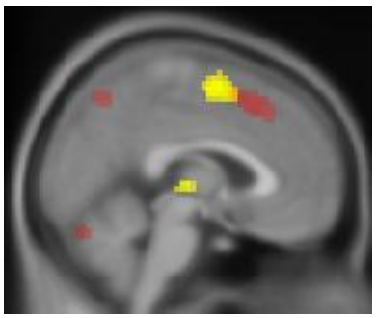

Figure S1.
(A) Voxels responding to expected value across all three models (contrast [1 1 1]) (z coordinate of slices, left-right: -12,0,12,24,36,48,60).
(B) Voxels responding to decision entropy across all three models.
(C) Voxels responding to the main effect of reward (correct > incorrect), at the time of feedback. In A, B and C, voxels are rendered onto a template brain at a threshold of $p < 0.001$ uncorrected.
(D) Juxtaposition of voxels responding to decision entropy predicted by the Bayesian (yellow voxels) and WM (red voxels) models, rendered onto a saggital slice of a template brain.

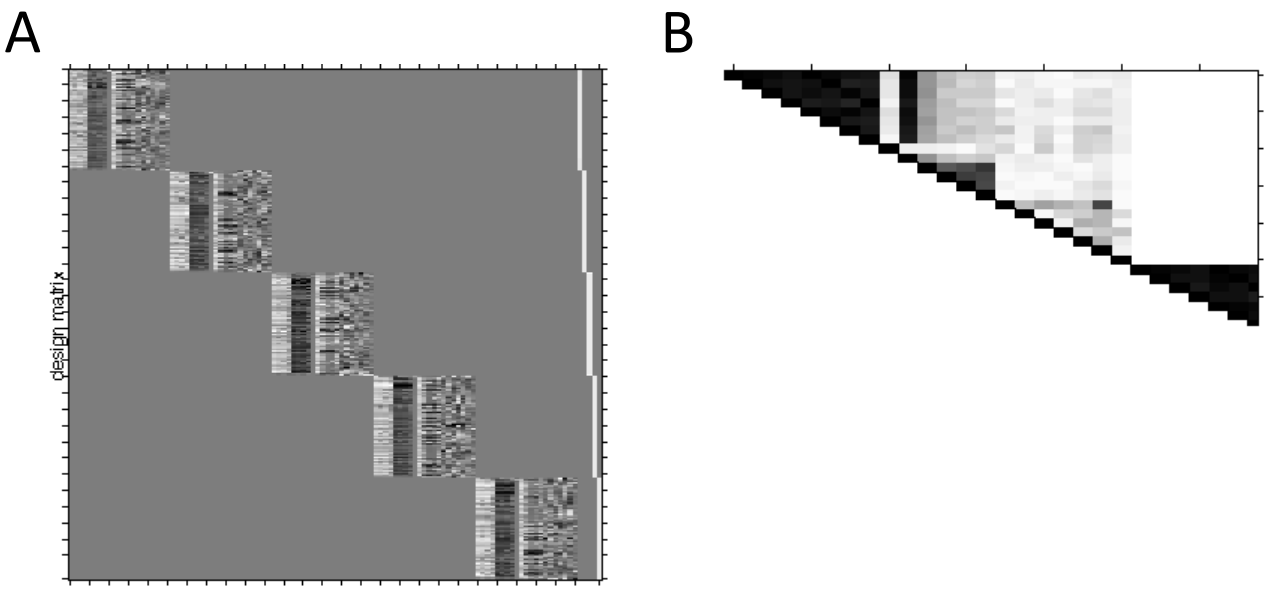

Figure S2.
(A) Design matrix for a representative subject (subject 1). 21 regressors per session were entered per session (n = 5). These regressors included the main effect of stimulation (1), the interaction between stimulation and choice probabilty under the Bayesian, QL and working memory models (2-4), the main effect of volatility (5), the interaction between stimulation, volatility and choice probability (6-8), the first trial of the experiment (9), the main effect of the feedback tone (10), correct feedback signals (11), prediction error signals for the the Bayesian, QL and working memory models (12-14), the main effect of the signal outside of the brain (15), and realignment parameters (16-21).
(B) The correlation matrix for the 110 regressors (including 5 extra regressors encoding the main effects of session).

