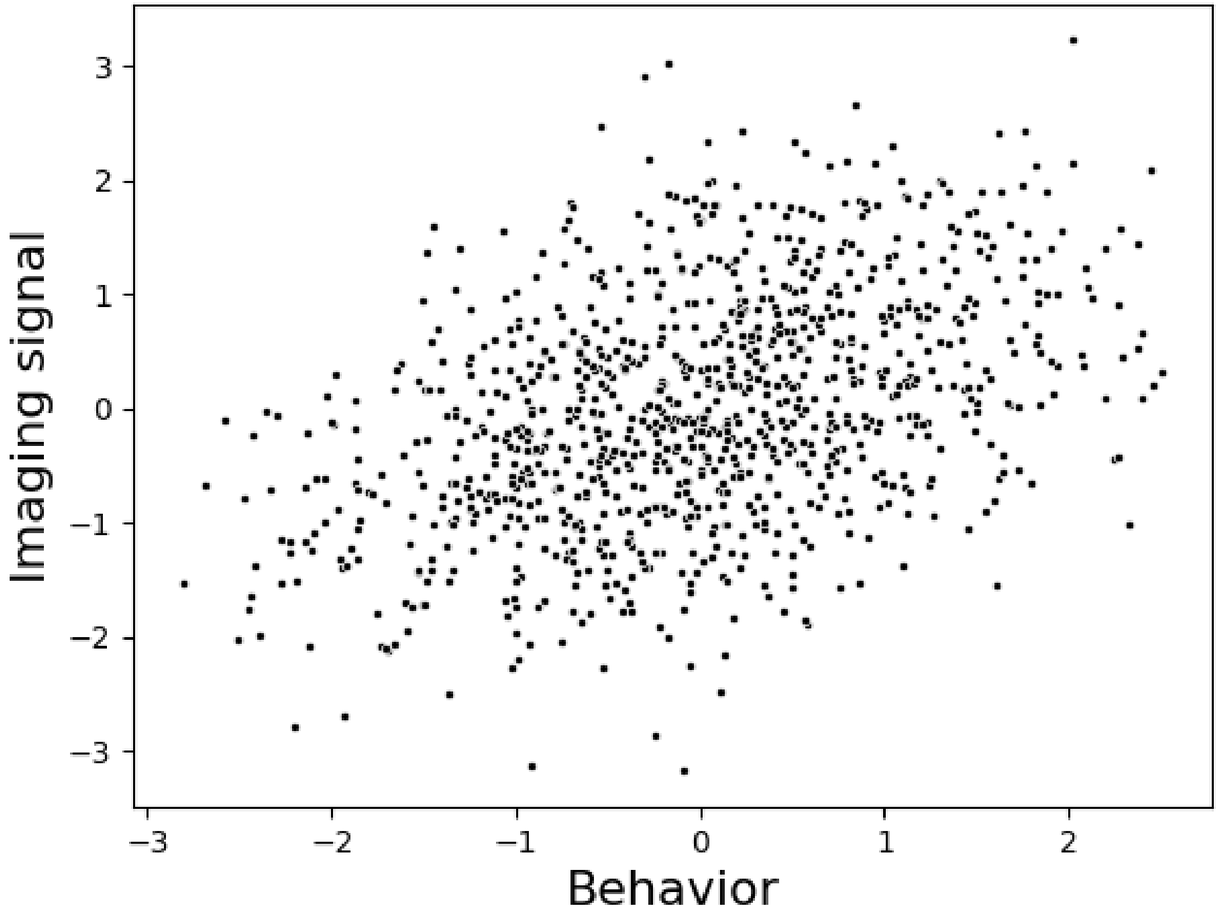
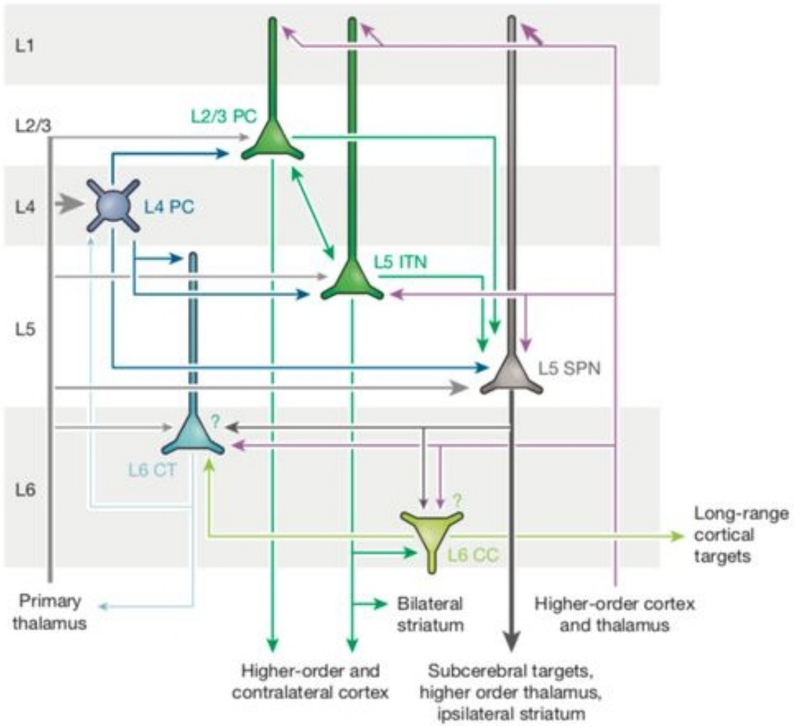
Improving the interpretability and validity of brain-behavior relations

Russ Poldrack
Stanford University

What do correlations between brain function/structure and behavior mean?



How does neural computation relate to behavior?



George et al., 2020

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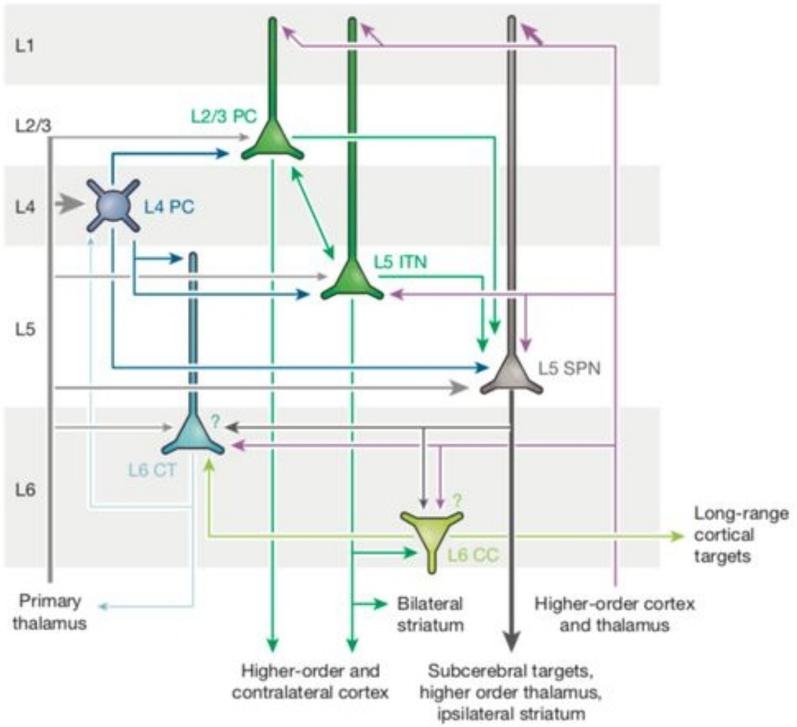
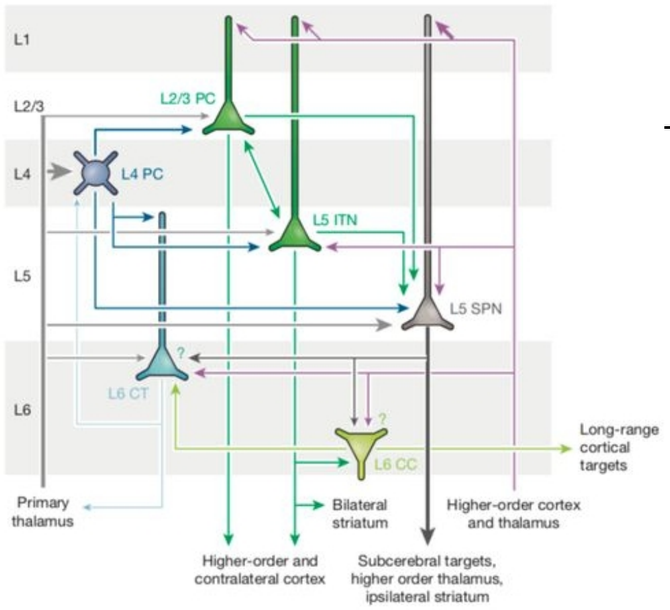


