

Neurosynth is a method proposed by Yarkoni et al., 2011, it has been widely demonstrated as a useful method.

Large-scale automated synthesis of human functional neuroimaging data

Tal Yarkoni¹, Russell A Poldrack²⁻⁴, Thomas E Nichols^{5,6}, David C Van Essen⁷ & Tor D Wager¹

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Large-scale automated synthesis of human functional neuroimaging data

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Abstract The rapid growth of the literature on neuroimaging in humans has led to major advances in our understanding of human brain function but has also made it increasingly difficult to aggregate and synthesize neuroimaging findings. Here we describe and validate an automated brain-mapping framework that uses text-mining, meta-analysis and machine-learning techniques to generate a large database of mappings between neural and cognitive states. We show that our approach can be used to automatically conduct large ...

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WHY AND HOW CAN IT HELP US?

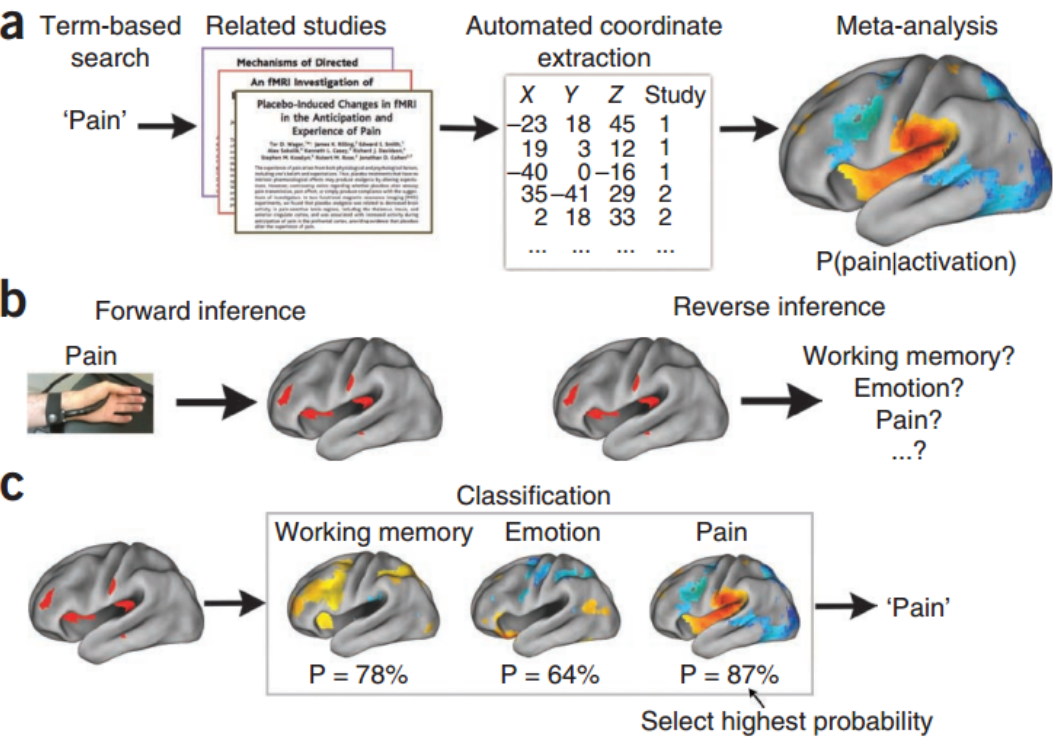
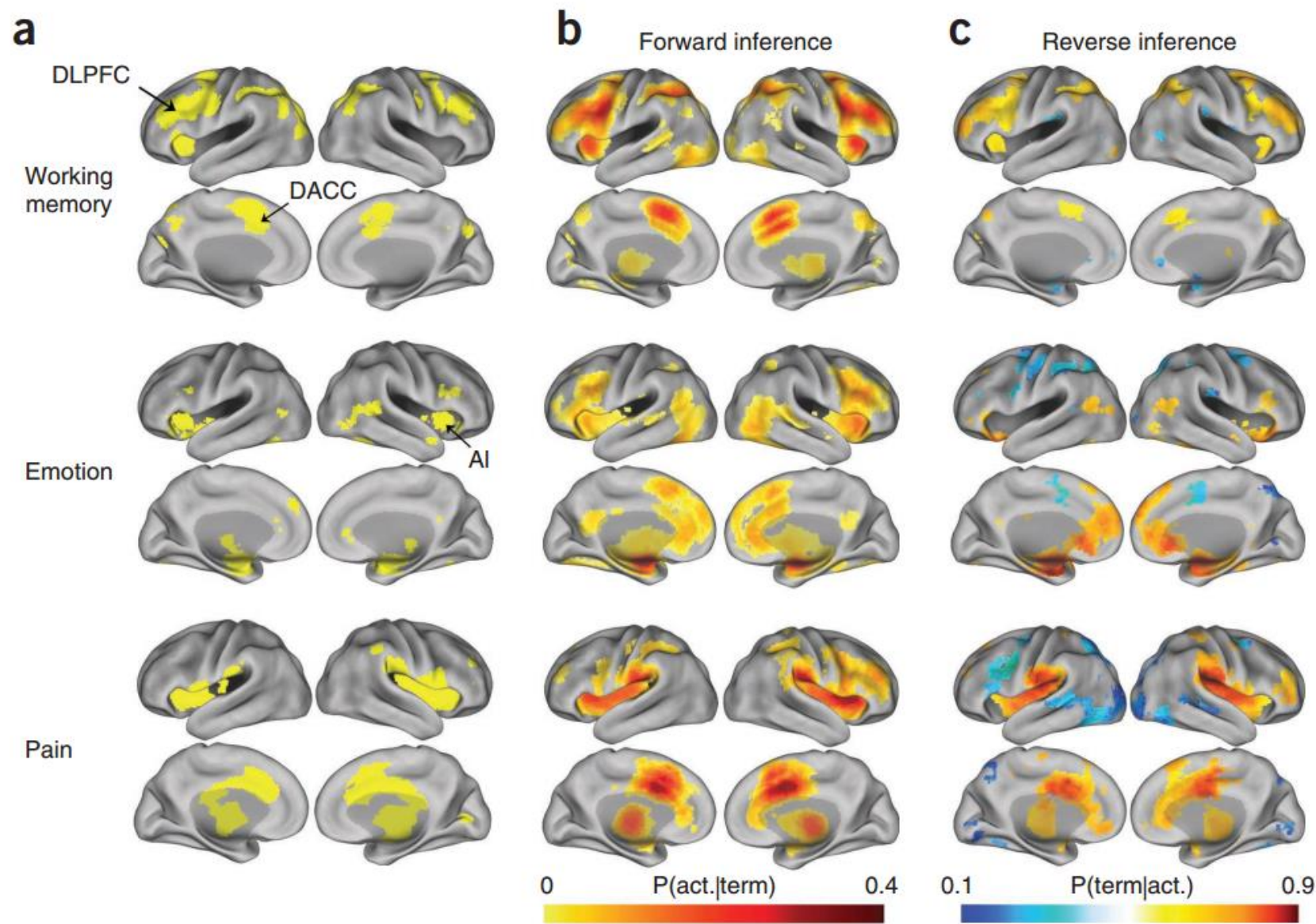


