

Supplementary material

Brain annotation toolbox: exploring the functional and genetic associations of neuroimaging results

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Supplementary method

Data

Task activation maps

The task activation maps from the Neurosynth database (<http://neurosynth.org>) provide voxel-level functional annotation, i.e., each voxel is associated with a number of terms or tasks which help to interpret the function of that region (Yarkoni, et al., 2011). This was obtained by integrating more than 11,000 journal articles (at the time of our analyses (May 2017) that provided the locations of task-related activations for various tasks. More than 3,000 search terms with their activation maps were obtained using text-mining techniques to analyze the abstract and automatically extract the coordinates of activations from all the articles. In our analysis, we deleted terms that were not useful in identifying tasks (e.g., ‘able’, ‘abstract’ etc.) and selected 217 terms that bear clear biological significance (details of the selection criteria are described in our previous work (Cheng, et al., 2017)), see Supplementary Table S1. We used forward inference maps to indicate the degree to which each voxel is consistently activated in studies that used a given term (FDR correction of $P < 0.01$). The activation maps were resliced to $1 \times 1 \times 1 \text{ mm}^3$ and transformed to binary images by setting all the non-zeros entries as 1.

Gene expression profile

The ‘all genes-all structure’ profiles from the Allen Human Brain Atlas (AHBA) (<http://human.brain-map.org/>) provided the brain’s genetic expression levels for different brain regions (Hawrylycz, et al., 2012), obtained from six adult human brains

from the AHBA (Hawrylycz, et al., 2012). Two of the brains were with both hemispheres and four only with the left hemisphere. The number of anatomic samples obtained from each brain varied from 363 to 946. We followed the pipeline provided by the Allen Brain Atlas to obtain and process the raw expression data (see <http://www.brain-map.org/api/examples/examples/doc/wgcna/preprocessData.R.html>). To get the expression value of genes from their corresponding probes, the ‘collapseRows’ function from the WGCNA package was employed to pick the probe with the highest average expression to represent that gene. In total, 3695 unique anatomic samples with 20,738 gene expression profiles were obtained (details of AHBA’s microarray information/data normalization: <http://help.brain-map.org/display/humanbrain/documentation/>). To further remove individual differences and pool all the AHBA samples from different subjects together to provide voxel-level genetic knowledge, a normalization procedure was applied: for each given gene in any individual, expressions were normalized by extracting the median of the gene's expression across all samples of the individual and were divided by the median. Then, for each AHBA tissue sample, we created a 6 mm sphere region of interest (ROI) in the MNI volume space centered on its MNI centroid coordinate. Finally, 3695 ROIs with their corresponding normalized gene expression profiles were used in our following analysis.

Method

Mapping from MNI volume space to the surface space

Both of the activation maps, from Neurosynth and the gene expression in AHBA

samples, were in MNI volume space (3D) and could not be directly used to interpret neuroimaging results in 2D surface space. A mapping scheme from the 3D volume space to the 2D surface space was therefore needed for both the Neurosynth and Allen Brain Atlas database. For Neurosynth, for each activation map of the 217 functional search terms, we mapped the coordinates of the activations from the MNI volume space to the Conte69 human surface-based atlas (http://brainvis.wustl.edu/wiki/index.php//Caret:Atlases/Conte69_Atlas) using the Human Connectome Workbench. The activation z-value of each surface vertex was transformed from the voxels in which the vertex lay. We performed this mapping for all the 217 functional terms' activation maps in volume space, and the surface-based activation maps were obtained in the 32k Conte69 surface-based space (Glasser and Van Essen, 2011; Van Essen, et al., 2012).

For the Allen Brain database, we mapped the AHBA ROIs in the MNI space to the Conte69 human surface-based atlas using the same method that we used to map the activation maps. For each AHBA sample, we obtained its corresponding vertices on the surface. We manually checked the NeuroSynth activation maps and the Allen Human Brain Atlas (<http://atlas.brain-map.org>) (Hawrylycz, et al., 2012; Sunkin, et al., 2013) ROIs that we mapped from their volume space to the surface space to ensure accuracy. We illustrate examples for comparison of the maps in the two spaces in Supplementary Fig 1. In the following, we use “voxel” to denote both the 3D and 2D pixel in the brain images for convenience.

The implementation of BAT

BAT is implemented as a free and open-source Matlab toolbox. The toolbox provides simple commands for users to perform genetic and functional annotation analysis on clusters/regions and FC results. A graphical user interface (GUI) is provided for users to perform the annotation analysis. A visual interface is also implemented to provide 3-D interactive visualization for the annotation results.

BAT provides a flexible setting so that users can choose to meet their requirements. BAT comes with a User Manual to describe its use. Before analysis, a background mask needs to be specified, which is a binary image describing the areas in which the user wishes to perform their analysis for permutation, e.g. the whole brain, cerebral cortex, subcortical areas, or a specific region. The user can choose whether or not to perform permutation (and to specify the permutation method and number of permutations to use). The default settings of the BAT are given in Supplementary Table S2.