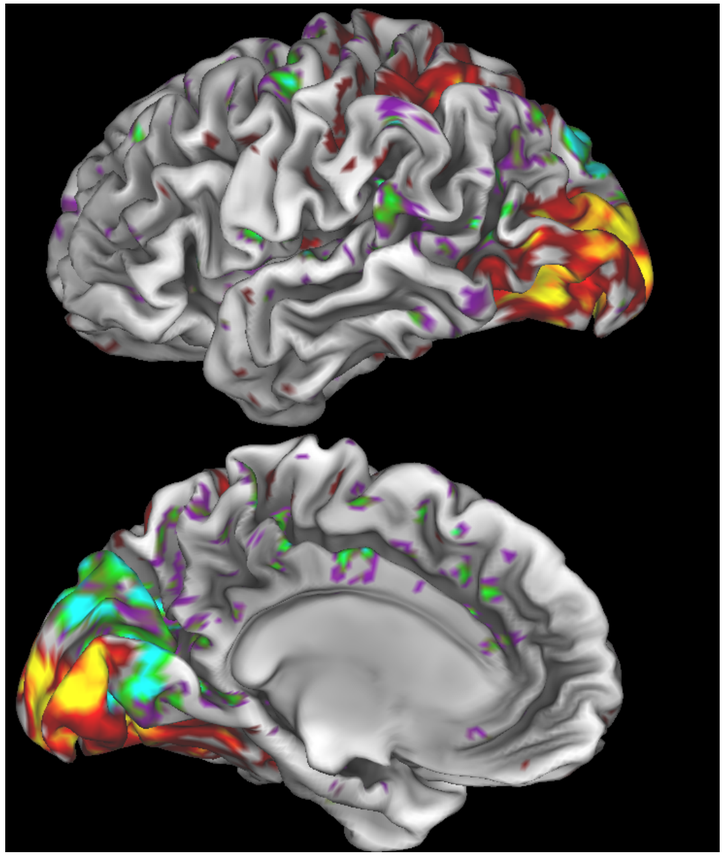
George et al., 2020

Pavlov's Dogz

How do differences in neural computation relate to differences in behavior?



What can imaging signals tell us about differences in neural computation?



"Neural Guitar Signature"

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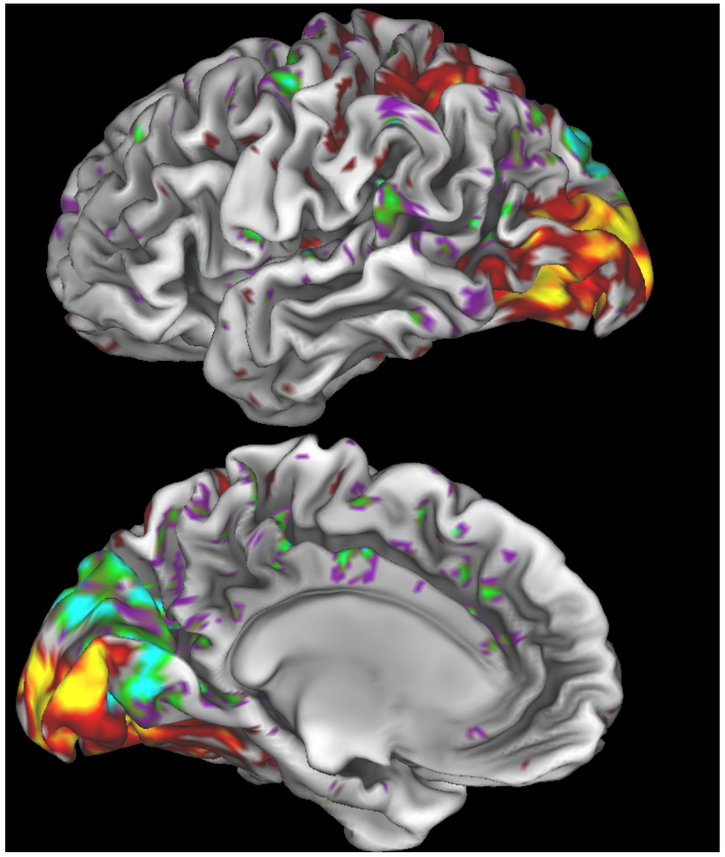

