

*Supplemental materials for: High-level cognition is supported by information-rich but compressible brain activity patterns*

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Topic label	Cognitive label	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10
Cognitive control and task performance	Cognitive control	tasks	control	network	conditions	comparison	common	experiment	correlates	pre	
Developmental aging and maturation	-	age	adults	children	development	performed	childhood	adult	adolescence	target	
Eye movements and visual attention	Attention	eye	gaze	eyes	visual	aging	gait	target	direction	facial	
Facial and voice recognition	Sensory perception	recognition	context	familiar	unfamiliar	movements	fluent	voices	agency	partner	
Social interaction and contextual behavior	Social cognition	semantic	game	human	interaction	familiarity	interactions	naming	target	phonological	
Language processing and semantic knowledge	Language processing	semantic	words	word	lexical	contextual	time	target	time	times	
Experimental design and behavioral performance	-	trials	stimulus	responses	trial	language	time	event	cont.	rs	
Genetic polymorphisms and risk factors	-	carriers	allele	gene	genotype	genetic	time	val	val	execution	
Sensorimotor integration and movement control	Motor control	motor	movement	movements	sensorimotor	finger	imagery	sensory	sensory	heroin	
Drug addiction and substance abuse	-	cocaine	users	drug	ppi	cannabis	craving	dependent	dependent	singing	
Music perception and auditory processing	Sensory perception	music	musical	pitch	auditory	sequences	listening	luteal	luteal	folicular	
Musical cycle and hormonal regulation	-	phase	women	cycle	phases	hf	sex	key	key	follicular	
Cognitive functions and role playing	Cognitive control	role	play	humans	plays	expression	critical	distinct	distinct	female	
Inhibition and gender differences	-	inhibition	women	inhibitory	sex	evidence	males	stop	male	female	
Somatosensory stimulation and motor control	Motor control	stimulation	stimulus	inhibitory	genotype	genetic	males	male	transcranial	sensory	
Sensory perception and cognition	Sensory perception	auditory	sound	inhibitory	ppi	finger	primary	transcranial	primary	metabolic	
Social cognition	-	social	experience	inhibitory	auditory	cannabis	musicians	primary	attachment	abnormal	
Attention	-	target	targets	inhibitory	phases	sequences	menstrual	stimulus	distractor	abnormal	
Reward	-	design	blocks	inhibitory	plays	hf	cognitive	individuals	blocked	metabolic	
Alcohol cue reactivity	-	design	block	inhibitory	sex	evidence	gender	writing	metabolic	schizophrenic	
Neuroimaging and metabolism	-	pet	cue	inhibition	genotype	genetic	gender	exposure	metabolism	schizophrenic	
Abnormalities in schizophrenia	Schizophrenia	food	tonography	emission	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Eating and body weight	-	sleep	controls	emission	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Sleep and olfactory processing	-	sleep	taste	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Alzheimer's disease and cognitive impairment	Sensory perception	olfactory	body	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Working memory and executive function	-	ad	odor	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Moral decision making and phobias	Memory	memory	odor	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Language processing	-	memor	task	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Attention	Language laterality	language	phobia	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Resting-state brain activity in smokers	Attention	attention	asymmetry	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Social cognition/judgment	Social cognition	reho	asymmetry	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Reward and decision making	-	social	attentio	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
ADHD and attention deficits	Attention	reward	attentio	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Neurobiological variability and individual diff...	-	adhd	attention	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Spatial cognition	Spatial cognition	individual	attention	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Therapeutic interventions and deception	-	spatial	space	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Neurodegenerative diseases and disorders	Sensory perception	training	space	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Cognitive control and inference	Cognitive control	color	space	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Fear conditioning and extinction	-	disease	search	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
PTSD and trauma	Emotion	conflict	pd	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Color perception and deception	Memory	volume	pd	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Temporal dynamics of stimulus processing	-	gray	pd	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Tinnitus and hearing loss	Sensory perception	fear	gray	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Abstract categories and representations	Language processing	learning	gray	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Pain perception and sensory stimulation	-	learning	switching	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Body and primates	Skill learning and extinction	training	practice	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Neural oscillations and electrophysiology	-	frequency	trauma	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Temporal dynamics of stimulus processing	Language processing	time	source	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Tinnitus and hearing loss	-	time	alpha	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Major depression disorder and mood... Blindness and vision	Sensory perception	timits	duration	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Pain perception and sensory stimulation	-	category	hearing	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Deafness and sign language	Sensory perception	pain	representations	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Genetic risk and familial factors in psychosis	-	body	stimulation	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Action observation and imitation	Language processing	genetic	humans	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Autism Spectrum Disorder (ASD) and social impa...	Cognitive control	complexity	phonological	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Cognitive control and inference	Social cognition	autism	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Pain perception and sensory stimulation	-	ndd	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Rule-based performance and complexity	Language processing	ndd	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Pharmacological effects in reading and writing	-	ndd	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Mental disorders and controls	Cognitive control	ndd	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Personality and anxiety	-	ndd	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Mental illness and math abilities	Cognitive control	anxiety	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Memory	Memory	mental	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Language processing	-	priming	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Phenological processing in reading and writing	Language processing	priming	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Memory	-	priming	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Resting state networks	Memory	wm	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Sentience comprehension and syntax	-	sentences	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Episodic memory encoding and retrieval	Memory	network	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Visual object recognition and retrieval	-	memory	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Effective causal modeling of neural networks	Sensory perception	object	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Relational reasoning and fluid intelligence	-	object	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Affective valence and fluid intelligence	Memory	positive	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Autobiographical memory in epilepsy	-	negative	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	
Evidence and effect in behavioral studies	Memory	autobiographical	size	reduced	genotype	genetic	metabolism	metabolism	metabolic	schizophrenic	

