

Lecture 18: Language I

Outline for Today & Wednesday:

O. Review of Representational Similarity Analysis (RSA)

a general case of MVPA

I. Introduction: What is language?

What do we want to understand?

II. Is language distinct from the rest of thought?

Evidence from neurological patients

Evidence from fMRI

III. Is there a functional organization within the language system?

Evidence from neurological patients

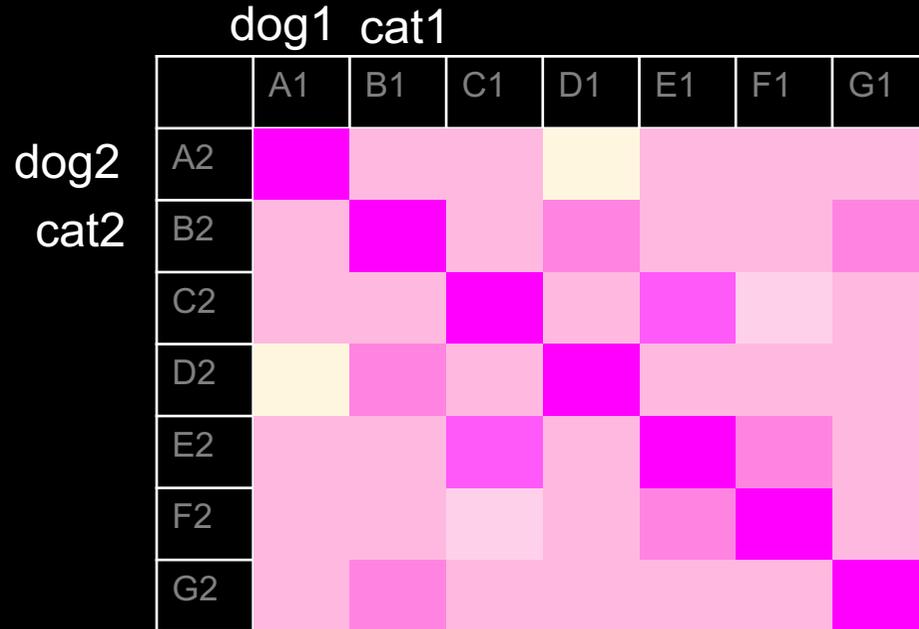
Evidence from fMRI

IV. How is meaning represented in the brain?

linguistic? amodal?

MVPA: Binary Discriminations vs RSA: Characterizing Representational Spaces

MVPA Correlation Method $r(\text{within}) > r(\text{between})$



MVPA: Can this ROI discriminate btwn class A (e.g. dog) vs class B (e.g. cat)?
worth knowing, but binary so somewhat impoverished/arbitrary
richer if you test generalization/invariance (e.g. across position, size, etc)

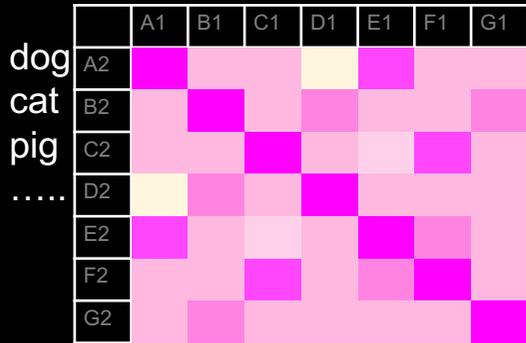
RSA: the *pattern of correlations across multiple conditions*.

You don't have to chose an arbitrary binary classification
a richer, more general characterization of representational spaces

*can compare this RSA matrix to an RSA matrix based on
a totally different kind of data (w/ same row and column labels).....*

Relating Different RSA Matrices to Each Other

Behavior

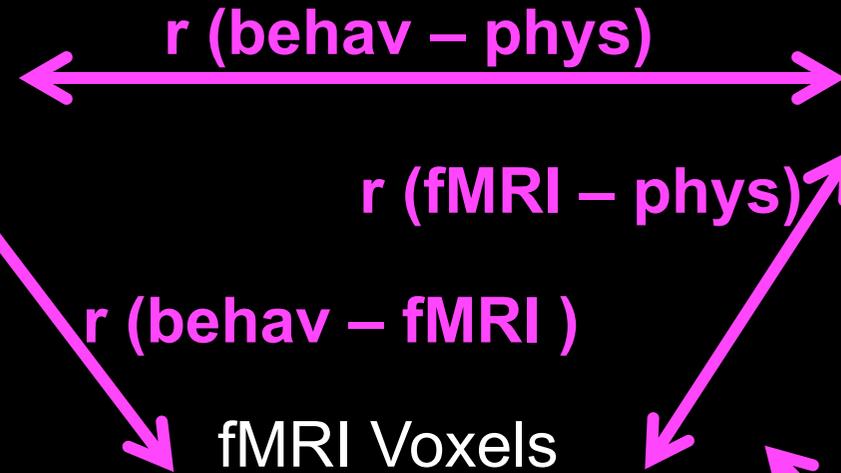


e.g. similarity ratings from ten subjs

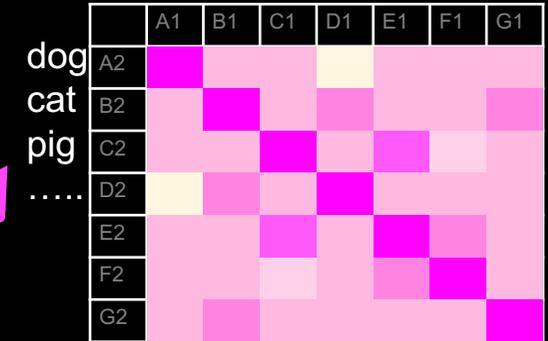
Or: e.g., diff ROIs



Now correlate these matrices!

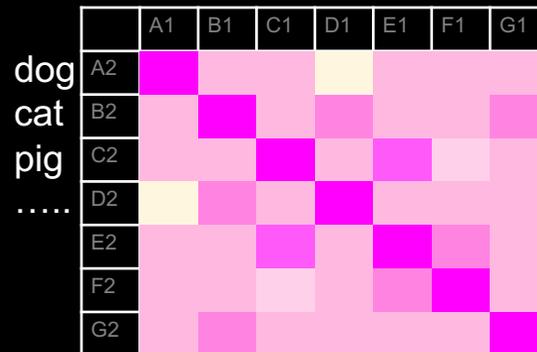


Neurophysiological similarity



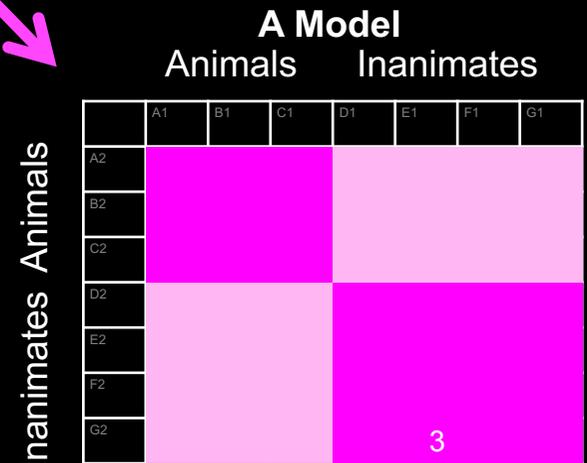
e.g. from responses of 100 neurons

fMRI Voxels



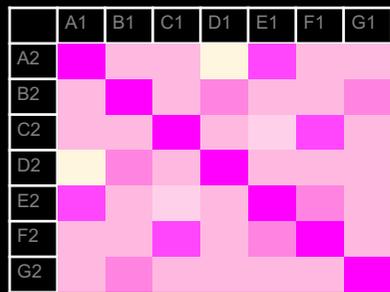
e.g. MVPA correlation across 1,000 voxels

One of W&C analyses:

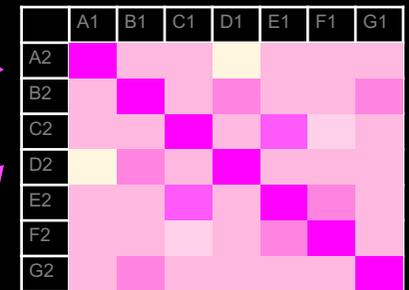


Why this is so totally cool

1. It enables us to compare representational spaces across ROIs, or across subject groups (no spatial registration required!) across species & methods: 200 neurons (monkeys) to 1000 voxels (humans) and hypothesized models of what the representation might be
2. It probes representations in a more comprehensive way. not just one or 2 discriminations (MVPA), but lots (RSA)
3. Key requirement: need same stimuli across data sets.

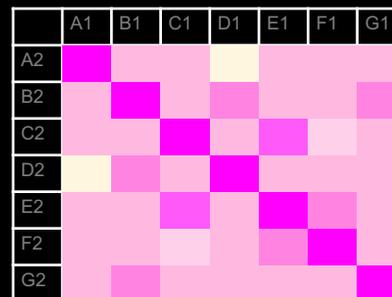


Behavior

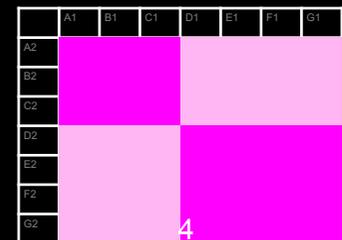


Ephys - neurons

fMRI Voxels



A Model
Animals Inanimates



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IV. How is meaning represented in the brain?

linguistic? amodal?