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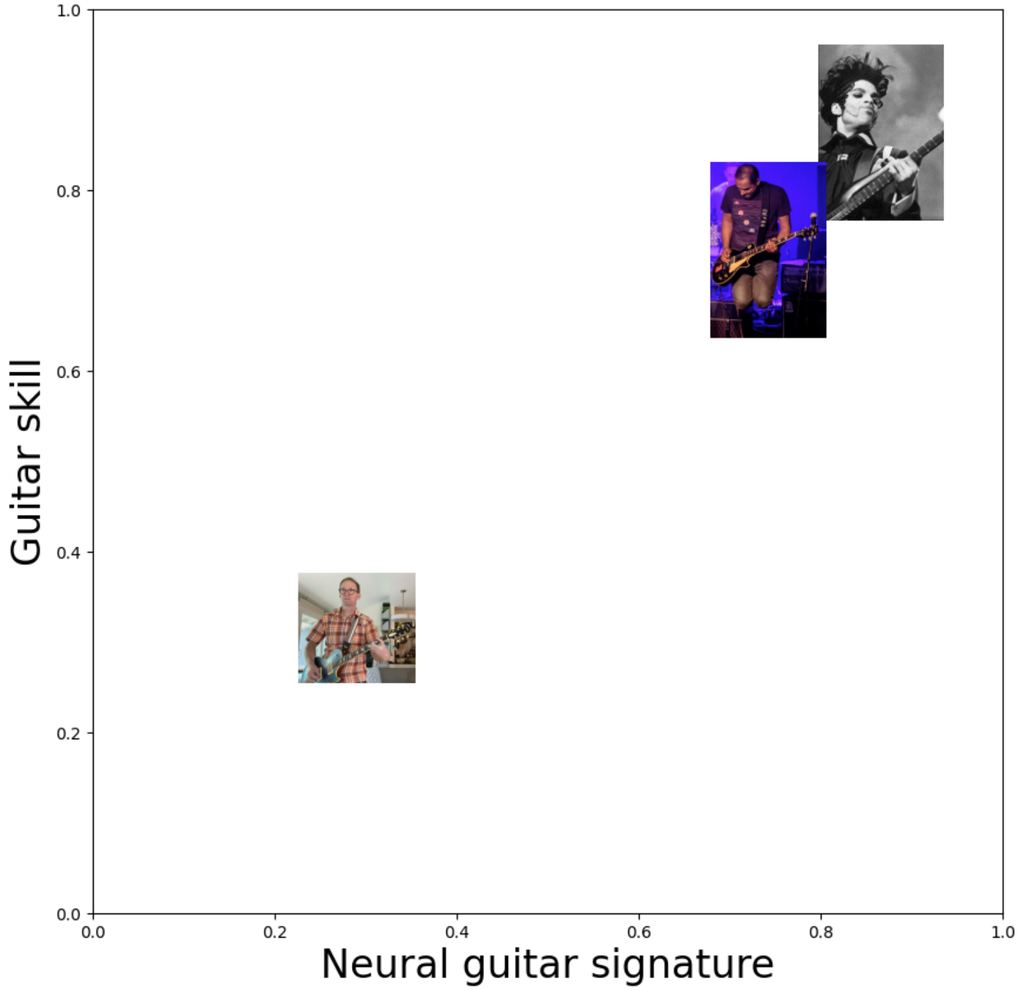
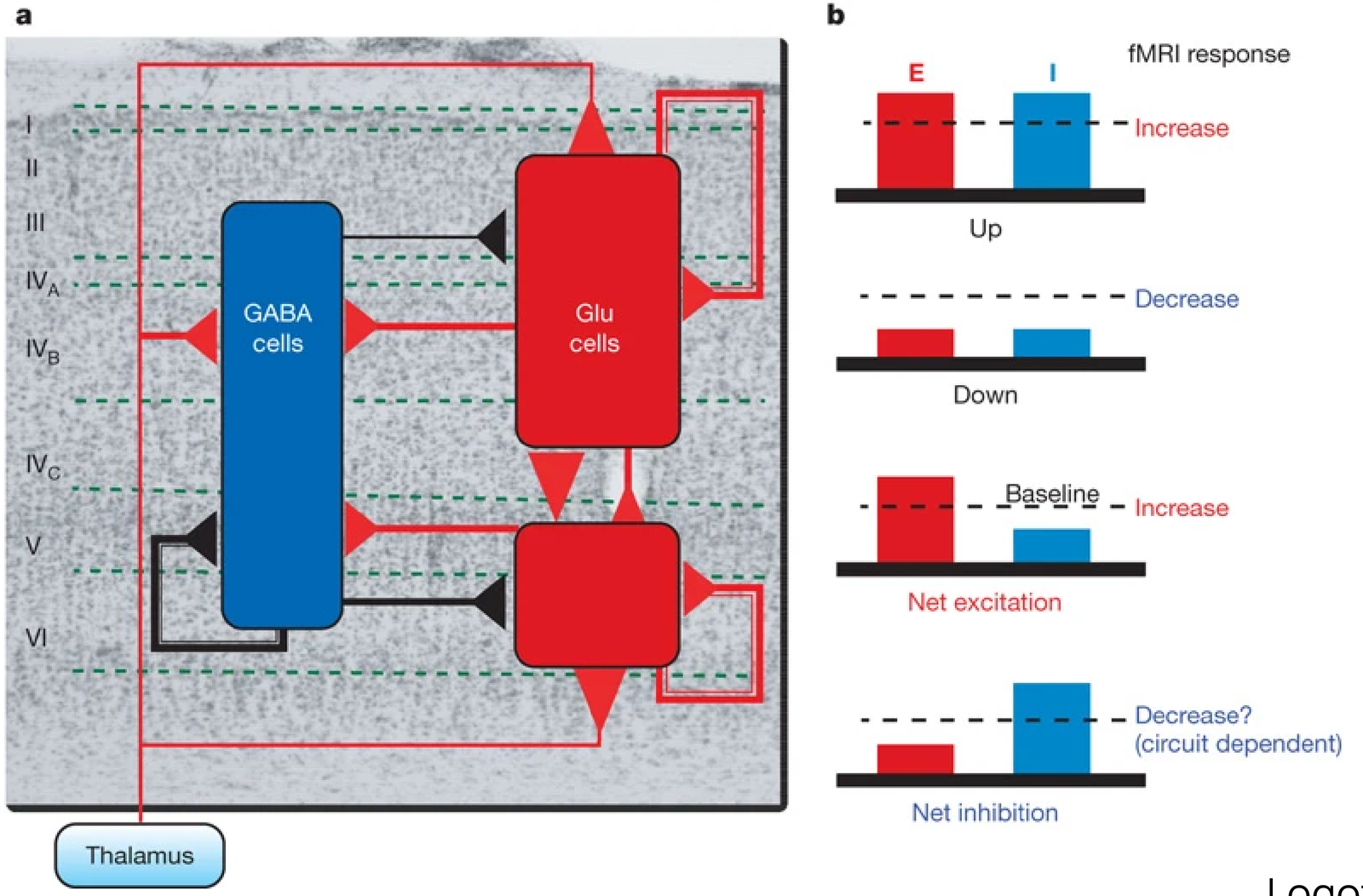


Functional imaging and neural computation: It's complicated



Logothetis, 2008

How might differences in neural computation give rise to differences in fMRI signals?

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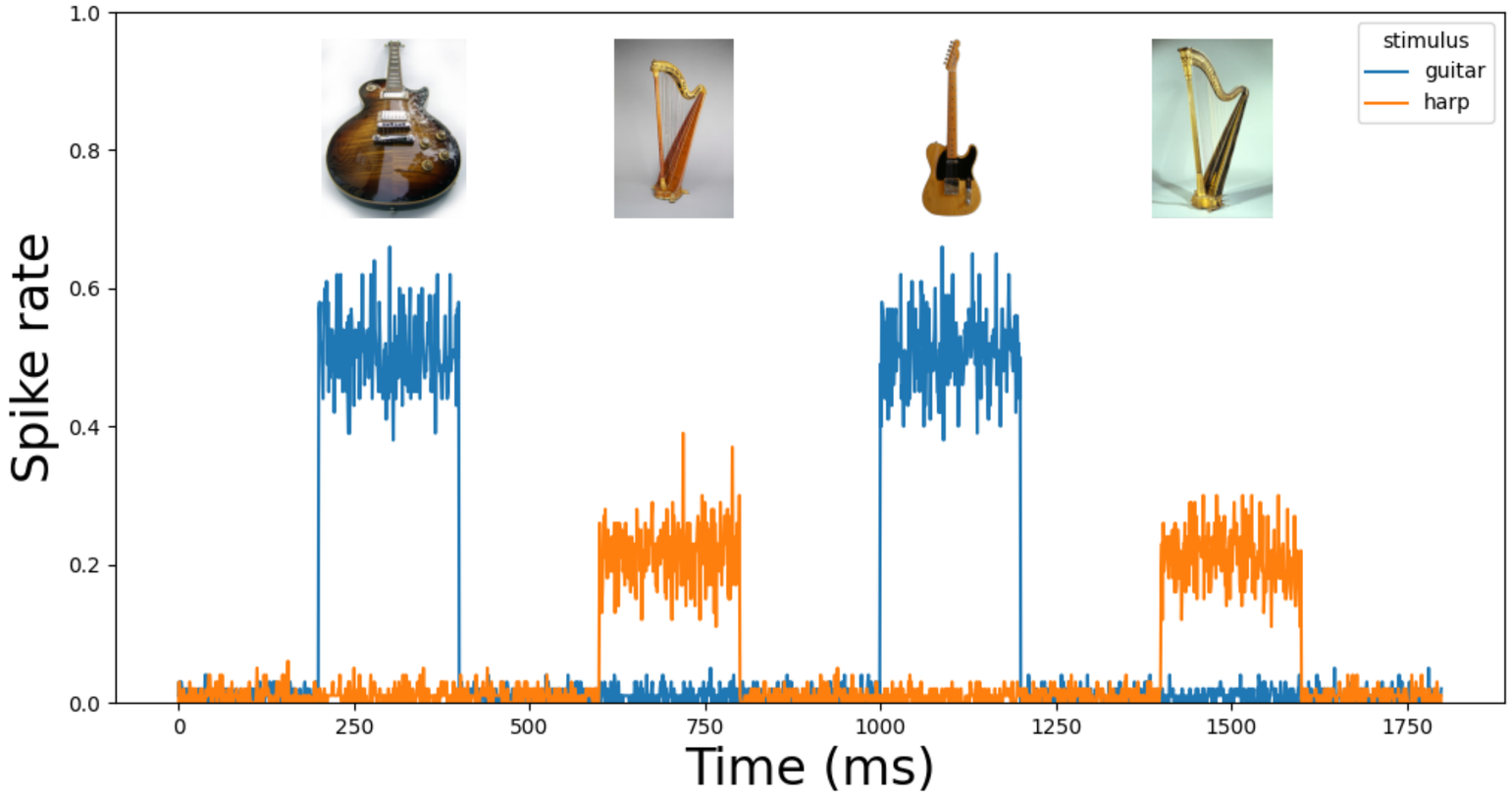
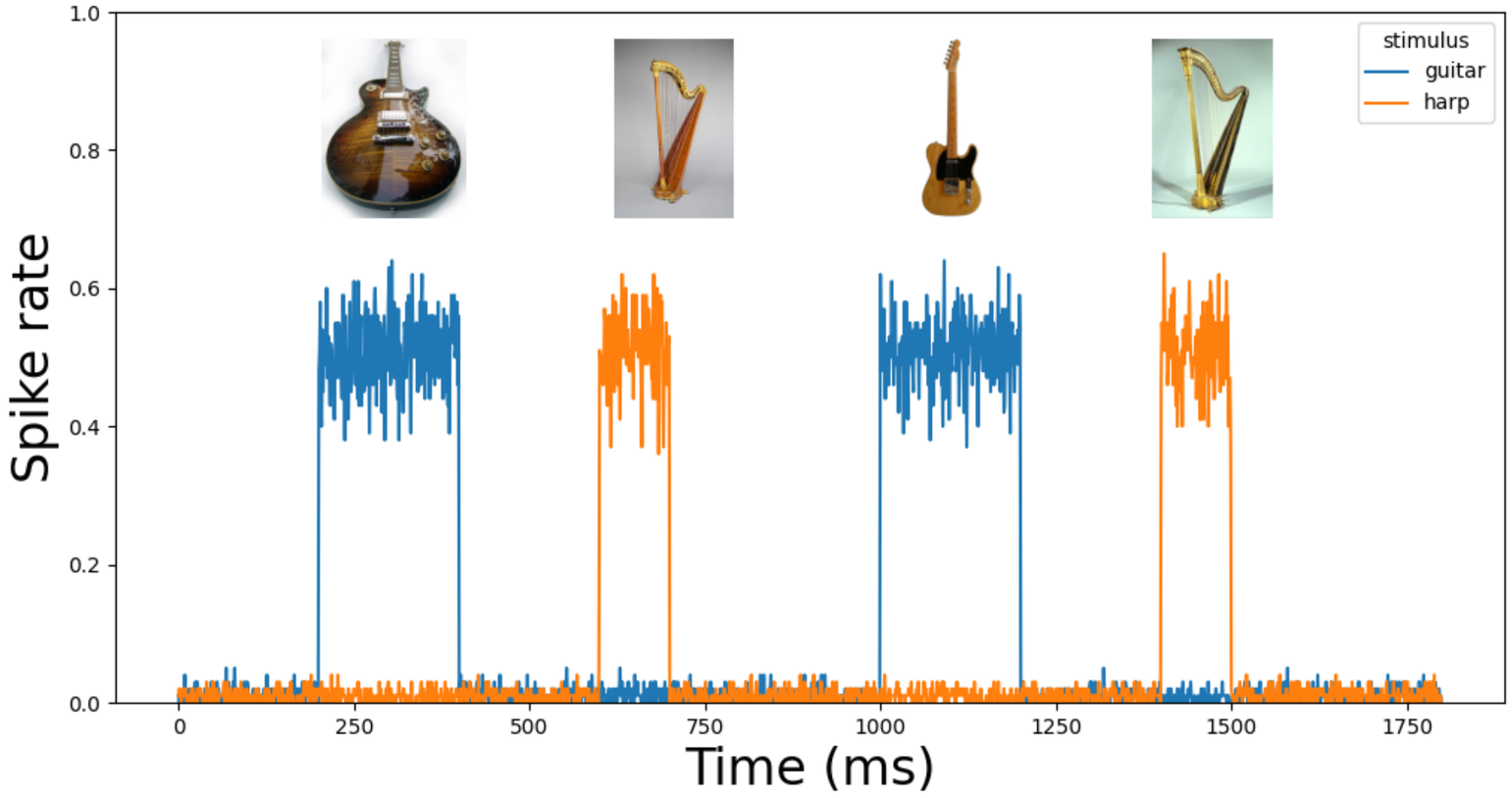
Difference in intensity of neural activity



