

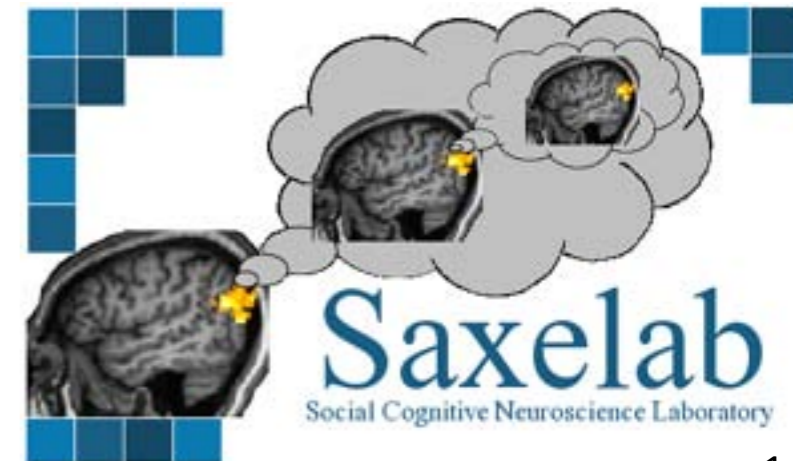
MVPA

Opening a new window on the mind via fMRI

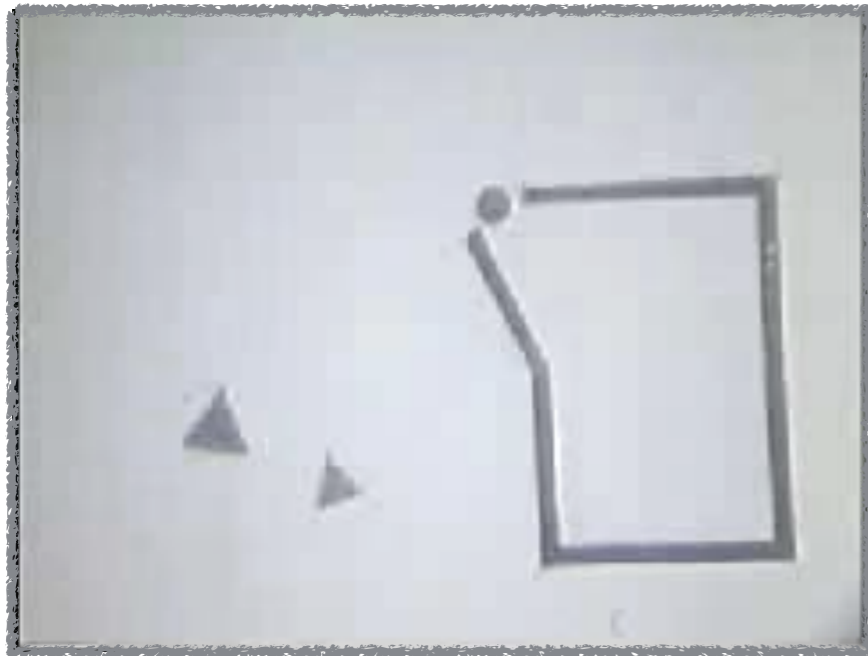
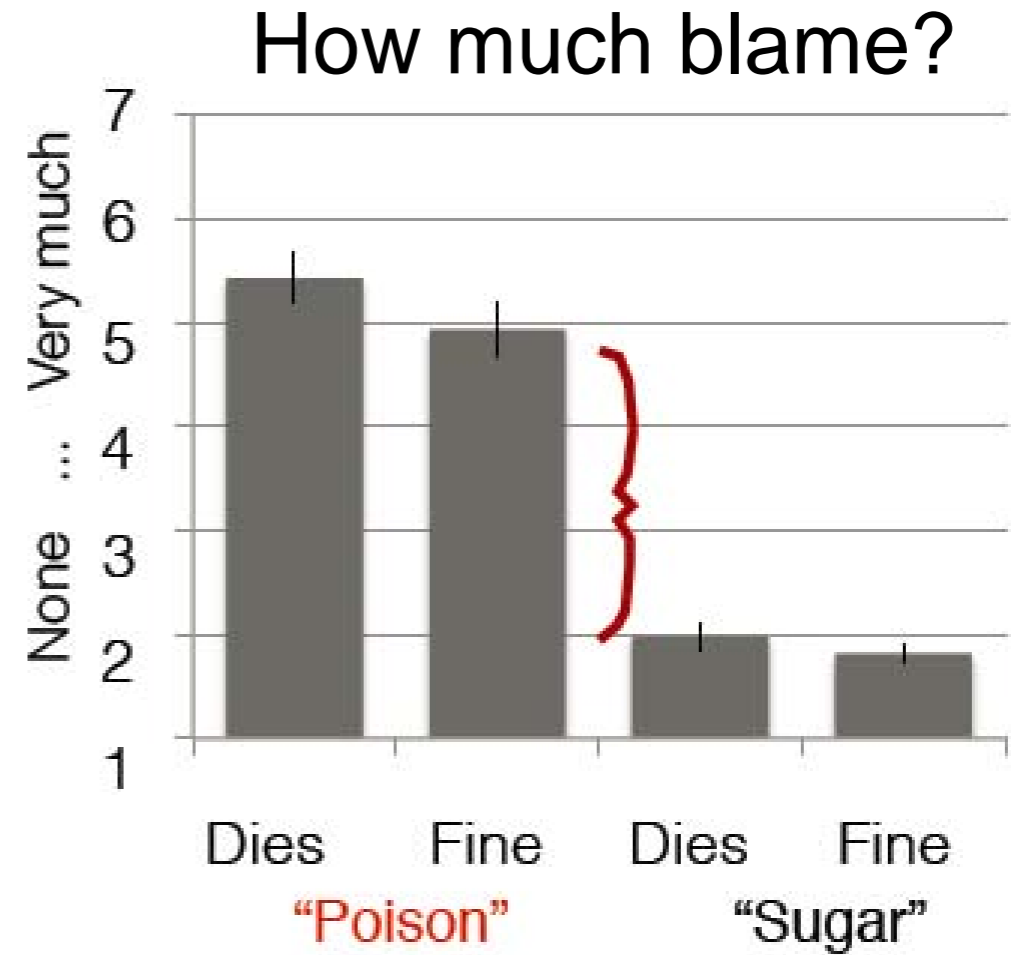
Image removed due to copyright restrictions. Please see the video.



Rebecca Saxe
Summer Course
2015



THINKING ABOUT THOUGHT



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 Source: Heider, F., & Simmel, M. (1944) "An experimental study in apparent behavior." The American Journal of Psychology, 57, 243-259.

This image is in the public domain.
 Source: Photographs of the IMF 2007 Annual Meetings, International Monetary Fund Photograph by Stephen Jaffe.

THEORY OF MIND

The False Belief Task



THEORY OF MIND

The False Belief Task



THINKING ABOUT THOUGHT

Anne made lasagna in the blue dish. After Anne left, Ian came home. He threw out the lasagna and made spaghetti in the blue dish and replaced it back in the fridge.

Anne thinks the blue dish contains...

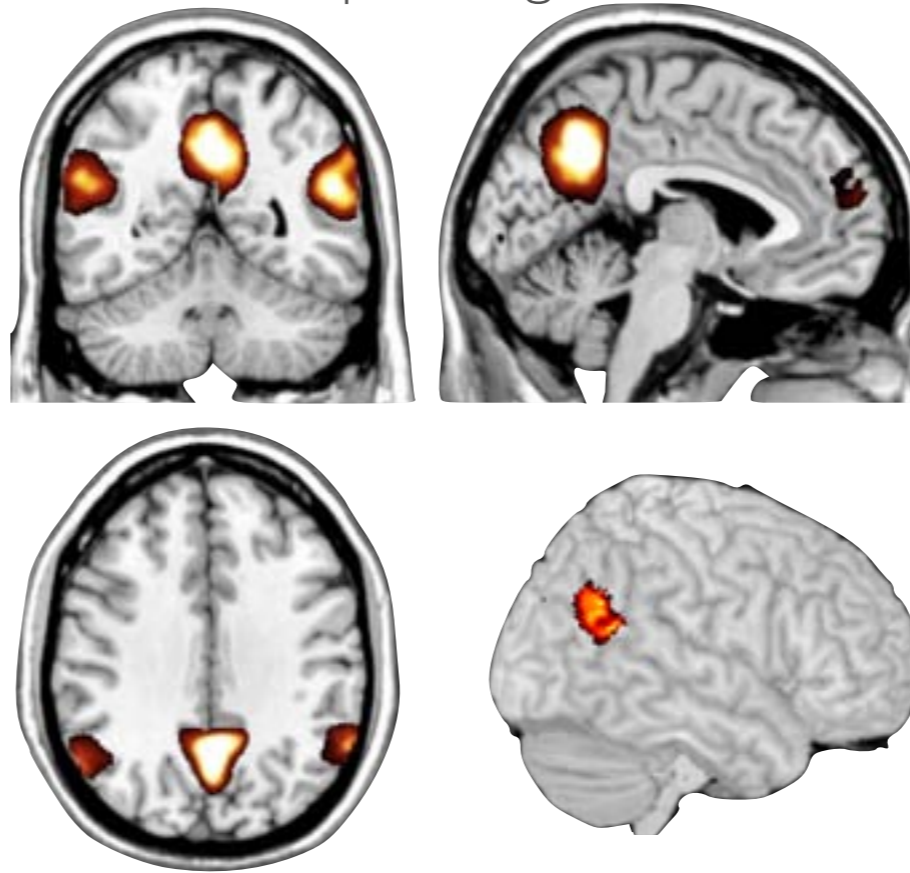
A volcano erupted on this Caribbean island three months ago. Barren lava rock is all the remains. Satellite photos show the island as it was before the eruption.

The photo shows the island as...

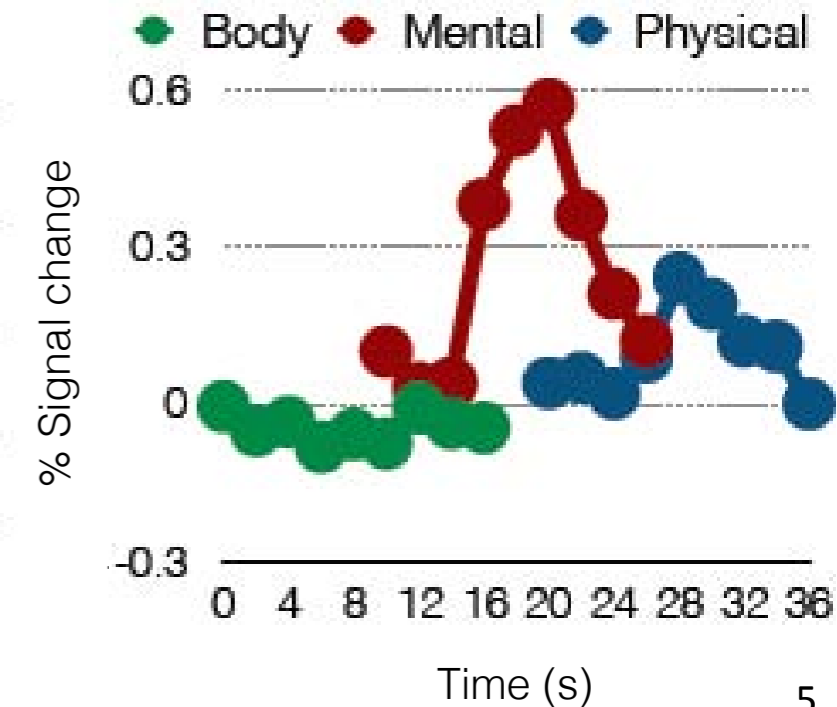
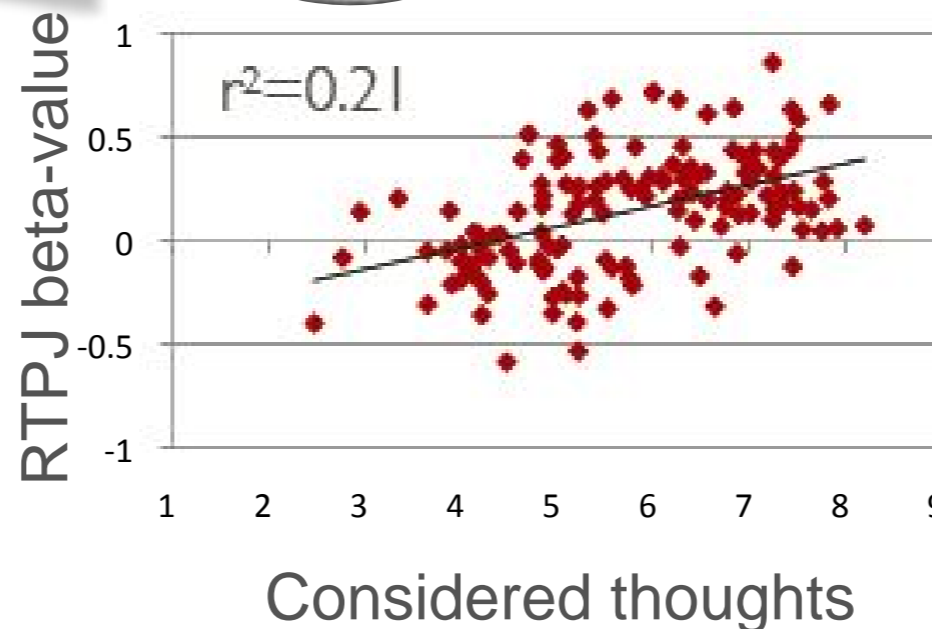
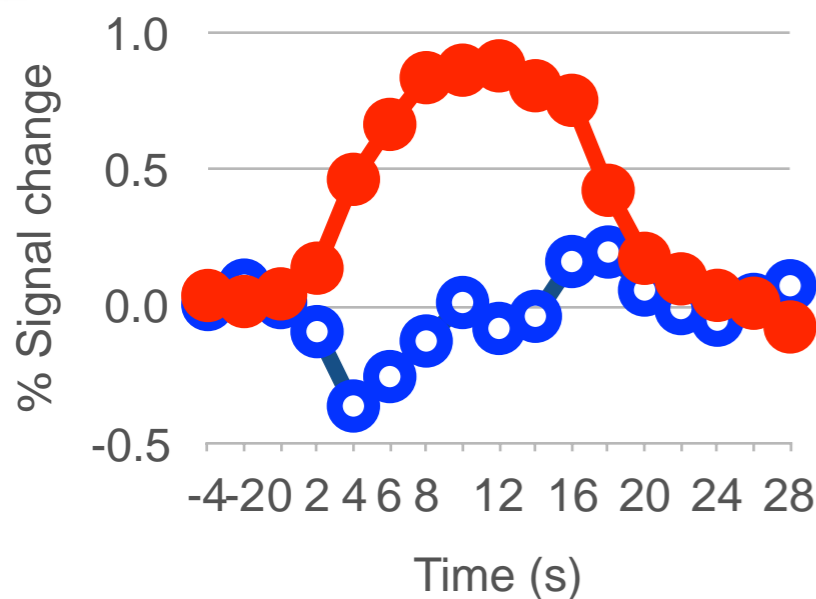
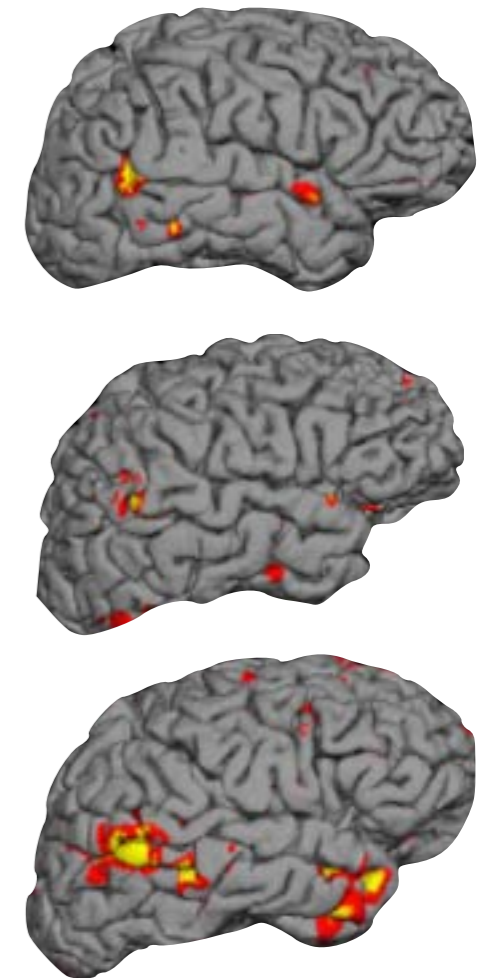
Belief