Language

- **Universally human**
about 7,000 languages
all richly expressive (including sign languages)
- **Uniquely human**
yes, chimps and parrots can accomplish impressive feats
Chaser the border collie.....

As you watch, be thinking:

***What is the difference between
your language ability and Chaser's?***

Chaser, 6 year old Border Collie

ABC News interview with Neil Degrasse Tyson about Chaser, the Border Collie:

[The Dog Who Knows 1,000 Words.](#) *YouTube.* Feb 9, 2011.

https://www.youtube.com/watch?v=_6479QAJuz8

Language

- **Universally human**
- **Uniquely human**
 - yes, chimps and parrots can accomplish impressive feats**
 - Chaser is a very good girl, who knows lots of nouns but she cannot understand who did what to who or why**
 - animals communicate about narrow restricted domains**
 - in contrast,**
- **Human languages are open-ended and *compositional***
 - we combine words to say new things**
 - that have never been said before**

So, What is a language cognitively?

That is, What must you know to know a language?

What is Language?

What you know when you know a language:

- **Phonology** - the sounds of language
“ba” vs “pa” (or equivalent in ASL)
(“speech region” responds to speech indep of meaning)
- **Semantics** - the meanings of words and word combinations
- **Syntax** - the structure/grammar of language, i.e.,
the set of rules concerning the structure of sentences in
a given language, usually including word order,
and how they determine meaning e.g.:
“Shark bites man.” vs. “Man bites shark.”
- **Pragmatics** - the use of language.
“It would be awesome if you would pass the salt.” >>
“Please pass the salt.”

For the next two class, we'll focus on sentence understanding.

What do we want to know?

Questions:

1. Is language distinct from the rest of thought?



Put another way:

what is the relationship between language and thought?

could you think without language?

discuss with your neighbors for a few minutes...

2. Does the language system itself have distinct components that do different things?

(and if so what is represented and computed in each?)

3. How is meaning represented in the brain?

Questions:

1. Is language distinct from the rest of thought?

Put another way:

what is the relationship between language and thought?

could you think without language?

discuss with your neighbors for a few minutes...

Some kinds of thinking can clearly go on without language

animals (e.g. numerosity)

infants (numerosity and lots of other things (take 9.85!)).

or in ppl whose language does not have the relevant words

for example...

The Piraha



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a hunter-gatherer tribe in the Amazonian rainforest
just a few 100 people
their language unrelated to any other
their language has no number words
So, do they have approximate magnitude?

Smart undergrads make similar mistakes if they are presented from counting



Screenshot of orthogonal organization counting video (see lecture video) © Edward Gibson/Gibson Lab. All rights reserved. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>.

Questions:

1. Is language distinct from the rest of thought?

Could you think without language?

Approximate number without language:

animals

infants

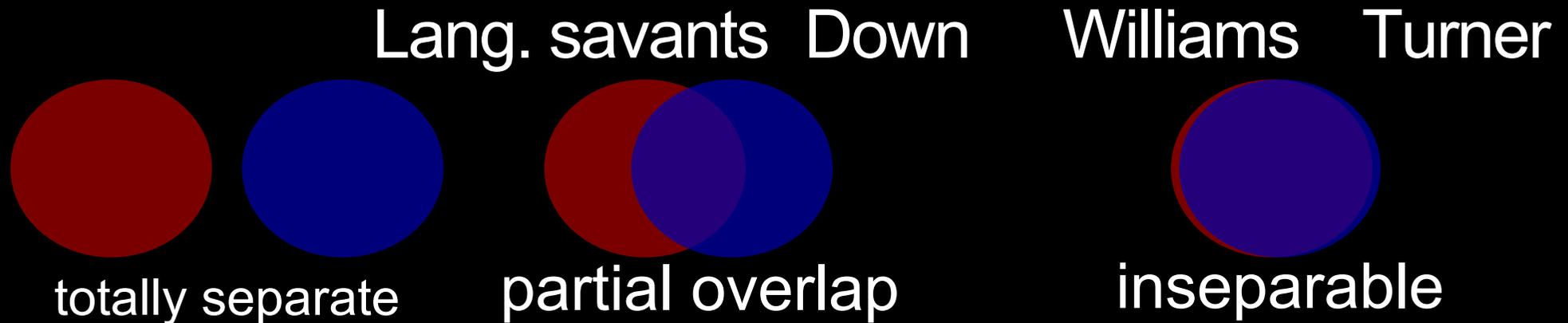
people with no number words

What about other aspects of thought?

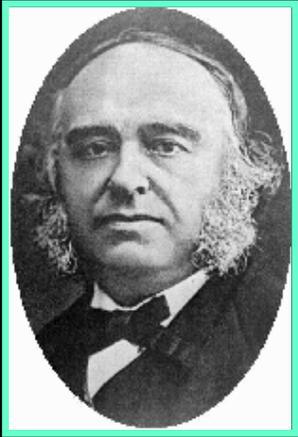
What can we learn from studying brain disorders?

Language and Cognition

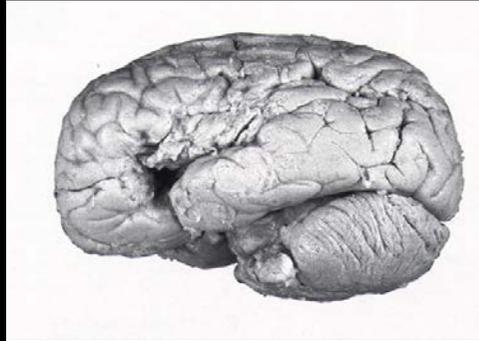
- Evidence from brain disorders:
~Intact **Language** despite impaired **Cognition** in devel. disorders:
In brain damage:
Language was 1st mental function localized in the brain...



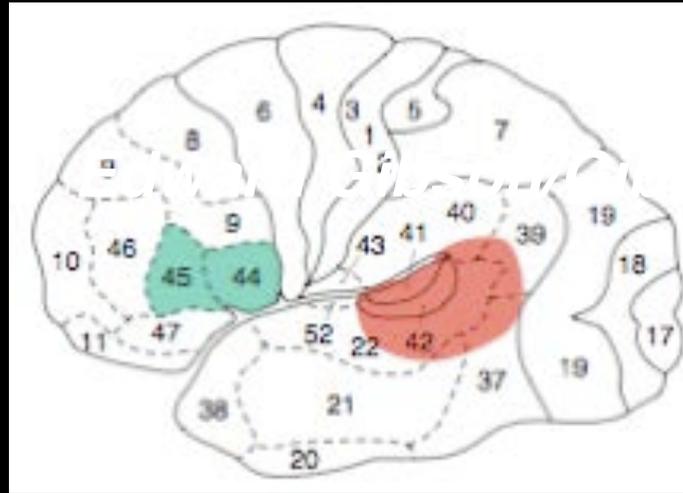
Broca's Radical Proposal in 1861



Pierre Paul Broca
(1824-1880)



Tan



Broca's Area

Back when mainstream thinkers did not believe in localization of function in the brain, Broca noted that Tan's cognition was preserved, hence speech and thought go on in different parts of the brain.

Photo of Broca is in the public domain. Brain images © sources unknown. All rights reserved.
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Broca (1861): **Left Frontal Lobe** is the seat of speech

What would it be like to have intact thought despite impaired language?

Language and Cognition

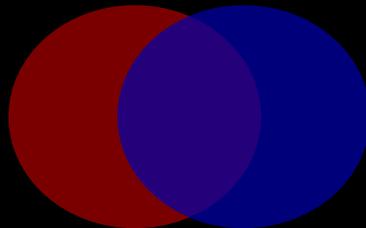
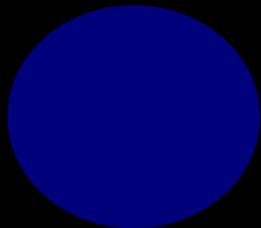
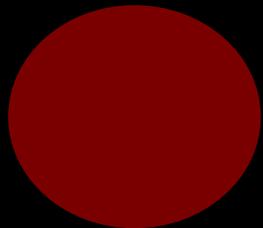
- Evidence from brain disorders:
~Intact **Language** despite impaired **Cognition**
Intact **Cognition** despite impaired **Language**:



Tom Lubbock,
chief art critic of *The
Independent*
(1957 - 2011)

"My language to describe things in the world is very small, limited. My thoughts when I look at the world are vast, limitless and normal, same as they ever were. My experience of the world is not made less by lack of language but is essentially unchanged."

(from Tom Lubbock: A memoir of living with a brain tumor)



totally separate

partial overlap

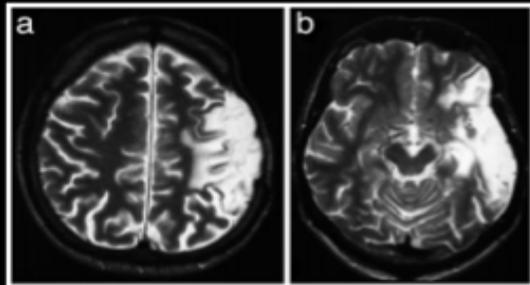
inseparable

But some language remains. What about total loss of language?