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Stress and physiological responses	-	cortisol	autonomic	heart	responses	rate	regulation	physiological	induced		
Speech and language processing	Language processing	tds	language	perception	comprehension	acoustic	acoustic	linguistic	prosody		
Network interactions and evidence in human systems	-	evidence	systems	support	process	integration	integration	provide	engaged		
Neuroimaging techniques	-	images	time	void	test	distinct	test	clinical	mapping		
Visual perception of motion and form	Sensory perception	visual	perceptual	image	spatial	spatial	human	static	illusion		
Emotional processing and regulation	Emotion	emotion	facial	biological	dynamic	moving	negative	regulation	emotions		
				expressions	affective	responses					

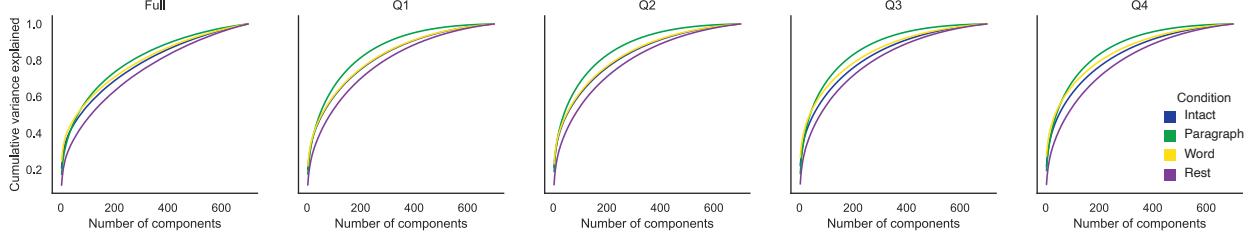
**Table S1: Neurosynth-derived topics.** We report the top-weighted terms for each of 80 topics identified using Latent Dirichlet Allocation (Blei et al., 2003) applied to 9,204 functional neuroimaging articles in the Neurosynth database (Rubin et al., 2017). See *Reverse inference* for additional information.

Cognitive label	Rank
Cognitive control	10
Language processing	9
Memory	8
Emotion	7
Social cognition	6
Spatial cognition	5
Attention	4
Reward	3
Sensory perception	2
Motor control	1
Resting state	0