Physical

Group average



Individual participants

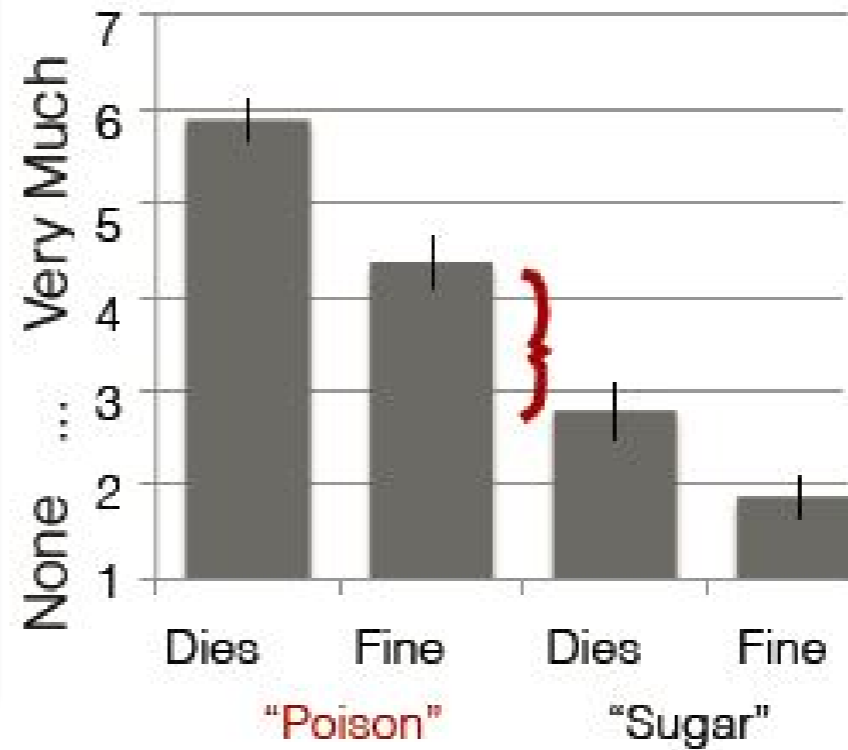


THINKING ABOUT THOUGHT

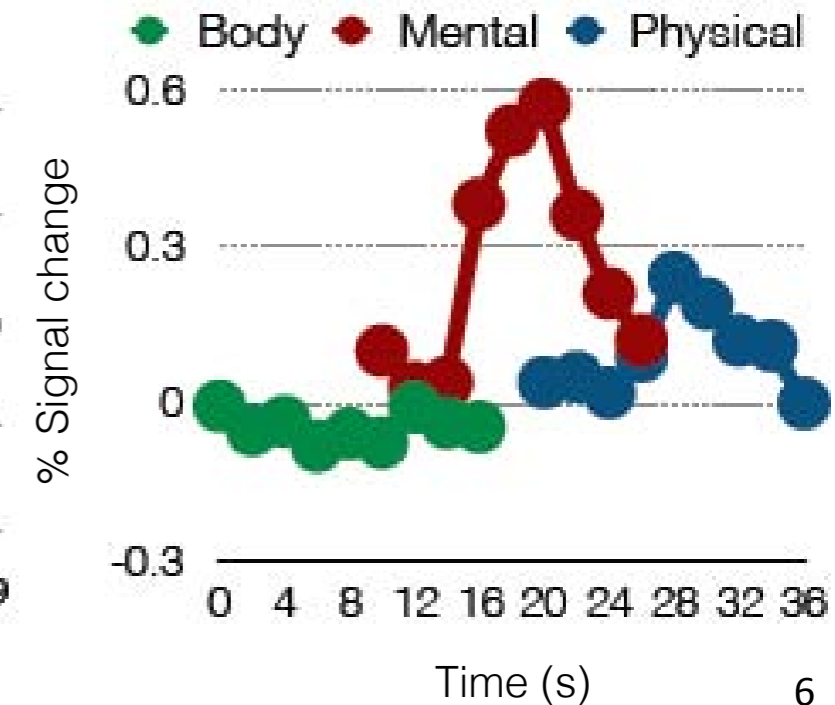
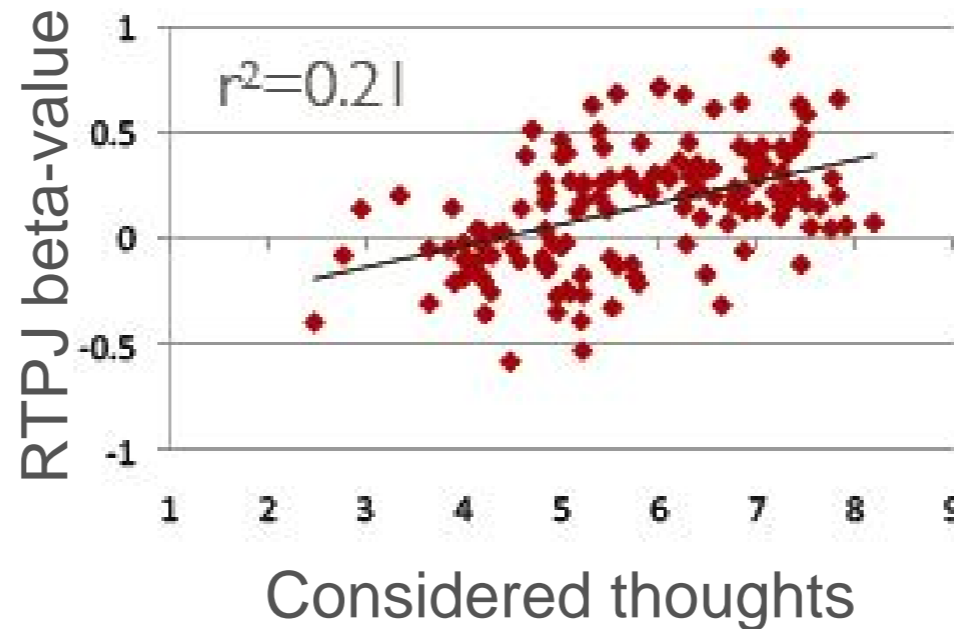
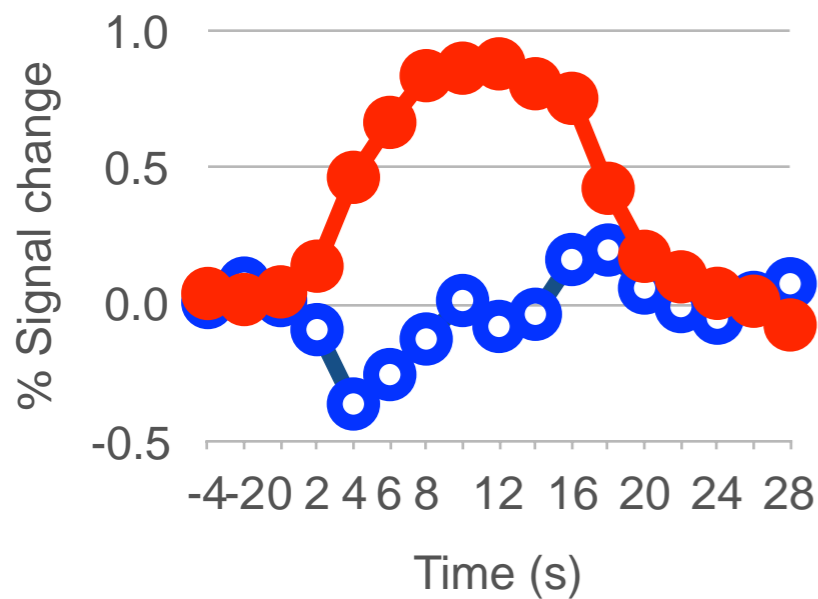
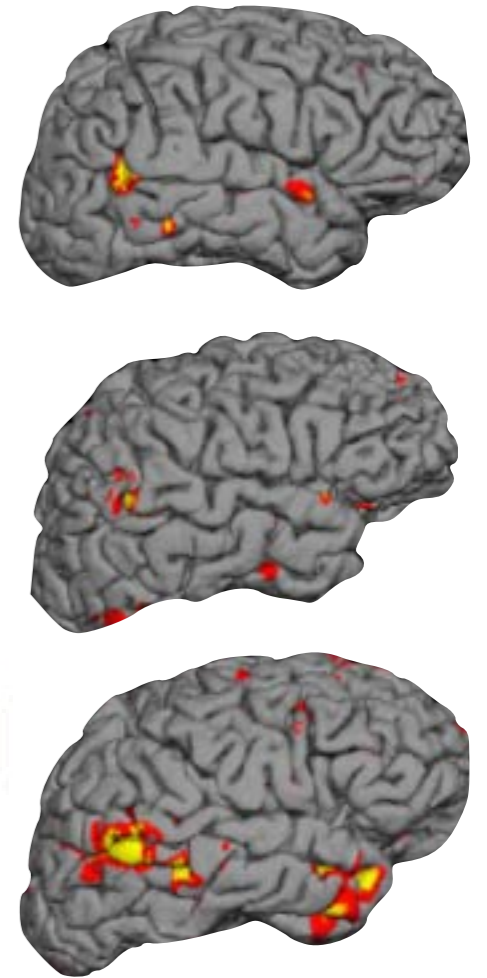


Causal role

TMS to RTPJ



Individual participants

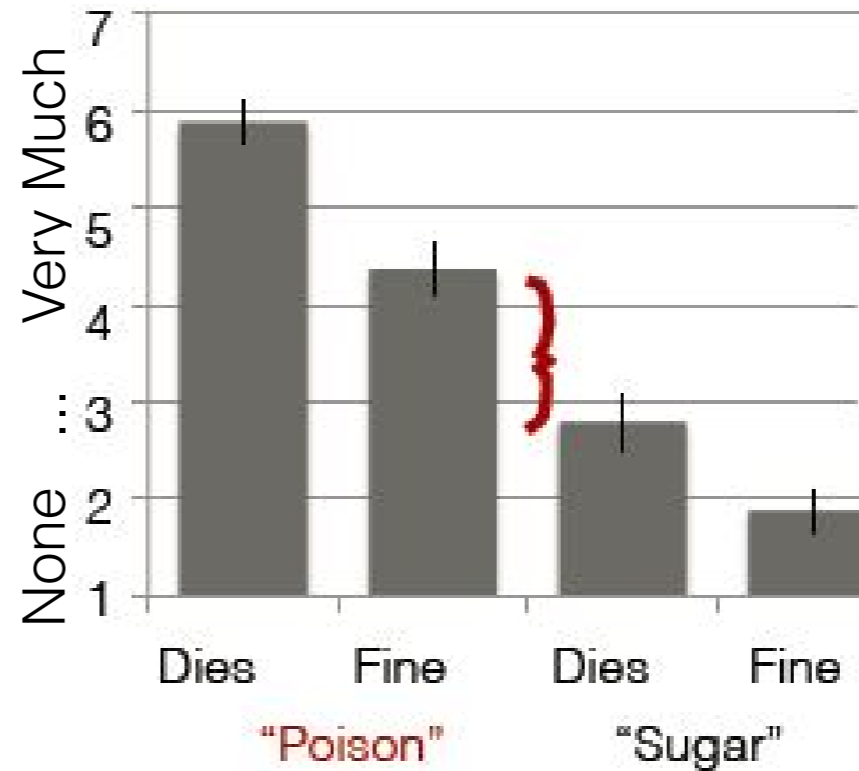


THINKING ABOUT THOUGHT

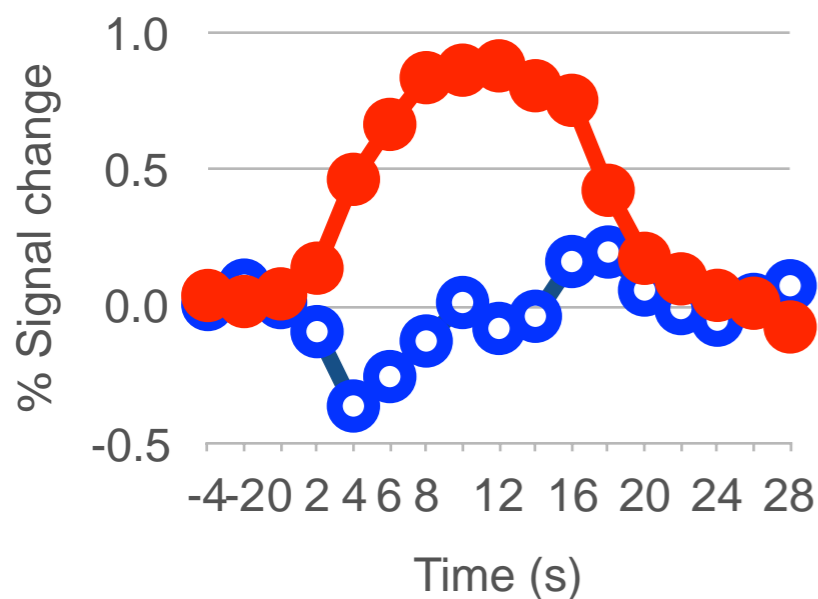
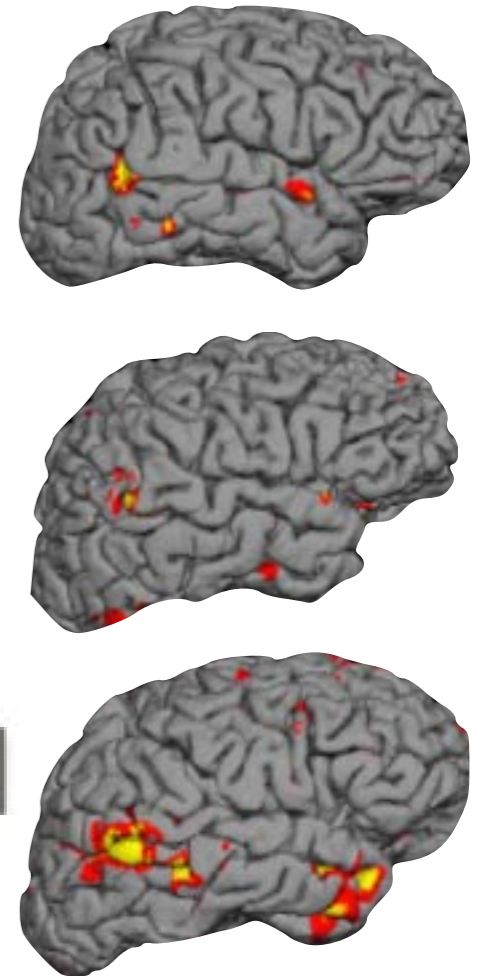


Causal role

TMS to RTPJ



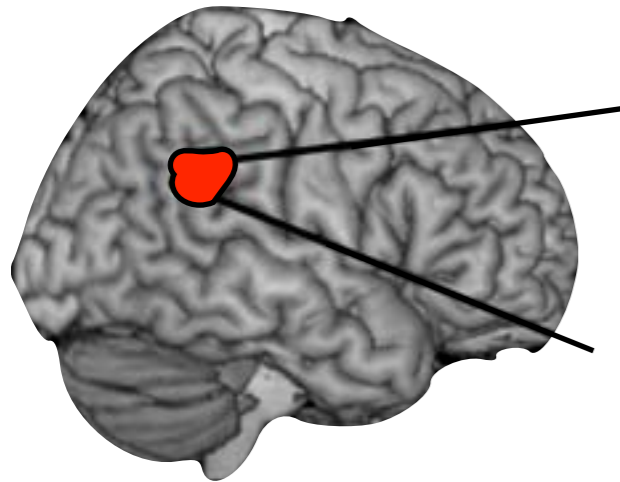
Individual participants



Hypothesis:
RTPJ selectively "involved in" ToM

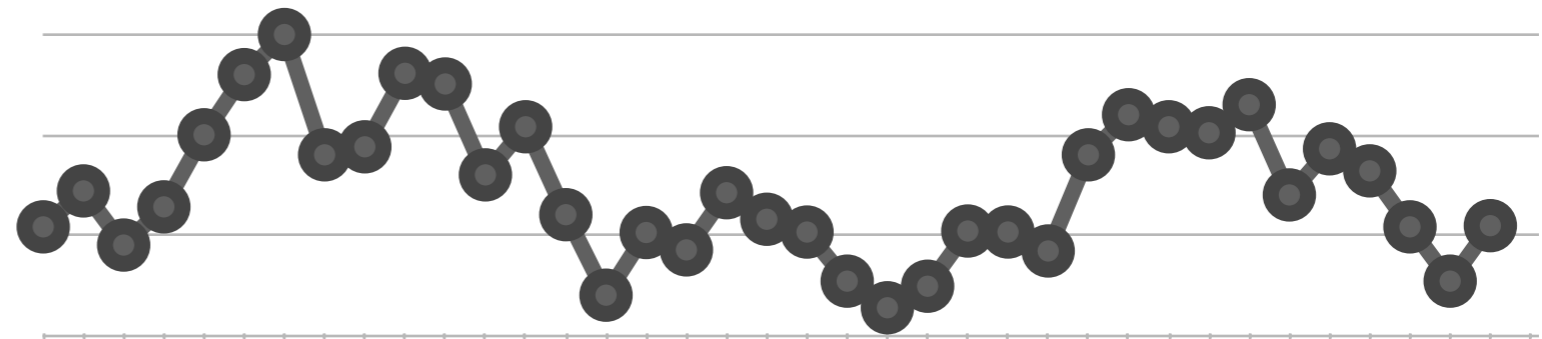
FMRI & COGNITION

Beyond “involvement”



Average

BOLD



Stories

Albert really wants this ski trip to be a success. Though the ice looks quite thin at points, Albert thinks the pond is sufficiently frozen over to support a person's weight. He tells his girlfriend to walk out on the ice.

During a trip Grace is irritated by her friend's constant whining. Grace sees a container labeled "toxic poison", so she thinks the powder is poison. She puts the powder in her friend's coffee.

Representations

Population codes of features/ dimensions

Computations

Transformation

Activity shows: both stories describe thoughts

Theory of Mind:

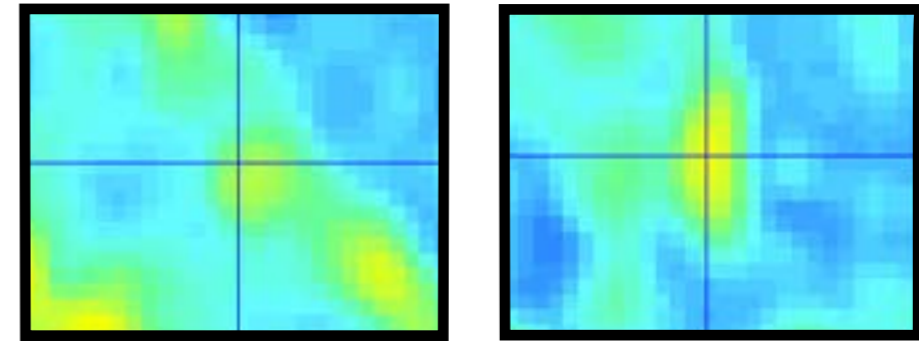
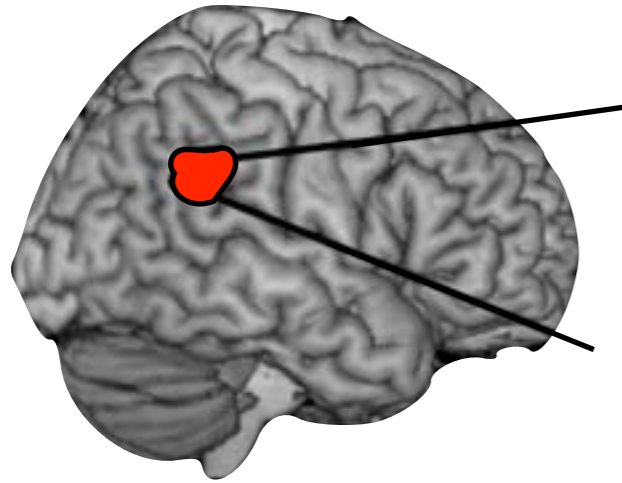
Who thinks what?

Why? (i.e. what reasons? what motivations?)

With what consequences?

FMRI & COGNITION

Beyond “involvement”



Traditional analysis

Univariate

avg magnitude across voxels

“Forward” / “Encoding” direction

Region scale

Stimulus “Type”

“MVPA” analysis

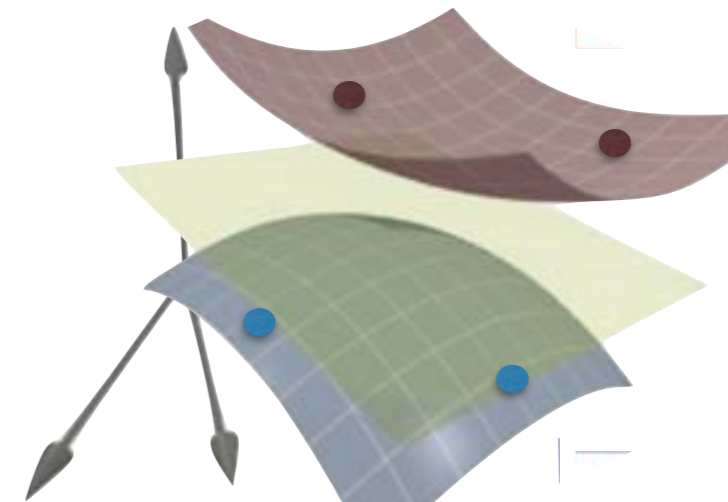
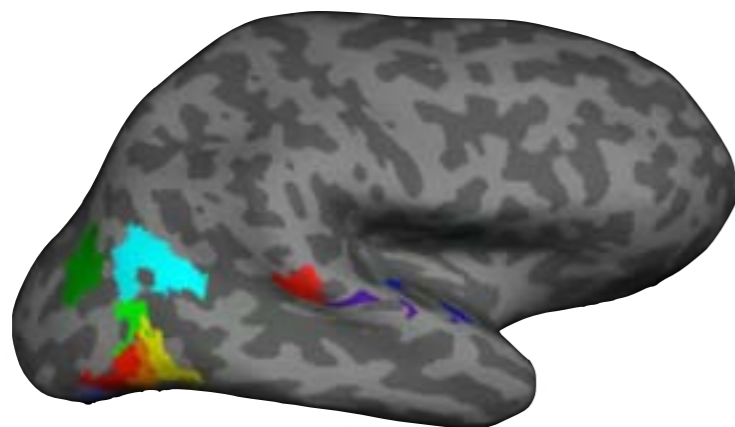
Multivariate

relative magnitude across voxels

“Reverse” / “Decoding” direction

Sub-region scale

Within type features



VERSION #1

Haxby style correlations

Experiment 1A Methods:

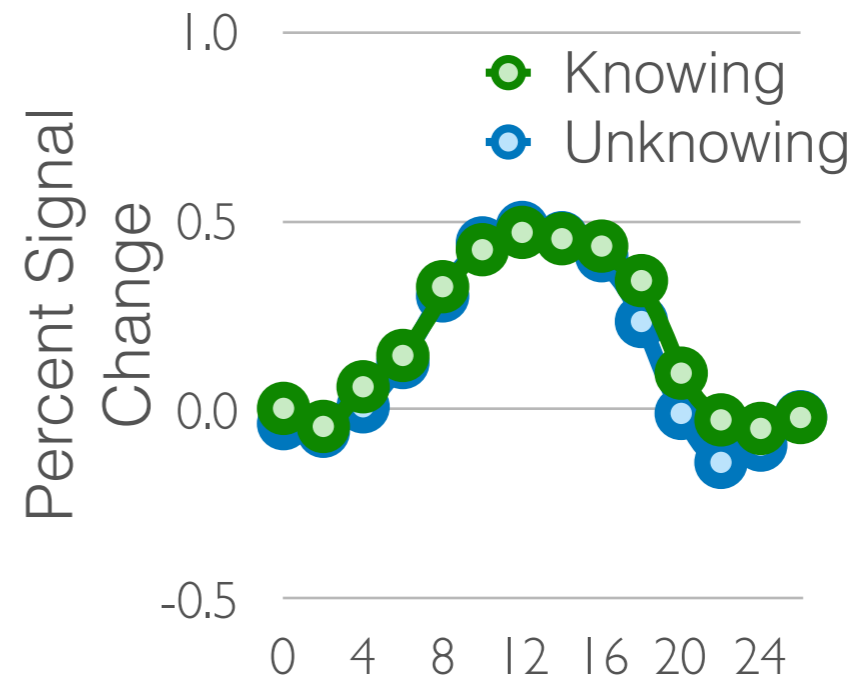
Your family is over for dinner. You wish to show off your culinary skills. For one of the dishes, adding peanuts will really bring out the flavor.

