Artifact concepts are more reliably represented than animal concepts across the cortex

Stephen Mazurchuk, Lisa L. Conant, Jeffrey R. Binder, Leonardo Fernandino
Departments of Neurology and Biophysics, Medical College of Wisconsin, Milwaukee WI

MEDICAL COLLEGE OF WISCONSIN knowledge changing life

MCW GRADUATE SCHOOL

BACKGROUND

- Brain damage can impair the ability to retrieve general knowledge about items belonging to a particular category with relatively preserved knowledge for other categories.
  - Known as category-specific semantic deficit
- The most common dissociation is between **animals** and **artifacts.**
- Selective impairment for animal concepts is more common than for artifacts[1].
- The reason for this differential frequency of impairment remains unknown.

HYPOTHESIS

We propose that, relative to animal concepts, artifact concepts are represented in the healthy brain in terms of a more diverse set of features and distributed across more cortical areas. We therefore hypothesized that fMRI activity patterns corresponding to individual artifact concepts are more discriminable from one another then those corresponding to individual animal concepts.

Item discriminability was operationalized as the reliability of neural RDMs. We examined this in:

- The general semantic network
- 3 cortical areas previously implicated in object representation (PH, PHT, PGi)
- A control region (V1)

We investigated whether reliability differences were related to semantic content by performing model-based RSA.

METHODS

- fMRI of 11 healthy adults
- Task: concept familiarity judgment
- Stimuli: 300 written nouns (150 animals, 150 artifacts) matched for 11 lexical variables.
- Word-specific activation maps were generated via GLMs.
- Pattern discriminability was quantified as the reliability (i.e., intraclass correlation) of the neural representational dissimilarity matrix (RDM).
- Representational similarity analysis (RSA) was performed using GloVe[2].
- Searchlight analysis used 10mm radius circles defined on the HCP cortical surface.

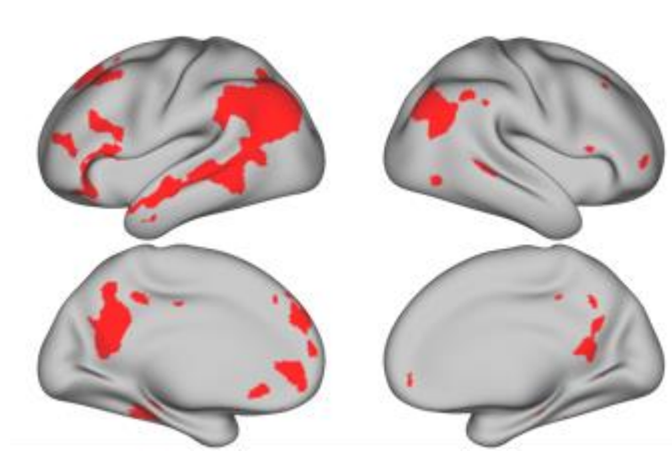
Word Stimuli

Animal						Artifact					
alligator	chipmunk	gazelle	kingfisher	panther	snail	accordion	bucket	fiddle	limousine	sailboat	streetcar
anaconda	cicada	gibbon	koala	parrot	snake	ambulance	bugle	flashlight	locomotive	sandal	submarine
ant	cobra	giraffe	ladybug	peacock	sparrow	apron	bus	flute	mallet	sandpaper	subway
anteater	cockroach	gnat	leech	pelican	spider	armchair	cab	footstool	mandolin	saxophone	suit
armadillo	cow	goat	lemur	pheasant	squid	armoire	cabinet	funnel	mask	scarf	sweater
baboon	coyote	goldfish	leopard	pig	squirrel	automobile	camera	glider	mattress	scissors	taxi
bear	crab	goose	lion	pigeon	starfish	axe	canoe	glove	mitten	scooter	teacup
beaver	cricket	gorilla	lizard	porcupine	starling	bagpipe	carafe	gong	mop	screwdriver	teaspoon
bedbug	crocodile	grasshopper	llama	python	stork	banjo	carriage	grater	motorcycle	sectional	tongs
bee	crow	groundhog	locust	quail	tarantula	barge	cello	guitar	necklace	shawl	tractor
beetle	deer	grouse	manatee	rabbit	termite	bathrobe	chime	hacksaw	nightgown	shelves	tricycle
boa	dog	hamster	mantis	rat	tick	bed	chisel	hairbrush	ottoman	sifter	trolley
bobcat	dolphin	hawk	marlin	rattlesnake	tiger	belt	clarinet	hammer	pajamas	skateboard	trombone
butterfly	dove	hedgehog	millipede	raven	toad	bench	closet	hamper	peeler	skillet	trowel
camel	dragonfly	heron	monkey	rhinoceros	toucan	bib	comb	handsaw	pencil	skirt	trumpet
cardinal	duck	hippopotamus	moose	robin	turtle	bicycle	convertible	hanger	pew	sled	tuba
carp	earthworm	hornet	mosquito	salamander	viper	bikini	corkscrew	harmonica	piano	sleigh	umbrella
cat	elk	horse	moth	scorpion	vulture	blender	cot	harp	platter	sneaker	van
caterpillar	falcon	horsefly	mouse	seagull	walrus	bobsled	counter	helicopter	pliers	sofa	violin
catfish	ferret	hummingbird	newt	seahorse	warthog	bookcase	crib	hose	poncho	spade	wagon
centipede	finch	hyena	opossum	seal	wasp	booth	cupboard	jeep	rake	spatula	wardrobe
chameleon	firefly	iguana	osprey	shark	weasel	bottle	dresser	kettle	rocker	spoon	wastebasket
cheetah	flamingo	jackal	ostrich	sheep	whale	bowl	drill	knife	rocket	stapler	whisk
chicken	flea	jellyfish	owl	skunk	woodpecker	bracelet	drum	ladder	rowboat	strainer	wrench
chimpanzee	frog	kangaroo	panda	slug	wren	broom	ferry	ladle	ruler	straw	xylophone