Table S1 The list of the selected functional terms from Neurosynth and their related cognition domains (see Wei Cheng et.al. for details)(Cheng, et al., 2017).

No.	Cognition domain	Functional Terms
1	Suppression	repetition suppression, repetition, suppression
2	Executive function	arithmetic, attentional control, cognitive control, cognitive processes, control network, control processes, executive control, executive function, memory task, memory wm, memory, ongoing, performance task, Stroop task, Stroop, switch, switching, sustained attention, term memory, verbal, working memory, memory tasks
3	Emotion	affective, anxiety, arousal, depression, emotion regulation, emotion, emotional information, emotional responses, fear, mood, negative affect, personality, pleasant, reactivity, stress, threatening, vulnerability
4	Semantic memory	semantic knowledge, semantic memory
5	Reward	anticipation, decision making, gain, gambling, incentive, learning task, monetary reward, motivation, reward anticipation, reward, self reported
6	Visual recognition	face, matching task, memory encoding, recognition, subsequent memory
7	Theory of mind	moral, theory mind
8	Perception	adaptation, attention, cognitive functions, cognitive tasks, discrimination task, goal directed, memory load, motor response, perception, perceptual, planning, response selection, sensory information, visual information, visual stimuli, executive functions
9	Social	autism, communication, empathy, social cognition, social interaction
10	Detection task	detection task, target detection
11	Somatosensory	primary somatosensory, secondary somatosensory, somatosensory, touch
12	Speech production	oral, speech production

13	Multisensory	multisensory, percept, sensory modalities
14	Motor	finger movements, hand movements, motor control, motor imagery, motor performance, motor task, primary sensorimotor, tapping
15	Memory	encoding retrieval, memory performance, memory processes, monitor, naming, neurocognitive, picture, reasoning, recall, verbal fluency, verbal working
16	Attention	attention network, eye movements, orientation, saccades, selective attention, spatial attention, visual attention, visual spatial, visuo spatial, visuospatial
17	Self	awareness, bipolar disorder, cognition, conscious, salience, schizophrenia, self, social, bipolar
18	Language	decision task, judgment, language comprehension, language network, language, lexical decision, phonological, reading, semantic information, semantic, sentence comprehension, syntactic, word recognition, written
19	Attention deficit	attention deficit, hyperactivity disorder, impulsivity, ADHD
20	Pain	nociceptive, pain, pressure, sensation
21	memory retrieval	episodic memory, memory retrieval, recognition memory, recollection, recognition task
22	Face	face recognition, face stimuli, fusiform face, image, object recognition, passive viewing, visual stream
23	Self referential	autobiographical memory, self referential, mild cognitive
24	Action observation	action observation, action, illusion, motion, moving, video, visual motion, visual perception
25	Inhibition	expectancy, inhibition, inhibitory control, NoGo, response inhibition, stop signal
26	Emotional faces	anger, anxiety disorders, disgust, emotional faces, emotional stimuli, emotional valence, facial expressions, fearful faces, happy, negative emotional, neutral faces, neutral pictures, neutral stimuli, sad, facial expression
27	Auditory	acoustic, auditory visual, hallucinations, listening, music, phonetic, primary auditory, speech perception, speech sounds, speech, spoken, visual auditory, voice
28	Others	rhythm, mental imagery, compulsive disorder, cognitive emotional, sleep, navigation, primary visual, major depression

Table S2 The default parameters of BAT and the parameters used in this research.

Cluster/region functional annotation analysis				
	Brain mask	Perform Permutation?	Permutation modal	Permutation times
Default	Whole brain	Yes	Single-component selection	10000
AAL2, Craddock 200, HCP MMP	Whole brain	Yes	Single-component selection	10000
Brodmann, Autism cluster	Whole brain	Yes	Multi-component selection	10000
Cluster/region genetic annotation analysis				
Default	Whole brain	Yes	Exclude-selection	25000
AAL2, Craddock 200, HCP MMP	Whole brain	Yes	Exclude-selection	25000
Brodmann, Autism cluster	Whole brain	Yes	Exclude-selection	25000
Functional connectivity functional annotation analysis				
	Brain mask	Perform Permutation?	Permutation modal	Permutation times
Default	Whole brain	Yes	Background-selection	10000
Schizophrenia	Whole brain	Yes	Parcellation-selection	10000
Cluster/region genetic annotation analysis				
Default	Whole brain	Yes	-	25000
Schizophrenia	Whole brain	Yes	-	25000

Table S3 The list of brain atlases on which annotation analyses were performed.