Figure 1 | Schematic overview of NeuroSynth framework and applications. **(a)** Outline of the NeuroSynth approach. The full text of a large corpus of articles is retrieved and terms of scientific interest are stored in a database. Articles are retrieved from the database on the basis of a user-entered search string (for example, 'pain') and peak coordinates from the associated articles are extracted from tables. A meta-analysis of the peak coordinates is automatically performed, producing a whole-brain map of the posterior probability of the term given activation at each voxel ($P(\text{pain}|\text{activation})$). **(b)** Outlines of forward and reverse inference in brain imaging. Given a known psychological manipulation, one can quantify the corresponding changes in brain activity and generate a forward inference, but given an observed pattern of activity, drawing a reverse inference about associated cognitive states is more difficult because multiple cognitive states could have similar neural signatures. **(c)** Given meta-analytic posterior probability maps for multiple terms (for example, working memory, emotion and pain), one can classify a new activation map by identifying the class with the highest probability, P , given the new data (in this example, pain).

Figure 2 | Comparison of previous meta-analysis results with forward and reverse inference maps produced automatically using the NeuroSynth framework. **(a)** Meta-analytic maps produced manually in previous studies^{14–16}. **(b)** Automatically generated forward inference maps showing the probability of activation given the presence of the term ($P(\text{act.}|\text{term})$). **(c)** Automatically generated reverse inference maps showing the probability of the term given observed activation ($P(\text{term}|\text{act.})$). Meta-analyses were carried out for working memory (top), emotion (middle) and physical pain (bottom) and mapped to the PALS-B12 atlas³⁰. Regions in **b** were consistently associated with the term and regions in **c** were selectively associated with the term. To account for base differences in term frequencies, reverse inference maps assumed uniform priors (equal 50% probabilities of 'term' and 'no term'). Activation in orange or red regions implies a high probability that a term is present, and activation in blue regions implies a high probability that a term is not present. Values for all images are shown only for regions that survived a test of association between term and activation, with a whole-brain correction for multiple comparisons (false discovery rate was 0.05). DLPFC, dorsolateral prefrontal cortex; DACC, dorsal anterior cingulate cortex; AI, anterior insula.



EXAMPLE

Neuron
Article

Empathic Care and Distress: Predictive
Brain Markers and Dissociable Brain Systems

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levels (quintiles) of care and distress (Figure 4). We also confirmed our interpretation of the care-specific regions as related to valuation processes and the distress-specific regions as related to mirroring processes by comparing our results with reverse inference meta-analytic maps from Neurosynth for the terms “value” and “mirror” (Yarkoni et al., 2011; Figure 3B). Neurosynth reverse inference maps show brain regions that are selectively related to a given term (i.e., value or mirror) relative to the hundreds of other terms in the database collected from more than 10,000 fMRI studies.