You grind up some peanuts, add them to that dish, and serve everyone.

Your cousin, one of your dinner guests, is severely allergic to peanuts.

You had absolutely no idea about your cousin's peanut allergy when you added the peanuts.

How much blame should you get?



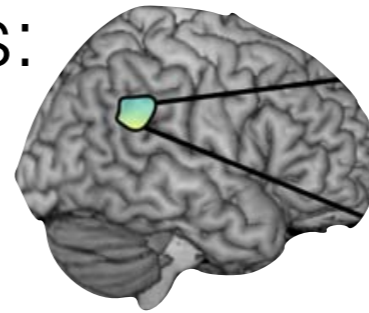
Minimal pair 4s; 2-4 words changed

You knew about your cousin's peanut allergy when you added the peanuts.

VERSION #1

Haxby style correlations

Generalize across heterogeneous items:
(NB every item is unique)



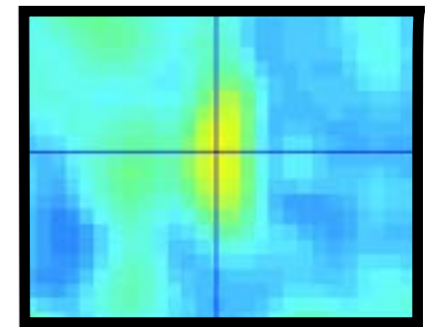
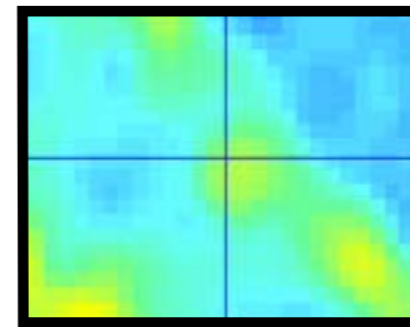
Knowing

Unknowing

You could see that your classmate was standing too close but you kicked anyway.

You had absolutely no idea about your cousin's allergy when you added the peanuts.

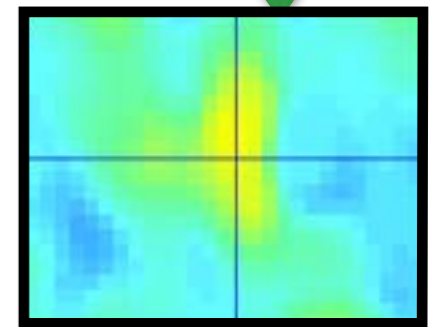
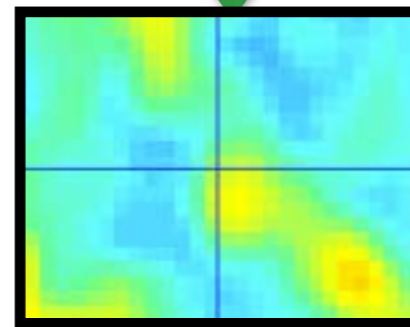
Even



Based on what the manager said, you definitely realized the chute was faulty.

The essay was typed, so you completely didn't realize who had written it.

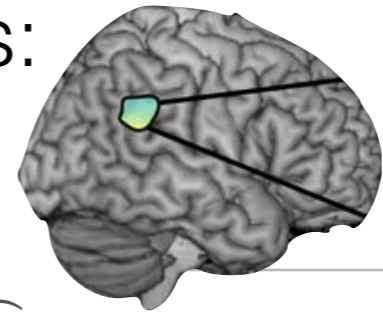
Odd



VERSION #1

Haxby style correlations

Generalize across heterogeneous items:
(NB every item is unique)



■ Across
■ Within

Knowing

Unknowing

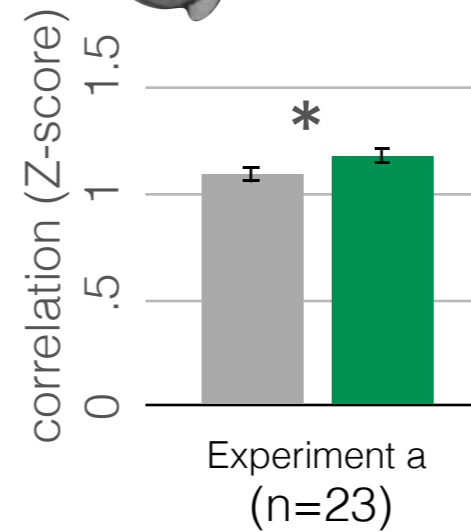
You could see that your classmate was standing too close but you kicked anyway.

You had absolutely no idea about your cousin's allergy when you added the peanuts.



Based on what the manager said, you definitely realized the chute was faulty.

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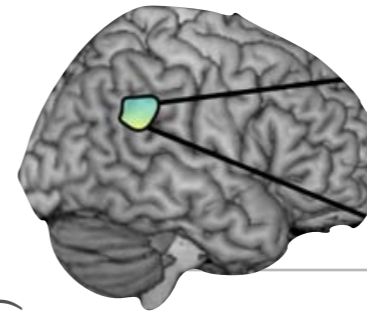


Knowing vs Unknowing Harm

VERSION #1

Haxby style correlations

Same distinction, new implementation



■ Across
■ Within

*old data

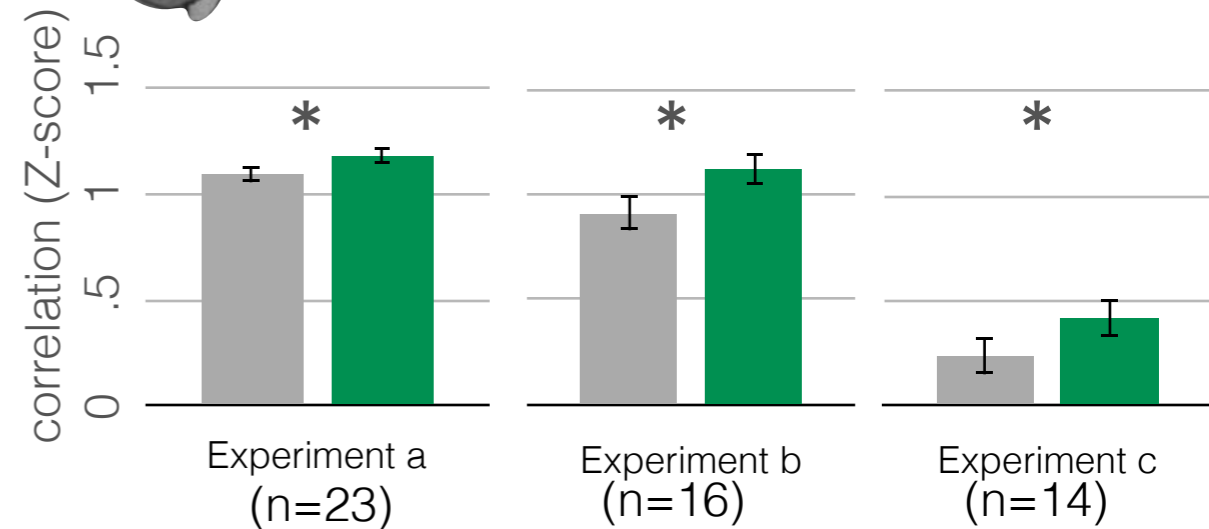
Knowing

You knew about your cousin's peanut allergy when you added the peanuts.

Unknowing

You had absolutely no idea about your cousin's allergy when you added the peanuts.

Experiment 1A



Knowing vs Unknowing Harm

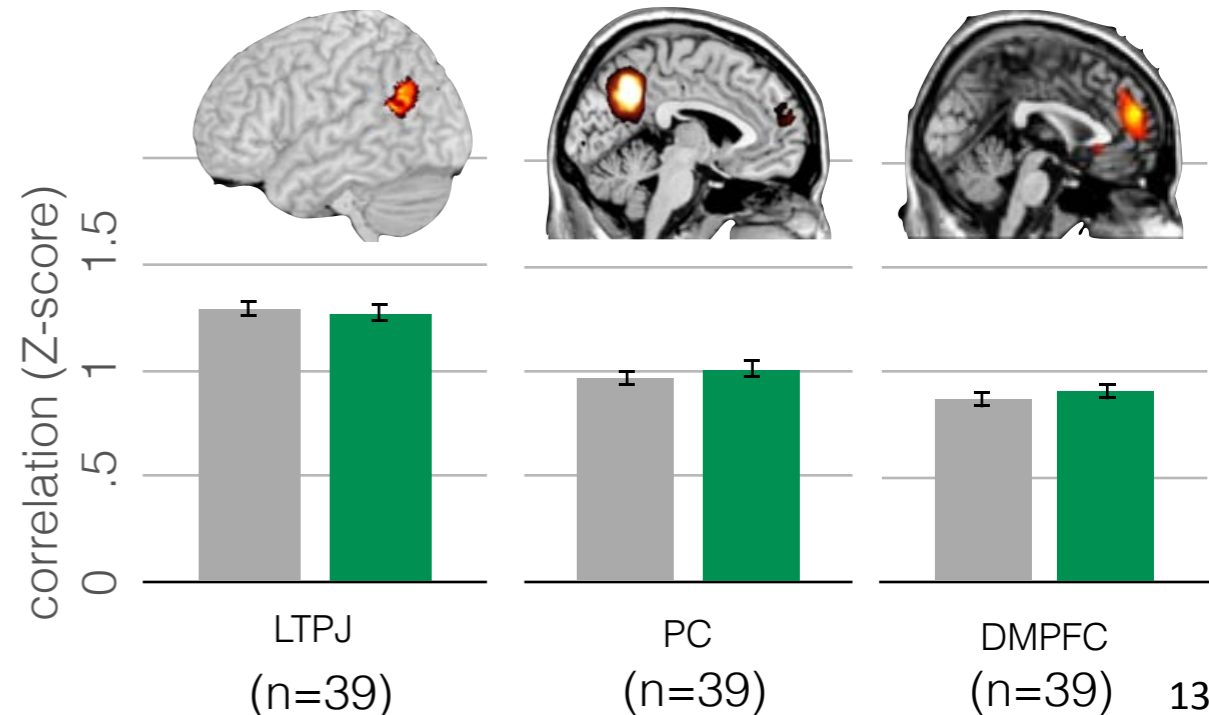
True Belief

The container is labeled "toxic", so Grace believes that the white powder is a toxic substance.

False Belief

The container is labeled "sugar", so Grace believes that the white powder is regular sugar.

Experiment 1B&C



VERSION #1

Haxby style correlations

One measurement per individual

Knowing

You knew about your cousin's peanut allergy when you added the peanuts.

Unknowing

You had absolutely no idea about your cousin's allergy when you added the peanuts.

Experiment 1A

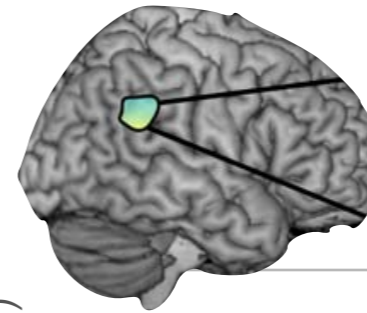
True Belief

The container is labeled "toxic", so Grace believes that the white powder is a toxic substance.

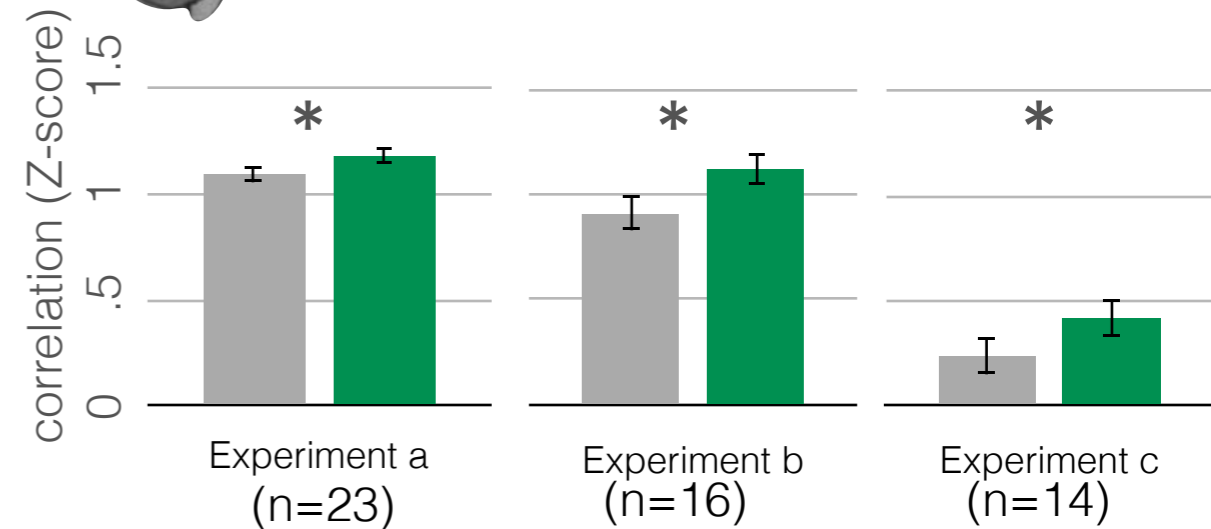
False Belief

The container is labeled "sugar", so Grace believes that the white powder is regular sugar.

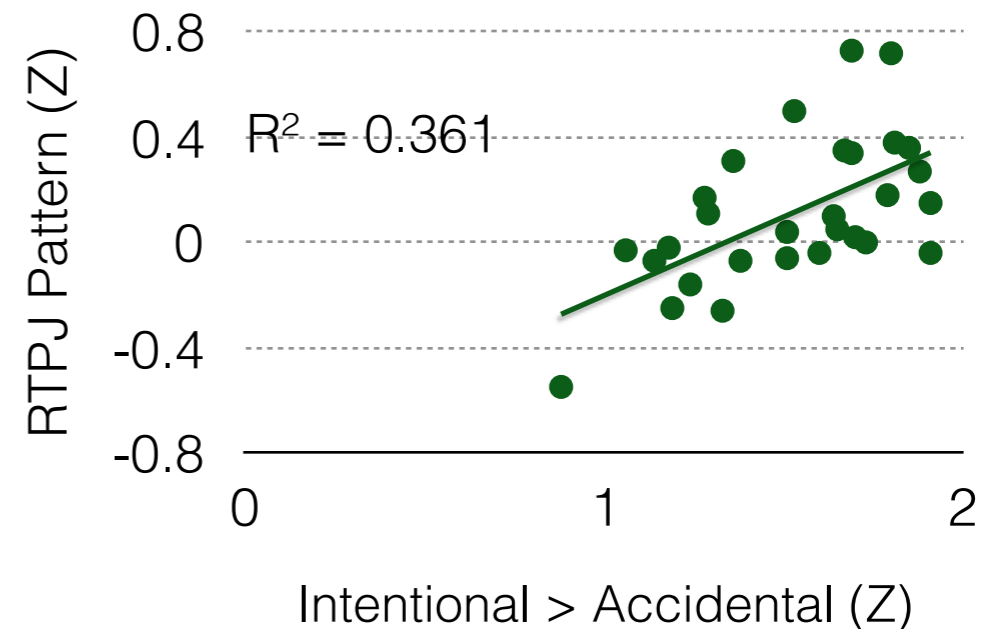
Experiment 1B&C



■ Across
■ Within

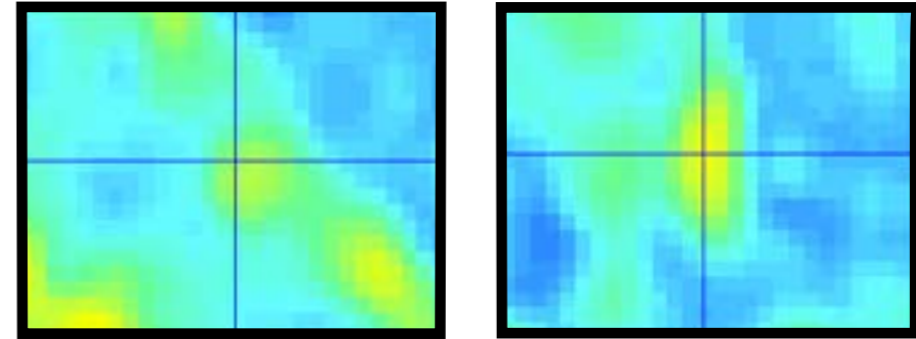
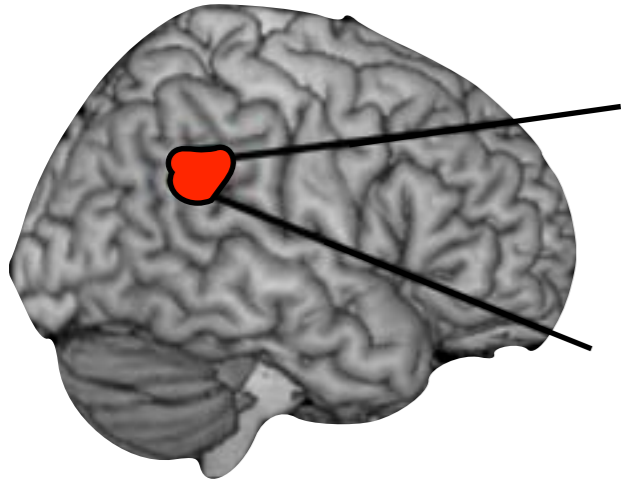


Knowing vs Unknowing



FMRI & COGNITION

Beyond “involvement”