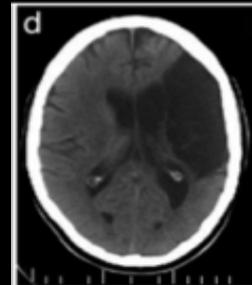
Language and Cognition

- Evidence from brain disorders:
 - ~Intact **Language** despite impaired **Cognition**
 - Intact **Cognition** despite impaired **Language**:
 - Intact **Cognition** despite *no Language*?

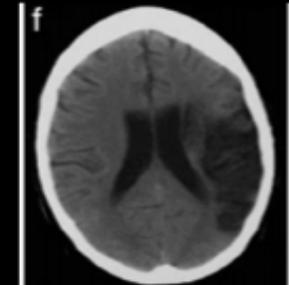
Global
Aphasia:



S.A.



S.O.



P.R.

Test	Chance score	S.A.	S.O.	P.R.
PALPA 54 spoken picture naming	—	0/60	0/60	1/60
PALPA 54 written picture naming	—	24/60	0/60	2/60
Comprehension of spoken reversible sentences	50	49/100	32/100	38/100
Comprehension of written reversible sentences	50	42/100	43/100	49/100
Written grammaticality judgments	20	26/40	35/40*	21/40

Figures © Taylor & Francis. All rights reserved. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>.
Source: R Varley, M Siegel & SC Want. *Neurocase*, 7:6, 489-493, <https://doi.org/10.1093/neucas/7.6.489>

Can these people think?

Varley *et al.* (2000), *Curr. Bio.*

Language and Cognition

- Evidence from brain disorders:
~Intact **Language** despite impaired **Cognition**
Intact **Cognition** despite impaired **Language**:
Intact **Cognition** despite *no Language*?

Global

Cause and Effect?

Perfect Score.

Aphasia:



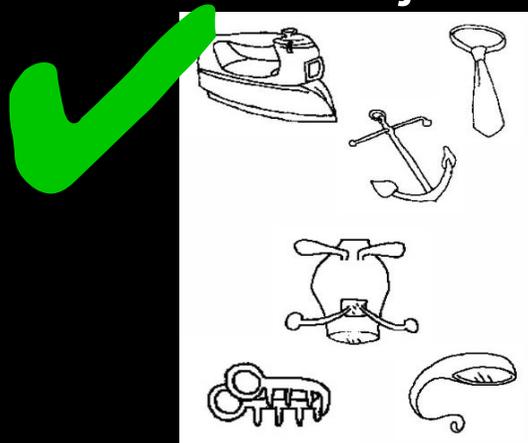
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Language and Cognition

- Evidence from brain disorders:
~Intact **Language** despite impaired **Cognition**
Intact **Cognition** despite impaired **Language**:
Intact Cognition despite *no Language*?

Global Cause and Effect? Perfect Score.
Aphasia: Nonverbal Meaning? Intact.

Real object?

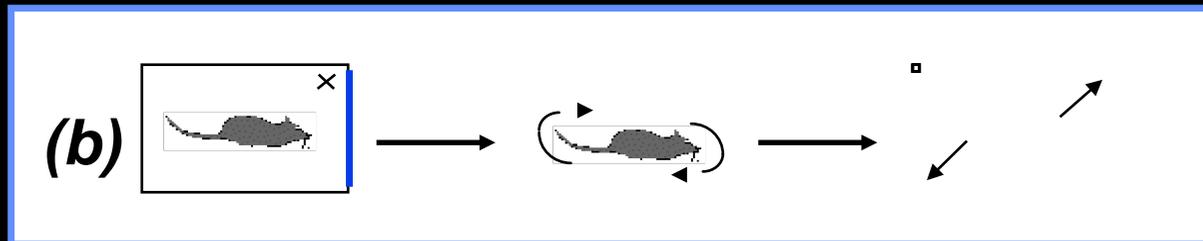


Plausible event?



These people have all cognitive abilities tested so far!...

Global aphasics can do every complex task tested so far:
causality,
nonverbal meaning,
reorientation,
arithmetic,
logic,
algebra,
music,
understanding other minds



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Source: Chang & Gallistel, Ch. 23 Animal Cognition. Erlbaum/Psychology Press, 1984/2014.

Suggests Language and thought are not the same thing!
You can still think after you lose most of language.

On the other hand:

a) Global aphasics *had language during development*
language is a key way we *learn about the world.*

e.g., deaf kids exposed to language later in life are not as good at understanding other people's thoughts

b) Even if not necessary, language can *influence* thought,
by making some information more salient....

Close your eyes and point south



If your language forced you to keep track,
you would be better at this,
as these people are.....

Pompuraaw

“Which way are you going?”

“North northwest in the middle distance, how about you?”

Pompuraaw

Don't talk about "left" or "right" or "behind"

But rather:

"You have a bug on your southeast leg"

People who speak this language have to be aware of compass headings all the time, just to speak.

In that sense, their language *influences* their thought.

But let's get back to whether language and thought are distinct...

Interrim summary:

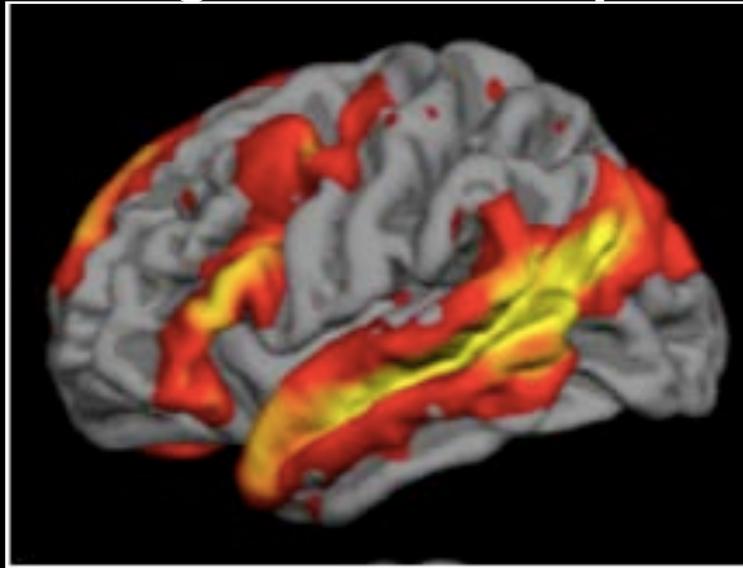
Question: Is thought separate from, and possible without, language?

Patient literature: **yes!**

Global aphasics have many forms of thought without language

What then would you predict from fMRI?

If these are the brain regions that respond during language tasks:



Brain scan © source unknown. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>.

Should they be activated only by language, not nonlinguistic tasks?

Well, here is the surprise....

Interrim summary:

Question: Is thought separate from, and possible without, language?

Patient literature: **yes!**

Most brain imaging studies show **overlap** btwn language and.....

Mental arithmetic:

“arithmetic ...recruits networks involved in word-association processes” Dehaene et al, 1999

Music:

“regions such as Broca’s and Wernicke’s, which have been considered ...specific to language ..[are]...also activated by certain aspects of music. Thus, the idea of [language] specificity...has been called into question.” Schon et al, 2010

Cognitive Control:

“...[Broca’s area has] a rather general role in complex cognition...when there is a need to resolve among competing representations” (Novick et al., 2010)

Lots of Stuff: *“...although language recruits specific neural areas with potentially different functional properties, these areas are not domain specific”* (Blumstein & Amso, 2013)

How to resolve this contradiction?

A methodological flaw with almost all of this prior work.....

Group Analyses can Overestimate Overlap

Hypothetical Situation:

Group Analysis

Language

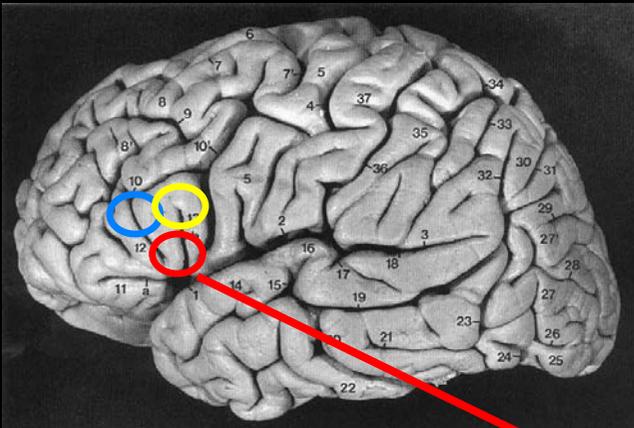
Arithmetic

Music

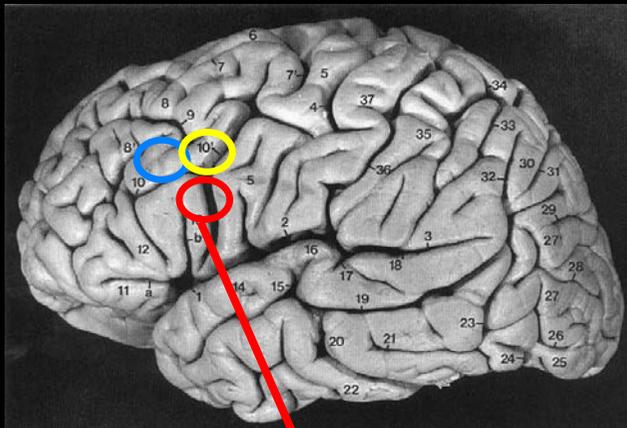
Problem: Group analyses blur data because each brain is different.