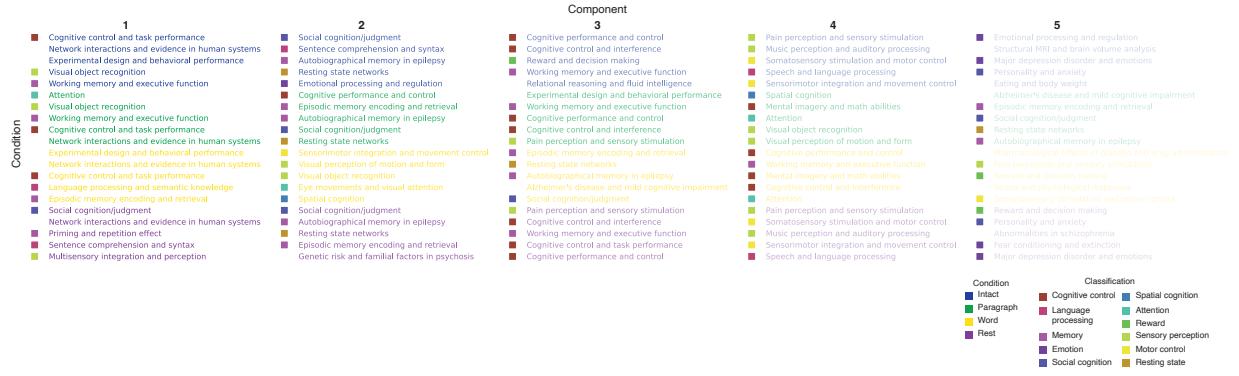
Table S2: **Ranking cognitive processes.** The table displays the output of a ChatGPT (OpenAI, 2023) prompt asking for a ranking of the cognitive processes reflected in the labels from Table S1. See *Ranking cognitive processes* for additional detail.

## Supplemental references

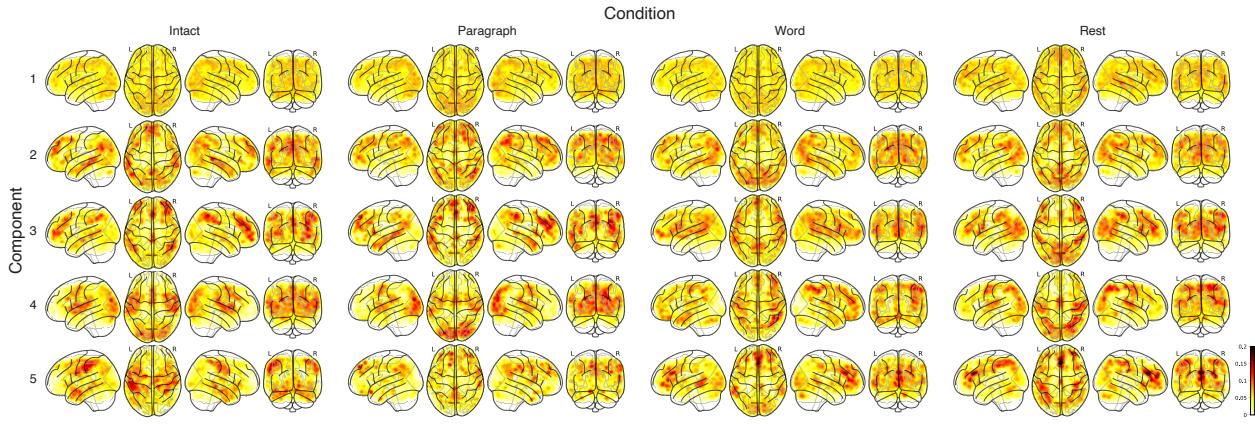
- Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *Journal of Machine Learning Research*, 3, 993–1022.
- OpenAI. (2023, March). *ChatGPT*. Personal communication.
- Rubin, T. N., Kyoejo, O., Gorgolewski, K. J., Jones, M. N., Poldrack, R. A., & Yarkoni, T. (2017). Decoding brain activity using a large-scale probabilistic functional-anatomical atlas of human cognition. *PLoS Computational Biology*, 13(10), e1005649.