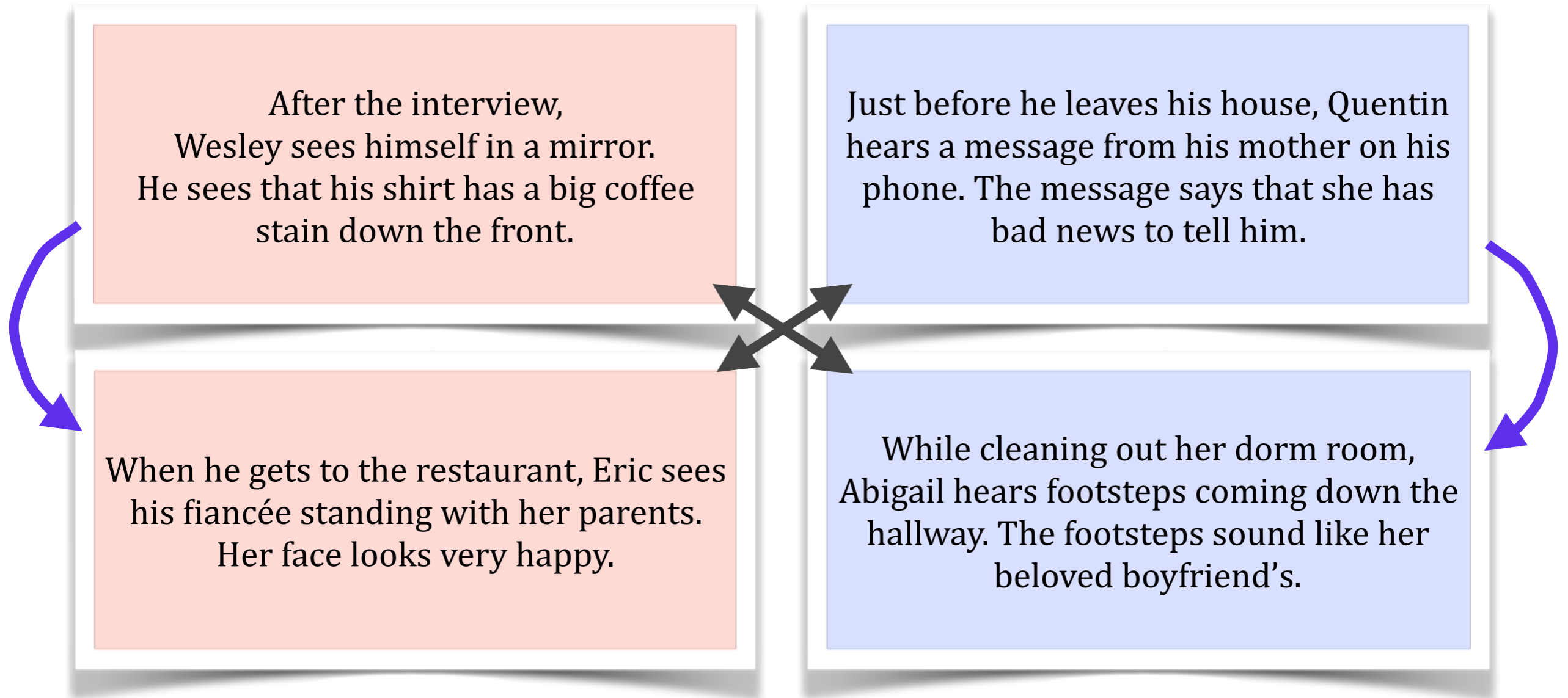
Haxby-style correlations:

- robust but simple measure
- sensitive to minimal manipulation
- generalises across heterogeneous stimuli
- stable in participant (relates to ID)
- different across regions

VERSION #1A

A few more Haxby style correlations

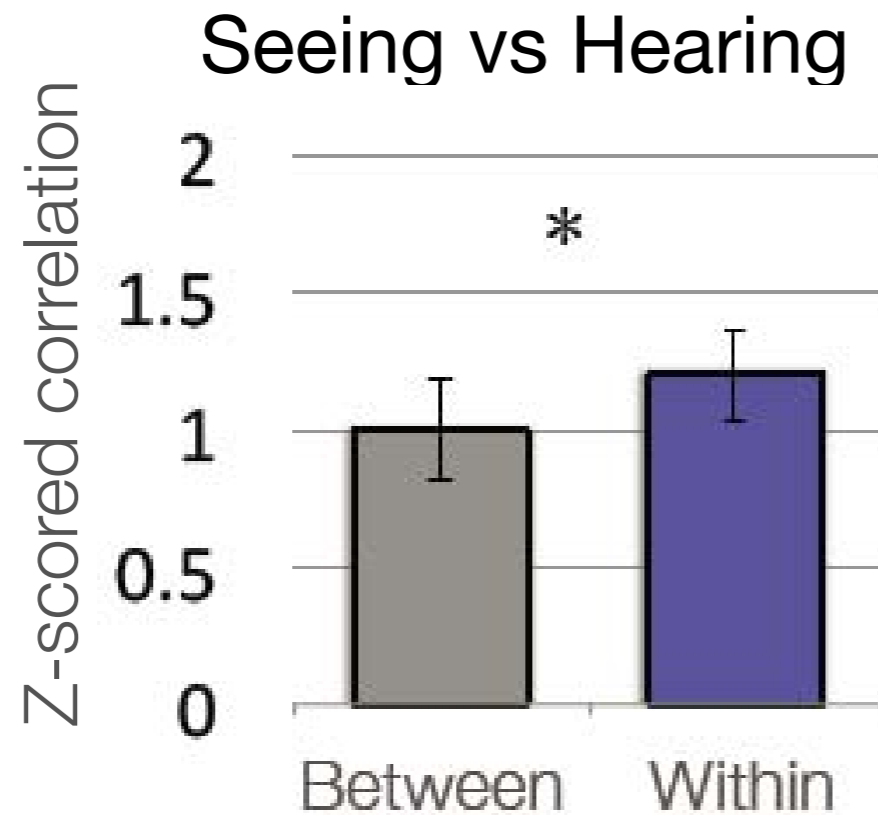
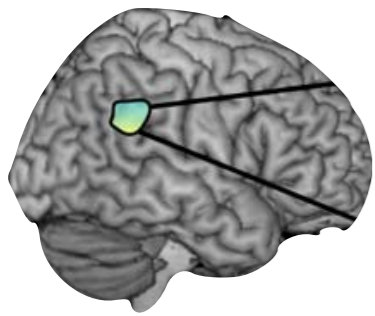
Two orthogonal differences:



VERSION #1A

A few more Haxby style correlations

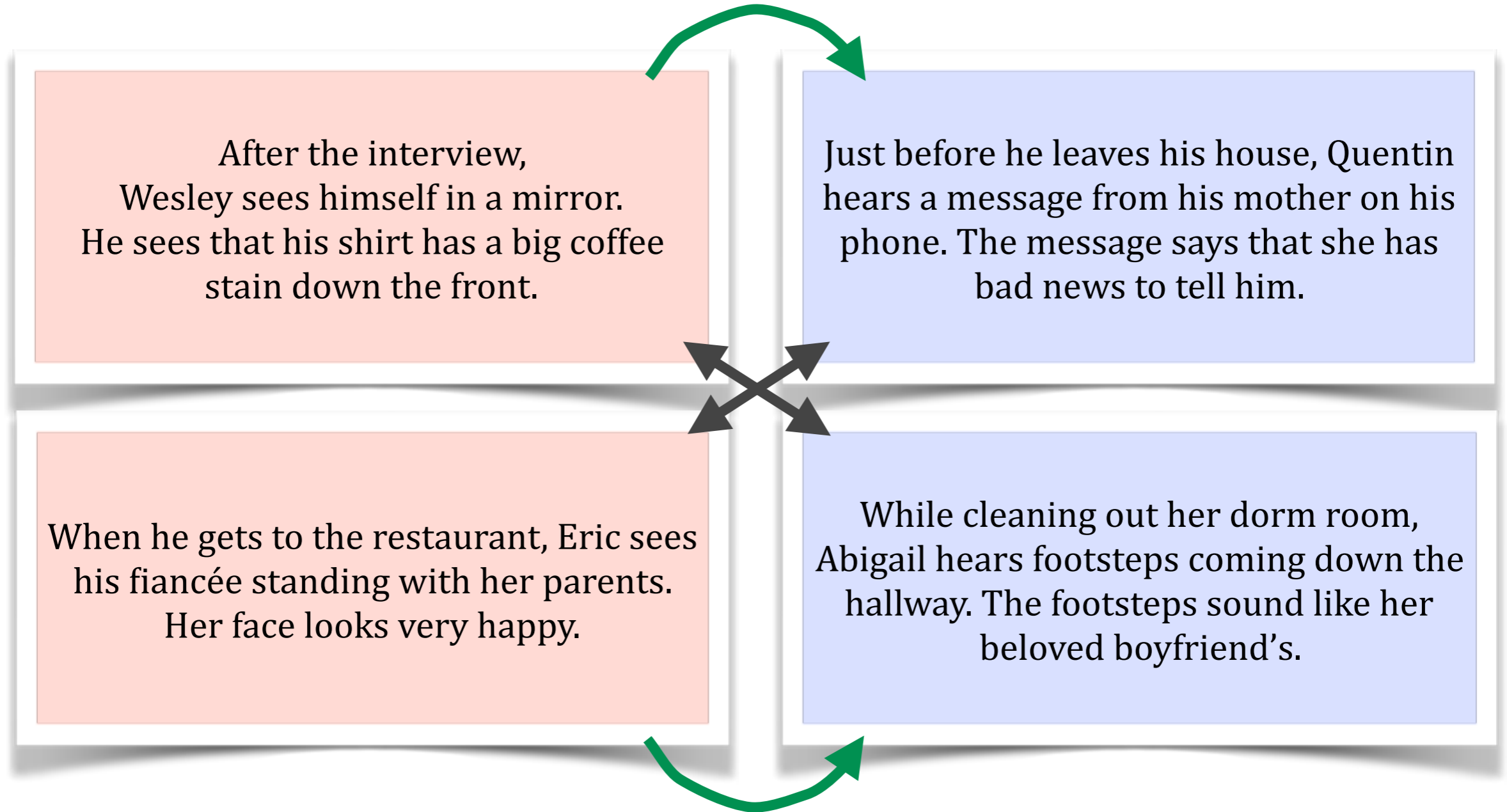
Two orthogonal differences:



VERSION #1A

A few more Haxby style correlations

Two orthogonal differences: **Negative**

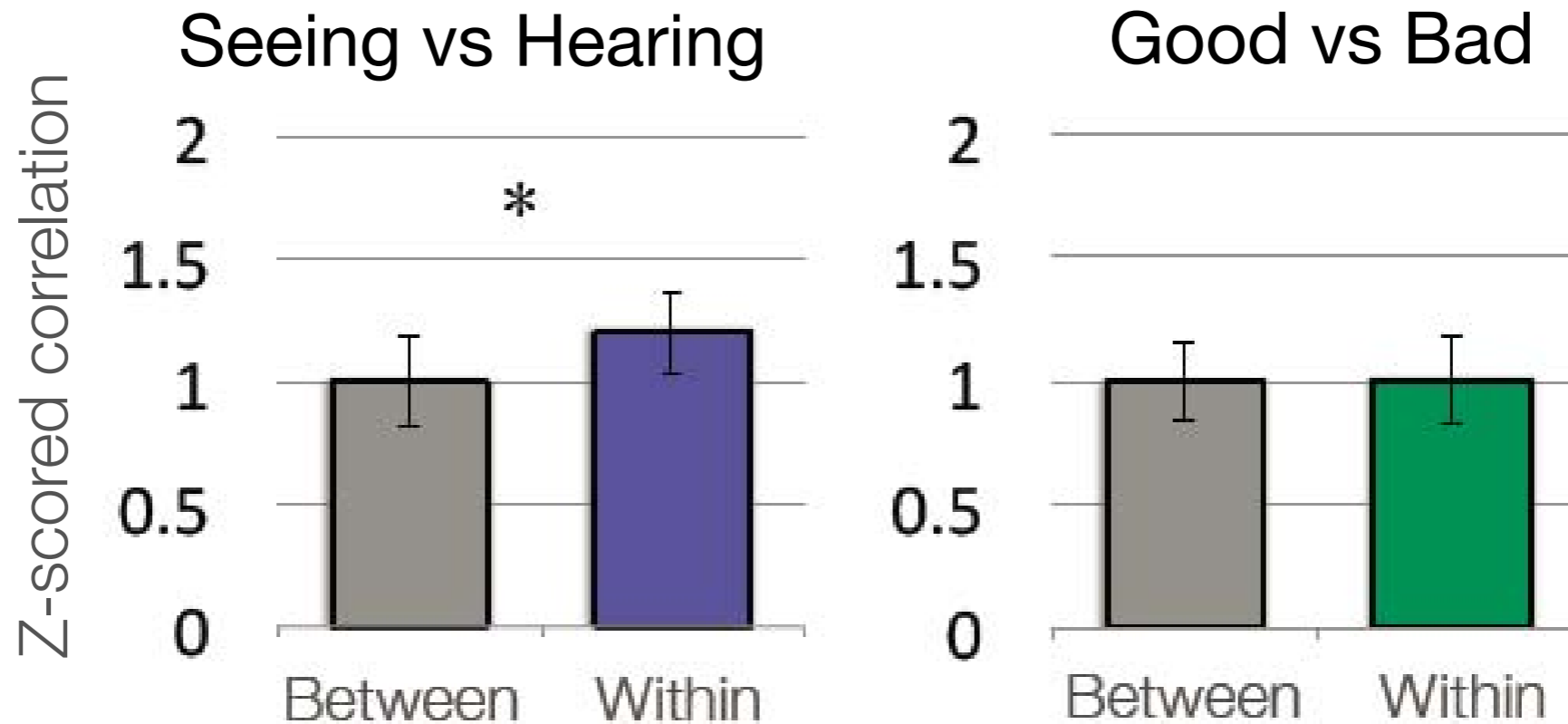
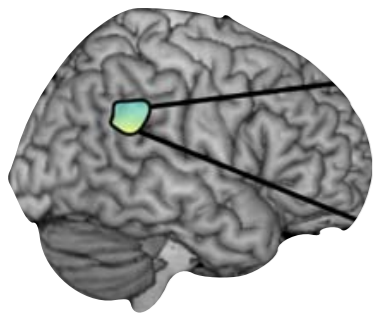


Positive

VERSION #1A

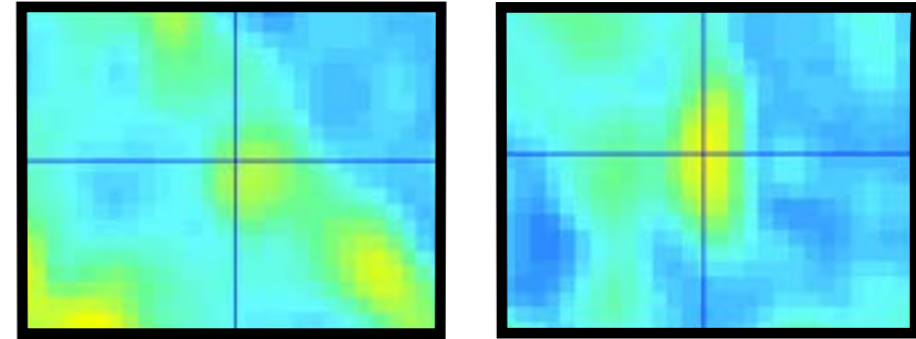
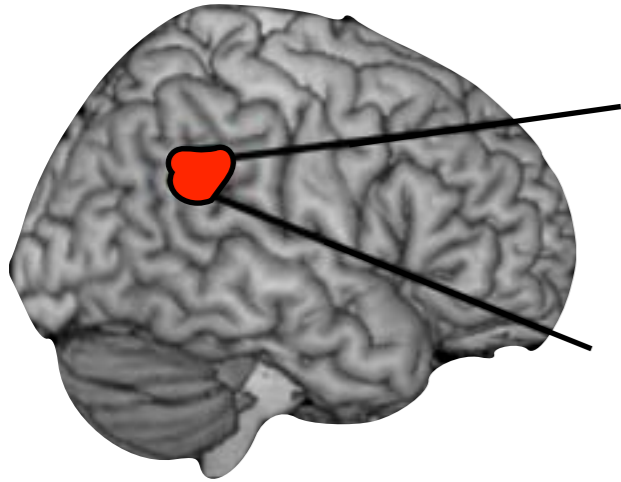
A few more Haxby style correlations

Two orthogonal differences:



FMRI & COGNITION

Beyond “involvement”



Haxby-style correlations:

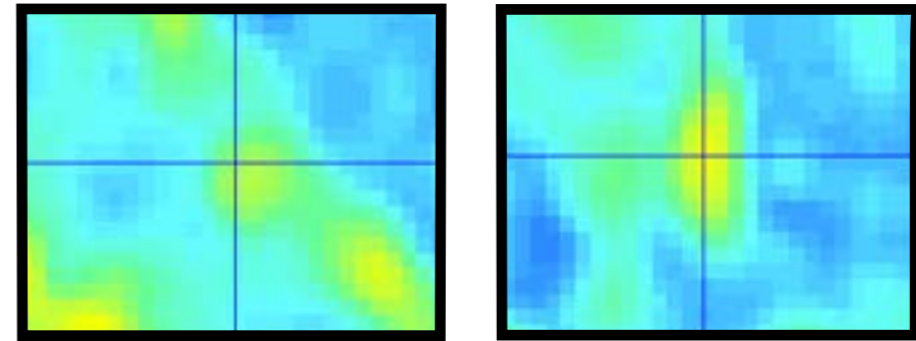
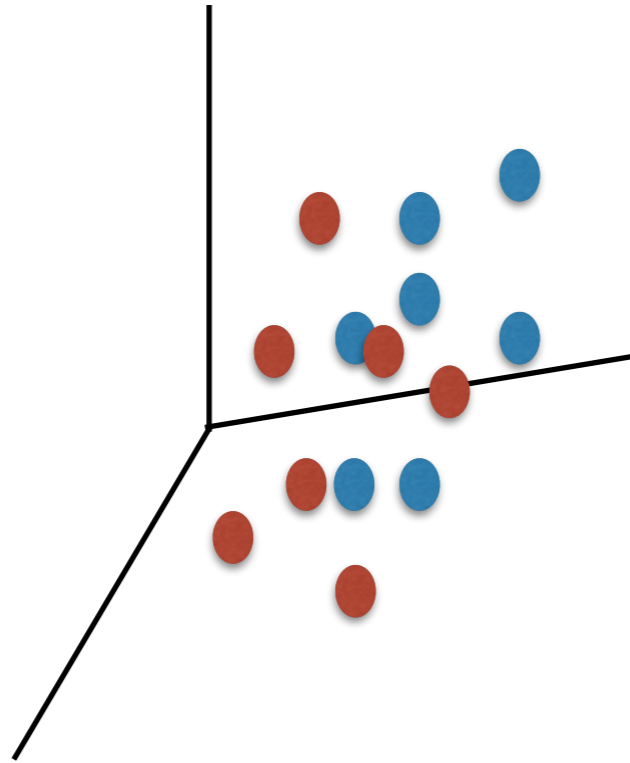
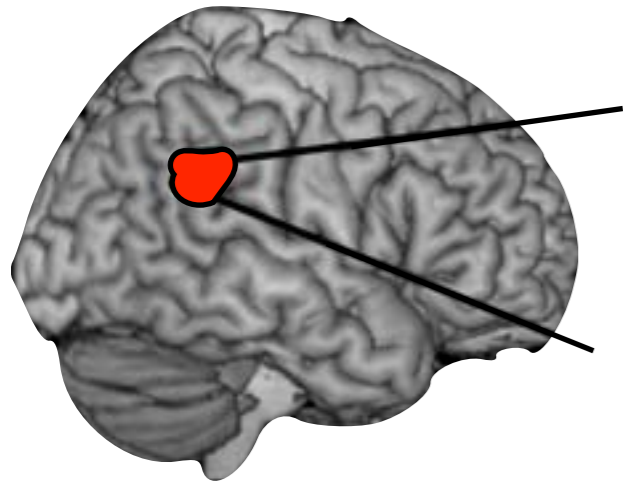
- robust but simple measure
- sensitive to minimal manipulation
- generalises across heterogeneous stimuli
- stable in participant (relates to ID)
- different across regions
- multiple orthogonal distinctions