Table S1a. Voxels Correlating with Expected Reward for the Bayesian Model

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	Region
0.000	164	0.000	0.071	0.038	6.66	4.73	0.000	18 33 60	SFG
			0.471	0.106	5.34	4.12	0.000	24 36 54	SFG
			0.950	0.204	4.40	3.61	0.000	21 39 42	SFG
0.479	23	0.060	0.993	0.210	4.08	3.42	0.000	6 -60 12	PCC
			0.999	0.210	3.83	3.26	0.001	9 -51 9	PCC

Voxels correlating with expected reward predicted by the Bayesian model at a threshold of p < 0.001 uncorrected, cluster threshold 20 voxels. Abbreviations: SFG, superior frontal gyrus; PCC, posterior cingulate cortex.

Column headings for this and succeeding tables are as follows:
Cluster p(cor): clusterwise p-value, corrected for multiple comparisons; *cluster equivk*: number of voxels in cluster; *cluster p (unc)*, uncorrected clusterwise p-value*; voxel p (FWE)*: voxelwise p-value, corrected for multiple comparisons with familywise error method; *voxel p (FDR)*: voxelwise p-value, corrected for multiple comparisons with false discovery rate method; *voxel T*: voxelwise t-value; *voxel equivz*: voxelwise z-score; *voxel p(unc)*: voxelwise p-value, uncorrected*; x,y,z {mm}*: x y and z coordinates of peak activated voxel in the standardised space of the template brain of the Montreal Neurological Institute; *Region*: approximate brain region, defined by Talairach Demon.

Table S1b. Voxels Correlating with Expected Reward for the Q-Learning Model

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
None > 20 voxels									

Voxels correlating with expected reward predicted by the Q-learning model at a threshold of p < 0.001 uncorrected, cluster threshold 20 voxels. For column headings see table 1a.

Table S1c. Voxels Correlating with Expected Reward for the Working Memory Model

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
0.000	958	0.000	0.000	0.000	11.19	6.14	0.000	12 -42 36*	PCC
			0.000	0.000	9.55	5.72	0.000	15 -51 30*	PCC
			0.005	0.000	8.05	5.25	0.000	-9 -48 33*	PCC
0.000	189	0.000	0.003	0.000	8.37	5.35	0.000	30 -24 -21	right PHG
			0.616	0.002	5.08	3.99	0.000	30 -36 -15	right PHG
0.000	1202	0.000	0.007	0.000	7.87	5.19	0.000	6 45 -18*	vmPFC
			0.008	0.000	7.82	5.17	0.000	-9 54 -9*	vmPFC
			0.016	0.000	7.43	5.03	0.000	0 39 -9*	vmPFC
0.000	161	0.000	0.134	0.001	6.23	4.55	0.000	60 -12 -6	right MTG
			0.880	0.005	4.60	3.73	0.000	57 -3 -24	right MTG
			0.918	0.006	4.50	3.67	0.000	54 -9 -18	right MTG
0.000	320	0.000	0.380	0.001	5.50	4.20	0.000	-60 -36 6	left MTG
			0.617	0.002	5.08	3.99	0.000	-69 -24 12	left MTG
			0.640	0.002	5.04	3.97	0.000	-51 -33 9	left MTG
0.363	28	0.043	0.412	0.001	5.44	4.17	0.000	0 15 -9	subgenual cingulate (BA25)
0.156	42	0.016	0.711	0.003	4.93	3.91	0.000	30 -18 6	right putamen
			0.999	0.013	3.85	3.27	0.001	39 -3 3	right putamen
0.081	53	0.008	0.760	0.003	4.84	3.86	0.000	-60 -12 -30	left anterior temporal lobe
			0.941	0.006	4.42	3.62	0.000	-57 -12 -21	left anterior temporal lobe
0.003	114	0.000	0.909	0.005	4.53	3.68	0.000	57 -63 30	right anterior temporal lobe
			0.943	0.006	4.42	3.62	0.000	63 -54 24	right anterior temporal lobe
			0.957	0.007	4.36	3.59	0.000	63 -45 21	right anterior temporal lobe
0.433	25	0.054	0.909	0.005	4.53	3.68	0.000	6 -96 30	right V3/BA19
			0.991	0.010	4.10	3.43	0.000	15 -96 24	right V3/BA19