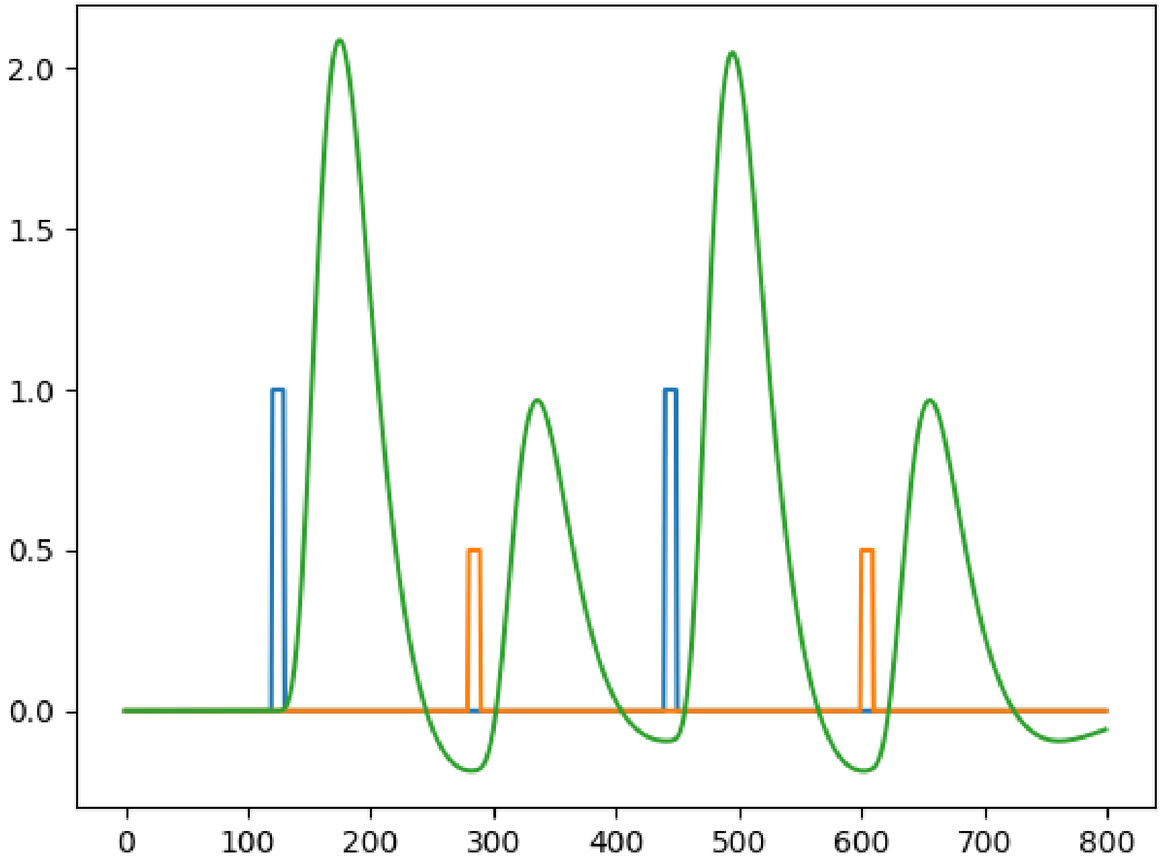
How might differences in neural computation give rise to differences in fMRI signals?