BUT

- binary, no info about ‘why’

FMRI & COGNITION

Beyond “involvement”



More general idea:

Response pattern ->

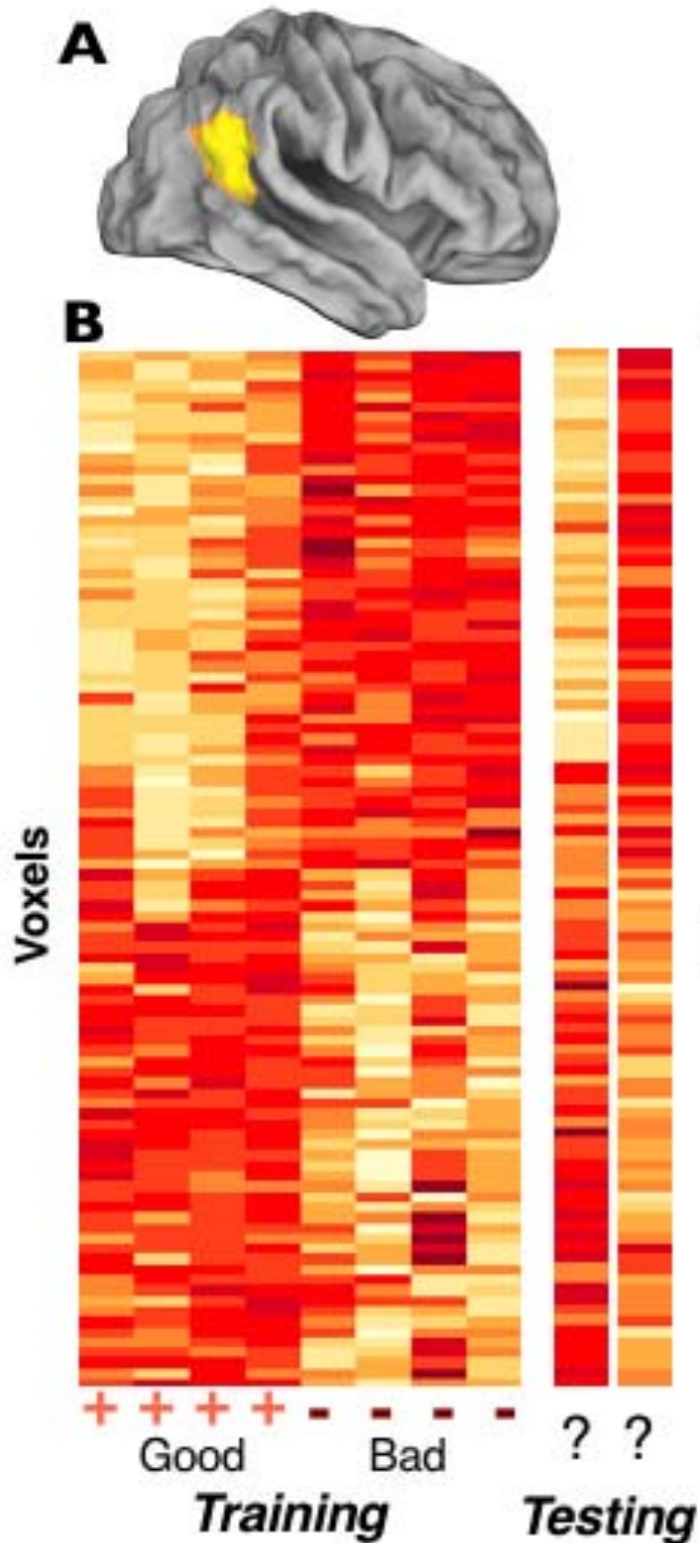
Vector ->

Point in *voxel* space

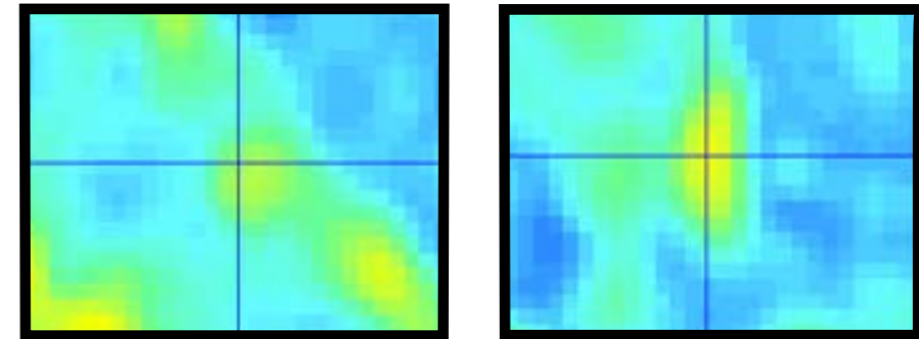
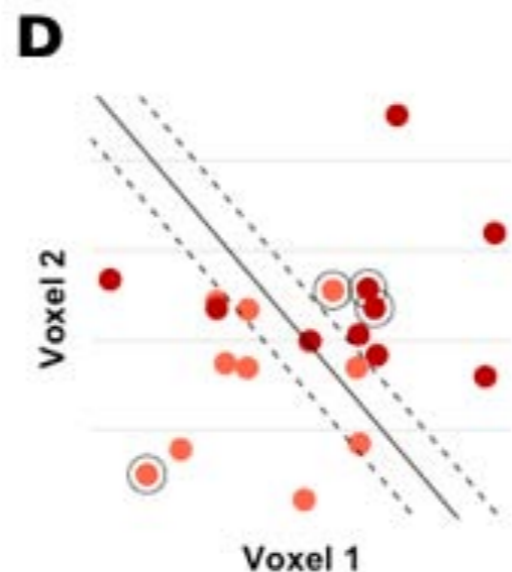
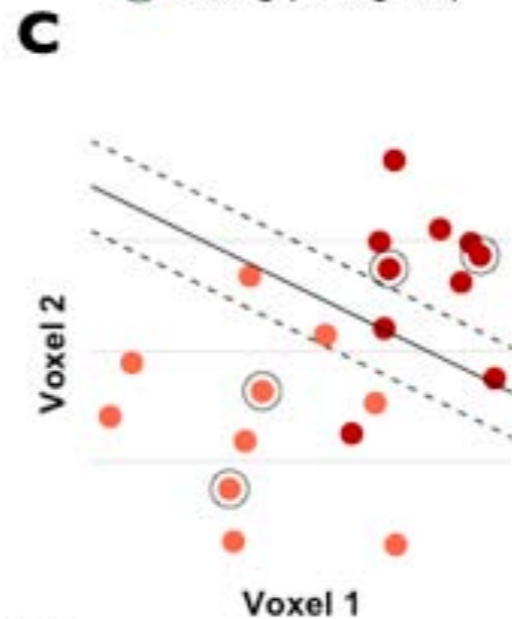
- Train classification
 - typically linear
- Independent test trials

VERSION #2

Classifying single trials



- Training (Seeing Good)
- Training (Seeing Bad)
- Testing (Seeing Good)
- Testing (Seeing Bad)



More general idea:

Response pattern ->

Vector ->

Point in *voxel* space

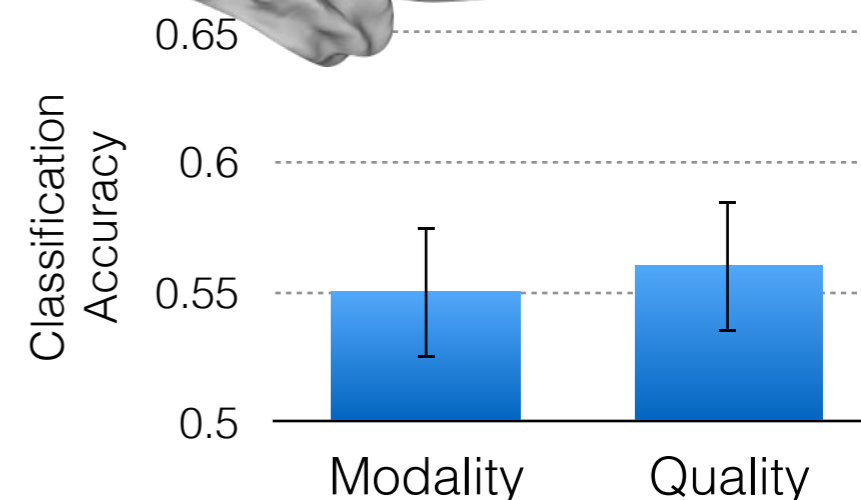
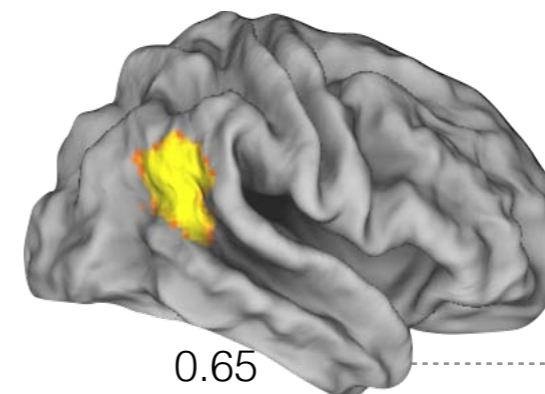
- Train classification
 - typically linear
- Independent test trials

DV: classification accuracy

VERSION #2

Classifying single trials

Bella poured the sleeping potion into Ardwin's soup and went into the next room, where her sister, Jen, was waiting. They held their breaths while Ardwin started to eat.



Modality Quality

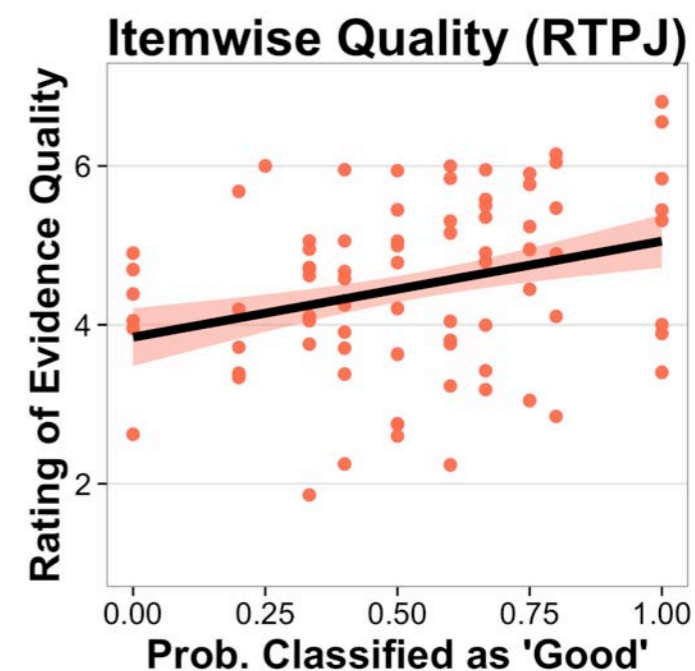
Bella stared through the secret peep hole and waited. In the bright light, Bella saw his eyes close and his head droop.

Bella pressed her ear against the door and waited. In the sudden quiet, Bella heard the spoon drop and a soft snore.

Bella tried to peer through a crack in the door. In the very dim light, Bella squinted to see his eyes close.

Bella grinned from ear to ear. "The potion worked!" she exclaimed.

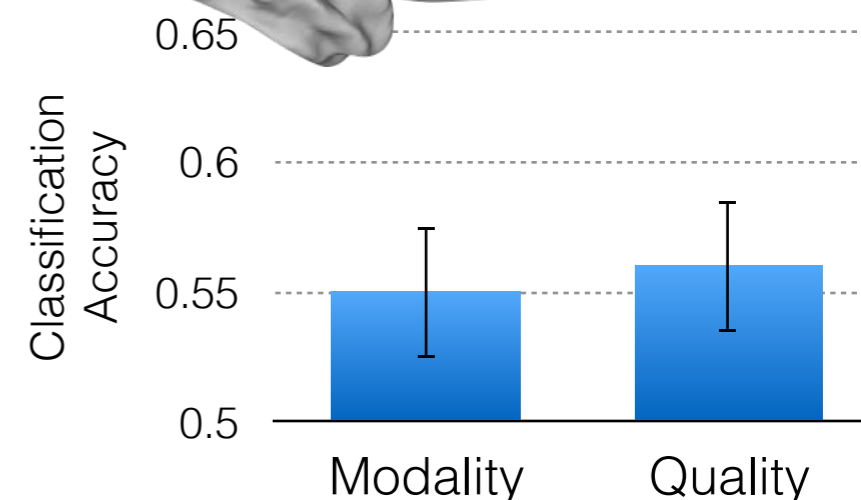
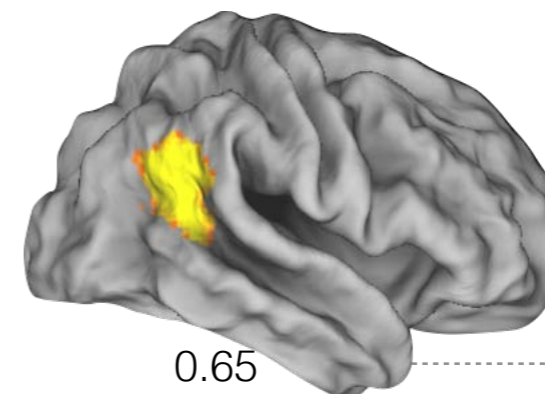
Not binary:



VERSION #2

Classifying single trials

Bella poured the sleeping potion into Ardwin's soup and went into the next room, where her sister, Jen, was waiting. They held their breaths while Ardwin started to eat.



Modality

Quality

Bella stared through the secret peep hole and waited. In the bright light, Bella saw his eyes close and his head droop.

Bella pressed her ear against the door and waited. In the sudden quiet, Bella heard the spoon drop and a soft snore.

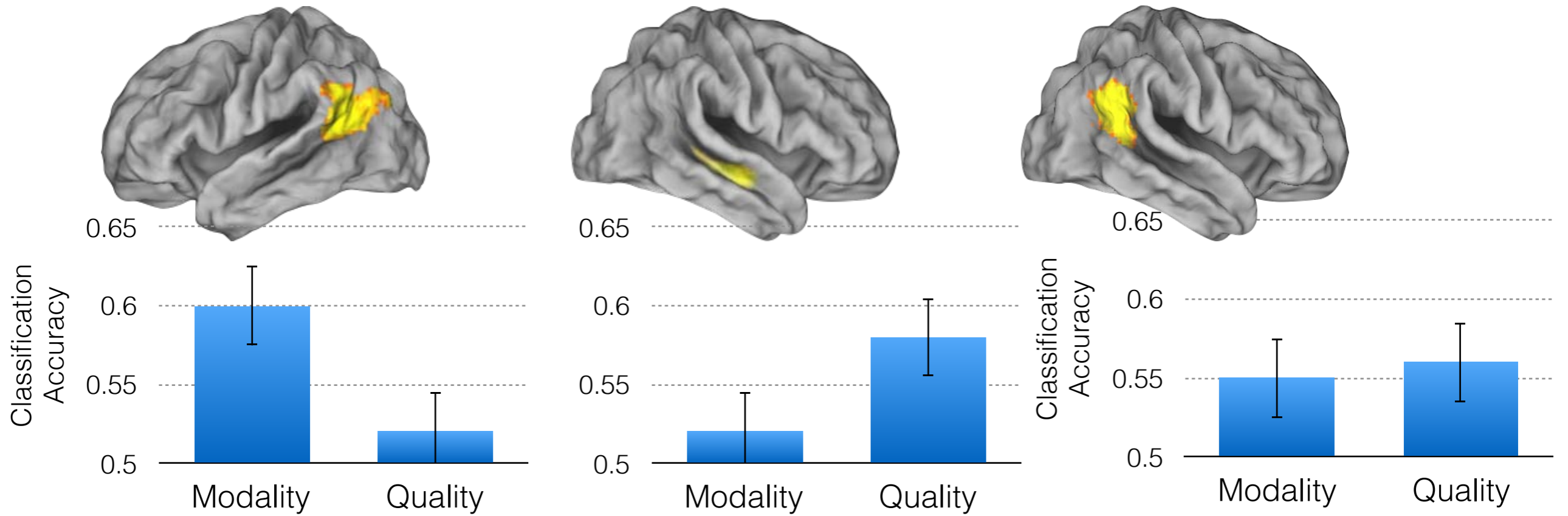
Bella tried to peer through a crack in the door. In the very dim light, Bella squinted to see his eyes close.

Bella grinned from ear to ear. "The potion worked!" she exclaimed.