Name of Brain Parcellations	Reference
Brodmann	Brodmann, K. Vergleichende Lokalisationslehre der Groshirnrinde. Leipzig: Barth 38, 644-645 (1909)
Automated Anatomical Labeling Atlas 2	Rolls, E.T., Joliot, M. & Tzourio-Mazoyer, N. Implementation of a new parcellation of the orbitofrontal cortex in the automated anatomical labeling atlas. <i>NeuroImage</i> 122, 1-5 (2015).
Craddock 200	Craddock, R.C., James, G.A., Holtzheimer, P.E., Hu, X.P.P. & Mayberg, H.S. A whole brain fMRI atlas generated via spatially constrained spectral clustering. <i>Hum Brain Mapp</i> 33, 1914-1928 (2012).
Power 264	Power, J.D. et al. Functional Network Organization of the Human Brain. <i>Neuron</i> 72, 665-678 (2011).
HCP multi-modal parcellation	Glasser, M.F. et al. A multi-modal parcellation of human cerebral cortex. <i>Nature</i> 536, 171-+ (2016)

Table S4 The functional and genetic annotation results for the left ‘Hippocampus’ in the HCP atlas.

Left Hippocampus			
Functional Annotation results		Gene Enrichment Results	
Neurosynth Term	p	GO Biological Term	p
recognition memory	0.0002	neuron projection development	9.23E-11
memory encoding	0.0018	synaptic signaling	1.85E-09
encoding retrieval	0.0025	behavior	2.18E-09
subsequent memory	0.0032	neuron development	2.52E-09
episodic memory	0.0048	dendrite development	2.73E-09
mild cognitive	0.005	axonogenesis	2.19E-08
semantic memory	0.005	cell morphogenesis	4.77E-08
recollection	0.0059	regulation of synaptic plasticity	8.39E-07
learning task	0.0086	learning or memory	2.76E-07
memory performance	0.0108	glutamate receptor signaling pathway	9.74E-07
recall	0.0123	ephrin receptor signaling pathway	1.04E-06
autobiographical memory	0.0201	neurogenesis	8.30E-06
recognition task	0.0274	learning	2.16E-05
recognition	0.0286	memory	3.68E-05
memory	0.0364	long-term synaptic potentiation	2.33E-04
navigation	0.0427	visual learning	3.52E-04
sad	0.0436		

Table S5 The functional and genetic annotation results for the left ‘Middle Insular Area’ in the HCP atlas.

Left Middle Insular Area							
Functional Annotation results						Gene Enrichment Results	
Neurosynth Term	p	Neurosynth Term	p	Neurosynth Term	p	Pathway	p
affective	0	passive viewing	0.0127	executive control	0.0384	Dopaminergic synaptic	5.98E-06
anticipation	0	social cognition	0.0129	phonological	0.0385	FGF signaling pathway	2.13E-05
arousal	0	incentive	0.0142	switch	0.0386		
awareness	0	control network	0.0147	executive function	0.0393		
nociceptive	0	stop signal	0.0153	speech	0.0409		
pain	0	goal directed	0.0169	autism	0.0413		
reward	0	negative emotional	0.0177	memory processes	0.0415		
saliency	0	performance task	0.0183	attention network	0.0423		
schizophrenia	0	response selection	0.0184	fearful faces	0.0427		
self	0	emotional stimuli	0.0185	motor response	0.0432		
self reported	0	speech production	0.0187	illusion	0.044		
somatosensory	0	visual spatial	0.0188	decision task	0.0442		
sleep	0.0009	touch	0.0206	language	0.045		
secondary somatosensory	0.0016	inhibition	0.0211	naming	0.0461		
motivation	0.002	recognition task	0.0211	recognition memory	0.0462		
emotion	0.0025	episode	0.0212	stroop task	0.0467		
pleasant	0.0025	depression	0.0215	adaptation	0.0479		
pressure	0.0032	gain	0.0235	sensory information	0.0481		
anxiety	0.0039	gambling	0.0237	personality			
ongoing	0.0043	neutral faces	0.0251				
sad	0.0043	social	0.0252				

conscious	0.004 5	verbal fluency	0.026				
perception	0.004 7	compulsive disorder	0.0272				
reactivity	0.004 9	obsessive compulsive	0.0276				
inhibitory control	0.005	social interaction	0.0285				
sustained attention	0.005	learning task	0.0286				
sensation	0.005 1	vulnerability	0.0288				
stress	0.005 5	action	0.0292				
empathy	0.005 9	repetition	0.0294				
hyperactivity disorder	0.005 9	stroop	0.0301				
emotional responses	0.006 7	cognitive processes	0.0307				
cognitive functions	0.007 3	nogo	0.0317				
negative affect	0.007 4	major depression	0.0327				
emotion regulation	0.007 7	cognitive control	0.0328				
anxiety disorders	0.008 2	suppression	0.0352				
threatening	0.009 5	perceptual	0.0354				
neutral pictures	0.009 6	control processes	0.0356				
visual information	0.009 6	primary somatosensory	0.0357				
attention deficit	0.010 6	response inhibition	0.0359				
monetary reward	0.0111	hallucinations	0.036				
decision making	0.011 2	attention	0.0362				
target detection	0.011 2	happy	0.0376				
fear	0.012 1	neutral stimuli	0.0377				

Table S6 Functional annotation results for Brodmann areas. The Neurosynth terms with permutation p-value less than 0.05 are shown for each area and are arranged according their p-value in descending order. Brodmann areas not included in this list did not have any significant functional annotations produced by Neurosynth.