Difference in duration of neural activity

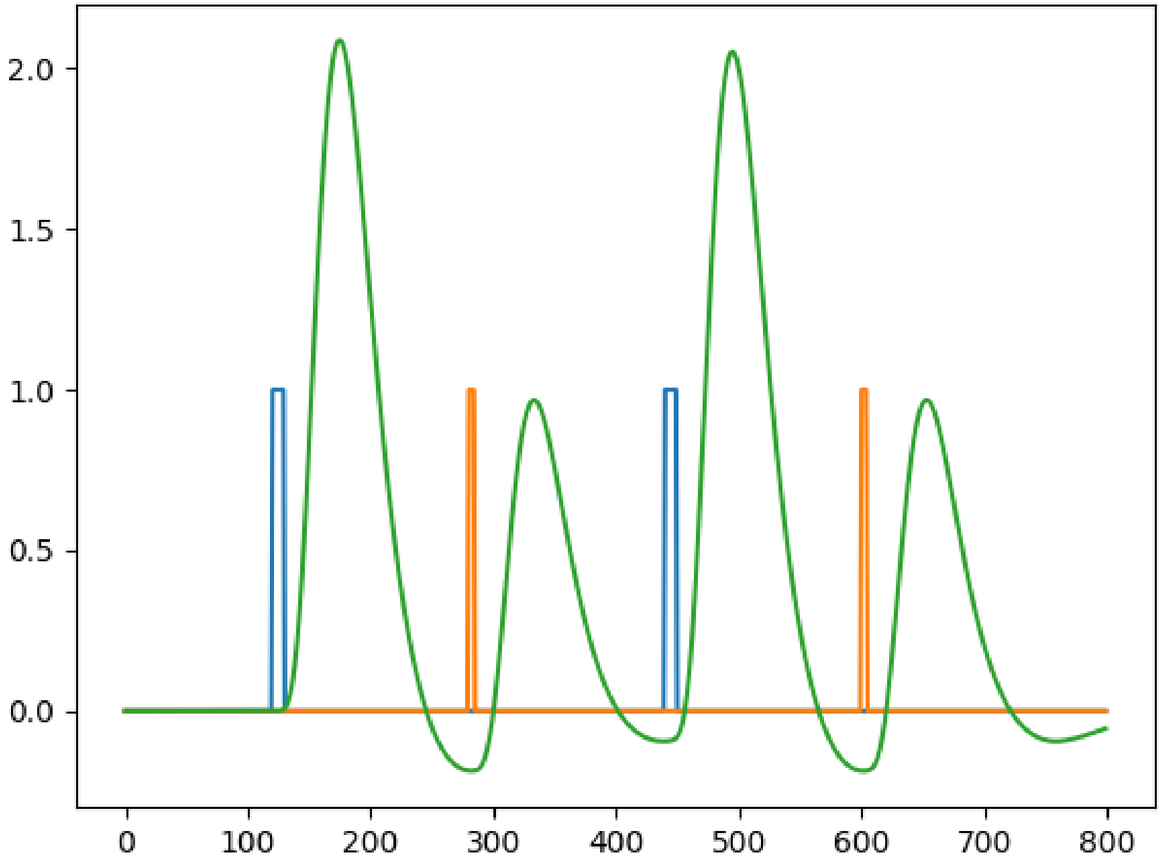


Changes in rate vs. duration of neural firing are indistinguishable in fMRI

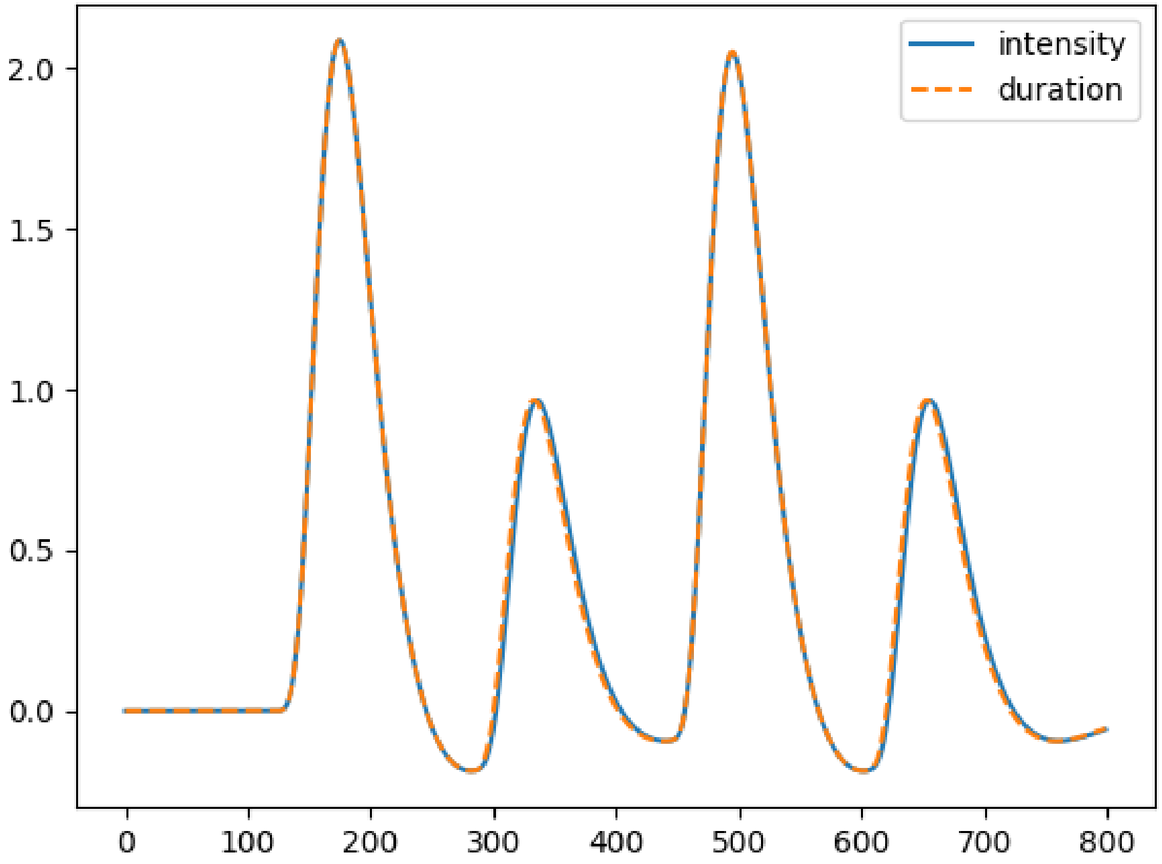
Same duration, different amplitude



Same amplitude, different duration



The effects of amplitude and duration are indistinguishable in the fMRI signal



The response time paradox

- In cognitive psychology, differences in RT are the measure of interest
  - Thus, nearly all task comparisons will exhibit a difference in RT