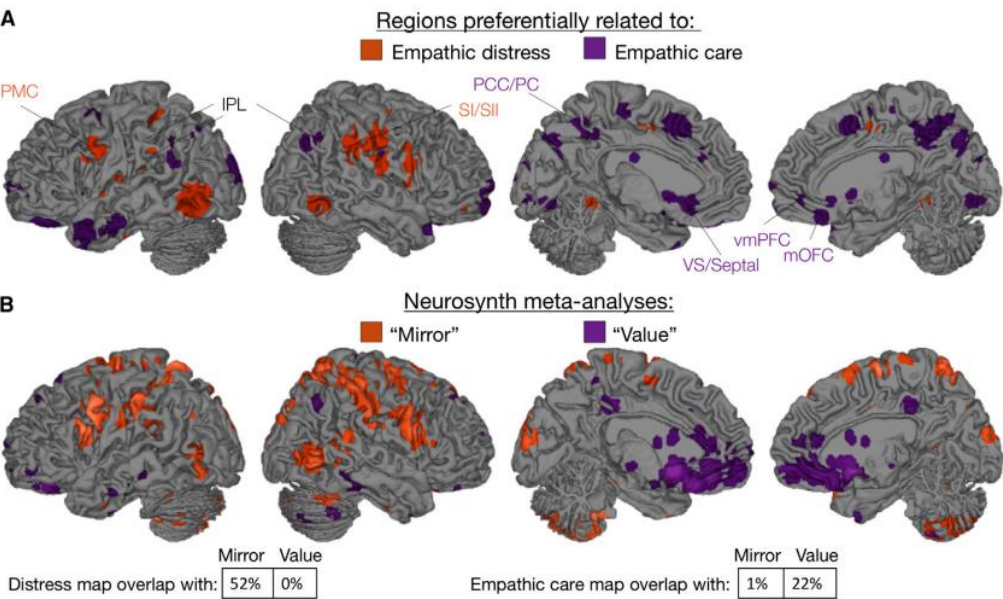


Figure 3. Brains Systems Preferentially Related to Empathic Care or Distress Overlap with Brain Systems Related to Value and Mirroring, Respectively
(A) Regions sensitive and relatively selective for empathic care and distress in both multivariate and univariate analyses (see text for details).
(B) Meta-analytic maps for the terms mirror and value (reverse inference), thresholded at FDR $q = 0.01$ (Yarkoni et al., 2011). PMC, premotor cortex; IPL, inferior parietal lobe; SI/SII, primary/secondary somatosensory cortex; PCC, posterior cingulate; PC, precuneus; VS, ventral striatum; vmPFC, ventromedial prefrontal cortex; mOFC, medial orbitofrontal cortex.

Intrinsic functional networks associated with any significant ICC or ILC analysis regions, and any contributors to the omnibus ICC analysis, were determined using Neurosynth (<http://neurosynth.org>); an open-source neuroimaging meta-analytic tool comprised of the activation coordinates and associated study subject terms from over 11406 peer-reviewed functional imaging studies. (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011) Functional connectivity and meta-analytic coactivation correlation values associated with the search terms “working memory, executive control, frontoparietal network, and default mode network” were generated by Neurosynth and used to determine the likelihood of working memory and default mode-associated large scale functional networks for the local maxima of any regions found in ICC or ILC analyses (Table 3) and any contributing regions to significant ICC analysis results (Table 4).

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RESEARCH ARTICLE

WILEY

Task-related changes in degree centrality and local coherence of the posterior cingulate cortex after major cardiac surgery in older adults

EXAMPLE

Functional ROIs

We analyzed the properties of the model in a variety of functionally defined cortical loci to illustrate the general validity of the common model, in particular its applicability in different information domains and the extent to which it captures fine-grained topographies, and to examine the relationships among the representational geometries of distributed cortical regions. We selected 20 loci using Neurosynth, a database derived from meta-analysis of over 10 000 fMRI studies (<http://www.neurosynth.org>; Yarkoni et al. 2011). We took the coordinates for the peak location associated with selected terms (Supplementary Table 1) and analyzed the properties of the model representational spaces that surrounded these loci in searchlights with a 3-voxel radius (mean volume = 119 voxels; Figs 2–5; Supplementary Figs 8 and 12).

Supplementary Table S1. Selected cortical loci from Neurosynth. V1 – primary visual cortex, MT – middle temporal visual motion area, FFA – fusiform face area, PPA – parahippocampal place area.

Search term	Hemi-sphere	MNI coordinates		
		x	y	z
V1	left	-4	-82	-4
	right	10	-94	2
MT	left	-42	-72	2
	right	44	-66	2
Visual word form area	left	-46	-60	-14
FFA	left	-42	-52	-20
	right	40	-50	-22
Scenes (PPA)	left	-26	-46	-10
	right	34	-38	-12
Primary auditory (A1)	left	-44	-30	10
	right	52	-14	4
Voice	left	-60	-14	0
	right	60	-4	-12
Music	left	-52	-14	0
	right	60	-20	4
Calculations	left	-30	-66	38
	right	34	-64	44
Broca's area	left	-52	14	12
Working memory	left	-44	26	24
	right	44	42	26