These group data could come from a situation like this:

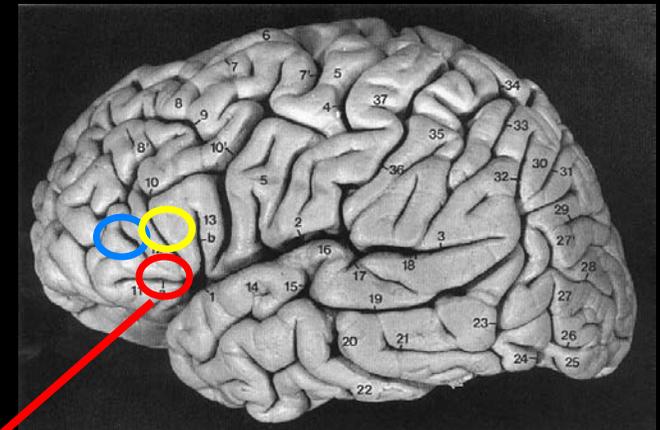
Subject 1



Subject 2



Subject 3



Group analyses:
Align brains as best
you can, then
average across
subjects.

Solution: Identify language regions in each subject, test response to non-language

standard for visual fMRI
less so for cognitive fMRI

Arithmetic??
Music??

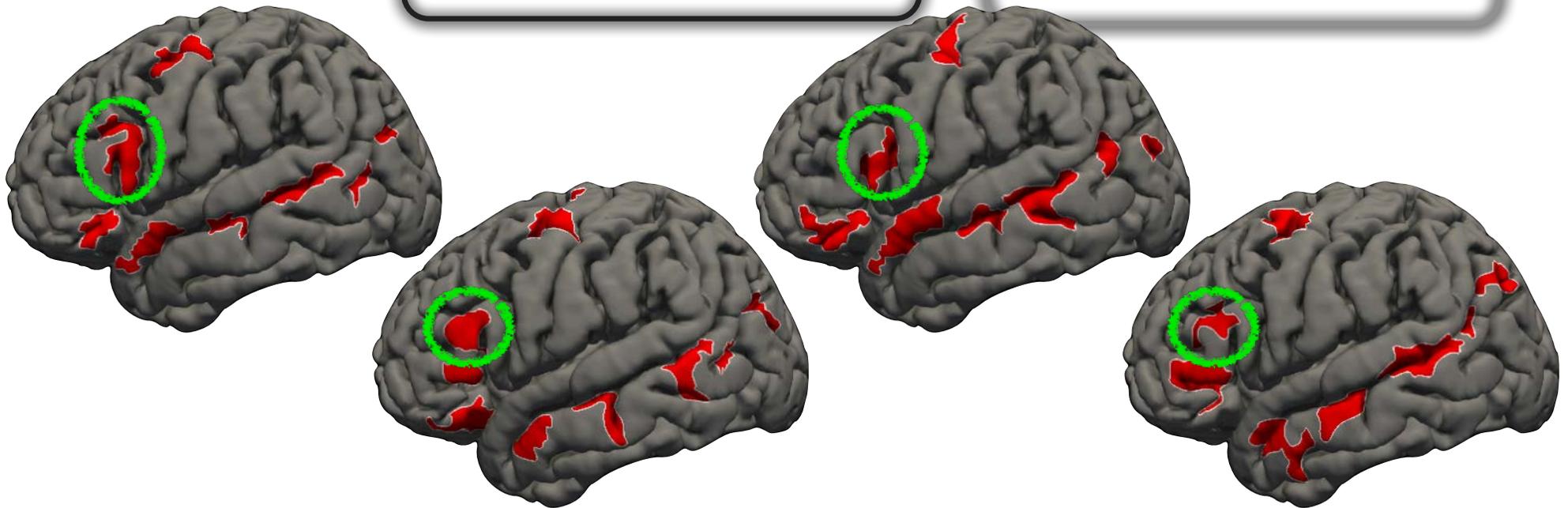
How do we identify language
regions in each S?

Functional Localization

- Let's find candidate brain regions that respond to language:
Contrast two conditions: **sentences** vs. **non-words**

CHANGED

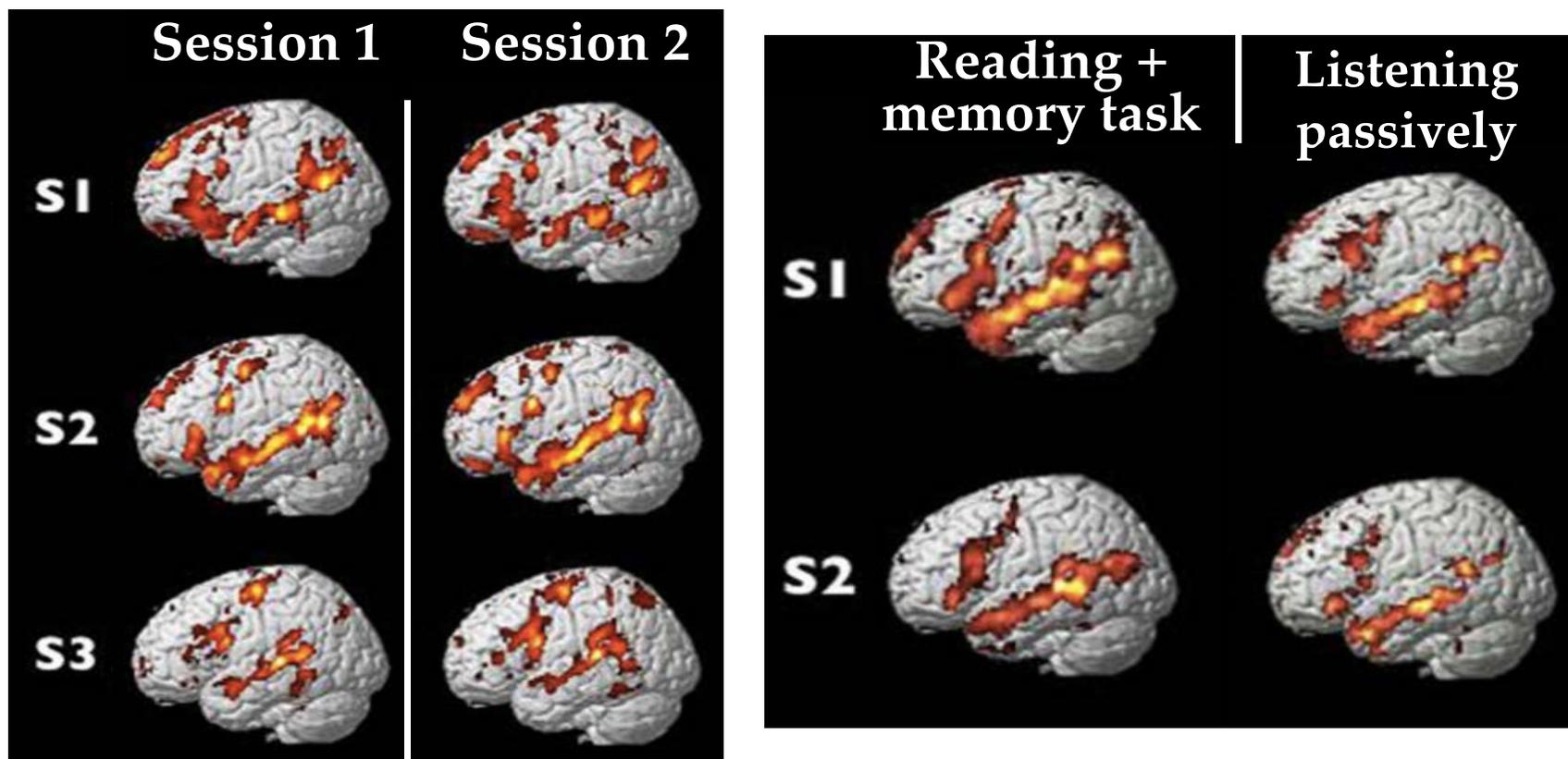
RIKINAEPOE



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Functional Localization

- Now we validate the hell out of the localizer task
- Is it reliable?
- Does it generalize across task and presentation modality??

