

NATURAL STIMULI

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AGENDA

- Natural stimuli - philosophy & examples
- Basic linear regression

NATURAL STIMULI: WHAT?

THIS:



NOT THIS:

chairs

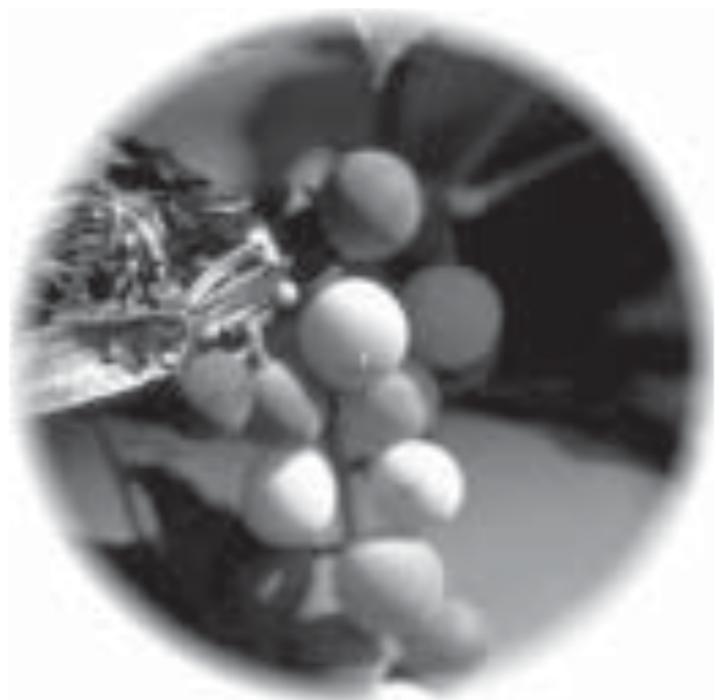


NATURAL STIMULI: HOW?

- 1. choose domain of interest**
- 2. sample stimuli randomly from domain**
- 3. present stimuli to subjects**
- 4. build models that predict responses**