Brodman area	Related Neurosynth Terms
2	touch, action observation, primary somatosensory, motor imagery, finger movements, somatosensory, video, action, motor task, secondary somatosensory, tapping, moving, primary sensorimotor
3	primary somatosensory, somatosensory, motor task, finger movements, primary sensorimotor, touch, hand movements, tapping, motor performance
4	primary sensorimotor, hand movements, oral, motor task
6	eye movements, finger movements, motor imagery, moving, saccades, planning, spatial attention, rhythm, motor task, action, mental imagery, motor control, motor performance, tapping, action observation, visual information, hand movements, primary sensorimotor, attention, oral, memory, wm (working memory), video, working memory, term memory, NoGo
7	arithmetic, detection task, eye movements, orientation, saccades, selective attention, spatial attention, visual attention, visual spatial, visuospatial, attention, visuospatial, attention network, memory load, percept, attentional control, moving, sensory information, visual information, working memory, memory, video, switching, target detection, performance task, switch, term memory, illusion, discrimination task, memory task, mental imagery, motion, memory wm, visual stimuli, navigation, executive function, planning, visual motion, memory retrieval, recollection, executive control, matching task, perceptual, judgment, judgment task, recognition memory, action observation, action, cognitive processes, control processes, cognitive tasks, repetition suppression
10	self-referential, theory mind, social cognition, moral
17	primary visual
19	visual perception, face recognition, visual stimuli, perceptual, face stimuli, motion, orientation, fusiform face, face, illusion, object recognition, matching task, primary visual, visual motion, visual stream, spatial attention, visual attention, adaptation, percept
21	social cognition, voice, theory mind, language comprehension, spoken, acoustic, listening, communication, speech, speech perception, language, syntactic, speech sounds, social interaction, phonetic, auditory visual, semantic, sentence comprehension, language network
22	communication, acoustic, phonetic, speech perception, speech sounds, voice, auditory visual, listening, spoken, music, primary auditory, visual auditory, speech, speech production, perception, hallucinations, sensory modalities, percept, multisensory, language, repetition, perceptual, language network, language comprehension, syntactic, theory mind, phonological, semantic, sentence comprehension, social interaction, autism, suppression, reading, verbal, written
23	mild cognitive, autobiographical memory, self-referential, moral, recollection,
24	pain, nociceptive, cognitive emotional, anxiety, arousal, Stroop task, negative affect, target detection, fear, affective, inhibition, anxiety disorders, Stroop, awareness, secondary somatosensory, stress, inhibitory control, incentive, response inhibition, sustained attention, somatosensory, cognitive control, self, decision making, schizophrenia, sensation, response selection, anticipation, salience, reward, emotion, attentional control, empathy, stop signal,