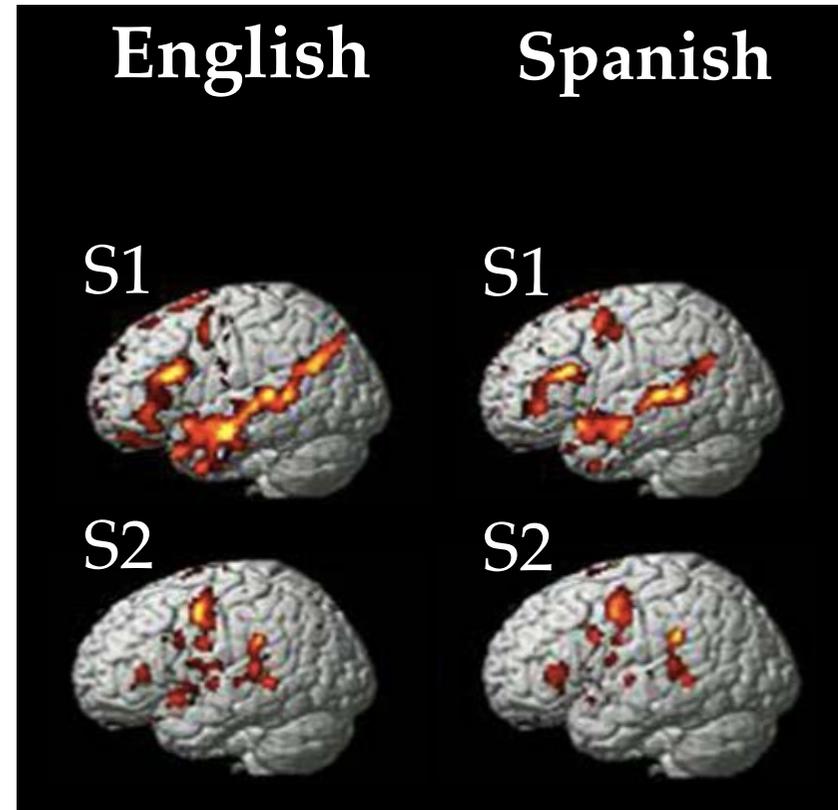


Functional localization brain figures © Frontiers Media S.A. All rights reserved. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>. Source: E Fedorenko 28 April 2014 | <https://doi.org/10.3389/fpsyg.2014.00335>

Functional Localization

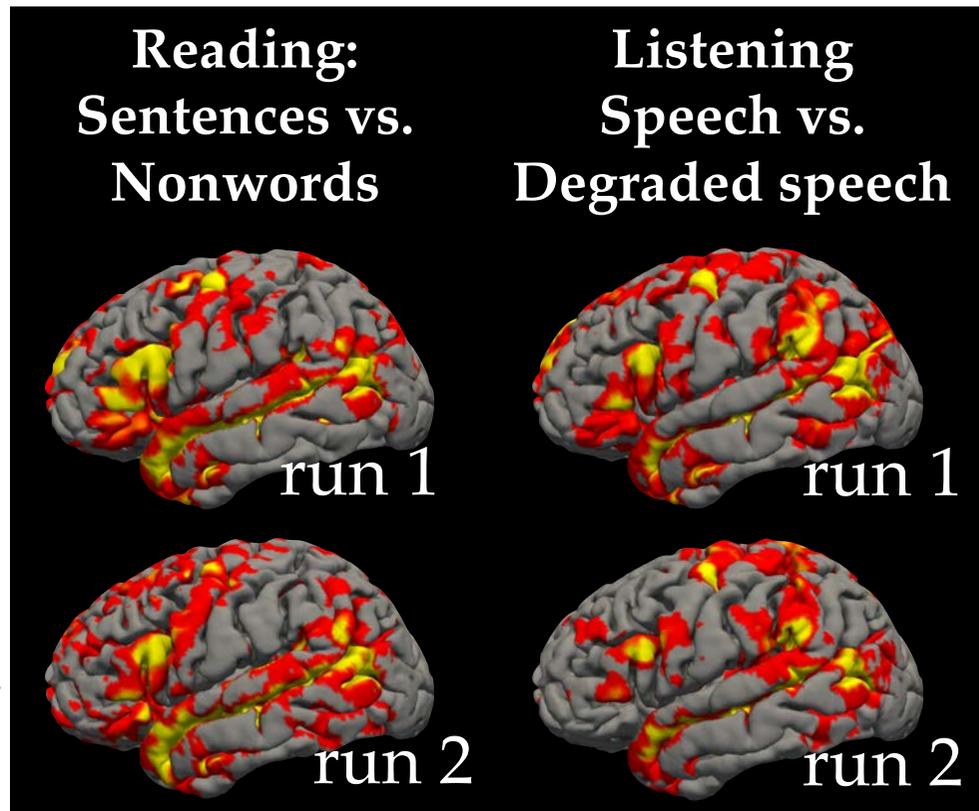
- Now we validate the hell out of the localizer task
- Is it reliable?
- Does it generalize across task and presentation modality??
- Does it generalize across language??

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Functional Localization

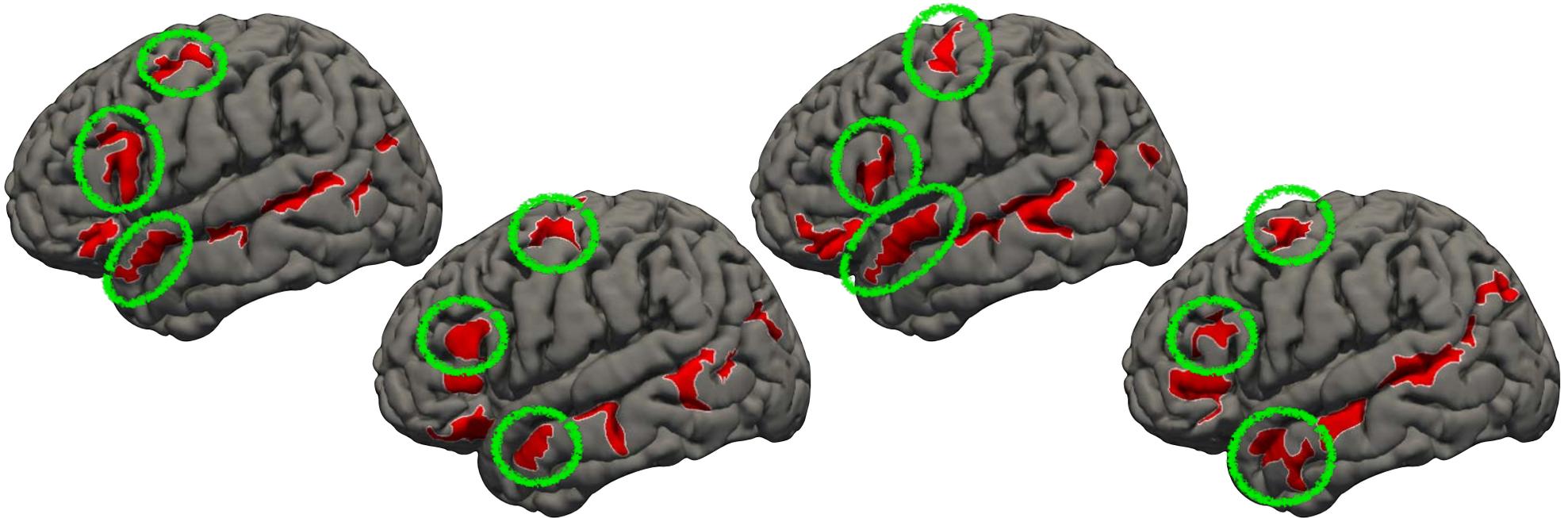
- Now we validate the hell out of the localizer task
- Is it reliable?
- Does it generalize across task and presentation modality??
- Does it generalize across language??
- Does it generalize across materials??



Scott *et al.* (2016), *Cog. Neurosci.*

Functional Localization

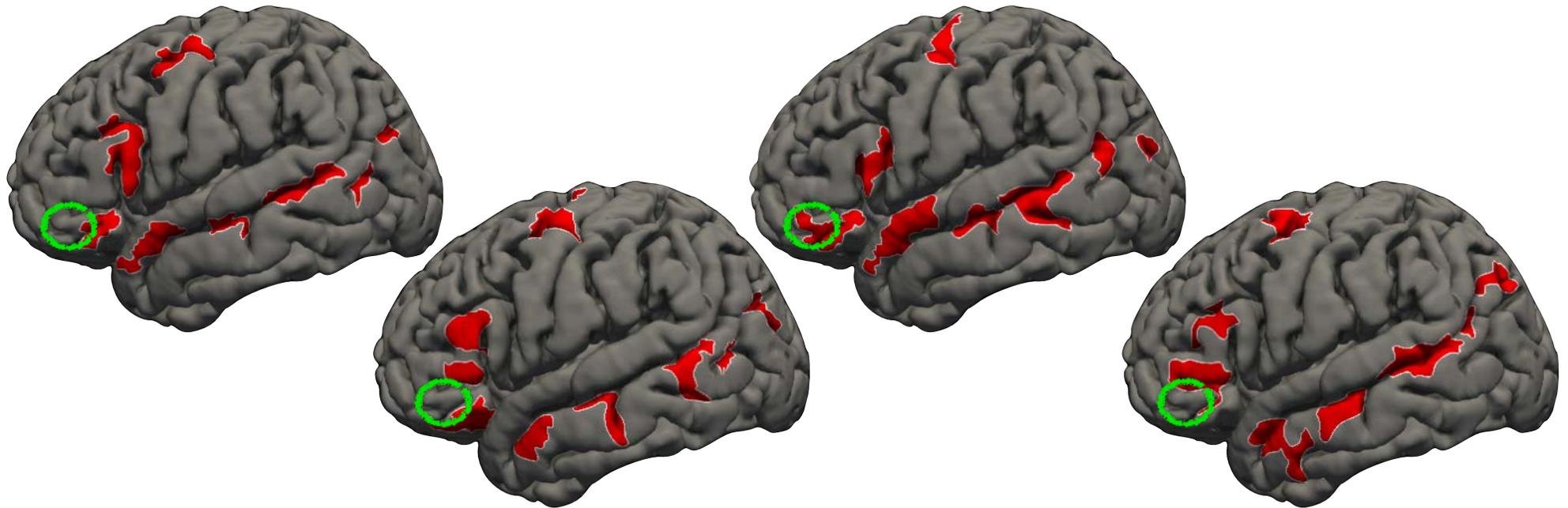
- Now we can ask: what does each of these regions do?
 1. In each participant, find regions that respond to $S > N$
 2. Then measure each region's response in new conditions.