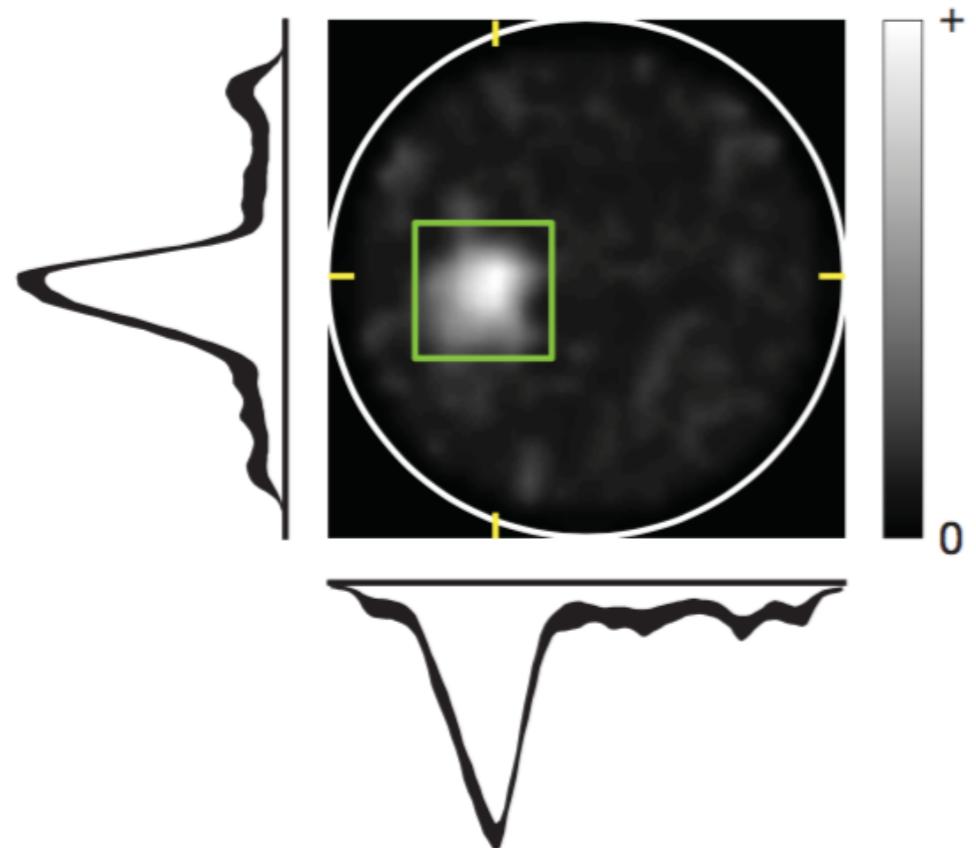
EXAMPLE: IMAGES

1700 natural images



predictive model
for each voxel

Subject S1, voxel 42205, area V1



HISTORICAL PERSPECTIVE

- ***OLD***: introspect to understand,
quantification be damned!
- ***NEWER***: we need quantification: controlled
experiments!
- ***NEWEST***: controlled experiments are
limiting, and we have *computers*: natural
stimuli!

**NATURAL STIMULI
ARE YOUR FRIEND**

NATURAL STIMULI: WHY?

- *quantitative:*
 - brain is non-linear system → non-natural stimuli don't generalize
 - natural stimuli enable testing many questions
- *qualitative:*
 - natural stimuli give stronger responses
 - natural stimuli give better control over cognition

BRAIN IS NON-LINEAR

- in linear system, one can extrapolate from simple stimuli to complex stimuli
- in non-linear system, extrapolation is never guaranteed