Voxels correlating with expected reward predicted by the working memory model at a threshold of $p < 0.001$ uncorrected, cluster threshold 10 voxels. Abbreviations: PCC, posterior cingulate cortex; PHG, parahippocampal gyrus; vmPFC, ventromedial prefrontal cortex; MTG, middle temporal gyrus; V3, visual area 3. For column headings see table 1a.

Table S2a. Voxels Correlating with Decision Entropy for the Bayesian Model

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	
0.000	216	0.000	0.131	0.020	6.26	4.56	0.000	3 0 57*	SMA
			0.841	0.021	4.70	3.78	0.000	-6 12 48*	SMA
			0.999	0.036	3.82	3.25	0.001	-6 18 39*	SMA
0.025	73	0.002	0.170	0.020	6.09	4.48	0.000	-12 9 -3*	left striatum
			0.780	0.020	4.82	3.85	0.000	-12 6 -12*	left striatum
0.007	96	0.001	0.207	0.020	5.95	4.42	0.000	51 6 30	right DLPFC
			0.959	0.024	4.36	3.59	0.000	63 12 30	right DLPFC
0.000	332	0.000	0.263	0.020	5.79	4.34	0.000	-39 6 24	left DLPFC
			0.466	0.020	5.35	4.13	0.000	-36 12 30	left DLPFC
			0.554	0.020	5.20	4.05	0.000	-48 6 27	left DLPFC
0.000	196	0.000	0.313	0.020	5.66	4.28	0.000	-24 -6 66	left PMC
			0.358	0.020	5.56	4.23	0.000	-30 -3 51	left PMC
			0.742	0.020	4.89	3.89	0.000	-36 3 54	left PMC
0.008	94	0.001	0.343	0.020	5.59	4.25	0.000	36 27 3	right anterior insula
0.077	53	0.007	0.537	0.020	5.23	4.07	0.000	27 -63 54	right anterior insula
0.104	48	0.010	0.559	0.020	5.19	4.05	0.000	0 -21 3	MD thalamus
			0.882	0.022	4.61	3.73	0.000	-9 -21 6	MD thalamus
0.007	97	0.001	0.738	0.020	4.89	3.89	0.000	-45 -42 45	left IPL
			0.952	0.024	4.40	3.61	0.000	-39 -48 48	left IPL
0.006	99	0.001	0.815	0.021	4.76	3.81	0.000	45 -36 42	right IPL
			0.860	0.021	4.66	3.76	0.000	54 -21 45	right IPL
			0.948	0.024	4.41	3.62	0.000	45 -45 42	right IPL
0.231	35	0.024	0.882	0.022	4.61	3.73	0.000	39 -3 63	right PMC
			0.999	0.034	3.90	3.30	0.000	39 0 54	right PMC
0.296	31	0.032	0.978	0.025	4.25	3.52	0.000	-63 -45 15	superior temporal gyrus
			0.980	0.025	4.24	3.51	0.000	-54 -48 3	superior temporal gyrus

Voxels correlating with decision entropy predicted by the Bayesian model at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. Abbreviations: SMA, supplementary motor area; DLPFC, dorsolateral prefrontal cortex; PMC, premotor cortex; MD, medial dorsal; IPL inferior parietal lobule; SPL, superior parietal lobule. For column headings see table 1a.