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Functional Localization

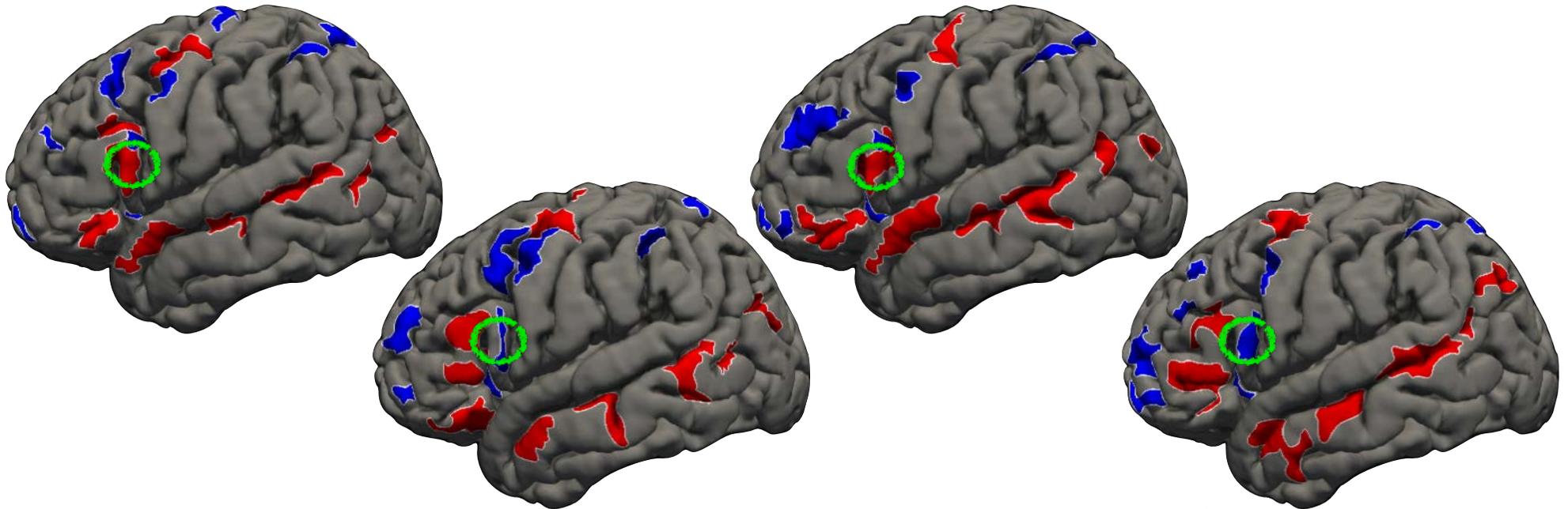
- This is different from traditional “group analyses”, where:
 - Regions are defined anatomically, not functionally
 - Might fail to detect neural activity



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Functional Localization

- This is different from traditional ~~“group analyses”~~, where:
 - Regions are defined anatomically, not functionally
 - Might fail to detect neural activity
 - Might fail to distinguish between different functional regions



Fedorenko & Kanwisher (2009), *Lang. & Ling. Compass*

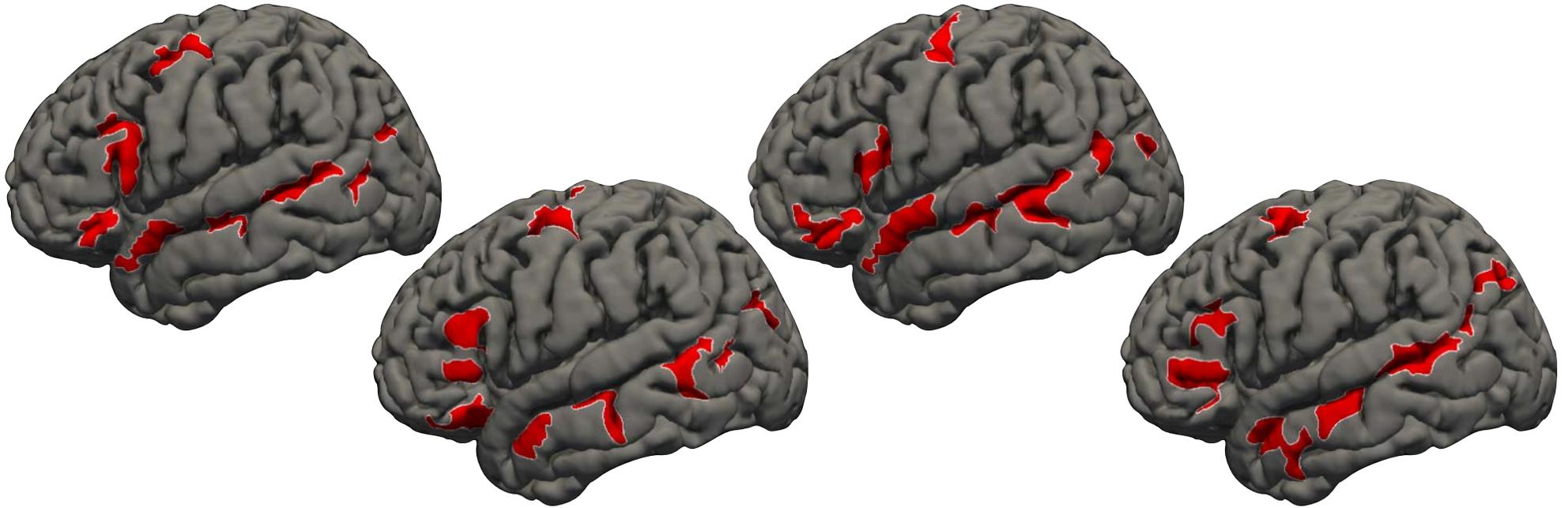
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Functional Localization

Back to conundrum:

Why do patient studies suggest that language is distinct from the rest of thought, whereas prior fMRI studies suggest that language overlaps with many other functions?