25	gambling, self-reported, reward anticipation, incentive, motivation, monetary reward, impulsivity, reactivity, learning task, anticipation, decision making, reward, gain, compulsive disorder, obsessive compulsive, bipolar disorder, vulnerability
27	episodic memory, navigation
28	neutral faces, fear, fearful faces, disgust, passive viewing, neutral pictures, anger, neutral stimuli, threatening, happy, emotional stimuli, facial expressions, reactivity, negative emotional, emotional faces, emotional valence, sad, anxiety, depression, mood, personality, stress, face stimuli, emotional information, pleasant, emotion regulation, anxiety disorders, vulnerability, major depression, conscious, emotion, negative affect, arousal, self reported, autism, affective, encoding retrieval, memory encoding, cognitive emotional, moral, face, subsequent memory
29	autobiographical memory
30	autobiographical memory, semantic memory, navigation, episodic memory, mild cognitive, recall, memory retrieval, recollection
34	affective, anger, anxiety disorders, anxiety, depression, disgust, emotion, emotion regulation, emotional faces, emotional information, emotional responses, emotional stimuli, emotional valence, facial expressions, fear, fearful faces, happy, mood, motivation, negative affect, negative emotional, neutral faces, neutral pictures, neutral stimuli, personality, pleasant, reactivity, sad, self reported, stress, threatening, vulnerability, arousal, cognitive emotional, conscious, passive viewing, face stimuli, learning task, monetary reward, reward, autism, awareness, social interaction, major depression, memory encoding, social, bipolar disorder, face, schizophrenia, anticipation, matching task, subsequent memory, picture, salience, social cognition, self, incentive, recall, image, mild cognitive, reward anticipation, ongoing, semantic knowledge, communication, recognition, sleep, encoding retrieval, gain, pain, recollection, perception, empathy, attention deficit, face recognition, memory, memory performance, fusiform face, decision making, moral, cognition, hyperactivity disorder, hallucinations, visual stimuli, recognition memory, episodic memory, gambling, semantic information
35	neutral stimuli, emotional valence, happy, subsequent memory, fearful faces, negative emotional, neutral faces, sad, neutral pictures, threatening, memory encoding, emotional stimuli, anger, recognition task, mild cognitive, emotional information, depression, mood, reactivity, autobiographical memory, pleasant, memory performance, major depression, episodic memory, recognition memory
36	fearful faces, happy, neutral faces
37	face, image, object recognition, face stimuli, fusiform face, passive viewing, illusion, visual perception, visual stream, face recognition, motion, recognition, subsequent memory, video, visual stimuli, perceptual, memory encoding, visual motion, facial expressions, adaptation, action observation, percept, picture, perception, navigation, repetition suppression, neutral faces, matching task, moving, visual auditory, repetition, written, sensory modalities, encoding retrieval, multisensory
38	language comprehension, impulsivity
40	attention network, attention, memory wm, visuospatial, expectancy, memory load, working memory, planning, attentional control, arithmetic, action, discrimination task, visual attention, adaptation, motor response, sensory information, cognitive tasks, visuospatial, mental imagery, moving, response selection, cognitive control, spatial attention, goal directed, verbal, memory, cognitive processes, action observation, cognition, visual spatial, detection task, selective attention,

	response inhibition, cognitive functions, perceptual, control network, inhibitory control, orientation, inhibition, NoGo, finger movements, Stroop, executive control, control processes, memory task, executive function, switch, motor control, target detection, switching, reasoning, perception, motion, stop signal, ongoing, suppression, sensory modalities, visual information, Stroop task, visual stream, multisensory, decision making, recognition, term memory, self, motor imagery, memory processes, visual stimuli, touch, tapping, hand movements
41	primary auditory, hallucinations, acoustic, speech perception, multisensory, music
42	auditory visual, listening, acoustic, multisensory, primary auditory, visual auditory, hallucinations, speech perception, perception, speech, rhythm, percept, sensory modalities, touch, music, image, sensation, speech production, secondary somatosensory, language, action, communication, phonetic, voice, speech sounds, attention, perceptual, action observation, somatosensory, spoken, motor response, primary somatosensory
43	speech production, oral, somatosensory, primary somatosensory
44	performance task, cognitive control, matching task, control processes, working memory, memory wm, memory, switching, term memory, judgment, schizophrenia, executive function, reasoning, Stroop, Stroop task, adaptation, visual information, switch, cognition, action observation, verbal, control network, recognition, recall, written, word recognition, memory task, cognitive functions, attention, suppression, judgment task, memory load, recognition memory, language, video, perceptual, phonological, repetition, executive control, repetition suppression, sensory information, verbal working, semantic, recognition task, cognitive processes, mood, episode, decision making, visual stimuli, attentional control, reading, memory performance, syntactic, discrimination task, inhibitory control, goal directed, communication, response inhibition, action, selective attention, arithmetic, mental imagery, visual spatial, semantic knowledge, major depression, visuospatial, attention network, memory retrieval, verbal fluency, memory processes, face, encoding retrieval, decision task, semantic information, perception, inhibition, planning, sentence comprehension, lexical decision, phonetic, depression, visual perception, empathy, picture, visual auditory, motion, stop signal, monitor, social, response selection, semantic memory, memory encoding, language network, vulnerability, cognitive tasks, autism, episodic memory, sustained attention, facial expressions, voice, music, expectancy, auditory visual, ongoing
45	memory, working memory, major depression, emotional responses, semantic, verbal, language, cognition, recognition, syntactic, language comprehension, semantic information, performance task, empathy, expectancy, written, judgment, cognitive processes, memory load, language network, memory task, emotion, semantic knowledge, inhibition, memory processes, face, phonological, cognitive control, memory wm, reasoning, control processes, picture, lexical decision, recall, verbal fluency, neutral stimuli, sentence comprehension, vulnerability, memory encoding, reading, social, affective, executive function, action
47	bipolar disorder, episode, conscious, emotional information, social interaction, hyperactivity disorder, attention deficit, neurocognitive, autism, personality, pleasant, vulnerability, emotion regulation, recognition task, anger, negative affect, compulsive disorder, obsessive compulsive, mood, memory processes, suppression, inhibitory control, recognition memory, cognitive processes, facial expressions, salience, control network, encoding retrieval, expectancy, affective, emotion, semantic knowledge, communication, ongoing, awareness, arousal, sustained attention, emotional responses, threatening, goal directed, social cognition, gain, memory performance, judgment task, social, stop signal, moral, reasoning, emotional stimuli, empathy, impulsivity,