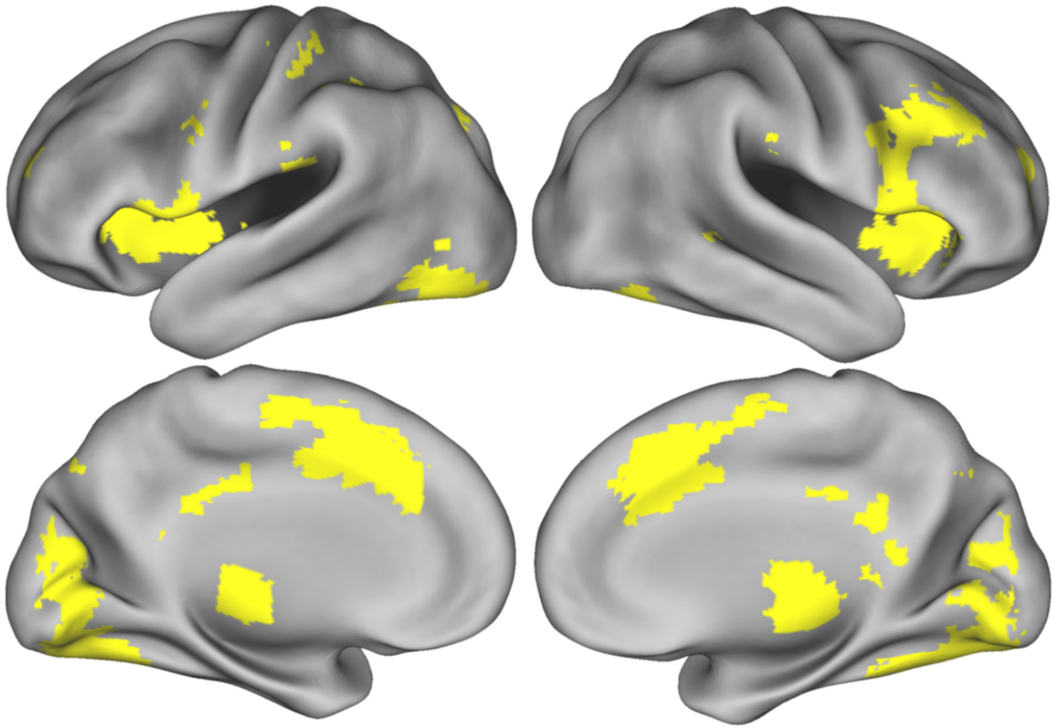
Mumford et al, 2023

The response time paradox

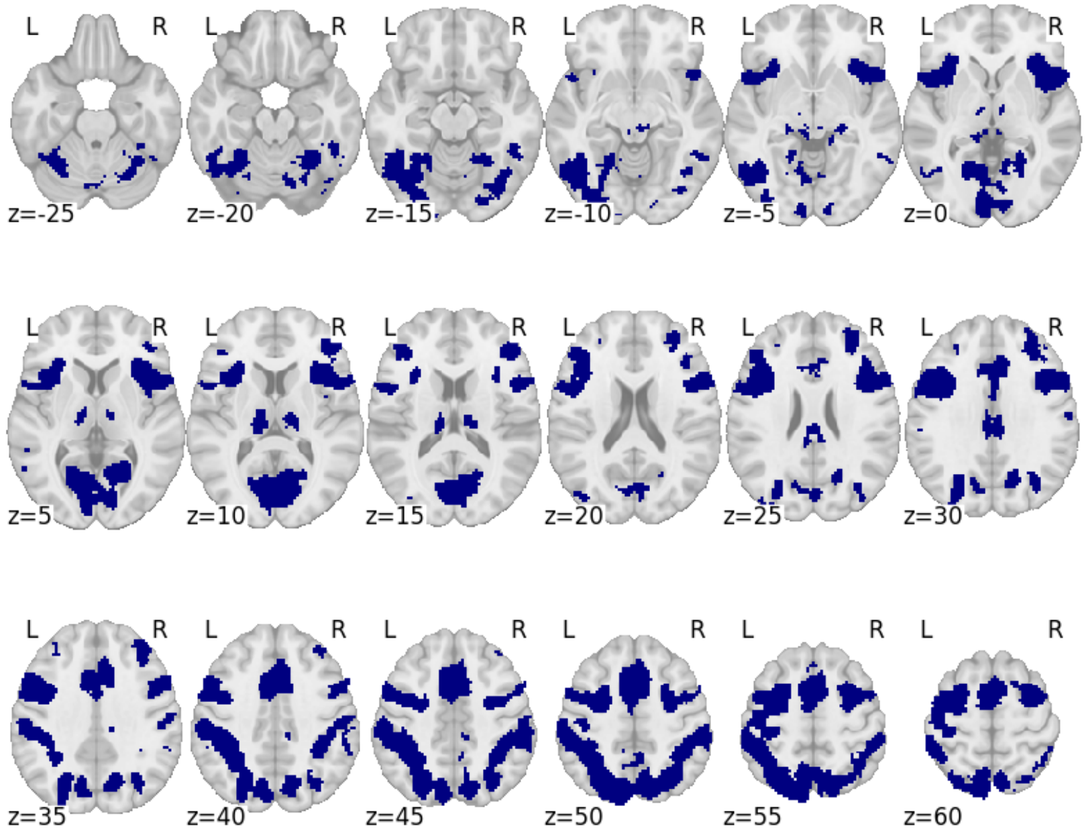
- From the standpoint of fMRI, these same RT differences reflect a potential confound
  - We can't tell whether the differences in activation are truly due to differences in neural computation, or simply due to "time on task"

Mumford et al, 2023

Response time correlates in fMRI are very strong



Yarkoni et al., 2009



Mumford et al, 2023

Solution: Model RT at the first level

Model name		Unconvolved regressor	Duration	Modulation
1	Constant Duration, no RT (ConsDurNoRT)		.1s	None
			.1s	None
2	RT Duration (RTDur)		RT	None
			RT	None
3	Constant Duration, RT (ConsDurRT)		.1s	None
			.1s	None
			.1s	RT*

← The standard model

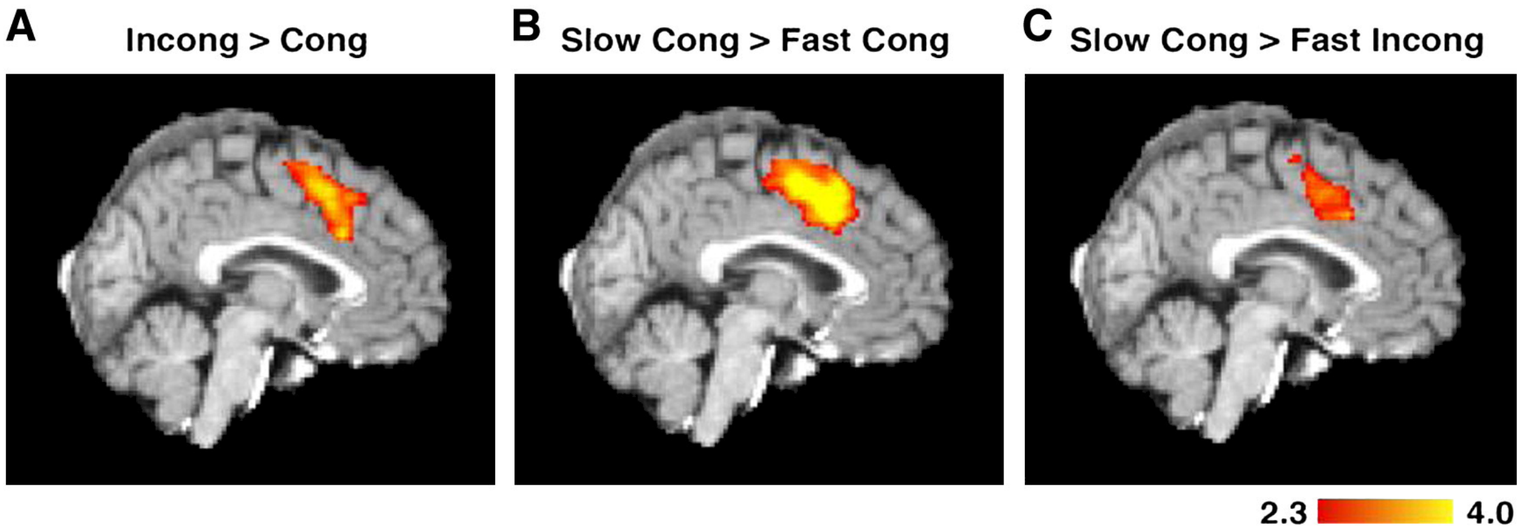
The Grinband model

← The Mumford et al. model

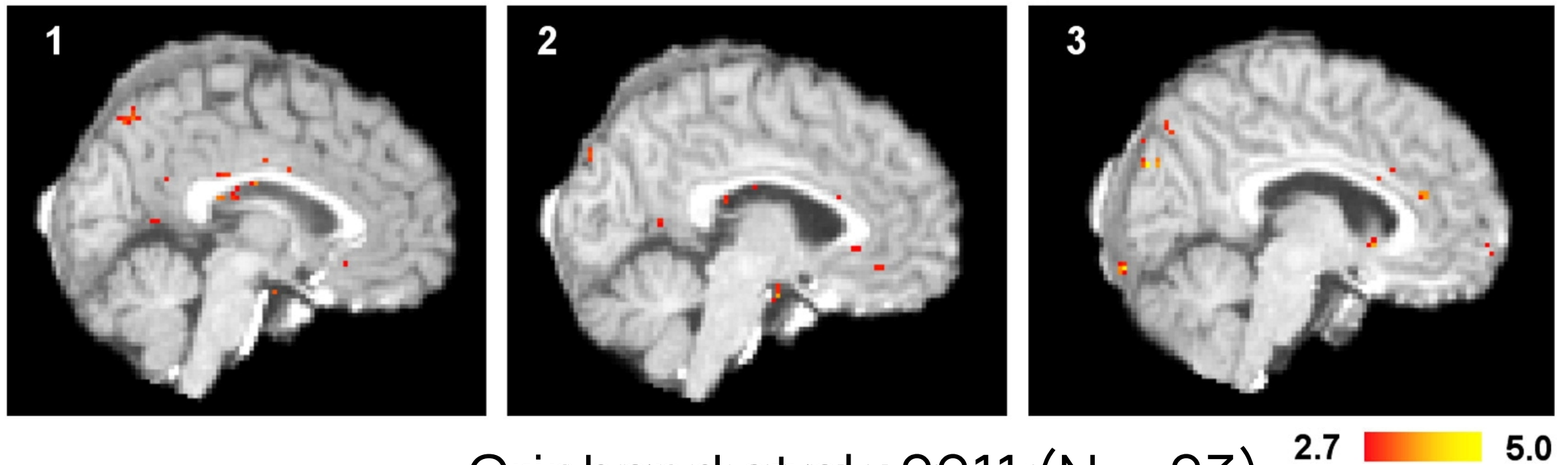
This allows understanding of the unique contributions of time on task and condition differences

Mumford et al, 2023

Are we throwing out the baby with the bathwater?