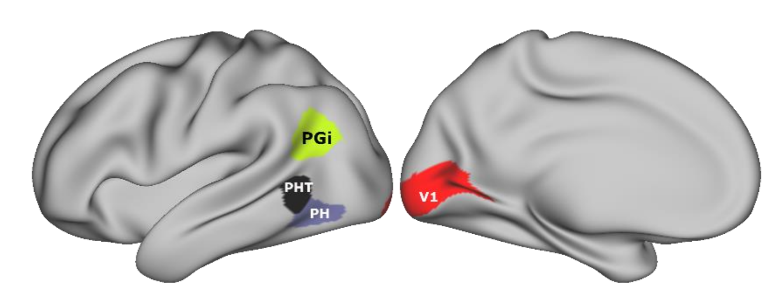
Matched Lexical Variables

Description	pValue
Log10 frequency Hyperspace Analogue to Language	0.997
Subjective familiarity (Glasgow norms)	0.092
Rated age of acquisition (Glasgow norms)	0.204
Number of letters	0.791
Average constrained unigram frequency	0.633
Average constrained bigram frequency	0.835
Average constrained trigram frequency	0.094
Orthographic neighborhood (Levenshtein distance)	0.109
Number of syllables	0.339
Rated concreteness (Glasgow Norms)	0.116
Semantic diversity	0.543

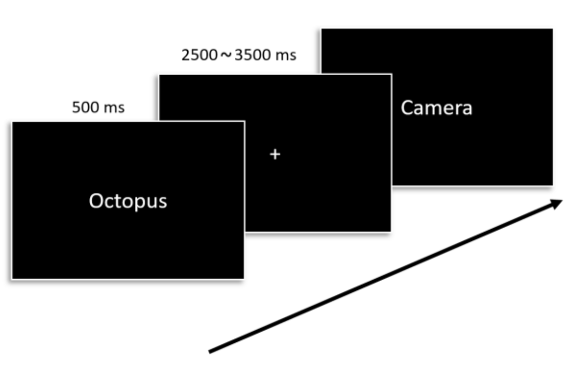
General Semantic Network[3]