Not binary
Not redundant

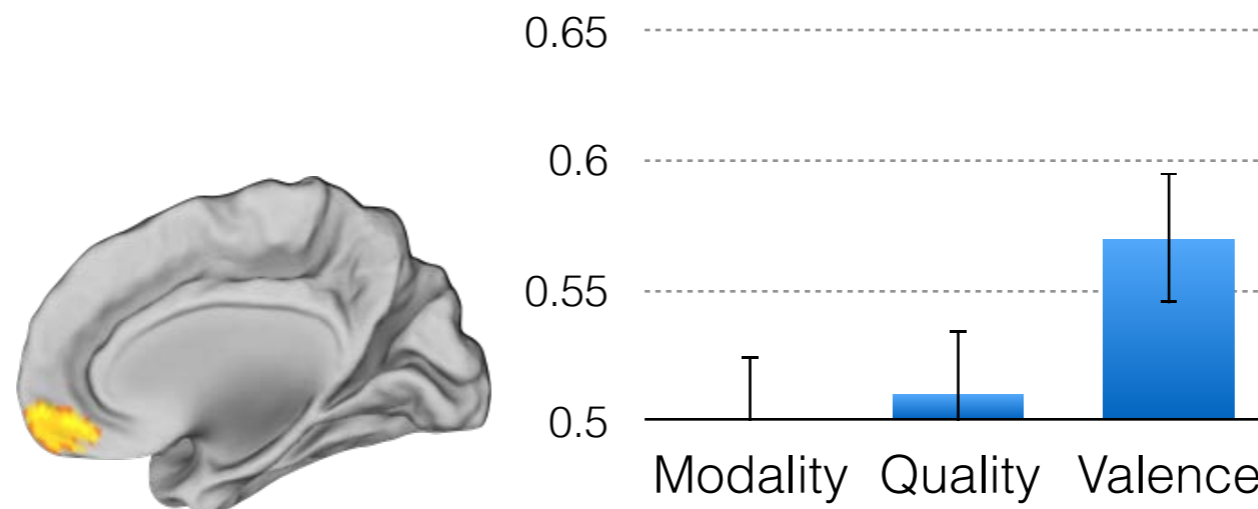
VERSION #2

Classifying single trials



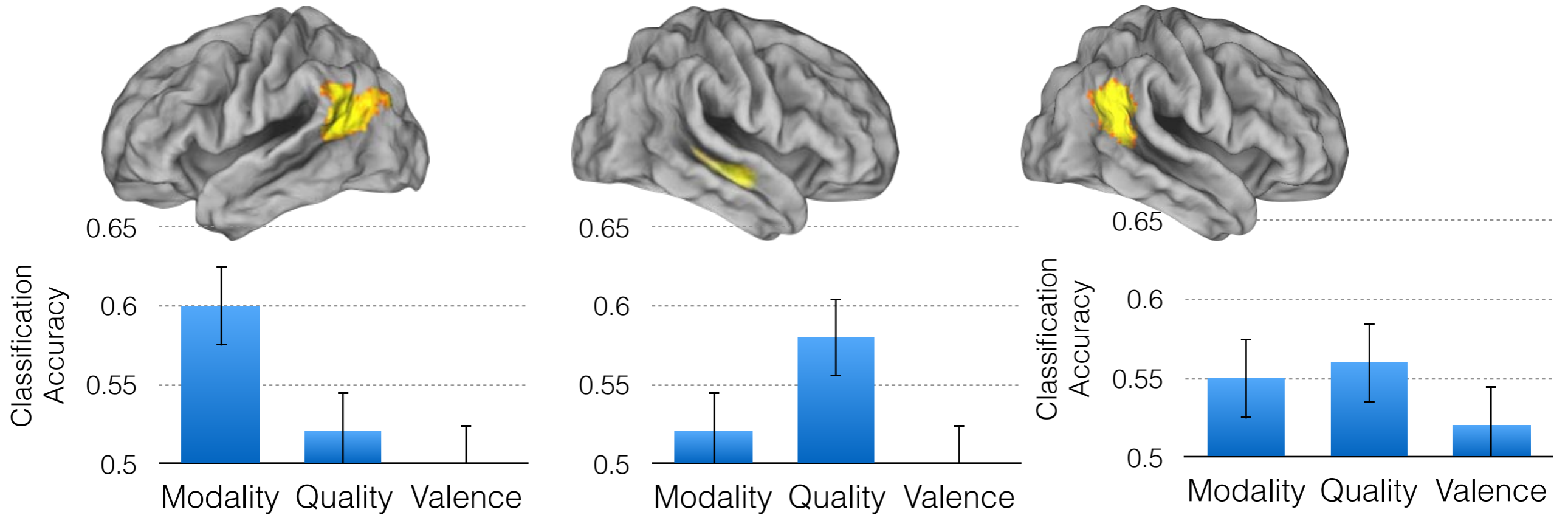
Distinct information across regions

Not binary
Not redundant



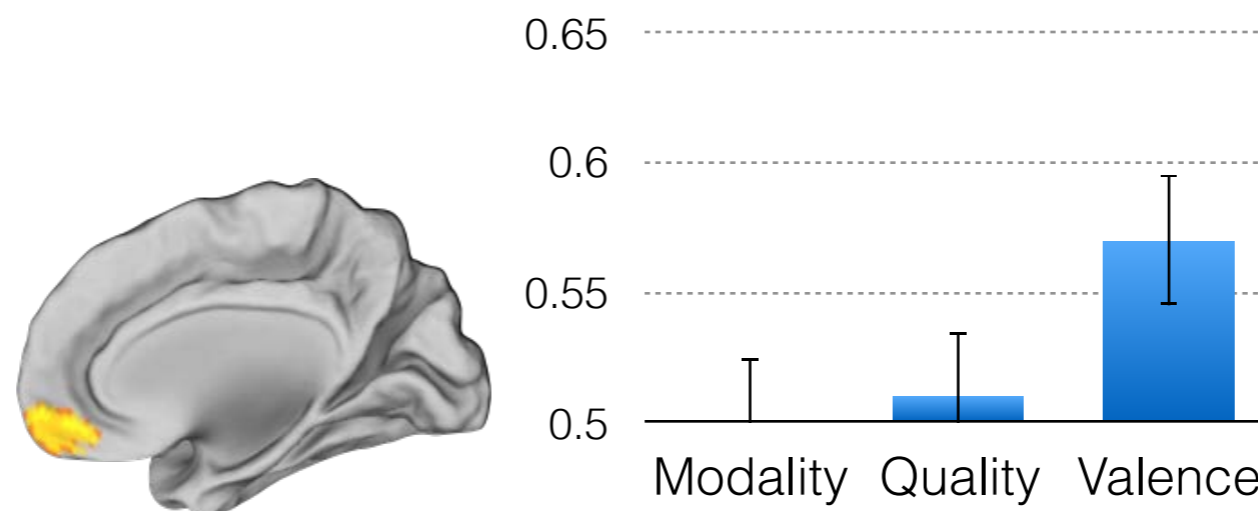
VERSION #2

Classifying single trials



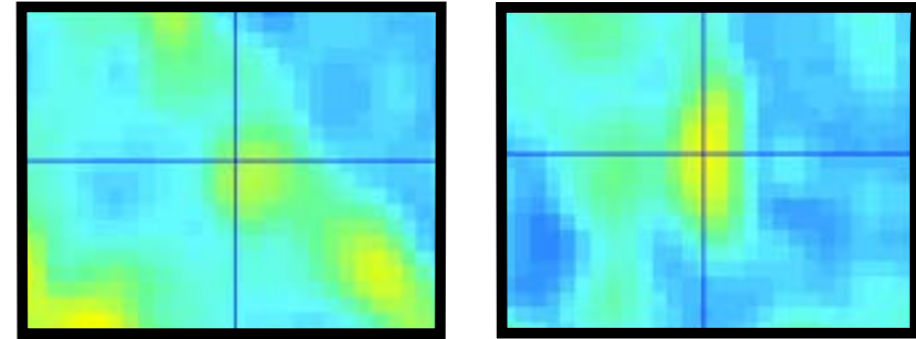
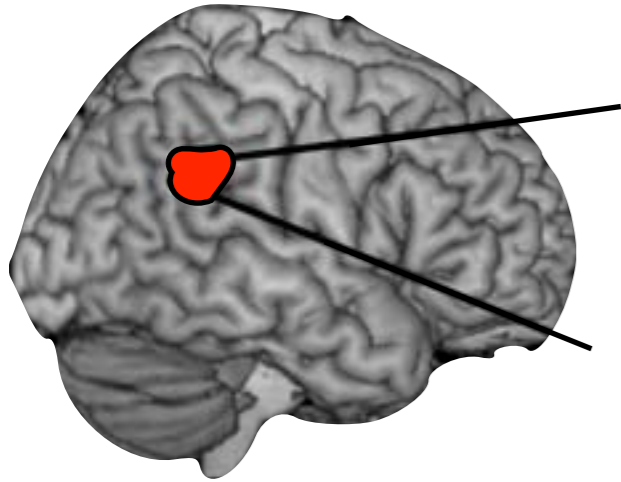
Distinct information across regions

Not binary
Not redundant



FMRI & COGNITION

Beyond “involvement”



Classification analyses

- sensitive to minimal manipulation
- generalises across heterogeneous stimuli
- different across regions
- multiple orthogonal distinctions
- item-specific, continuous (not binary)

BUT

- tests hypotheses / features *sequentially*

VERSION #3

Representational (dis)similarity matrices

After an 18 hour flight, Alice arrived at her vacation destination to learn that her baggage (including necessary camping gear for her trip) hadn't made the flight. After waiting at the airport for 2 nights, Alice was informed that the airline had lost her luggage altogether and wouldn't provide any compensation.

Sarah swore to her roommates that she would keep her new diet. Later, she was in the kitchen getting a glass of water, and took a bite of a cake she had bought for their dinner party the following evening. Sarah's roommates arrived home to find that she had eaten half the cake and broken her diet.

For the months before her marathon, Dianne trained even harder than usual, running extra miles and adding strenuous weight sessions at the gym. Dianne hoped to shave at least 10 minutes off of her previous best of 3:14. On race day, she came in 23rd in her age group with a new personal record of 2:46.

Brenda was texting while driving. She went through a red light and hit a boy on a bike. She jumped out of the car to see if the boy was okay. He had a couple scrapes, but, somehow, was otherwise okay. Brenda put away her phone and vowed to never text while driving again.

20 AFC

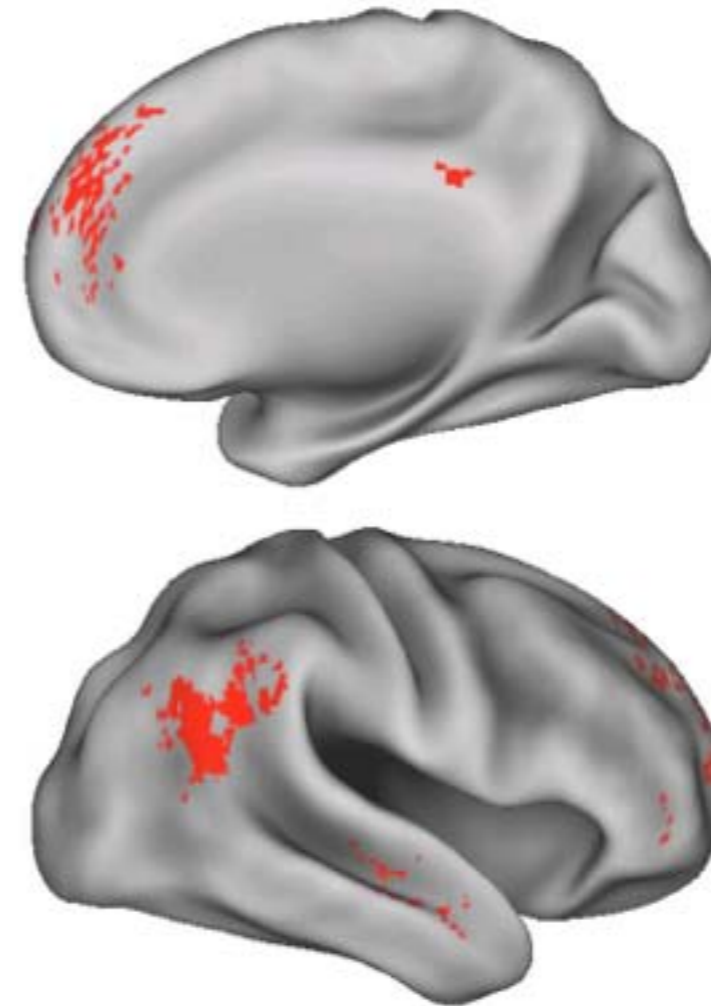
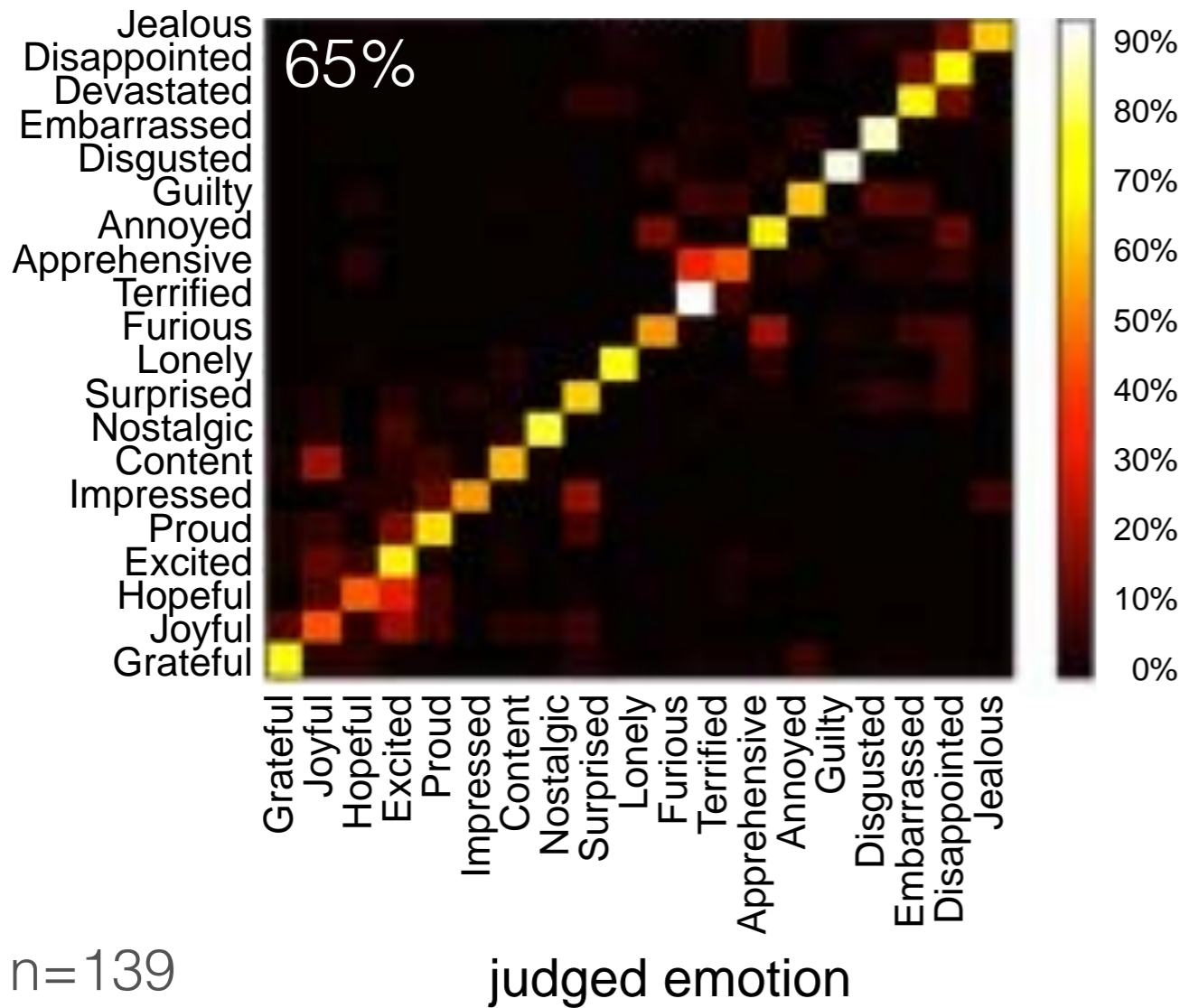
Jealous
Disappointed
Devastated
Embarrassed
Disgusted
Guilty
Annoyed
Apprehensive
Terrified
Furious
Lonely
Surprised
Nostalgic
Content
Impressed
Proud
Excited
Hopeful
Joyful
Grateful

VERSION #3

Representational (dis)similarity matrices

Whole brain searchlight

Confusion Matrix (Behavioral)



Sig. Class 

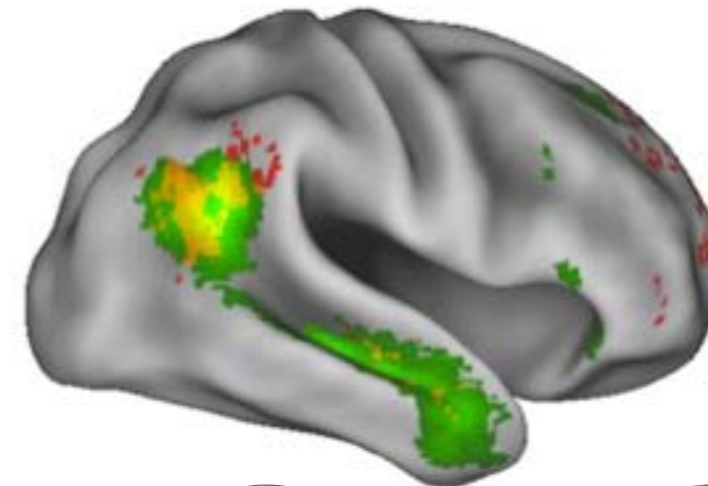
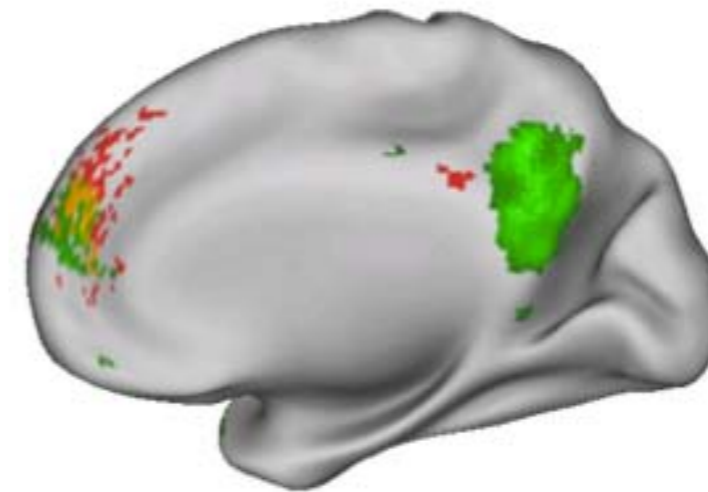
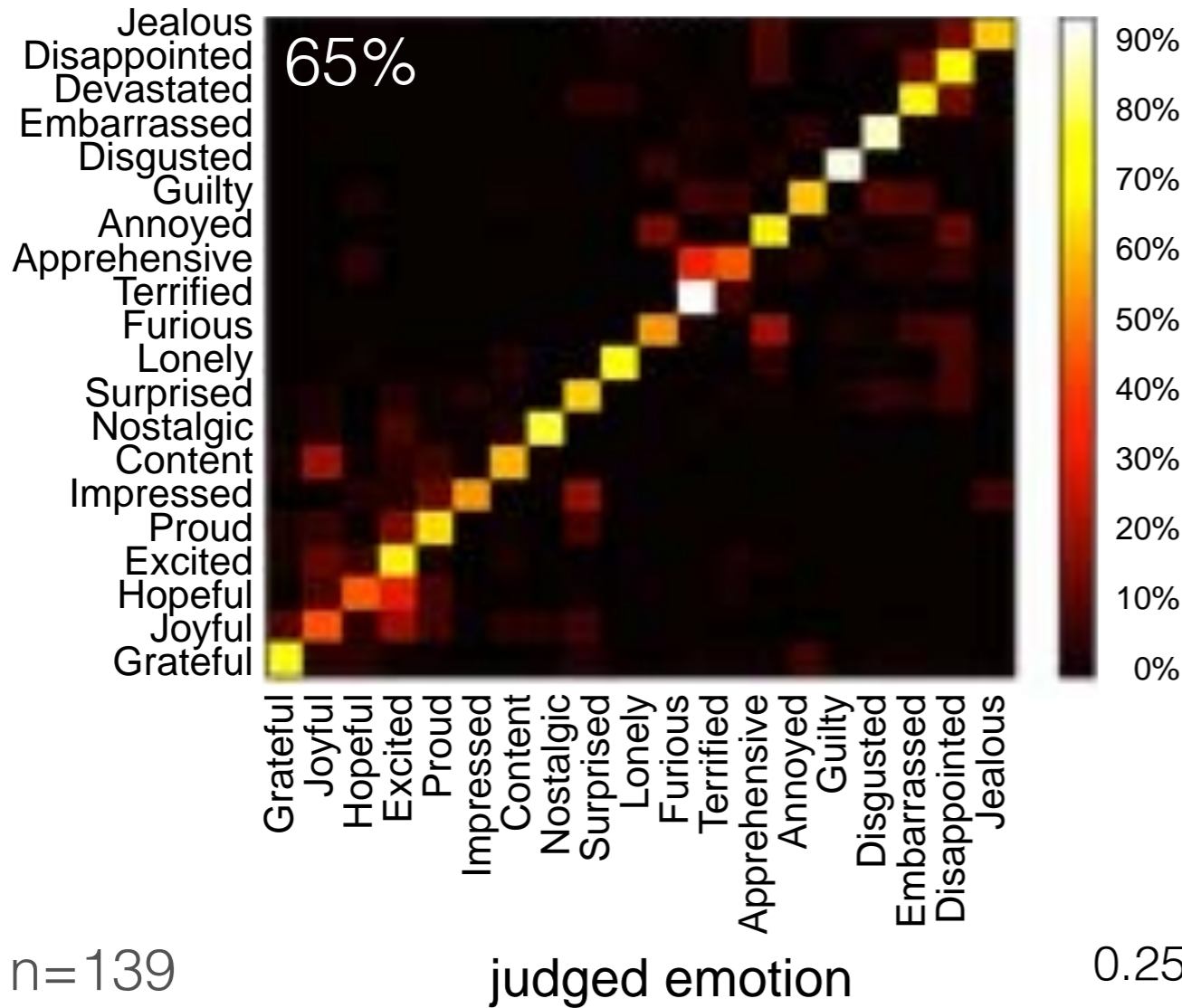
n=22
FWE $p < .05$, $k > 25$