A Model of Representational Spaces in Human Cortex

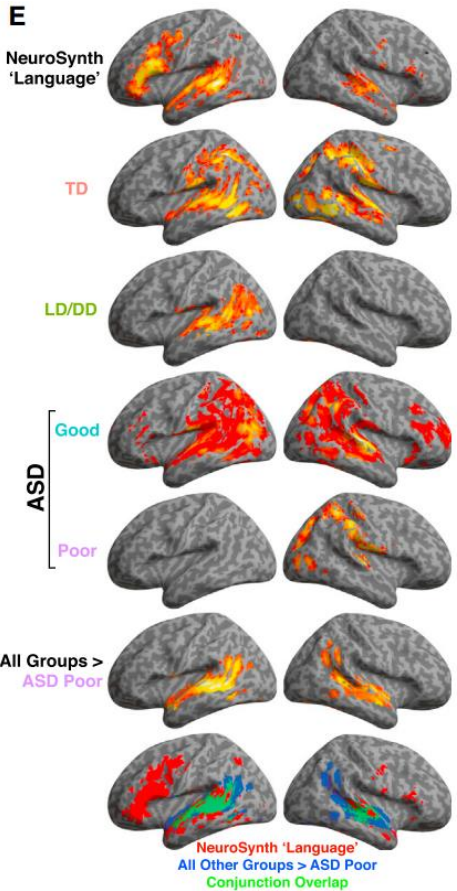
J. Swaroop Guntupalli¹, Michael Hanke², Yaroslav O. Halchenko¹,
Andrew C. Connolly¹, Peter J. Ramadge³ and James V. Haxby^{1,4}

¹Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH 03755, USA, ²Department of Psychology, University of Magdeburg, Magdeburg 39106, Germany, ³Department of Electrical Engineering, Princeton University, Princeton, NJ 08544, USA and ⁴Center for Mind/Brain Sciences (CIMEC), University of Trento, Rovereto, Trentino 38068, Italy

EXAMPLE

2006). To illustrate these “canonical” neural systems, we extracted a meta-analysis map from the NeuroSynth database (<http://www.neurosynth.org>) (Yarkoni et al., 2011) of 725 studies associated with the feature “language” (Figure 2E). This map shows involvement primarily within large clusters in bilateral lateral frontal and superior temporal cortex. Visually, the within-group all speech versus rest activation maps from all groups except ASD Poor appear very similar to the NeuroSynth language map, particularly in temporal and parietal cortex. TD, ASD Good, and LD/DD groups showed activation broadly distributed across perisylvian temporo-parietal areas such as planum polare, planum temporale, anterior, middle, and posterior superior temporal sulcus and gyrus, Heschl’s gyrus, middle temporal gyrus, and inferior temporal sulcus as well as in angular gyrus, supramarginal gyrus, intraparietal sulcus, and inferior parietal lobule/parietal operculum (Figure 2E). In contrast, the ASD Poor group showed no left hemi-

ure 2E). The conjunction overlap (Nichols et al., 2005) of this whole-brain analysis with the NeuroSynth “language” meta-analysis map was considerable in bilateral superior temporal cortex (Figure 2E). Further whole-brain analyses specifically



(E) The full spatial extent of the NeuroSynth “language” meta-analysis map along with activation observed at a whole-brain corrected level (FDR $q < 0.05$) within each group individually. The second to last row of (E) shows the whole-brain analysis for the specific contrast of All Other Groups > ASD Poor. The last row of (E) shows the conjunction overlap between the NeuroSynth “language” map and the whole-brain contrast of All Other Groups > ASD Poor.

Neuron Article

Different Functional Neural Substrates for Good and Poor Language Outcome in Autism

Michael V. Lombardo,^{1,2,3,*} Karen Pierce,⁴ Lisa T. Eyler,^{4,5,6} Cindy Carter Barnes,⁴ Clelia Ahrens-Barbeau,⁴ Stephanie Solso,⁴ Kathleen Campbell,⁴ and Eric Courchesne^{4,*}

Neurosynth Review

The online Neurosynth platform (www.neurosynth.org) (Yarkoni et al. 2011) contains a database of activation coordinates from over 11406 published studies (as of 16 September 2016). The database provides a metric for the likelihood of the association between functional activation at an ROI's coordinates and prespecified search terms. Publications reporting activation at an ROI can also be searched for the high-frequency use of specific behavioral terms of interest.

Searches for frequently connected ROIs, specified as the top 25% of ROIs contributing to enriched network blocks, were conducted in Neurosynth to systematically explore whether these ROIs were implicated in studies of motor function. MNI coordinates for these highly connected ROIs were entered into Neurosynth to determine the likelihood of association with the search term “motor,” which also referenced words or phrases containing “motor,” for example, “sensorimotor” and “motor performance.” The standard search setting of 6 mm was used to identify functional activations for each ROI. For each motor-related term, Neurosynth provided a posterior probability value indicating the likelihood of that term being frequently used in a manuscript reporting activation at a given ROI (Yarkoni et al. 2011). Posterior probabilities for general motor terms (e.g., “sensorimotor”) and terms indicating a motor behavior (e.g., “motor response”) were ranked separately. For these 2 categories, terms with the top 3 posterior probabilities >0.5 were reported for each ROI (Table S2). Next, publications containing a functional activation for a given ROI were searched for whether they included the following motor-related terms: motor, walk, gait, or biological motion. Each identified study was reviewed to confirm the relevance of the functional activation at that ROI for motor behavior.