Select Glasser Parcels

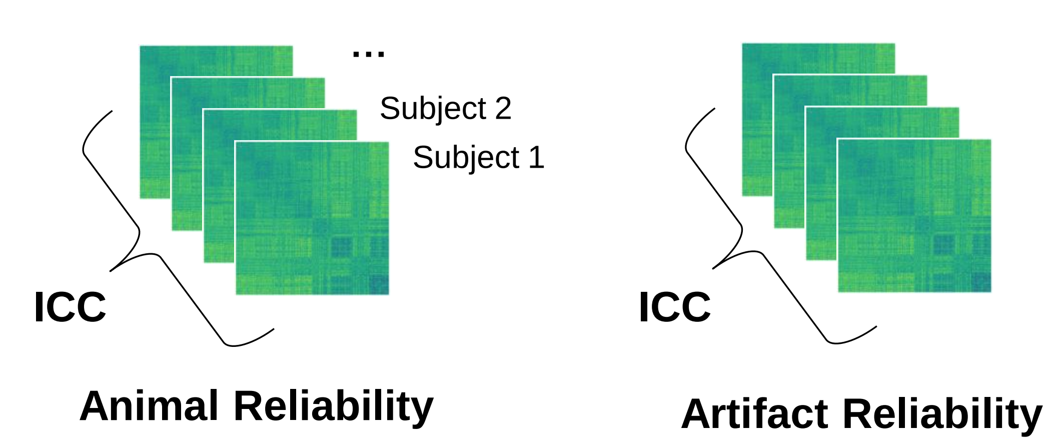


Task



Task: How much have you experienced each thing?
Response: 1 → rarely; 2 → sometimes; 3 → often

Neural RDMs



RESULTS

General Semantic Network

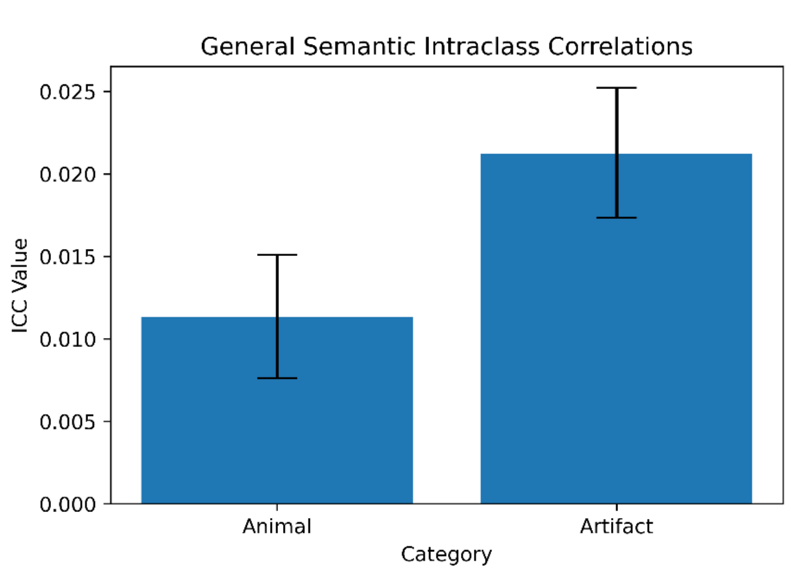


Fig 1. Intraclass correlation of neural RDMs. Error bars represent 95% confidence interval.

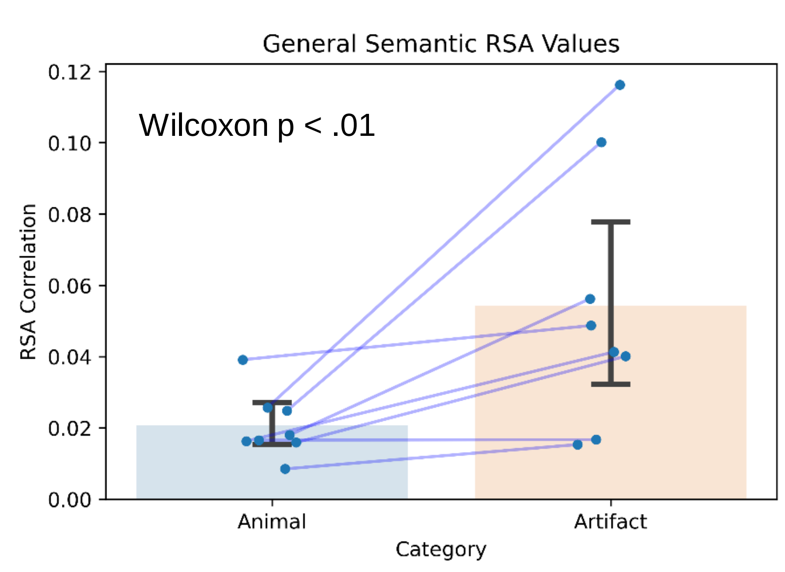


Fig 2. RSA values with GloVe vectors. Error bars show 95% confidence interval derived from 1,000 bootstraps.