	<p>sentence comprehension, sad, neutral stimuli, monitor, semantic, cognition, attentional control, language network, pressure, control processes, word recognition, judgment, motor response, decision making, major depression, NoGo, happy, memory encoding, decision task, cognitive emotional, fear, reactivity, neutral faces, gambling, schizophrenia, semantic information, picture, face, language comprehension, anxiety, memory retrieval, executive control, inhibition, cognitive tasks, executive function, recall, episodic memory, term memory, response selection, memory task, reading, response inhibition, cognitive functions</p>
48	<p>hallucinations, listening, multisensory, music, nociceptive, pain, perception, pressure, primary auditory, primary somatosensory, secondary somatosensory, sensation, somatosensory, sustained attention, touch</p>

Table S7 The functional annotation results and the gene enrichment analysis results of the over-expression genes for the clusters obtained from a Brain-Wide functional connectivity Association Study (BWAS) analysis of autism (Cheng, et al., 2015).

Functional Annotation results						Gene Enrichment Results	
Neurosynth Term	p	Neurosynth Term	p	Neurosynth Term	p	GO Biological Process	P
autobiographical memory	0	suppression	0.0119	episode	0.0435	cell-cell signaling	1.01E-19
communication	0	reward	0.012	hyperactivity disorder	0.0448	synaptic signaling	3.88E-19
moral	0	primary auditory	0.0124	anticipation	0.0457	behavior	5.98E-15
self	0	sad	0.0134	language network	0.046	regulation of synapse structure or activity	3.88E-14
self referential	0	arousal	0.014	motor task	0.0469	neurogenesis	5.07E-14
social cognition	0	depression	0.014	emotion regulation	0.0482	neuron differentiation	7.75E-13
social	0	spoken	0.014	language comprehension	0.0491	Pathway	P
theory of mind	0	nociceptive	0.0141			Neuronal System	6.90E-11
social interaction	0.0002	vulnerability	0.0145			Transmission across Chemical Synapses	2.85E-07
mild cognitive	0.0006	NoGo	0.0149			Potassium Channels	6.16E-07
personality	0.0007	cognitive tasks	0.0157			Neurotransmitter Receptor Binding And Downstream Transmission In The Postsynaptic Cell	8.83E-07
cognition	0.0008	performance task	0.0158			Ionotropic glutamate receptor pathway	1.37E-05
emotion	0.0008	recognition task	0.0163			Disease	P
schizophrenia	0.0008	somatosensory	0.0179			Bipolar Disorder	3.70E-11
saliency	0.0009	episodic memory	0.0191			Autistic Disorder	2.80E-10
hallucinations	0.0011	gambling	0.0203			Schizophrenia	1.93E-09
memory retrieval	0.0011	semantic knowledge	0.0204			Major Depressive Disorder	2.78E-07
sleep	0.0011	conscious	0.0211			Epilepsy	3.78E-07
emotional responses	0.0014	bipolar disorder	0.0219			Intellectual Disability	9.23E-07
voice	0.0014	pressure	0.0222			Autism Spectrum Disorders	1.20E-06
autism	0.0015	syntactic	0.024			Unipolar Depression	1.35E-06
memory	0.0021	perception	0.0251			Seizures	1.70E-06
semantic	0.0023	language	0.026			Mental disorders	6.22E-06

music	0.0026	sensory information	0.0262			Epilepsy	3.78E-07
speech sounds	0.0033	verbal	0.0264			Mood Disorders	9.18E-06
speech perception	0.0045	sensation	0.0273			Substance-Related Disorders	1.24E-05
speech production	0.0047	ongoing	0.0276				
recollection	0.0048	primary somatosensory	0.028				
acoustic	0.005	awareness	0.0286				
semantic memory	0.0055	recognition	0.0288				
listening	0.0056	judgment	0.0297				
self reported	0.0057	empathy	0.0319				
cognitive emotional	0.0059	stress	0.032				
goal directed	0.0064	rhythm	0.0349				
phonetic	0.0064	phonological	0.0354				
affective	0.0069	memory task	0.0358				
visual auditory	0.0077	attention	0.0367				
auditory visual	0.0079	repetition	0.0391				
cognitive processes	0.0085	percept	0.0414				
expectancy	0.0102	sentence comprehension	0.0418				
mood	0.0105	recall	0.0421				
speech	0.011	monitor	0.0423				
decision making	0.0112	reasoning	0.0432				