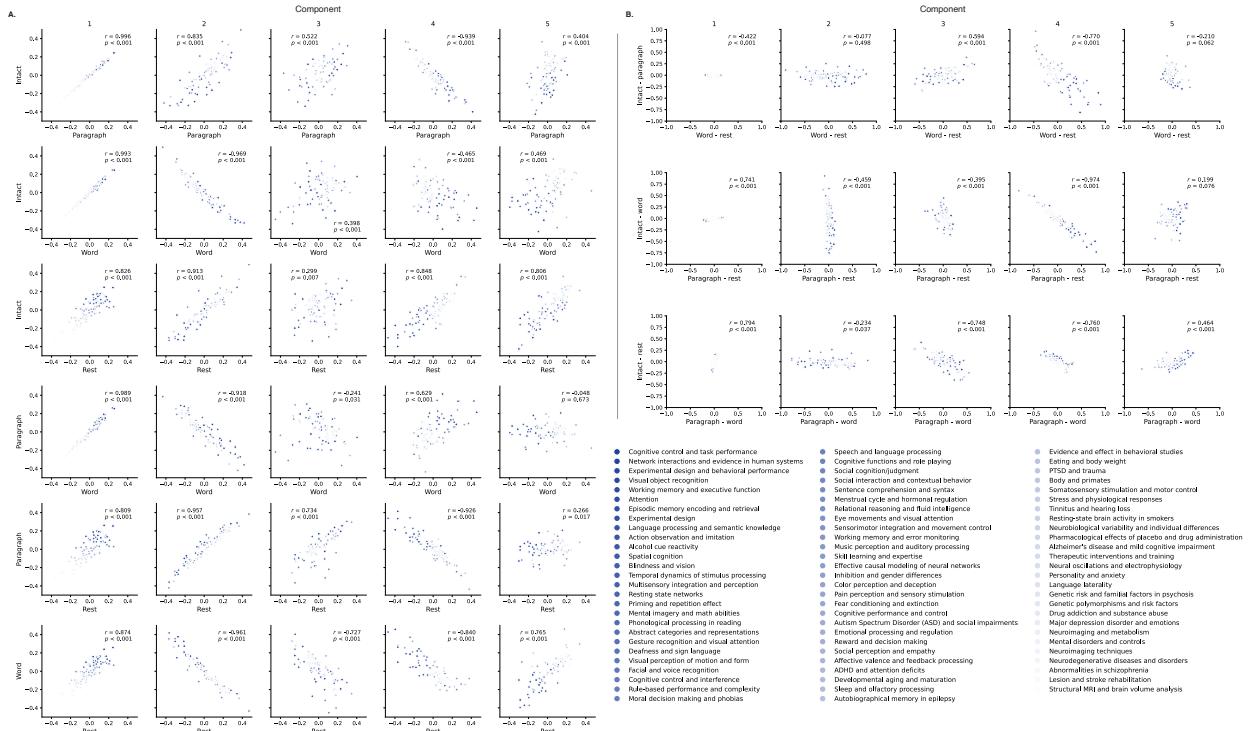
**Figure S1: Cumulative variance explained by component, condition, and part.** Each panel displays the cumulative variance explained in the neuroimaging data as a function of the number of principal components. Colors denote experimental conditions. The left panel displays results for all data, and the right panels display results separated by story segment (Q1: first quarter; Q2: second quarter; Q3: third quarter; Q4: fourth quarter).



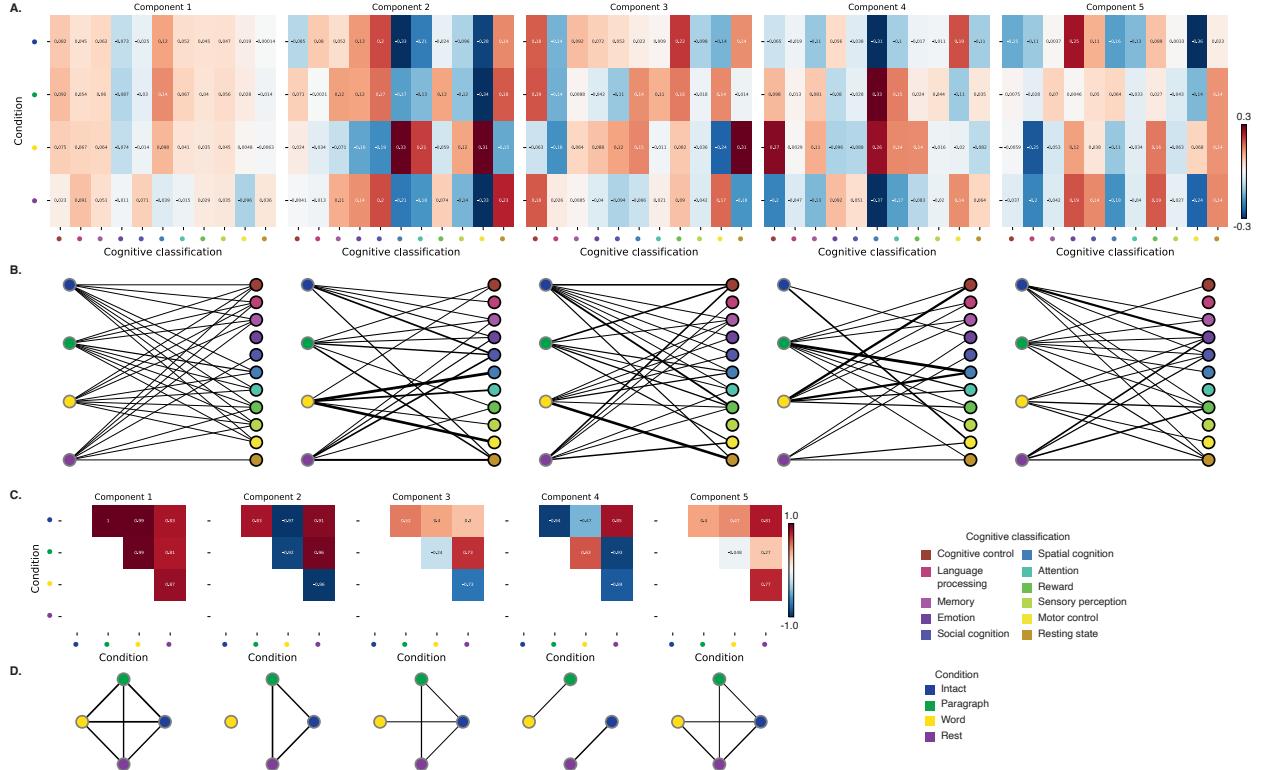
**Figure S2: Highest-weighted topics associated with the highest-weighted components by condition, broken down by story segment.** Each group of five rows corresponds to an experimental condition (denoted by color, as indicated in the legend in the lower right), and the columns and shading correspond to the component number (ranked by proportion of variance explained). The colored squares in front of many of the topics denote manually identified cognitive labels (Tab. S1).