Searchlight ICC

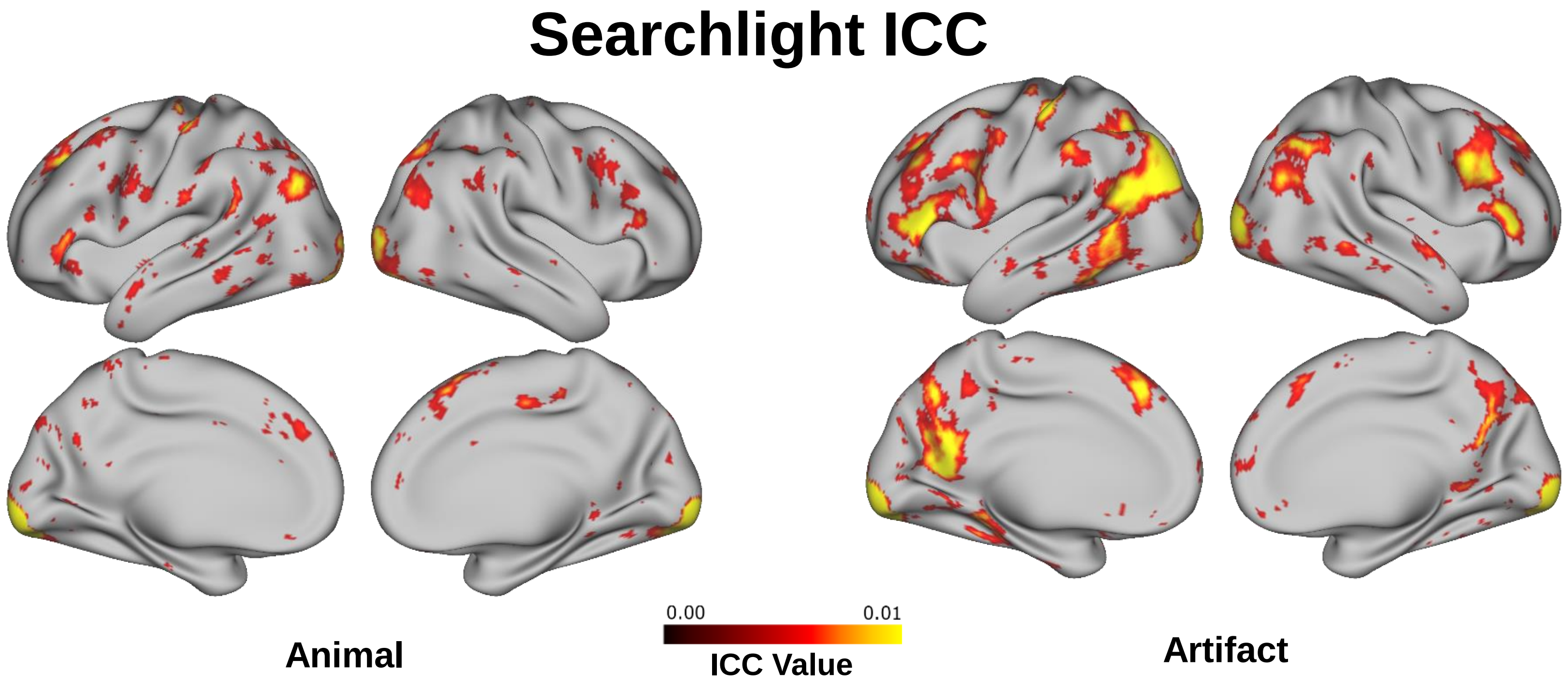


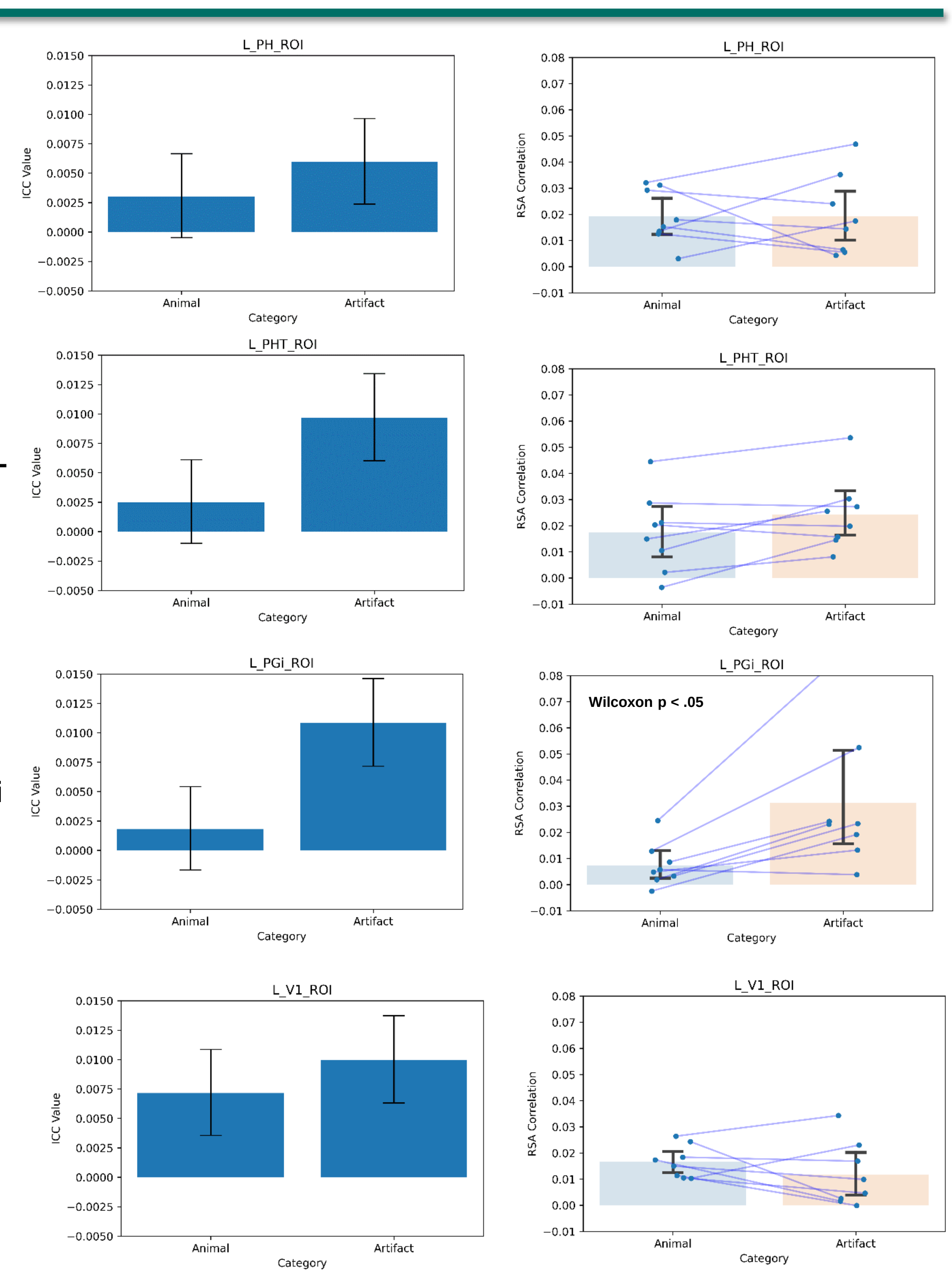
Fig 3. Searchlight (10 mm radius) intraclass correlation analysis. Neural RDMs were derived using only one category of concepts. Searchlight maps were thresholded at a significance level of uncorrected p < .01. Overall reliability was higher for artifact concepts throughout the association cortex.

Glasser L_PH

Glasser L_PHT

Glasser L_PGi

Glasser L_V1



CONCLUSION

- Relative to animal concepts, artifact concepts have a more reliable representational geometry across much of the cortex.
  - This difference in reliability was not significant in non-semantic regions (e.g., V1)
- This finding lends support to the hypothesis that, relative to animal concepts, artifact concepts rely on a wider variety of semantic features and cortical areas.

Future Directions

- Determine the differences in relevant semantic content between the two categories using experiential models[4].

REFERENCES

[1]Capitani, E., Laiacona, M., Mahon, B. & Caramazza, A. What are the Facts of Semantic Category-Specific Deficits? A Critical Review of the Clinical Evidence. Cognitive Neuropsych 20, 213–261 (2003).

[3]Pennington, J., Socher, R. & Manning, C. Glove: Global Vectors for Word Representation. Proc. 2014 Conf. Empir. Methods Nat. Lang. Process. (EMNLP) 1532–1543 doi:10.3115/v1/d14-1162.

[3]Binder, J. R., Desai, R. H., Graves, W. W. & Conant, L. L. Where Is the Semantic System? A Critical Review and Meta-Analysis of 120 Functional Neuroimaging Studies. Cereb Cortex 19, 2767–2796 (2009).

[4]Binder, J. R. *et al.* Toward a brain-based componential semantic representation. *Cognitive Neuropsych* **33**, 1–45 (2016).

STEPHEN MAZURCHUK | smazurchuk@mcw.edu | smazurchuk.com