ORIGINAL ARTICLE

Walking, Gross Motor Development, and Brain Functional Connectivity in Infants and Toddlers

Natasha Marrus¹, Adam T. Eggebrecht², Alexandre Todorov¹, Jed T. Elison³,

ROI-Level Associations With Motor Behavior

Because enrichment analyses implicated motor networks as well as networks less directly associated with motor behavior, we investigated whether ROIs contributing to enriched network blocks for walking, the primary behavior analyzed, were associated with motor function according to prior literature. To systematize our literature search, we selected those ROIs demonstrating a high frequency of connections in significantly enriched network blocks (Materials and Methods) and reviewed these ROIs in Neurosynth (Yarkoni et al. 2011), a database containing information on whether functional activations of these ROIs is associated with motor-related behaviors. Our search confirmed associations with several motor-related behaviors, including motor execution (Fink et al. 1997; Zapparoli et al. 2013; Gandolla et al. 2014), action observation (Iseki et al. 2008; Wagner et al. 2008; Villiger et al. 2013), visuomotor integration (Iacoboni and Zaidel 2004; Martuzzi et al. 2006), biological motion detection (Vaina et al. 2001; Bidet-Caulet et al. 2005), motor learning (Sacco et al. 2009; Lungu et al. 2014), motor inhibition (Nakata et al. 2008, Cai et al. 2014), and motor imagery (Cremers et al. 2012; van der Meulen et al. 2014; Taube et al. 2015) (Table S2). Further, ROIs from several networks were associated with behaviors relevant to walking, including motor execution involving the leg or ankle, motor imagery related to gait, and biological motion detection of walking.

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Advance Access Publication Date: 23 November 2017
Original Article

EXAMPLE

Traditional GLM analysis. The aim of these analyses was to reveal brain regions that were positively (or negatively) associated with CS and hence provide neuro-physiological basis for the core (or periphery) nodes in the shape graph. A weighted GLM analysis was performed. First, the coreness score of each node was mapped back to the time frames contained in that node. Thus, if a node has a CS of 0.5, then the corresponding time frames contained in that node also got a proportional weighting of 0.5 in the GLM analysis. Using a multiple regression analysis, weighted time frames were entered for each task separately creating four explanatory variables. Two contrasts were run to examine brain regions that show positive as well as negative association with the coreness scores. We qualitatively compared the cluster-corrected ($Z > 2.3$ and FWER $p < 0.05$) group-level results with task-specific meta-analysis statistical maps derived from the NeuroSynth library⁴⁴.

and lateral occipital cortex, and paracingulate gyrus. Higher coreness scores during the math task were associated with increased engagement of the R. angular gyrus, inferior parietal sulcus areas and the paracingulate gyrus. Lastly, for the video task, higher coreness scores were positively associated with activation in the bilateral fusiform gyrus and right frontal pole. Qualitatively, the brain regions associated positively with coreness scores largely overlapped with regions previously shown to be recruited for the respective tasks (Fig. 4c). This qualitative

assessment was performed by overlaying the observed results on the meta-analysis maps generated by NeuroSynth.org⁴⁴ for each task term (i.e., “working memory,” “arithmetic,” and “object recognition,” respectively). For the negative association contrast, across all three tasks, significant clusters were observed in the posterior cingulate cortex (PCC) and medial prefrontal cortex (Supplementary Fig. 5), suggesting nodes with lower coreness scores (i.e., periphery nodes) were associated with increased activation in the PCC irrespective of the task type. No significant