VERSION #3

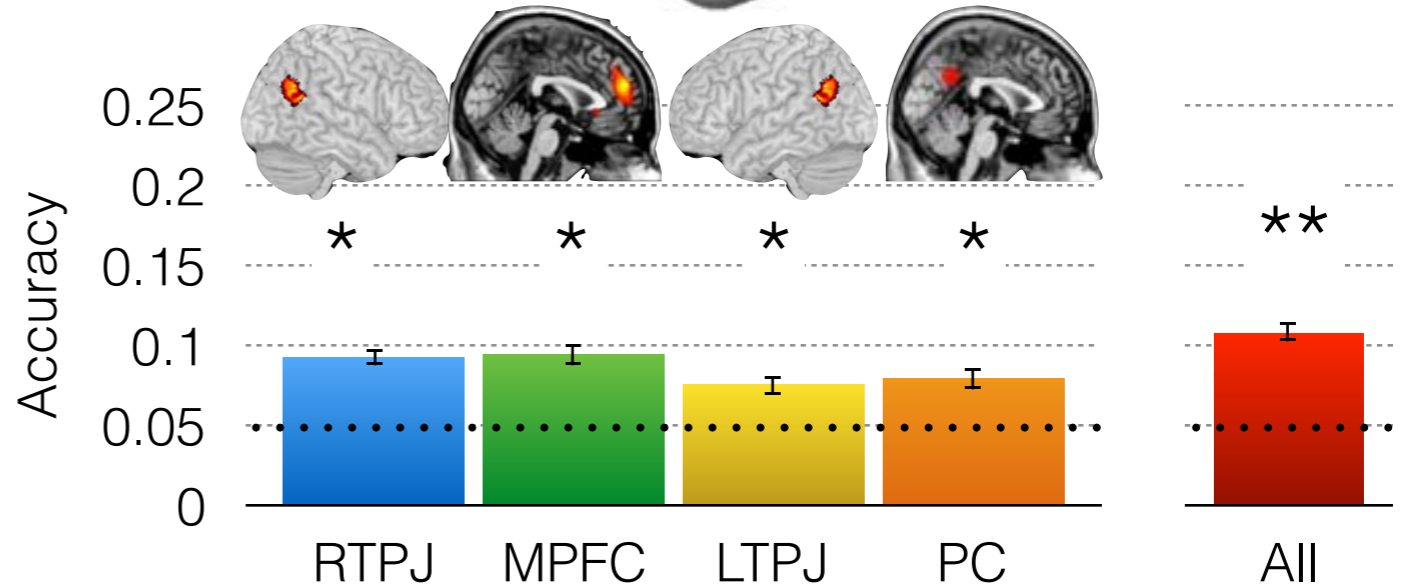
Representational (dis)similarity matrices

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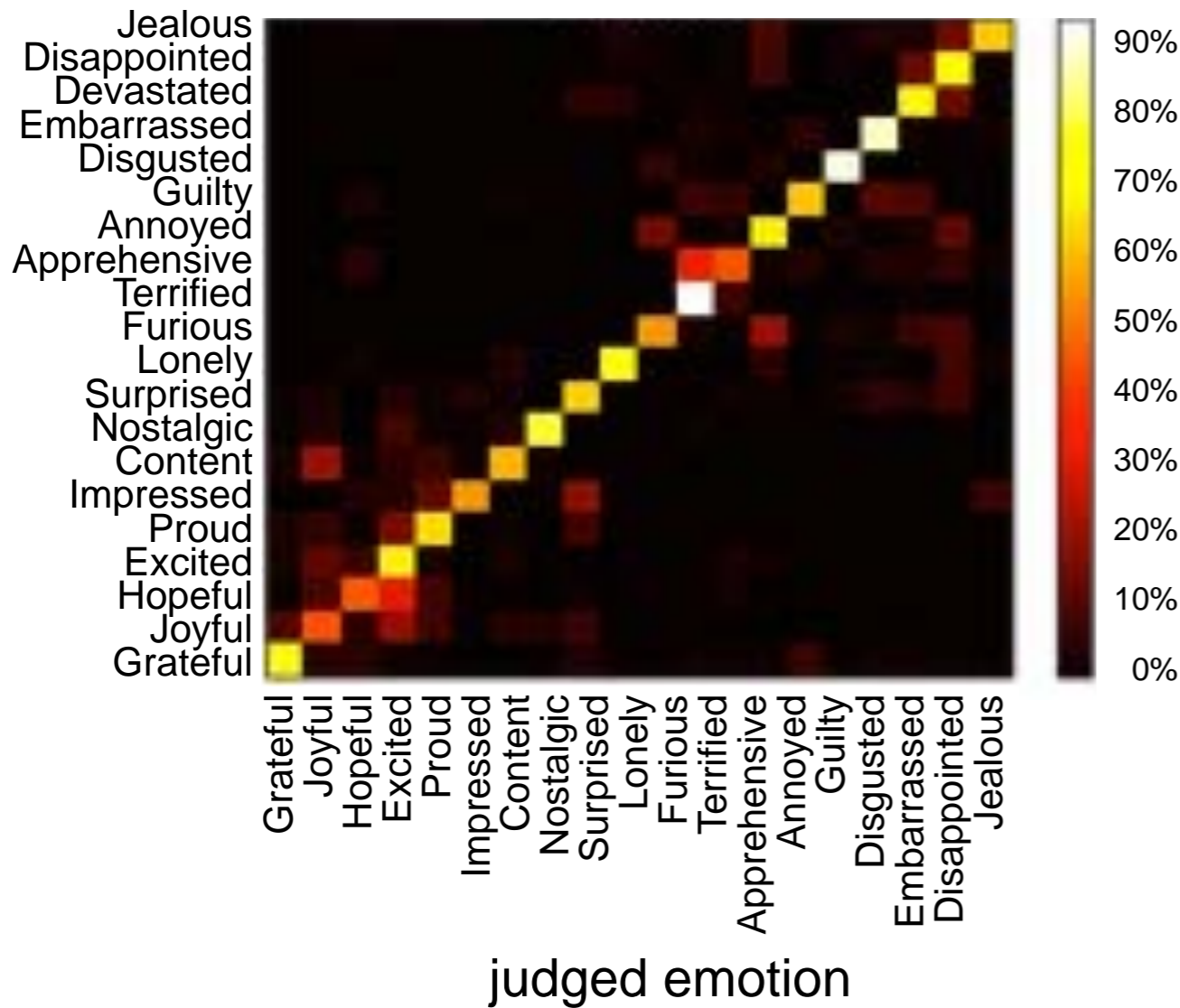
n=22
FWE $p < .05$, $k > 25$



VERSION #3

Representational (dis)similarity matrices

Confusion Matrix (Behavioral)



Representation

After an 18 hour flight, Alice arrived at her vacation destination to learn that her baggage (including necessary camping gear for her trip) hadn't made the flight. After waiting at the airport for 2 nights, Alice was informed that the airline had lost her luggage altogether and wouldn't provide any compensation.

Event features

Was this situation caused by a person or some other external force?

Was this situation caused by Alice herself?

Does the situation refer to something in her past?

Was Alice interacting with people?

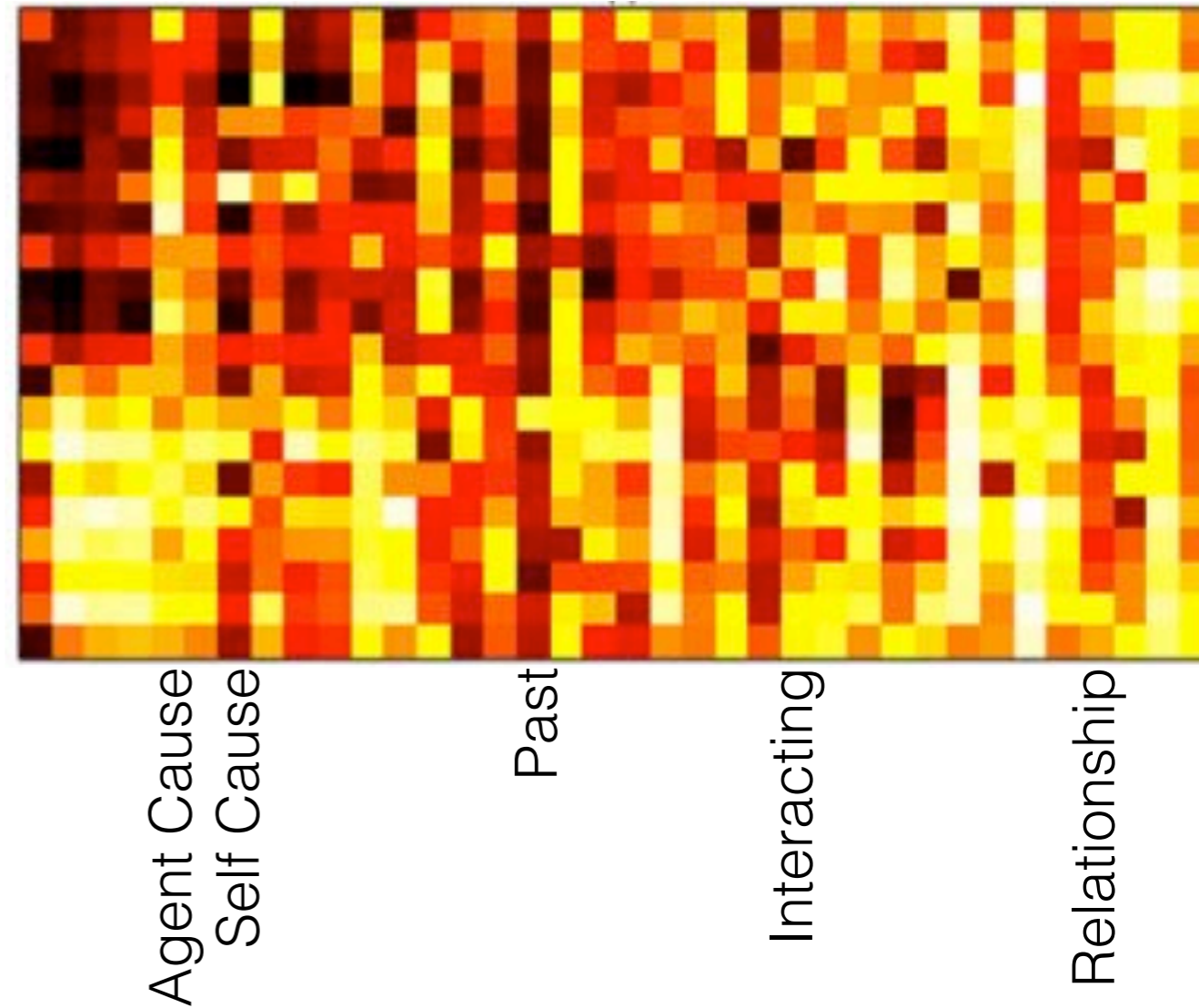
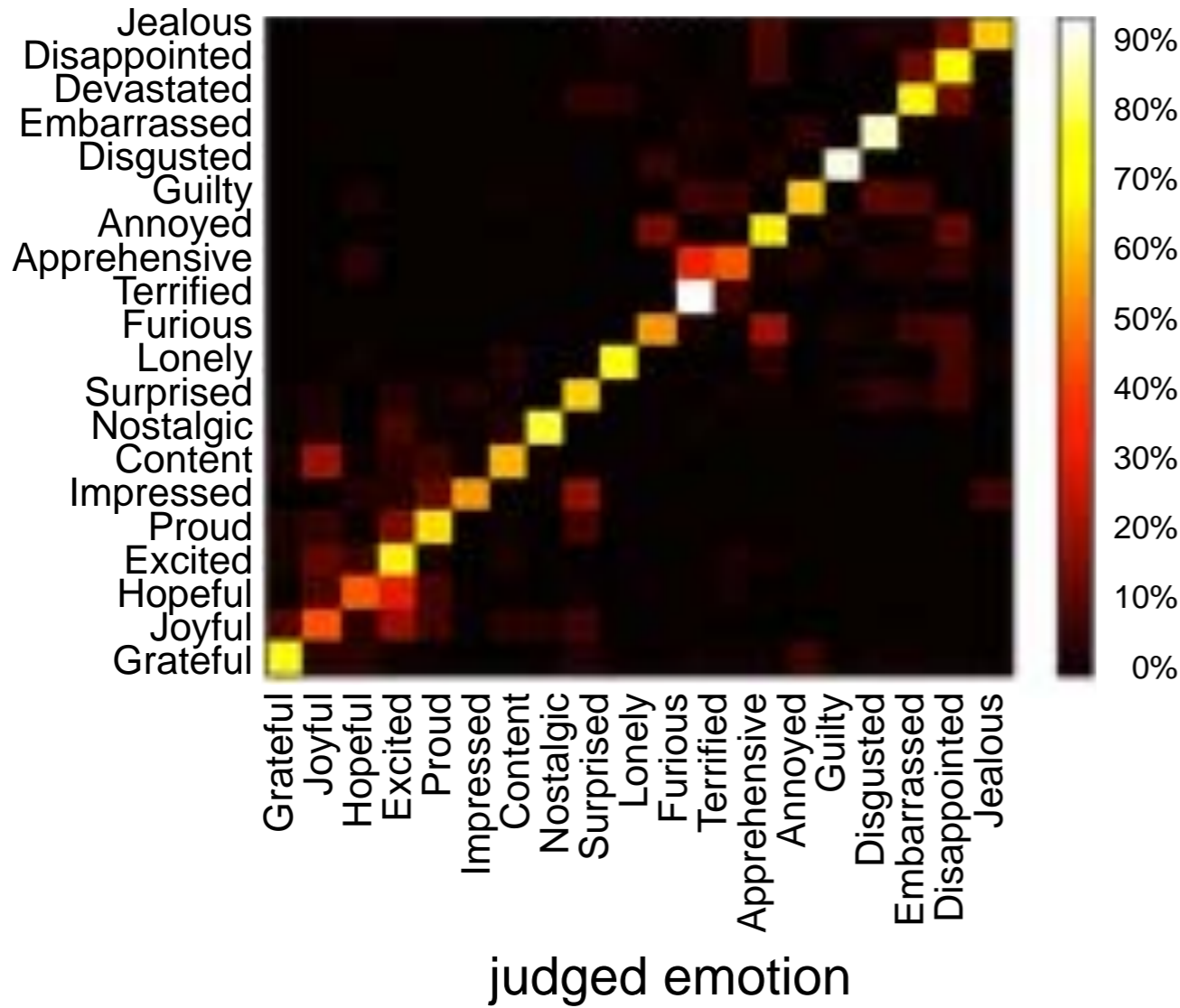
Did this situation affect her relationships with other people?

...

VERSION #3

Representational (dis)similarity matrices

Confusion Matrix (Behavioral)