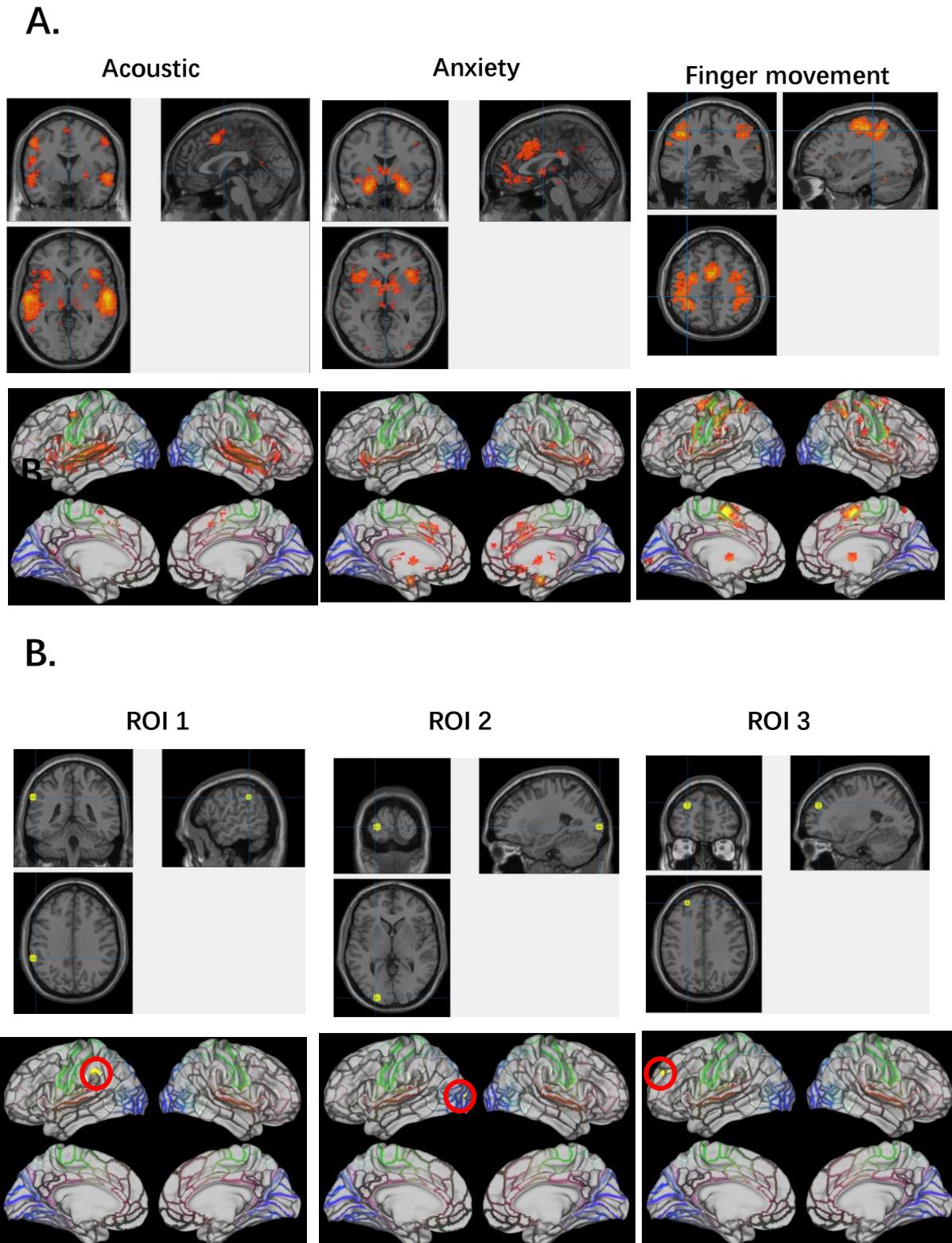
Table S8 Functional annotation results and the gene enrichment analysis results for the over-expression genes for the FCs that were significantly increased in an investigation of chronic schizophrenia patients (Li, et al., 2017).

Functional Annotation results				Gene Enrichment Results	
Neurosynth Term	p	Neurosynth Term	p	GO Biological Process	P
sleep	0	pressure	0.0142	brain development	2.99E-09
primary sensorimotor	0.0001	monitor	0.0165	synaptic signaling	1.84E-08
cognitive tasks	0.0004	motor performance	0.0194	neurogenesis	2.26E-08
discrimination task	0.0004	motion	0.0205	regulation of nervous system development	5.81E-08
primary visual	0.0008	pain	0.021	Mouse Phenotype	P
motor task	0.0012	memory	0.0249	abnormal CNS synaptic transmission	4.97E-05
primary somatosensory	0.0018	tapping	0.026	abnormal sensory capabilities /reflexes /nociception	2.48E-04
sensation	0.0022	cognitive control	0.0293	abnormal social/conspecific interaction	2.16E-03
detection task	0.0033	speech production	0.0296	abnormal sleep behavior	3.35E-03
motor response	0.004	working memory	0.0304	Disease	P
attention	0.0046	visual attention	0.0317	Schizophrenia	8.89E-07
somatosensory	0.0063	rhythm	0.0343	Autism Spectrum Disorders	1.81E-06
hand movements	0.0064	schizophrenia	0.0349	Bipolar Disorder	6.63E-05
oral	0.0068	multisensory	0.0351	Sleep Disorders	5.64E-04
sensory information	0.0076	planning	0.0355		
hallucinations	0.0081	finger movements	0.036		
target detection	0.0092	self	0.0369		
nociceptive	0.0111	acoustic	0.0376		
visual information	0.0116	selective attention	0.0451		
touch	0.013	eye movements	0.0454		
perception	0.0137	motor control	0.048		
secondary somatosensory	0.0139				