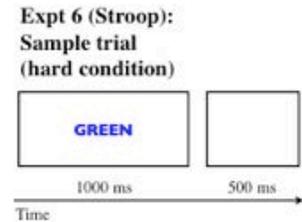
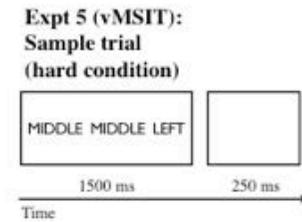
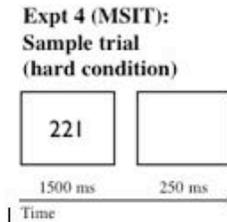
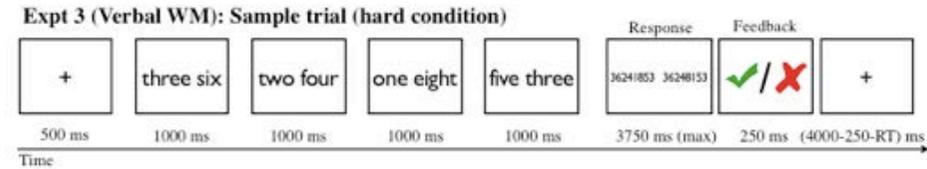
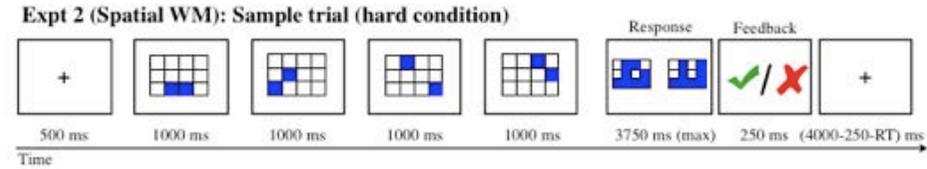
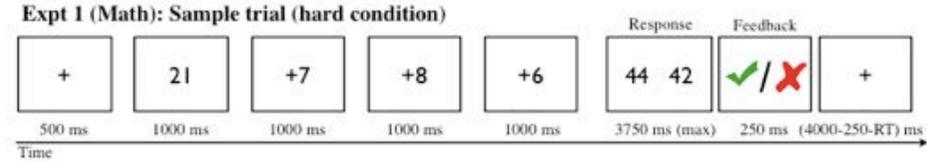
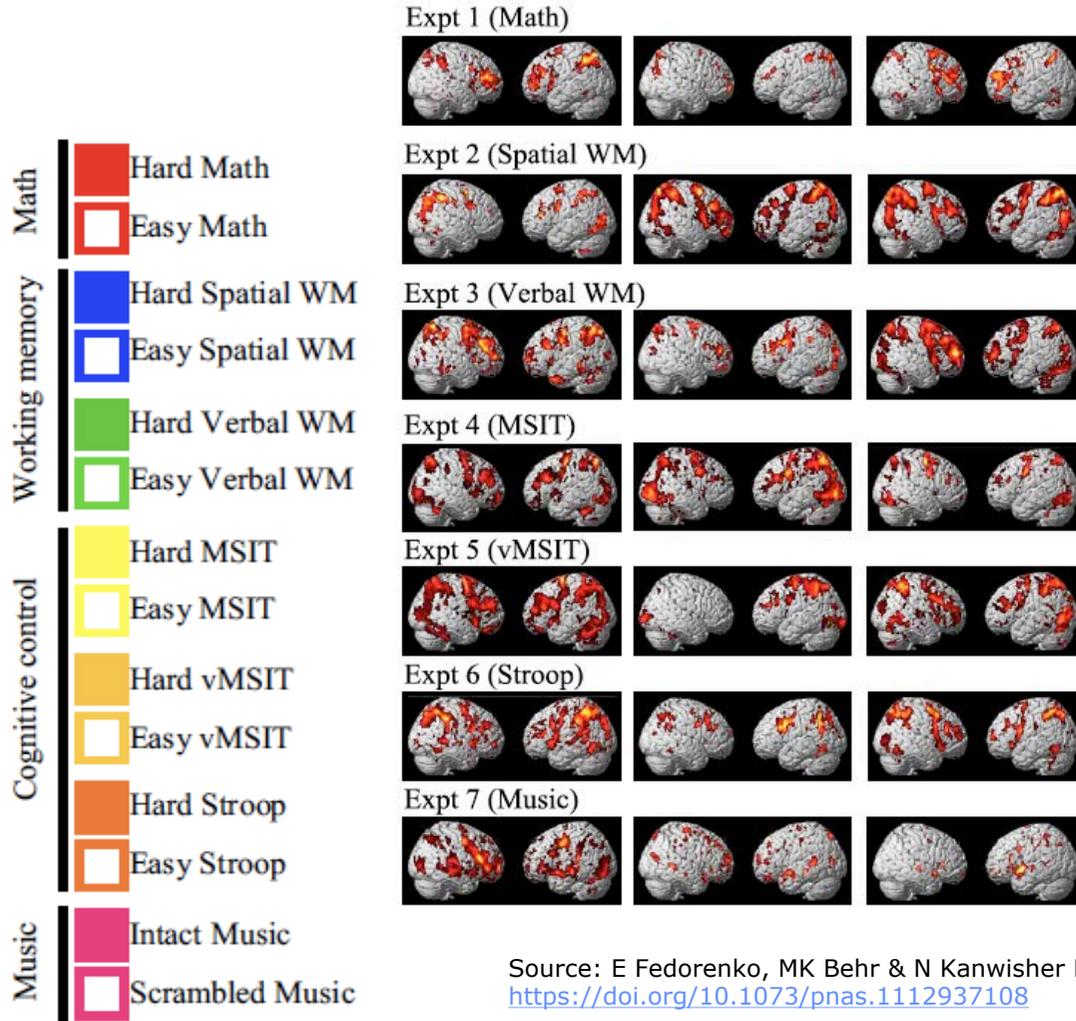
Hypothesis: If you study individual brains, and localize candidate language regions individually in each subject, the story might be different...



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1. Localizer: Reading sentences > nonword strings

2. Seven tasks:

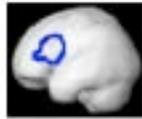
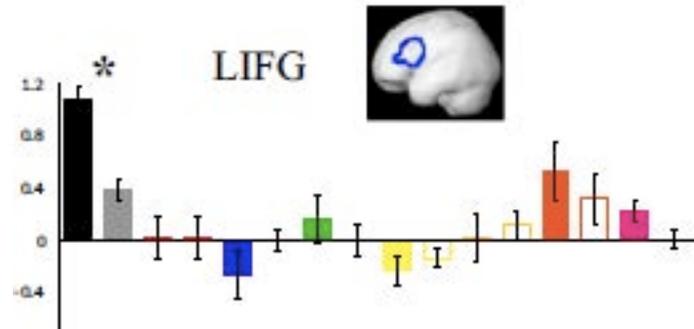
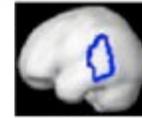
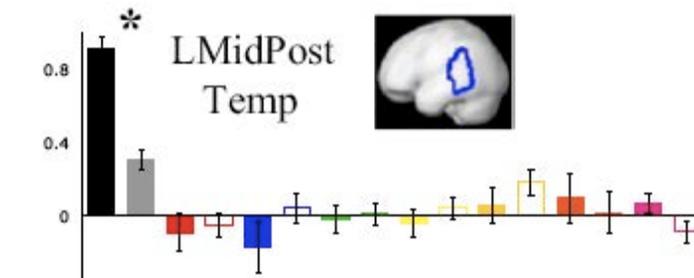
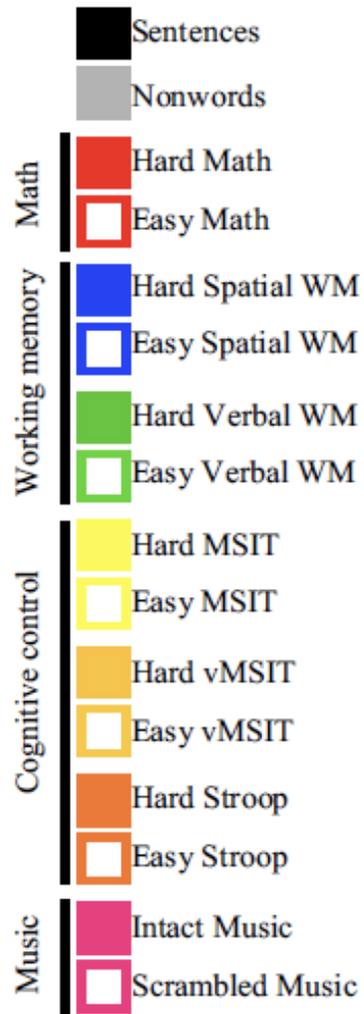


Source: E Fedorenko, MK Behr & N Kanwisher PNAS September 27, 2011 108 (39) 16428-16433;
<https://doi.org/10.1073/pnas.1112937108>

Do these tasks produce decent activations? **Yes!**
 Do these tasks activate the candidate language fROIs?

Functional Specificity for High-level Language? **Yes!**

fROIs: sentences > nonwords



Source: E Fedorenko, MK Behr & N Kanwisher PNAS September 27, 2011 108 (39) 16428-16433;
<https://doi.org/10.1073/pnas.1112937108>

But, several alternatives still remain to be tested.....

e.g., Might these regions represent amodal meaning? i.e. even meaning in pictures?

Fedorenko et al, 2011

Do these tasks activate the candidate language fROIs? **No!**

Lecture 18: Language I

Outline for Today & Wednesday:

O. Review of RSA

I. Introduction: What is language?

What do we want to understand?

II. Is language distinct from the rest of thought?

Yes! Language may be necessary to *learn to think*, but,

Evidence from neurological patients

Global aphasics with ~no language, can think in myriad ways

Evidence from fMRI

Language regions not active during nonlinguistic thinking

III. Is there a functional organization within the language system?

Evidence from neurological patients

Evidence from fMRI

IV. How is meaning represented in the brain?

linguistic? amodal?



Questions:

1. Is language distinct from the rest of thought?

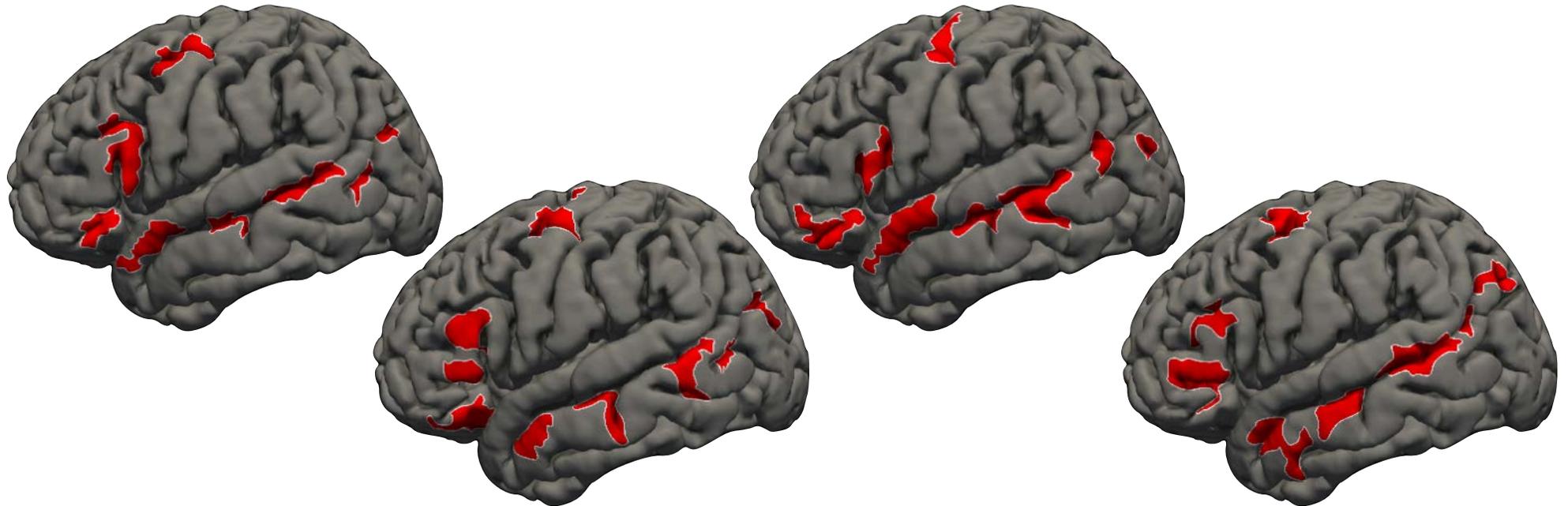
Yes! Language may be necessary to *learn to think*, but,
Global aphasics with ~no language, can think in myriad ways
Language regions not active during nonlinguistic thinking

2. Does the language system itself have distinct components that do different things?

(and if so what is represented and computed in each?)