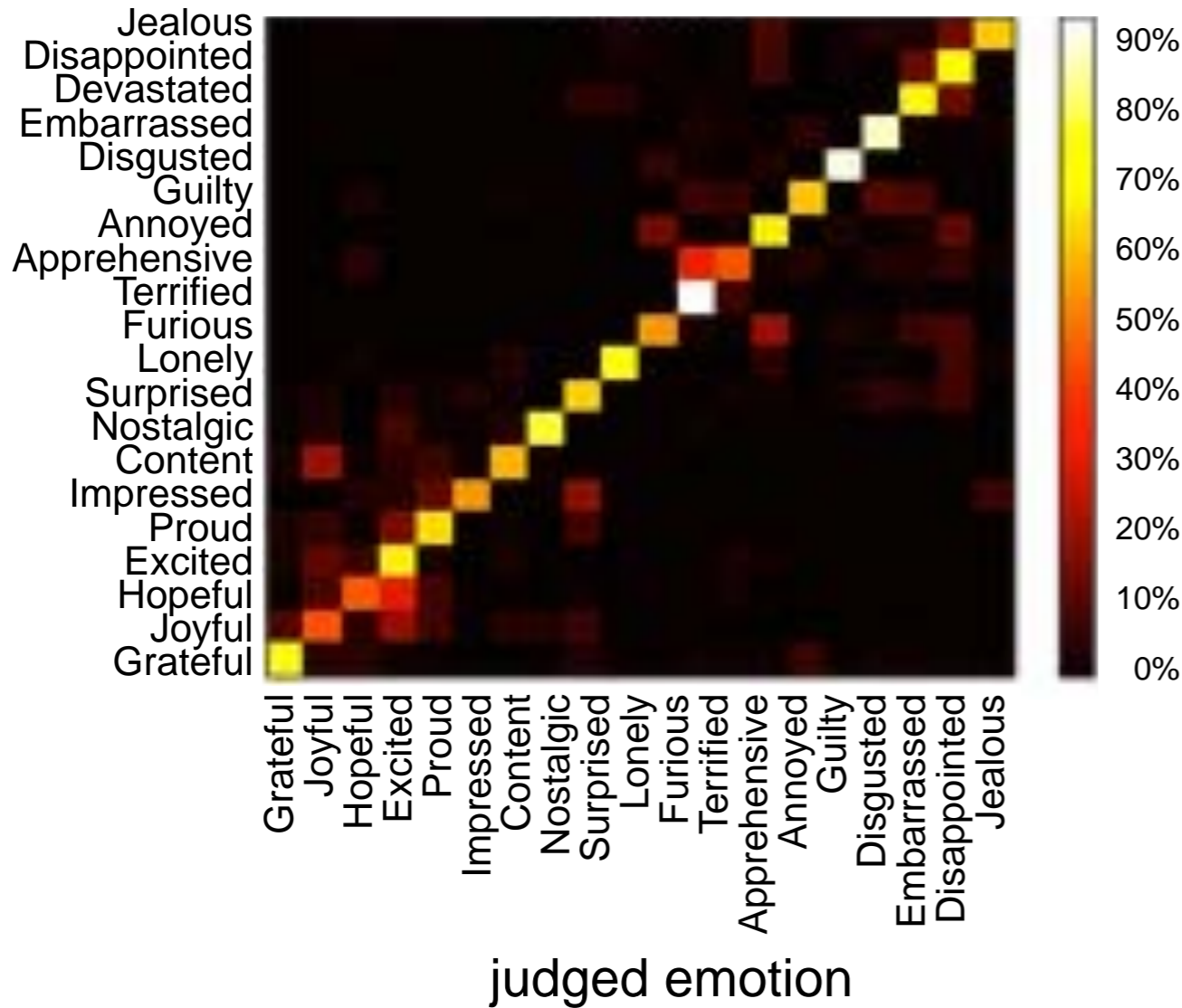


38 appraisal features

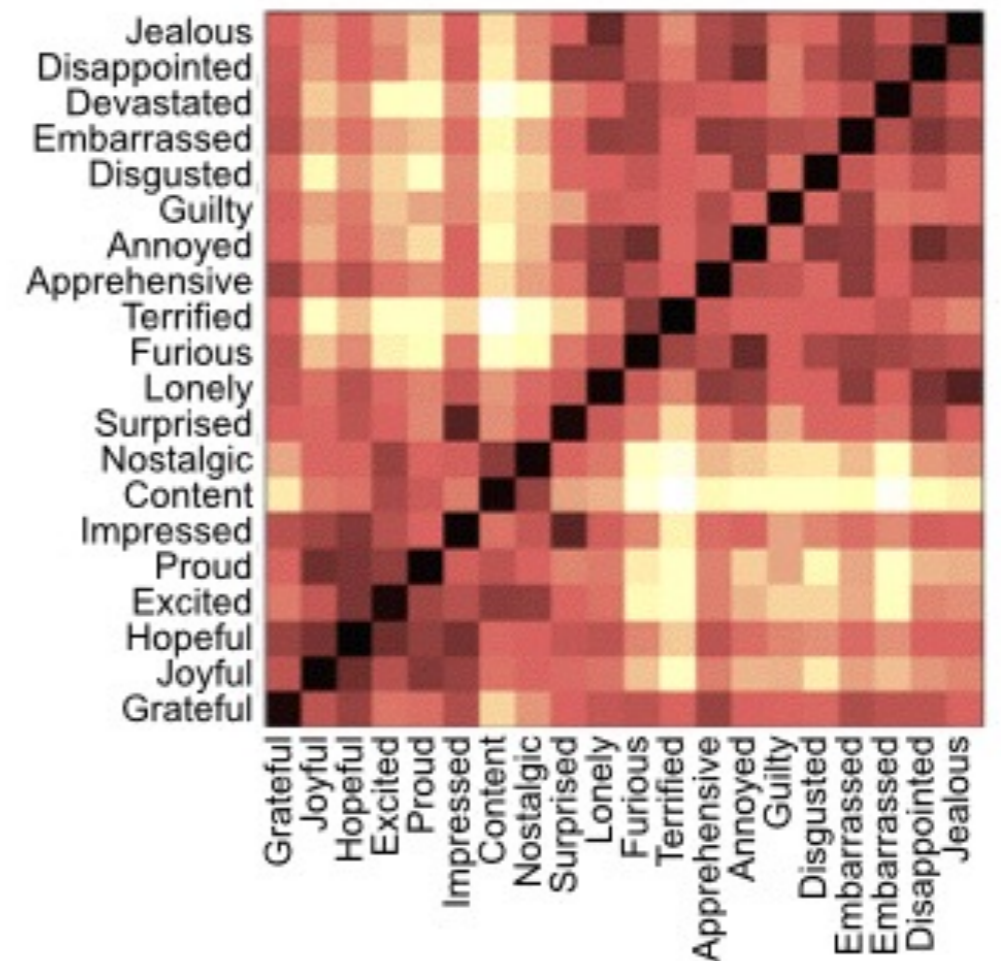
VERSION #3

Representational (dis)similarity matrices

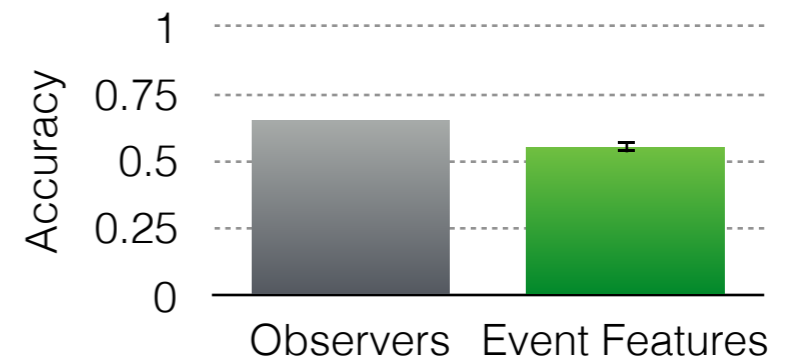
Confusion Matrix (Behavioral)



Representational dissimilarity

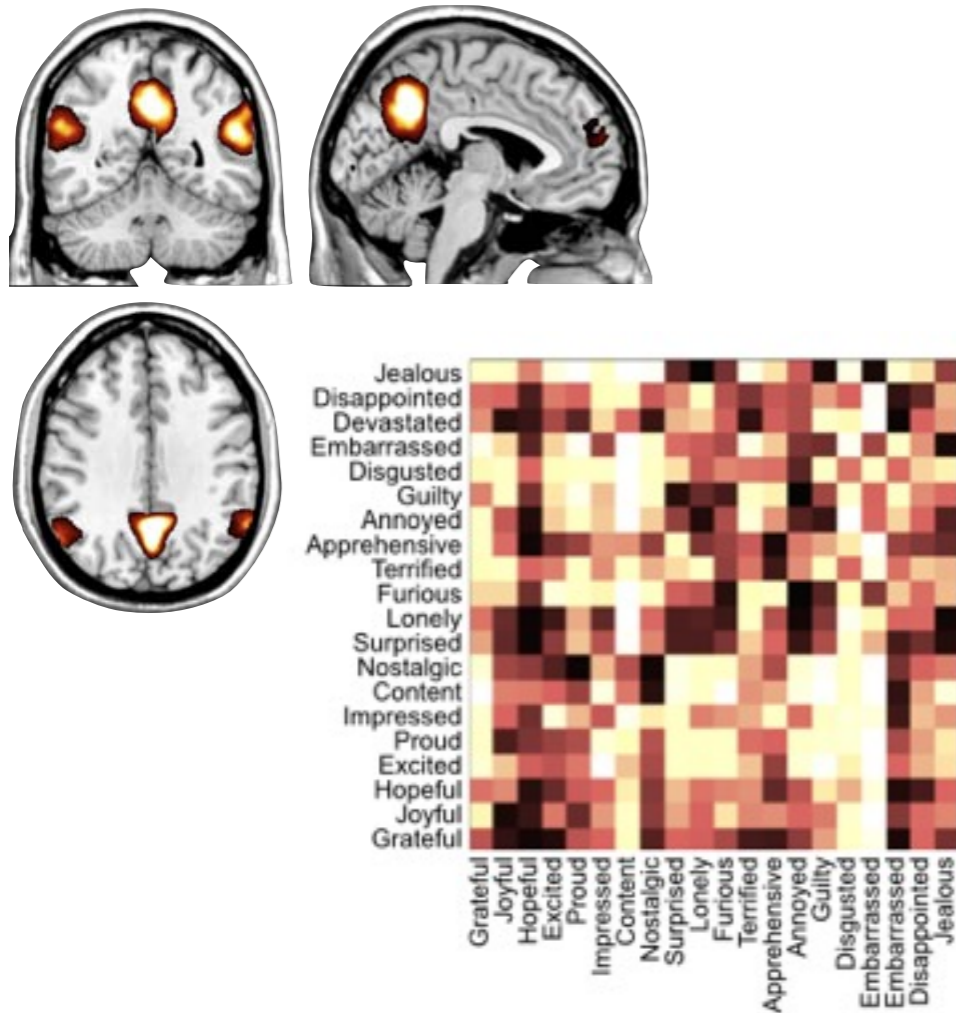


Classification of test stories

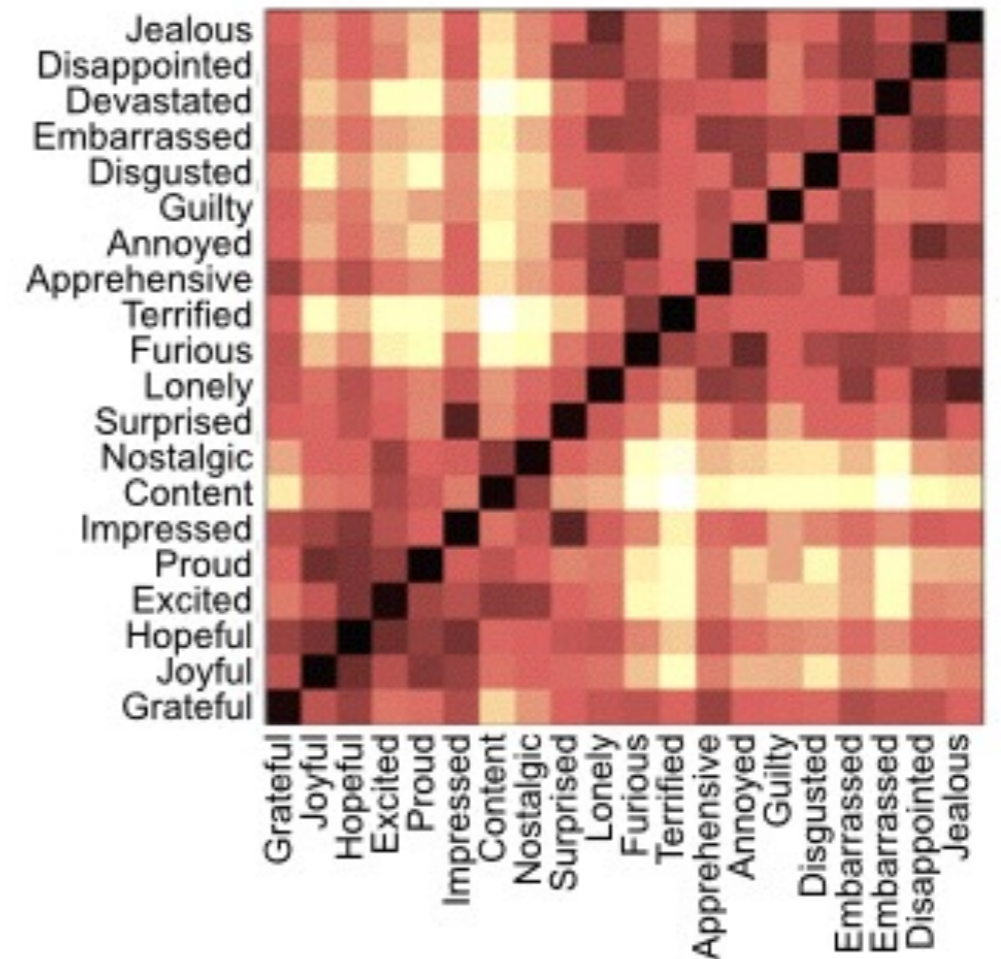


VERSION #3

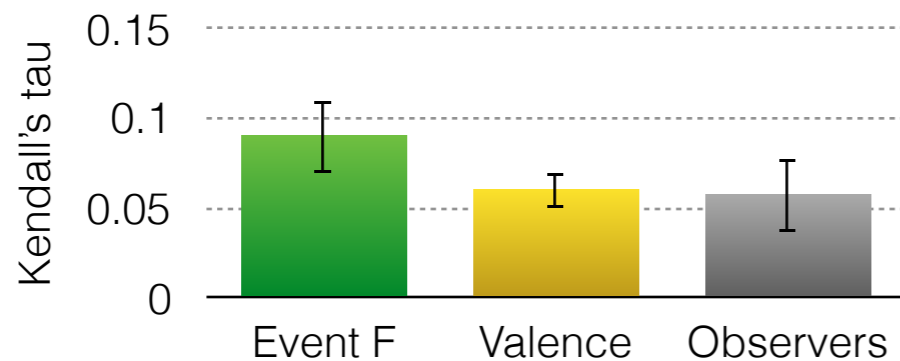
Representational (dis)similarity matrices



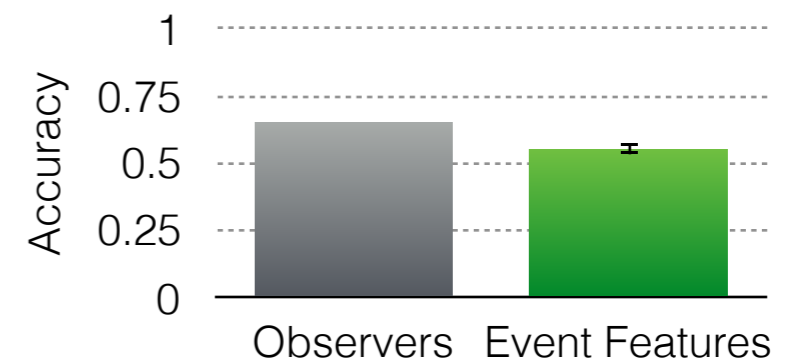
Representational dissimilarity



Correlation to neural RDM

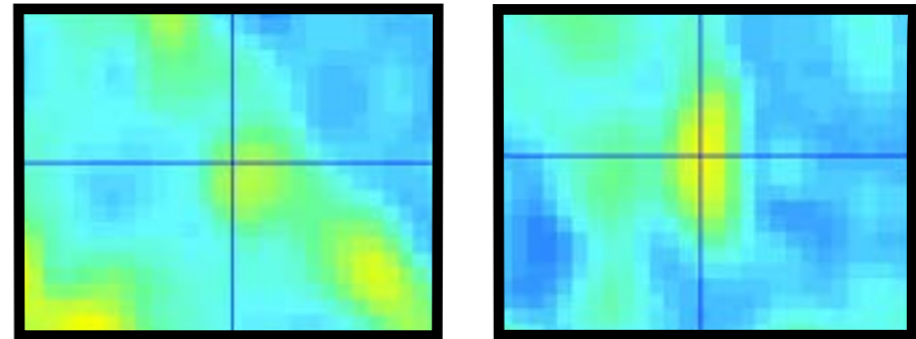
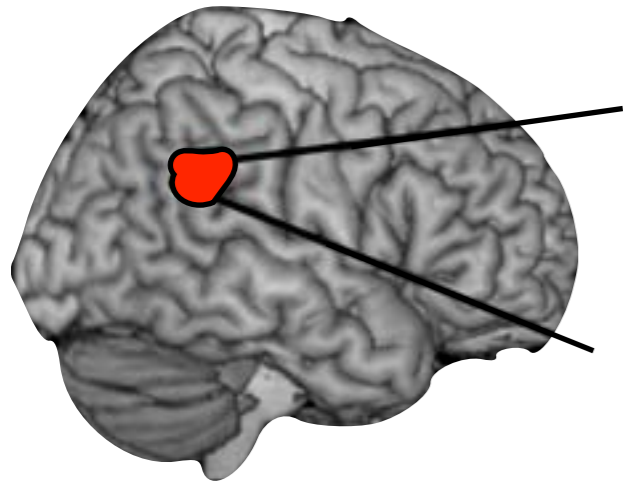


Classification of test stories



FMRI & COGNITION

Beyond “involvement”



RDM analyses

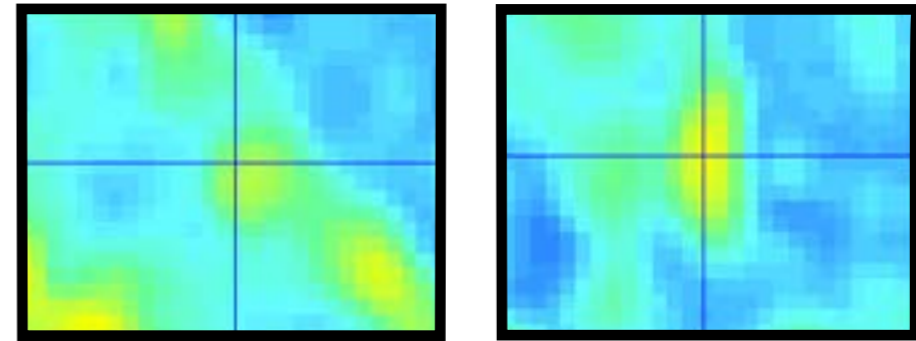
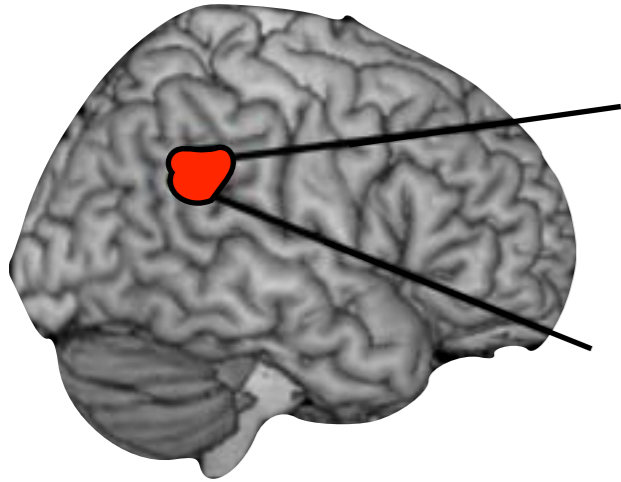
- parameter free fit
- models of different complexity
- sensitive to overall “structure” of representation
- direct comparison of multiple hypotheses

BUT

- less info about specific features

FMRI & COGNITION

Beyond “involvement”



Traditional analysis

Univariate

avg magnitude across voxels

“Forward” / “Encoding” direction

Region scale

Stimulus “Type”

“MVPA” analysis

Multivariate

relative magnitude across voxels

“Reverse” / “Decoding” direction

Sub-region scale

Within type features

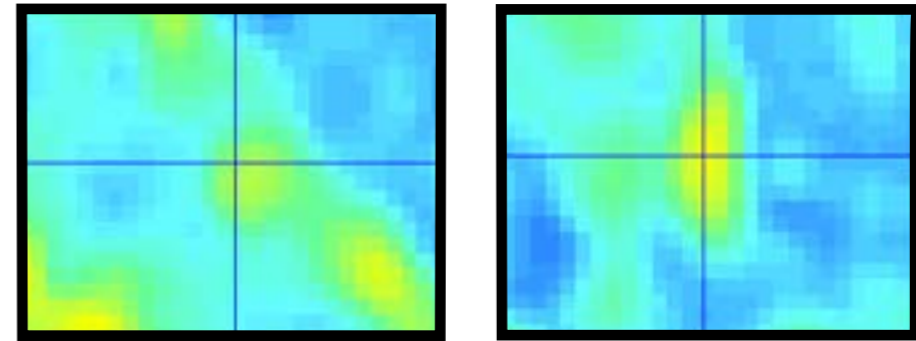
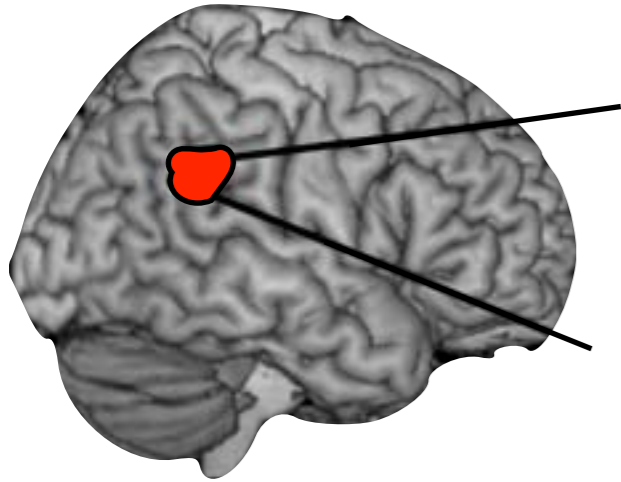
Key problems:

Null results

Theory of concepts

FMRI & COGNITION

Beyond “involvement”



Traditional analysis

Univariate

avg magnitude across voxels

“Forward” / “Encoding” direction

Region scale

Stimulus “Type”

“MVPA” analysis

Multivariate

relative magnitude across voxels

“Reverse” / “Decoding” direction

Sub-region scale

Within type features

Future Applications

Conceptual change in children

Combine with dynamics

THANKS



Funding

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John Merck Fellows Program

Ellison Medical Foundation

Simons Foundation

ONR

NSF CAREER

NIH RO1

DARPA

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Resource: Brains, Minds and Machines Summer Course
Tomaso Poggio and Gabriel Kreiman

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