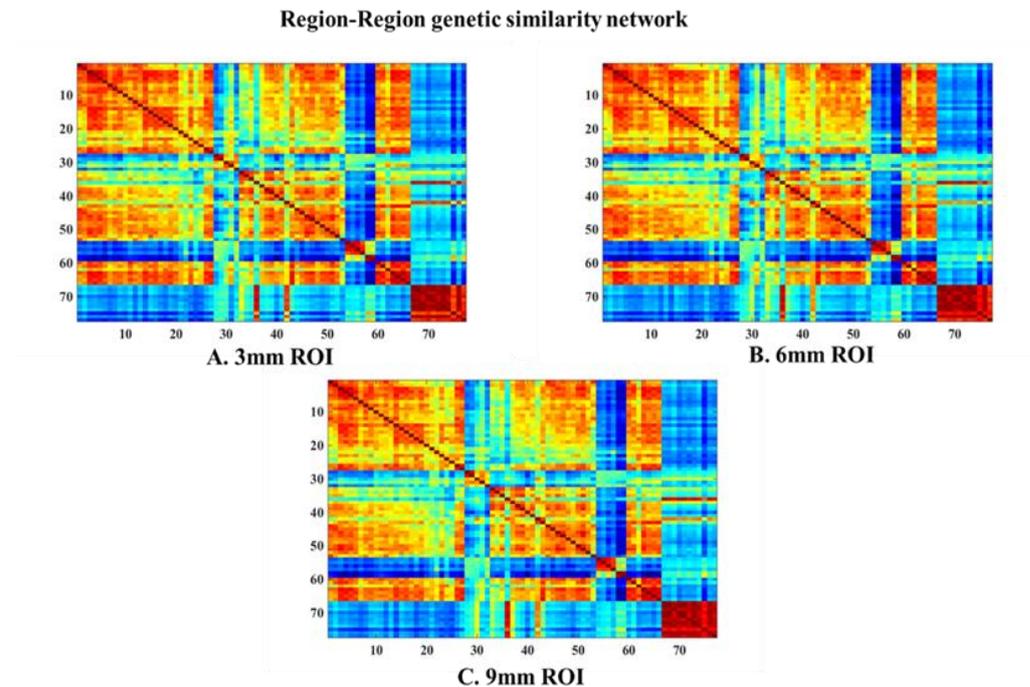
Table S9 Network-level functional annotation results for the FCs that were significantly increased in an investigation of chronic schizophrenia patients (Li, et al., 2017). The network parcellations were obtained from Yeo and colleague's work (Yeo, et al., 2011) and two significant networks are in bold (permutation test, p-value<0.05).

Yeo 7 Networks			Yeo 17 Networks		
Index	p-value	Network name	Index	p-value	Network name*
7_1	0.6263	Visual	17_1	0.8904	Visual A
7_2	0.908	Somatomotor	17_2	0.8539	Visual B
7_3	0.3261	Dorsal Attention	17_3	0.5795	Somatomotor A
7_4	0.9865	Ventral Attention	17_4	0.8067	Somatomotor B
7_5	0.9206	Limbic	17_5	0.1682	Dorsal Attention A
7_6	0.5506	Frontoparietal	17_6	0.7364	Dorsal Attention B
7_7	0.2512	Default	17_7	0.958	Saliency/Ventral Attention A
			17_8	0.9788	Saliency/Ventral Attention B
			17_9	0.8299	Limbic B
			17_10	0.9072	Limbic A
			17_11	<0.0001	Control C
			17_12	0.5985	Control A
			17_13	0.736	Control B
			17_14	0.8293	TempPar
			17_15	0.0617	Default C
			17_16	0.0437	Default A
			17_17	0.9936	Default B

*The network name for the 17 networks was obtained from Yeo and colleague's work. (Yeo, et al., 2015).



Supplementary Figure 1. Verification that the 3D (above) and 2D (or surface) (below) maps corresponded. A.) The correspondence of the maps produced by 3 NeuroSynth search terms. B.) The correspondence of the maps produced by 3 of the regions sampled in the Allen Human Brain Atlas.



Supplementary Figure 2. Region-region genetic similarity networks which constructed using expression profiles obtained from AHBA samples with different ROI size.

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