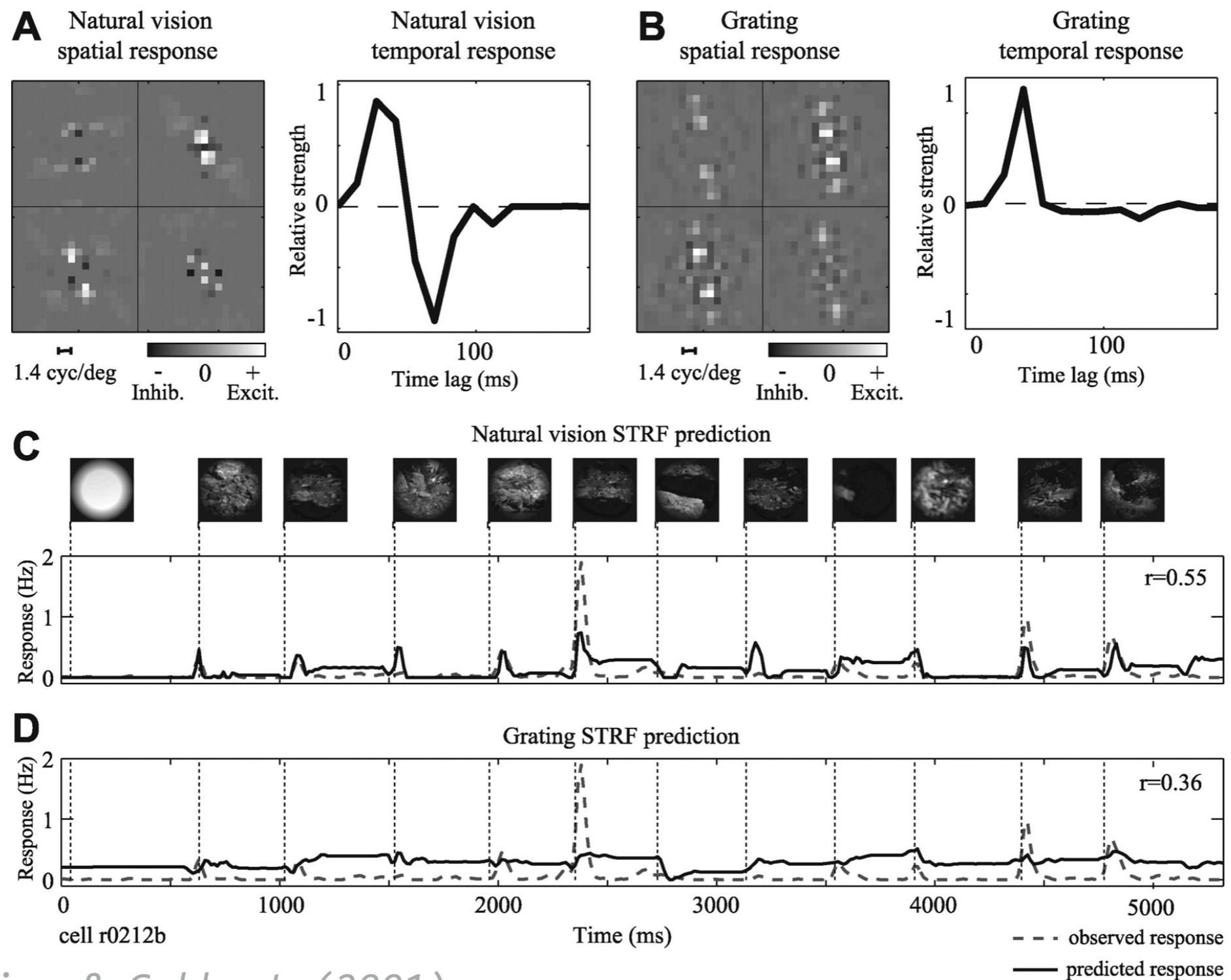
BRAIN IS NON-LINEAR

- *Thought experiment:* record brain response to every individual pixel on a screen.

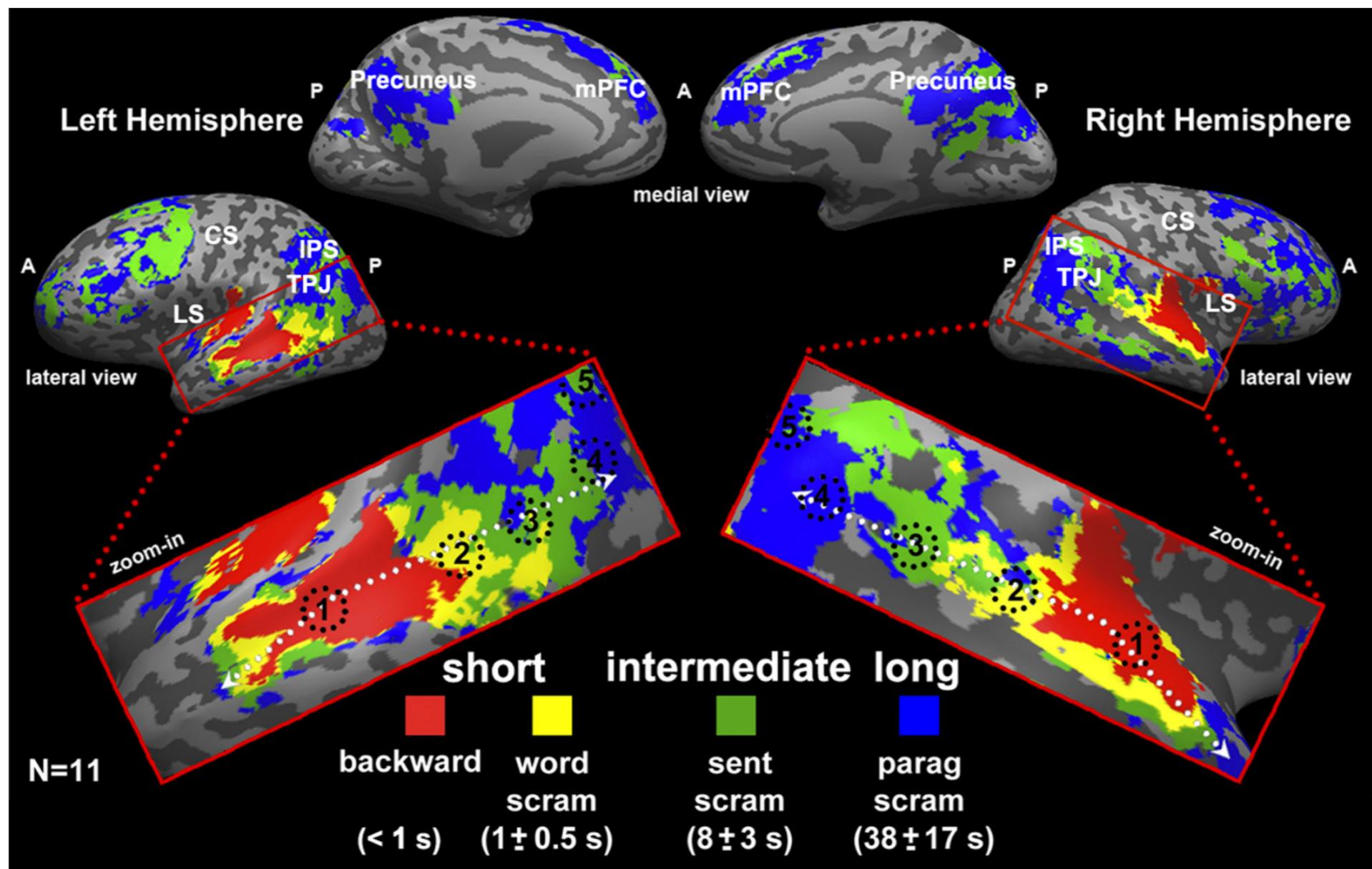
Then record response to a face.