3. How is meaning represented in the brain?

- 1. Do the language regions differ functionally from e.o.?**
- 2. Are the language regions sensitive to lexical or syntactic information or both?**



Language brain regions © American Physiological Society. All rights reserved. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>. Source: Fedorenko et al. (2010), J. Neurophys. 104(2) 1177-1194. <https://doi.org/10.1152/jn.00032.2010>

Classical Idea

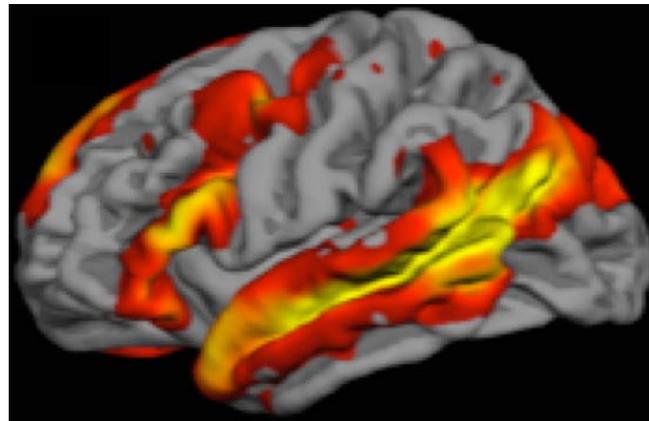
1. Do different parts of the language system do different things?
2. For example, do **distinct regions** of the language system: hold meanings of words (**semantic processing**) vs. perform combinatorial operations (**syntactic processing**)?

Semantics

~ meanings of particular words

How to test this?

???



Brain scan © source unknown. This content is excluded from our Creative Commons license, see <https://ocw.mit.edu/fairuse>.

Syntax

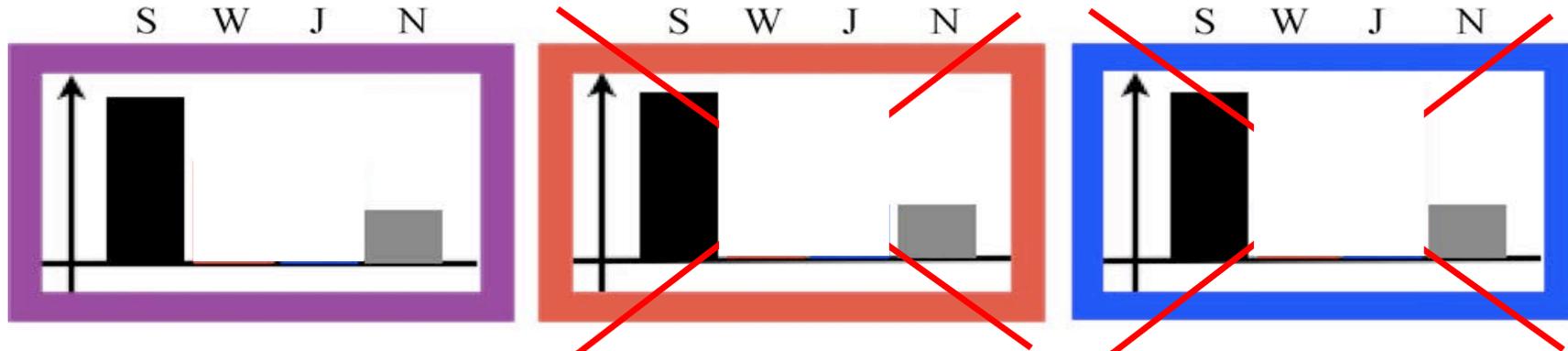
~ rules for how to put those words together

Classical view:
syntax is at the core of what makes human language unique.
Is it “special” in the brain?

More recent view: no sharp distinction btwn semantic & syntactic processing. Syntax not based on abstractions (e.g. nouns vs. verbs); tied to specific words. Psycholinguistic results: Humans are highly sensitive to contingencies between particular words during online language processing. (also EM study)

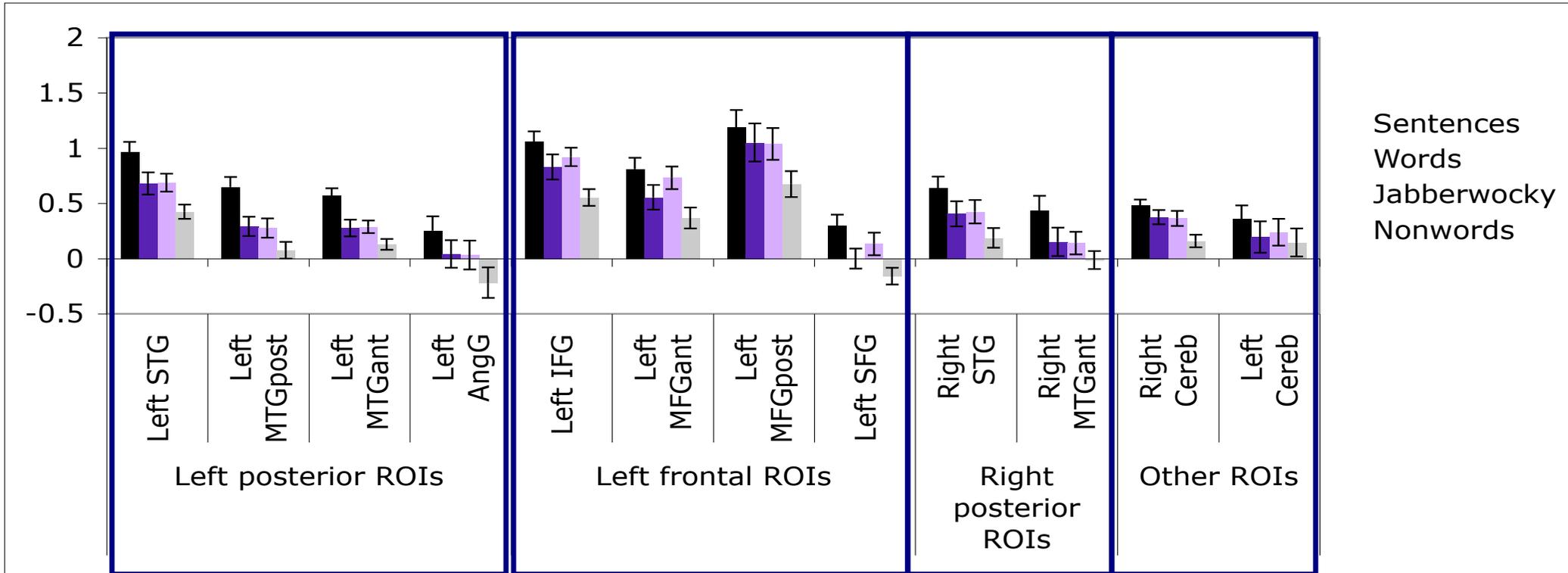
1. Do the language regions differ functionally from e.o.?
2. Are the language regions sensitive to lexical or syntactic information or both?

	+	Syntactic information	-
Lexical information	+	Sentences THE SPEECH THAT THE POLITICIAN PREPARED WAS TOO LONG FOR THE MEETING	
	-		Nonword lists WAS DURING CUSARISTS FICK PRELL PRONT THE POME VILLPA AND WORNETIST SHE



What would this mean?

Within-language specificity: semantics vs. syntax



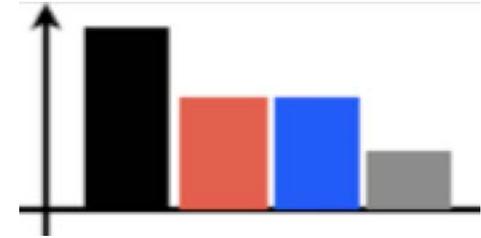
- most fROIs: $S > W, J > N$

1. Do the language regions differ functionally from e.o.?

Not yet!

2. Are the language regions sensitive to lexical or syntactic information or both?

They all seem to do both!



Questions

1. What representations are extracted, and what computations performed, during language understanding (and production)?

sentence understanding is very fast

syntax is affected online by knowledge of the environment

syntax is not “encapsulated” from world knowledge

2. Is language even a distinct thing from the rest of cognition?

put another way:

what is the relationship between language and thought?

could you think without language?

language is not the same thing as thought

global aphasics can think without language

language regions show v little response in nonlinguistic tasks

3. Are there distinct components within the language system?

what is represented and computed in each component?

No division of labor evident yet across language regions

All are engaged equally in syntax and semantics

There must be more to this!

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9.13 The Human Brain

Spring 2019

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