**Figure S3: Brain maps by component and condition.** For the top five highest-weighted principal components (rows), from each experimental condition (columns), the components' brain maps are projected onto four views: left sagittal, axial, right sagittal, and coronal. The color scale is the same for all panels and matches the coloring in Figure 5C.



**Figure S4: Comparisons between per-component topic correlations across conditions.** Each sub-panel displays a scatterplot comparing the per-topic correlations for two or more experimental conditions. Each dot denotes the correlations for a single topic (indicated by the legend on the right). The topics are colored according to the ranked order of the correlations between the topic's brain maps and the brain map for the first principal component in the intact condition. **A. Comparisons between correlations for each pair of experimental conditions.** The conditions being compared are marked on the  $x$  and  $y$  axes. Each sub-panel (column) reflects the correlations for one principal component. **B. Comparisons between differences in correlations for pairs of experimental conditions.** In these sub-panels, the  $x$  and  $y$  coordinates reflect differences in correlations for the indicated experimental conditions, for the given component (column). All panels: the across-topic correlations reported in each panel are between each topic's  $x$  and  $y$  coordinates.



**Figure S5: Functions associated with top-weighted components by condition.** **A. Top-weighted topics by condition.** Here we display per-condition (rows, indicated by colored dots) topic correlations, averaged across topics that pertain to each of several broad cognitive functions (columns within each sub-panel, indicated by colored dots). Each sub-panel reflects correlations for the components indicated in the panel titles. A legend for the condition and cognitive function classifications is displayed in the lower right of the figure. Table S1 provides a list of each topic's top-weighted terms, along with each topic's manually labeled cognitive classification. A full list of the topics most highly associated with each component may be found in Figure S2. **B. Associations between per-condition components and cognitive functions.** The network plots denote positive average correlations between the component images for each condition (gray-outlined dots on the left sides of each network; colors denote conditions) and topic-specific brain maps associated with each indicated cognitive function (black-outlined dots on the right sides of each network; colors denote cognitive functions). The line thicknesses are proportional to the correlation values (correlation coefficients are noted in the heat maps in Panel A). **C. Correlations between each principal component, by condition.** The heat maps display the correlations between the brain maps (Fig. S3) for each principal component (sub-panel), across each pair of conditions (rows and columns of each sub-panel's matrix, indicated by colored dots). **D. Associations between per-condition topic weights, by component.** Each sub-panel's network plot summarizes the pattern of correlations between the topic correlations from each of the  $n^{\text{th}}$  top-weighted principal components (sub-panel), for each experimental condition (gray-outlined dots). The line thicknesses are proportional to the correlation values (correlation coefficients are noted in the heat maps in Panel C).