Can face response be predicted from single pixel responses? **No!**

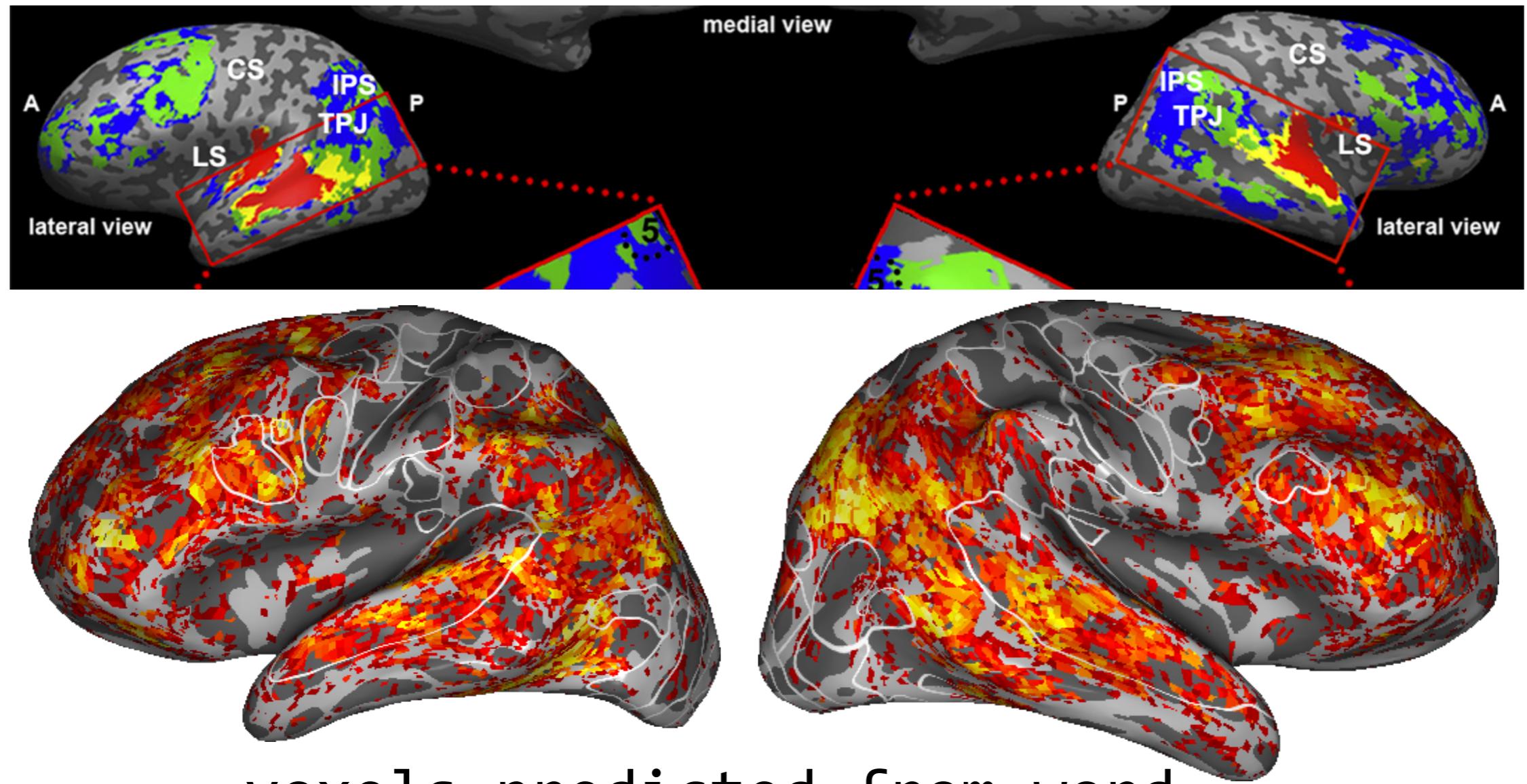
EXAMPLE: V1 NEURONS



EXAMPLE: LANGUAGE



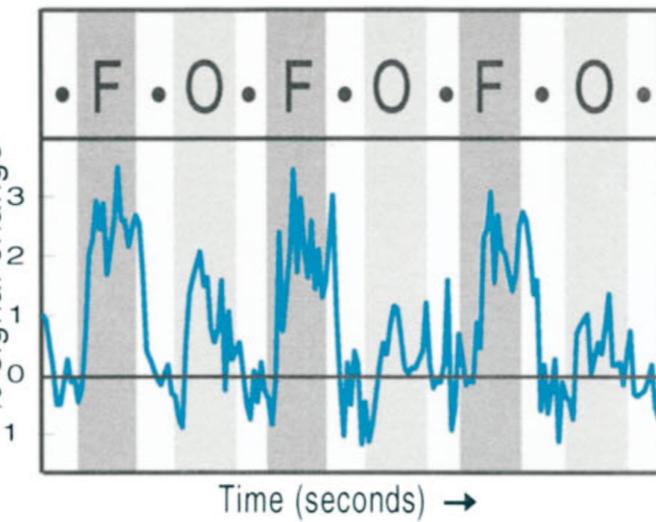
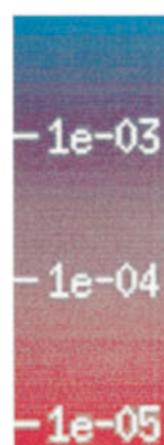
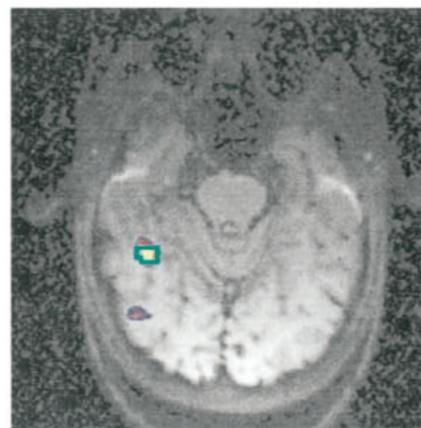