Table S2b. Voxels Correlating with Decision Entropy for the Q-Learning Model

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
0.000	184	0.000	0.107	0.044	6.45	4.64	0.000	-48 24 3	left IFG
			0.490	0.044	5.36	4.13	0.000	-33 21 -9	left IFG
			0.554	0.044	5.25	4.08	0.000	-30 27 3	left IFG
0.003	109	0.000	0.120	0.044	6.37	4.61	0.000	39 21 -6	right anterior insula
			0.336	0.044	5.66	4.28	0.000	30 12 -9	right anterior insula
0.000	182	0.000	0.466	0.044	5.40	4.16	0.000	-33 -57 48	left IPL/STG
			0.906	0.053	4.60	3.73	0.000	-21 -63 45	left IPL/STG
			0.925	0.053	4.54	3.69	0.000	-45 -51 15	left IPL/STG
0.478	22	0.055	0.521	0.044	5.31	4.11	0.000	-15 12 66	left SFG
			0.997	0.073	4.04	3.39	0.000	-21 9 60	left SFG
0.063	53	0.005	0.623	0.046	5.14	4.02	0.000	-33 -6 42	PFC/white matter
			0.915	0.053	4.58	3.71	0.000	-30 -24 45	PFC/white matter
			1.000	0.081	3.82	3.25	0.001	-30 -18 57	PFC/white matter
0.540	20	0.066	0.799	0.046	4.84	3.86	0.000	15 6 -12	right putamen

Voxels correlating with decision entropy predicted by the Q-learning model at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. Abbreviations: STG, superior temporal gyrus; IPL, inferior parietal lobule; IFG, inferior frontal gyrus; SFG, superior frontal gyrus. For column headings see table 1a.

Table S2c. Voxels Correlating with Decision Entropy for the Working Memory Model

STATISTICS: p-values adjusted for search volume

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
0.000	2954	0.000	0.000	0.000	15.09	6.91	0.000	24 -69 54	right SPL
			0.000	0.000	10.00	5.84	0.000	-21 -69 54	left SPL
			0.000	0.000	9.71	5.76	0.000	-39 -45 54	left IPL
0.000	597	0.000	0.000	0.000	10.29	5.91	0.000	36 -90 3	right occipital gyrus
			0.001	0.000	8.85	5.51	0.000	36 -90 -12	right occipital gyrus
			0.019	0.000	7.33	4.99	0.000	15 -96 -6	right V1
0.002	122	0.000	0.000	0.000	9.37	5.66	0.000	36 18 3	right anterior insula
0.000	789	0.000	0.002	0.000	8.51	5.40	0.000	-42 6 27	left IFG
			0.011	0.000	7.61	5.09	0.000	-45 30 36	left IFG
			0.166	0.000	6.09	4.48	0.000	-33 27 0	left anterior insula
0.000	414	0.000	0.004	0.000	8.18	5.29	0.000	-21 6 69	left PMC
			0.008	0.000	7.77	5.15	0.000	-30 -3 54	left PMC
			0.019	0.000	7.33	4.99	0.000	-30 3 60	left PMC
0.000	453	0.000	0.007	0.000	7.84	5.18	0.000	51 6 36	right DLPFC (BA 9)
			0.008	0.000	7.78	5.16	0.000	51 30 36	right DLPFC (BA 9)
			0.238	0.000	5.84	4.37	0.000	51 39 24	right DLPFC (BA 9)
0.000	222	0.000	0.020	0.000	7.30	4.98	0.000	-3 24 42	pre-SMA
			0.026	0.000	7.17	4.93	0.000	6 15 48	pre-SMA
0.005	105	0.000	0.490	0.001	5.30	4.10	0.000	30 -3 63	right PMC
			0.654	0.001	5.02	3.96	0.000	30 -6 54	right PMC
0.304	31	0.034	0.689	0.001	4.96	3.93	0.000	3 -78 -24	cerebellum
0.068	56	0.007	0.941	0.003	4.42	3.62	0.000	48 45 -18	right OFC
			0.991	0.004	4.11	3.44	0.000	39 54 -15	right OFC
			0.993	0.005	4.07	3.41	0.000	42 48 0	right OFC
0.486	23	0.063	0.993	0.005	4.08	3.41	0.000	-42 54 -15	left OFC
			0.999	0.007	3.86	3.28	0.001	-39 51 -6	left OFC

Voxels correlating with decision entropy predicted by the working memory model at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. Abbreviations: SPL, superior parietal lobule; IPL, inferior parietal lobule; IFG, inferior frontal gyrus; pre-SMA, pre-supplementary motor area; DLPFC, dorsolateral prefrontal cortex; PMC, premotor cortex; MD, medial dorsal; OFC orbitofrontal cortex. For column headings see table 1a.