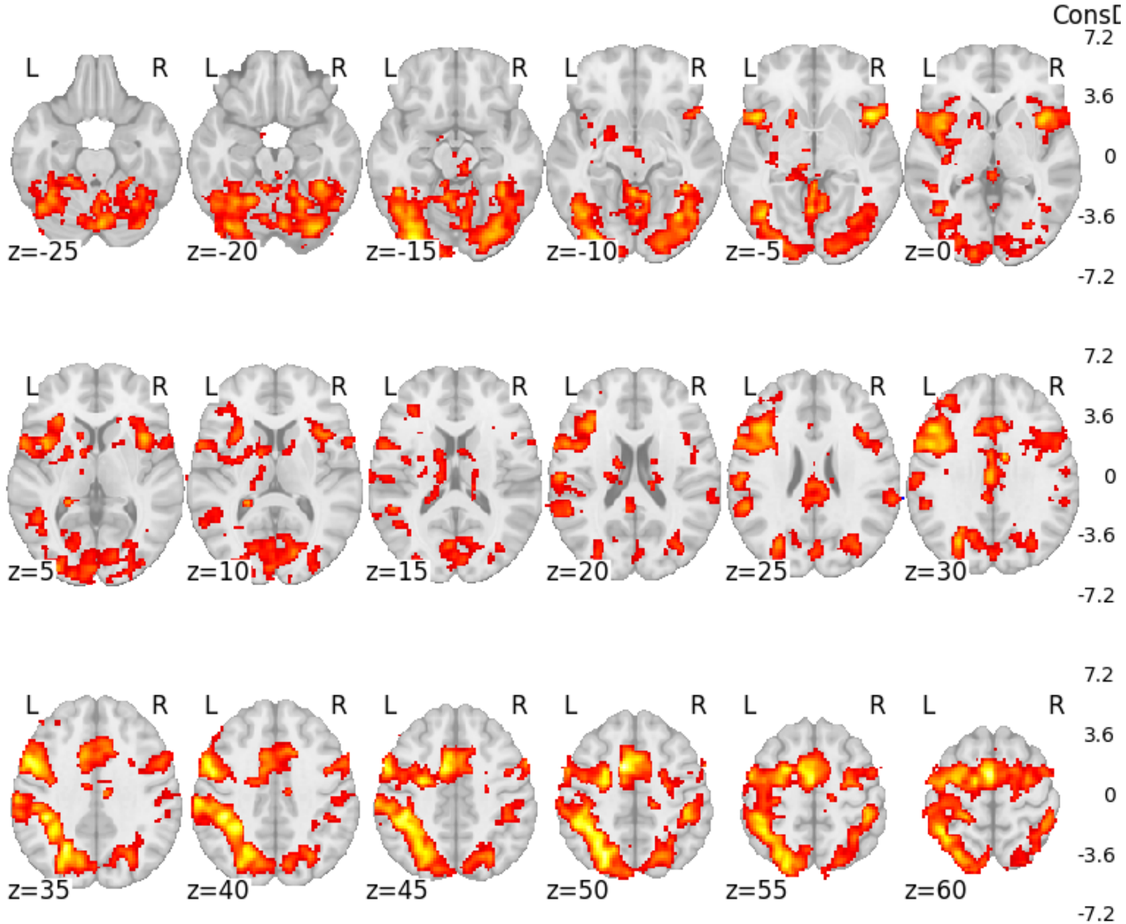
Activation for Stroop effect disappears after removing RT effect



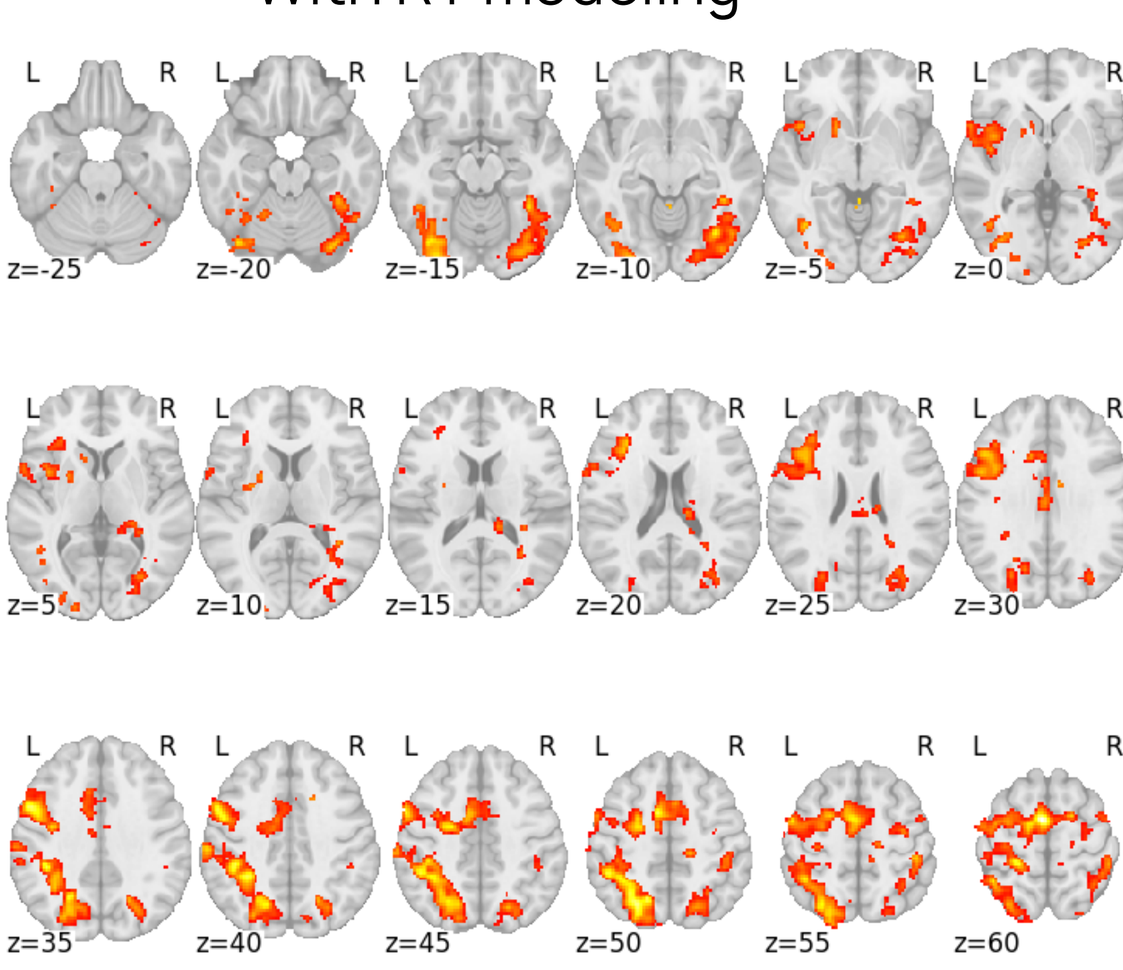
Grinband et al., 2011 (N = 23)

With sufficient power, we can find specific effects even after removing RT

Without RT modeling



With RT modeling



Bissett et al., unpublished

Modeling response times is essential to valid

interpretation of activation results.

What about brain-behavior associations?