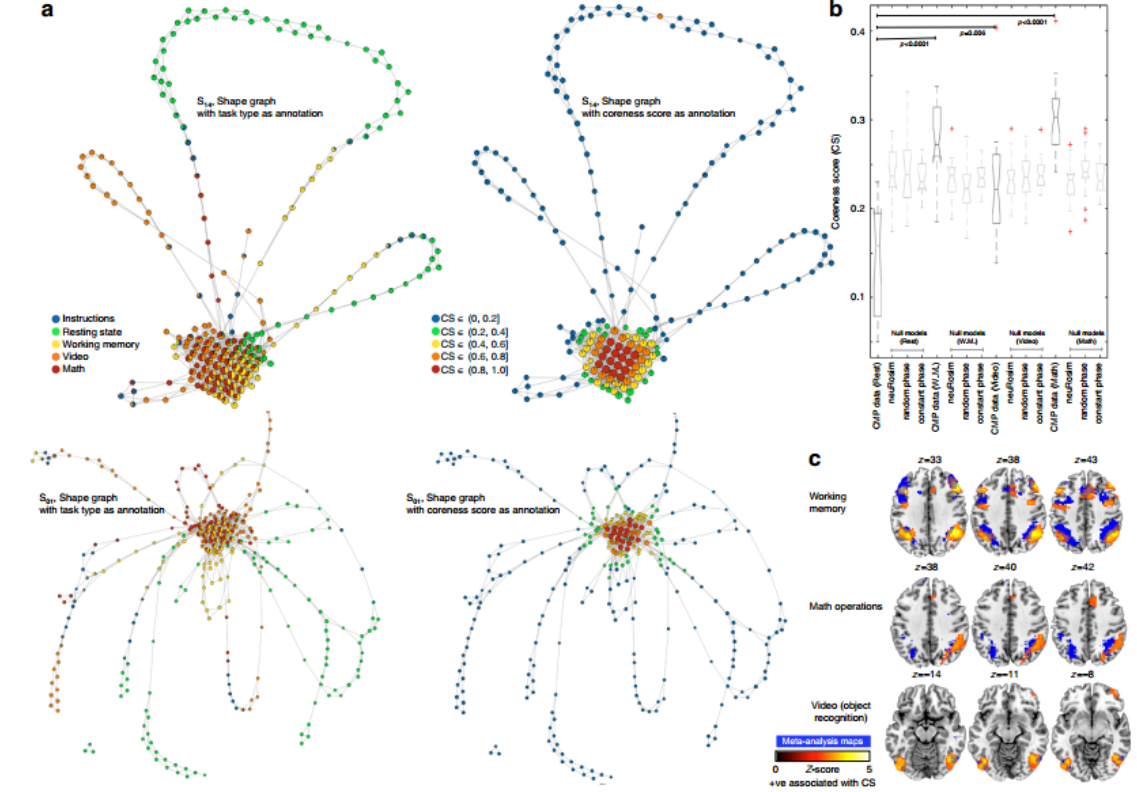
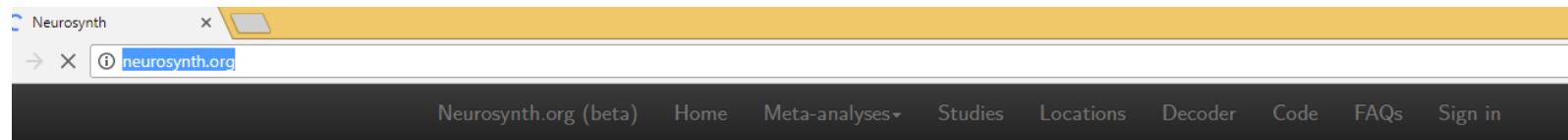


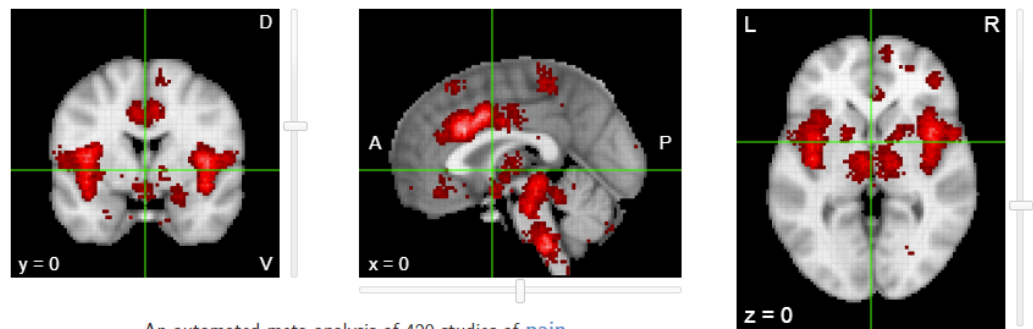
Fig. 4 Quantifying the mesoscale core–periphery structure of shape graphs. **a** Shows shape graphs for two representative participants (S₁₄ and S₀₁). In the left column, we annotated the nodes using task-type and in the right column the nodes are annotated using the coreness scores (CS). As evident, the more central and densely connected nodes have high CS and more sparsely and peripheral nodes have less CS. **b** Shows boxplots of CS derived from the CPM data as well as from the three null models (neuRosim, phase randomization with random, and constant phase). Across the four CPM tasks, nodes containing resting time frames had the lowest CS, while the nodes containing time frames from cognitively demanding tasks mainly lied relatively deeper inside the shape graph (i.e. higher CS). The CS of nodes with resting time frames was also lower than all the three corresponding null models ($p < 0.001$), and the CS of nodes with working memory or math frames was higher than all the three corresponding null models ($p < 0.005$). No significant difference was observed for the CS of nodes with time frames from the video task and the corresponding null models. **c** Shows the brain regions that were positively associated with coreness scores, i.e., higher the CS, higher the activation in these regions. The group-maps (in red-yellow scale) for positive relation with CS are overlaid on the task-associated meta-analysis maps from NeuroSynth⁴⁴. As shown, higher CS was associated with higher engagement of task-related brain regions