Table S3a. Voxels Correlating with the Interaction between Decision Entropy for the Bayesian Model and Log-Volatility

STATISTICS: p-values adjusted for search volume

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	Region
0.000	316	0.000	0.017	0.004	7.40	5.02	0.000	0 9 60	pre-SMA/ACC
			0.158	0.008	6.15	4.51	0.000	6 -6 57	pre-SMA/ACC
			0.911	0.042	4.54	3.69	0.000	3 21 33	pre-SMA/ACC
0.031	68	0.003	0.264	0.011	5.79	4.34	0.000	-21 9 -9	left putamen
0.005	103	0.000	0.472	0.017	5.35	4.13	0.000	27 -6 63	right PMC
			0.938	0.045	4.46	3.64	0.000	39 -6 57	right PMC
			0.985	0.058	4.20	3.49	0.000	39 -3 48	right PMC
0.079	52	0.008	0.558	0.019	5.20	4.05	0.000	-24 0 57	left PMC
			0.819	0.032	4.75	3.81	0.000	-24 -3 66	left PMC
			0.984	0.058	4.21	3.49	0.000	-36 -3 54	left PMC
0.474	23	0.059	0.651	0.022	5.05	3.97	0.000	9 -12 12	MD thalamus
			0.963	0.049	4.35	3.58	0.000	3 -24 3	MD thalamus
0.373	27	0.043	0.995	0.066	4.05	3.40	0.000	42 -36 51	IPL

Voxels correlating with the interaction between decision entropy for the Bayesian model and log-volatility. Abbreviations: pre-SMA, pre-supplementary motor area; ACC, anterior cingulate cortex; PMC, premotor cortex; MD, medial dorsal. For column headings see table 1a.

Table S3b. Voxels Correlating with the Interaction between Decision Entropy for the Q-Learning Model and Log-Volatility

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
None > 20 voxels									

Voxels correlating with the interaction between decision entropy for the Q-learning model and log-volatility at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. For column headings see table 1a.

Table S3c. Voxels Correlating with the Interaction between Decision Entropy for the Working Memory Model and Log-Volatility

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
None > 20 voxels									

Voxels correlating with the interaction between decision entropy for the working memory model and log-volatility at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. For column headings see table 1a.

Table S4. Voxels Responding to the Interaction between Angular Update, Estimated Variance, and Volatility

STATISTICS: p-values adjusted for search volume

cluster p(cor)	cluster equivk	cluster p(unc)	voxel p(FWE)	voxel p(FDR)	voxel T	voxel equivZ	voxel p(unc)	x,y,z {mm}	region
0.000	180	0.000	0.182	0.066	6.03	4.45	0.000	3 -30 27	PCC
			0.844	0.107	4.68	3.77	0.000	12 -39 42	PCC
			0.965	0.121	4.32	3.56	0.000	-6 -42 27	PCC
0.031	70	0.003	0.638	0.091	5.05	3.97	0.000	12 -54 9	retrosplenial cortex
			0.855	0.107	4.66	3.76	0.000	18 -60 21	retrosplenial cortex
			0.951	0.115	4.39	3.60	0.000	18 -48 3	retrosplenial cortex
0.574	20	0.081	0.735	0.093	4.89	3.88	0.000	48 -33 3	STG
0.460	24	0.058	0.806	0.097	4.76	3.81	0.000	-15 -48 6	

Voxels responding to the interaction between angular update, estimated variance, and volatility at a threshold of $p < 0.001$ uncorrected, cluster threshold 20 voxels. Abbreviations: PCC, posterior cingulate cortex; STG, superior temporal gyrus.