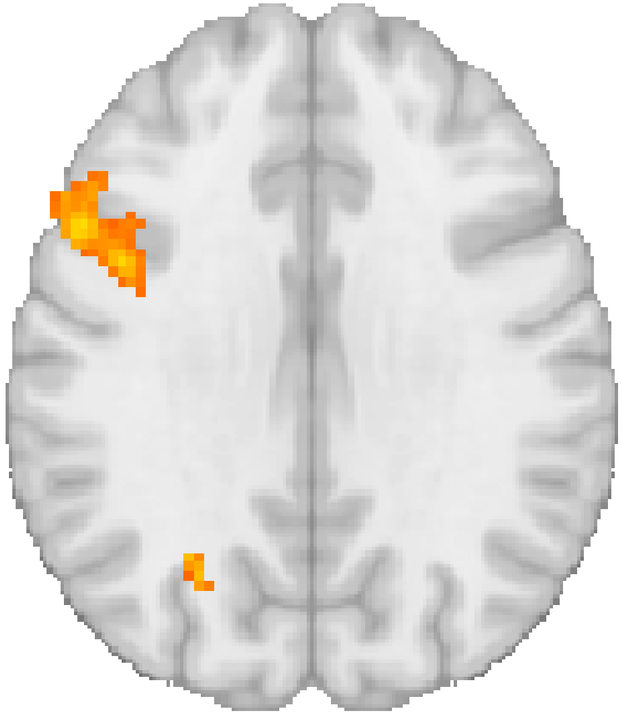
Unmodeled RT effects from first level can leak into the second level

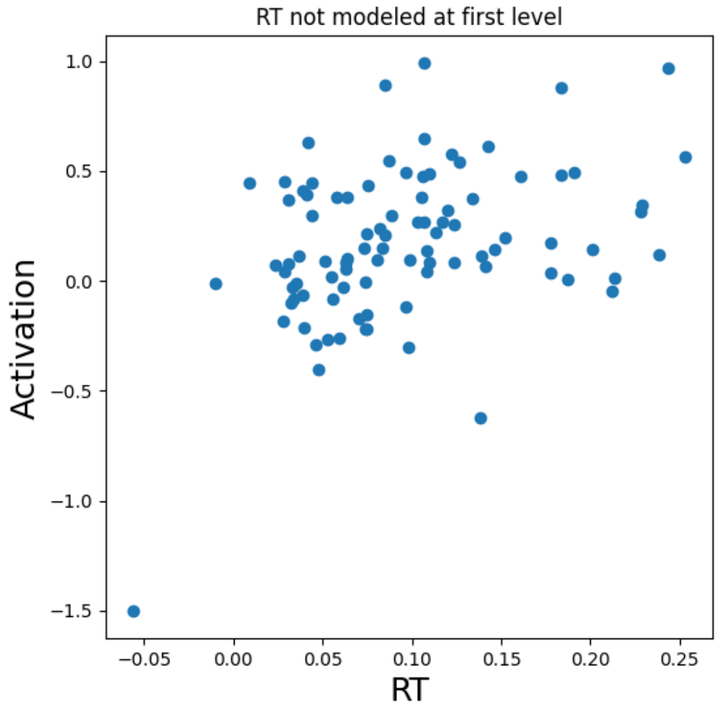
Anything that correlates with RT can then

correlate with activation

Unmodeled RT effects from first level can leak into the second level

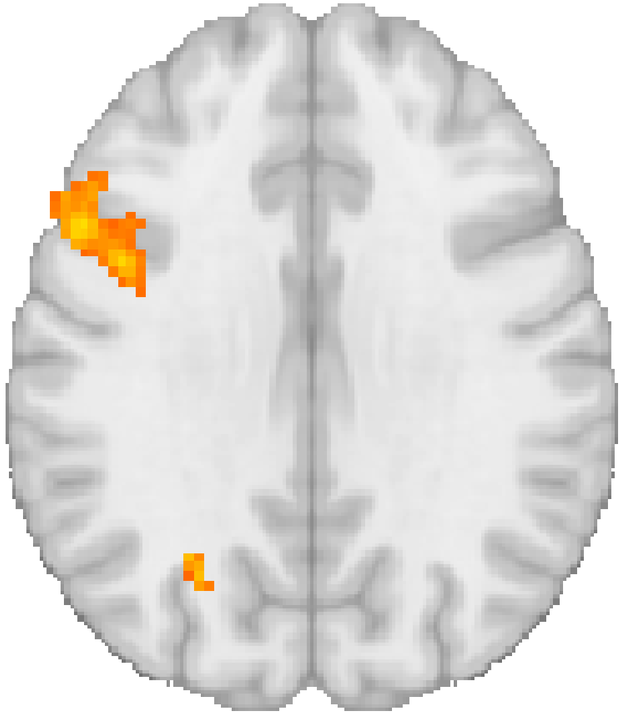
Without RT modeling

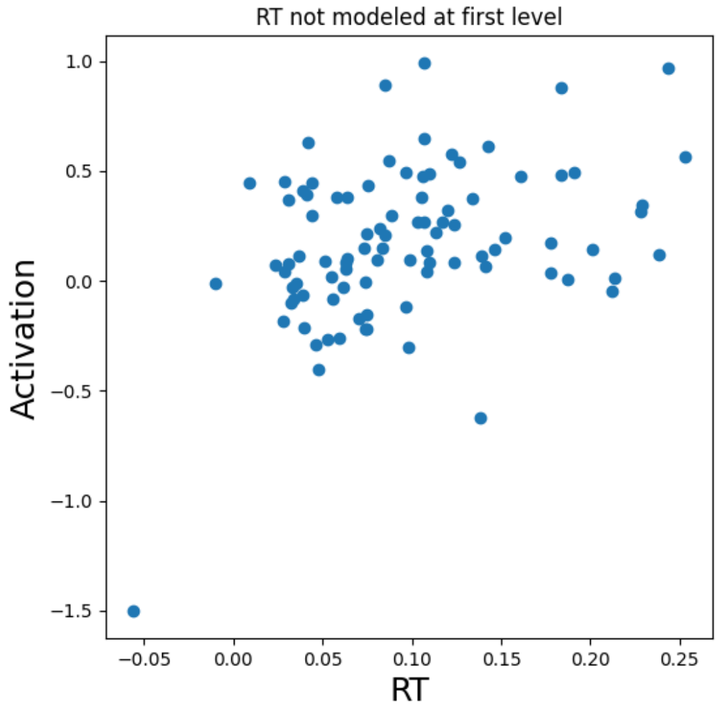




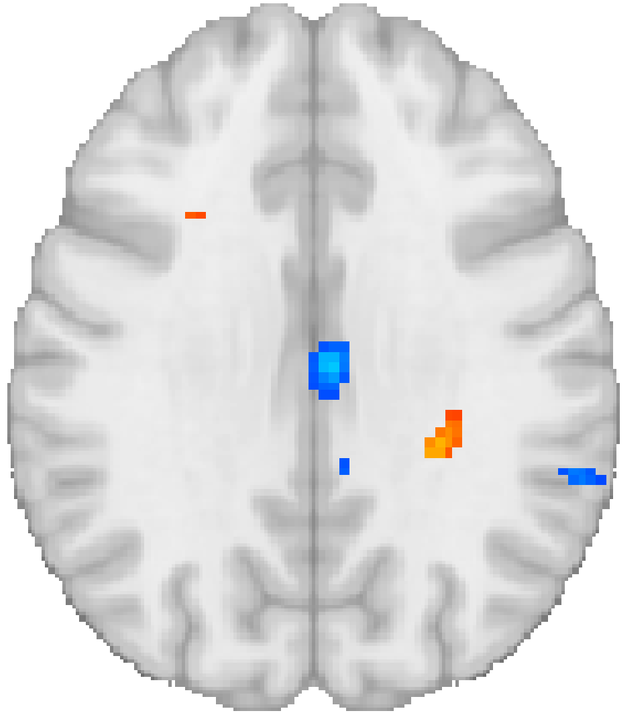
Unmodeled RT effects from first level can leak into the second level

Without RT modeling





With RT modeling



RT effects cannot be removed by including RT in the group-level model

In fact, this can actually induce artifactual

correlations!

Conclusions

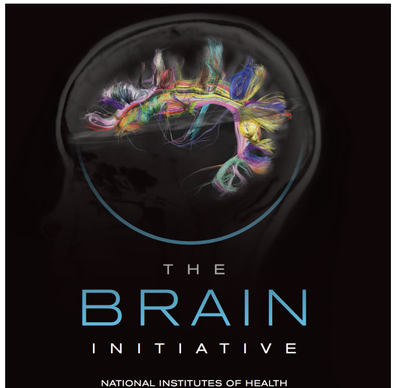
- Response time is a major potential confound for all task fMRI studies
  - Without adjustment, it is impossible to determine whether activations simply reflect time on task
- If response time effects are not modeled at the first level, they can creep into the group analysis

Acknowledgments

The Poldrack Lab

Jeanette Mumford

Funding



NSF

NIH National Institute of Mental Health

How should we address potential confounds in brain-behavior association analyses?

- “Statistical control”
  - Put every possible confound into the group-level model
- Three problems with this:
  - It doesn’t work for RT
  - It can result in false positives when confounds are measured with error
  - Conditioning on a common effect can result in incorrect inferences

The problem of measurement error in regression

- yarkoni/westfall

Collider bias

An example of collider bias: Selection bias

What can we do?

Acknowledgments