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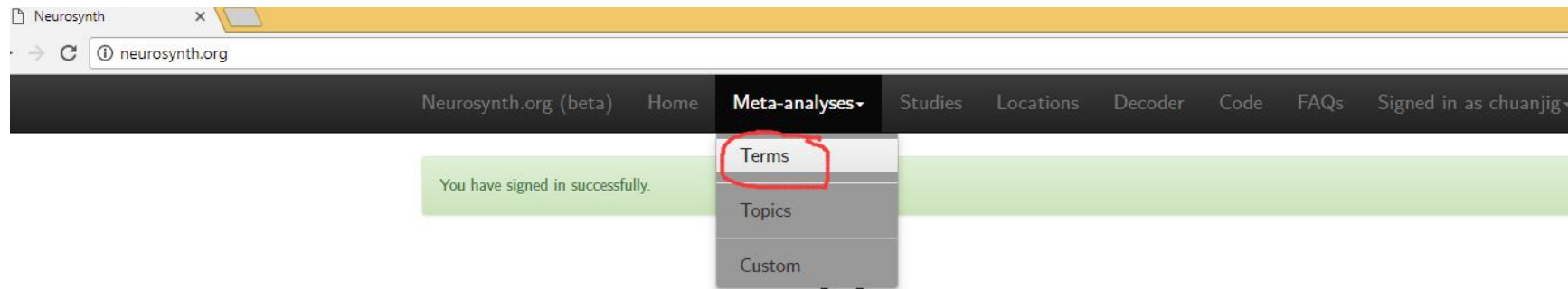
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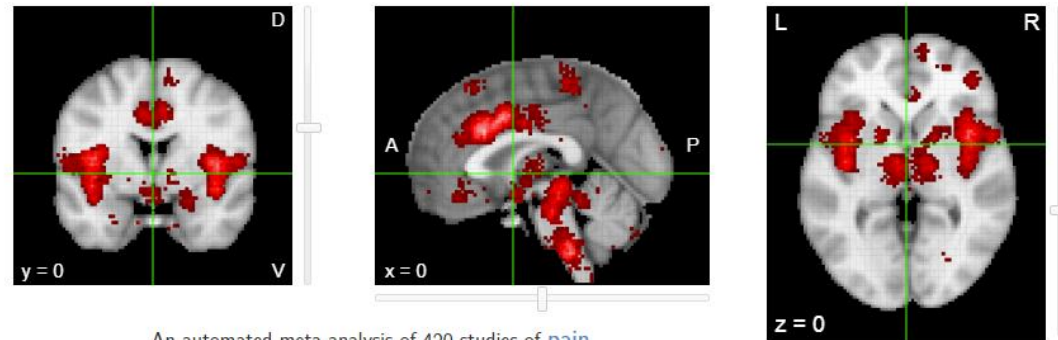
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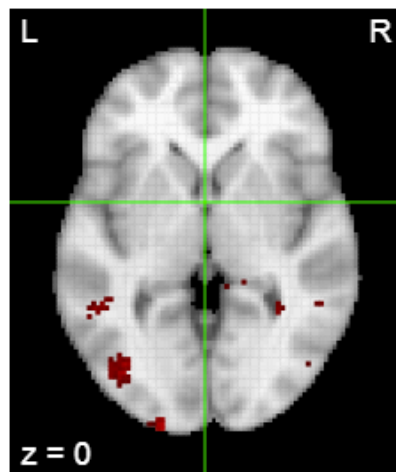
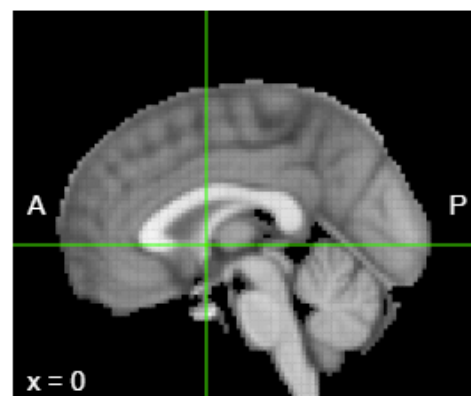
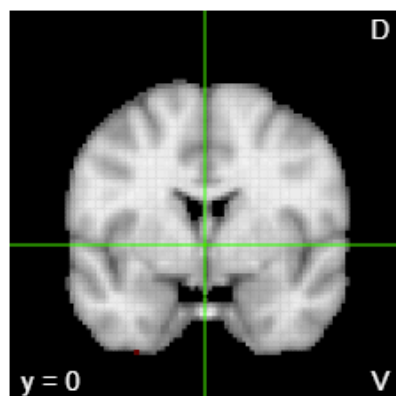
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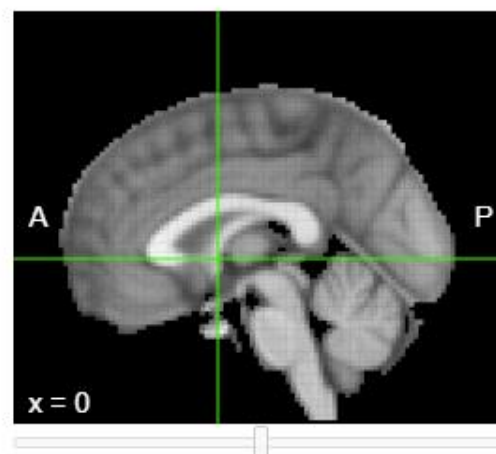
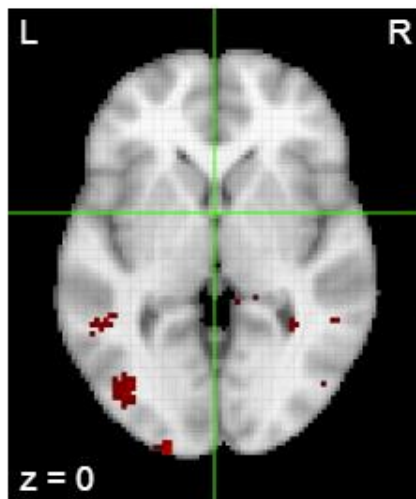
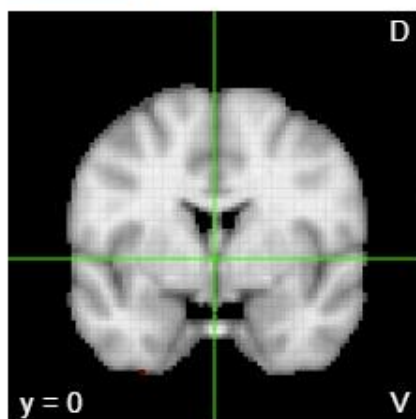
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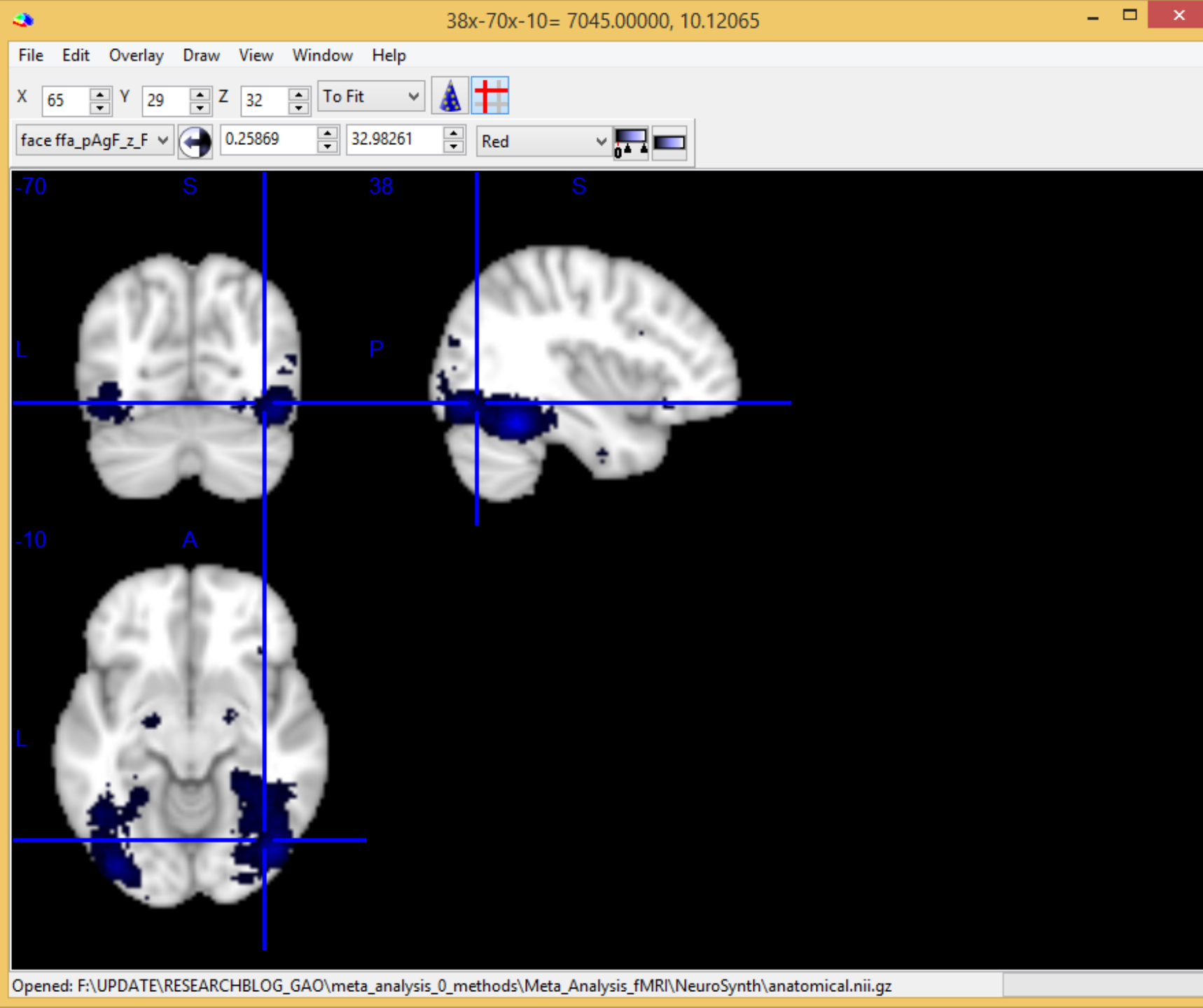
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