EXAMPLE: LANGUAGE



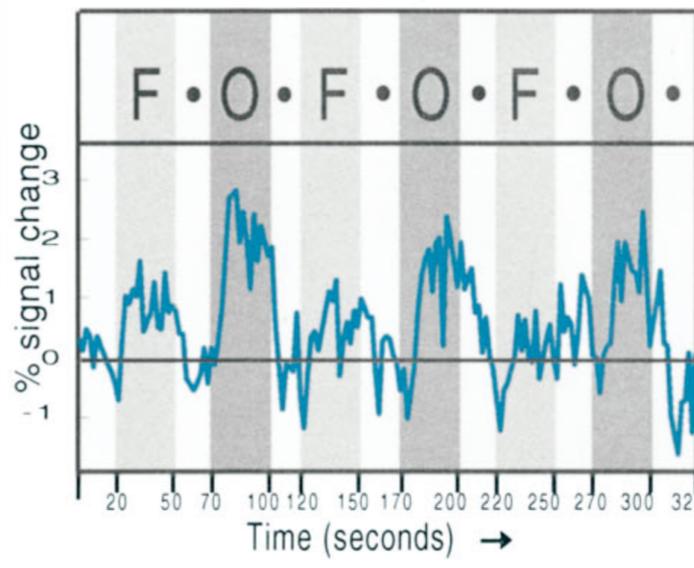
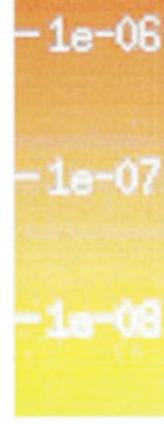
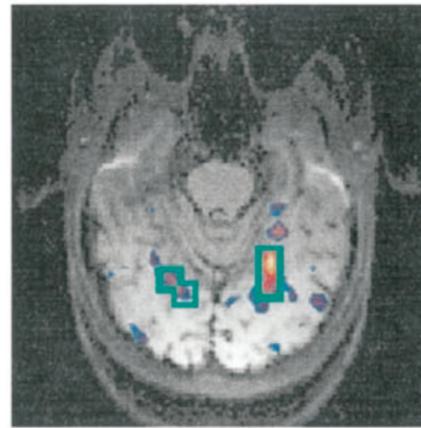
voxels predicted from word-level semantic information

HYPOTHESIS-DRIVEN EXPERIMENTS ANSWER ONE QUESTION

1a. Faces > Objects



1b. Objects > Faces

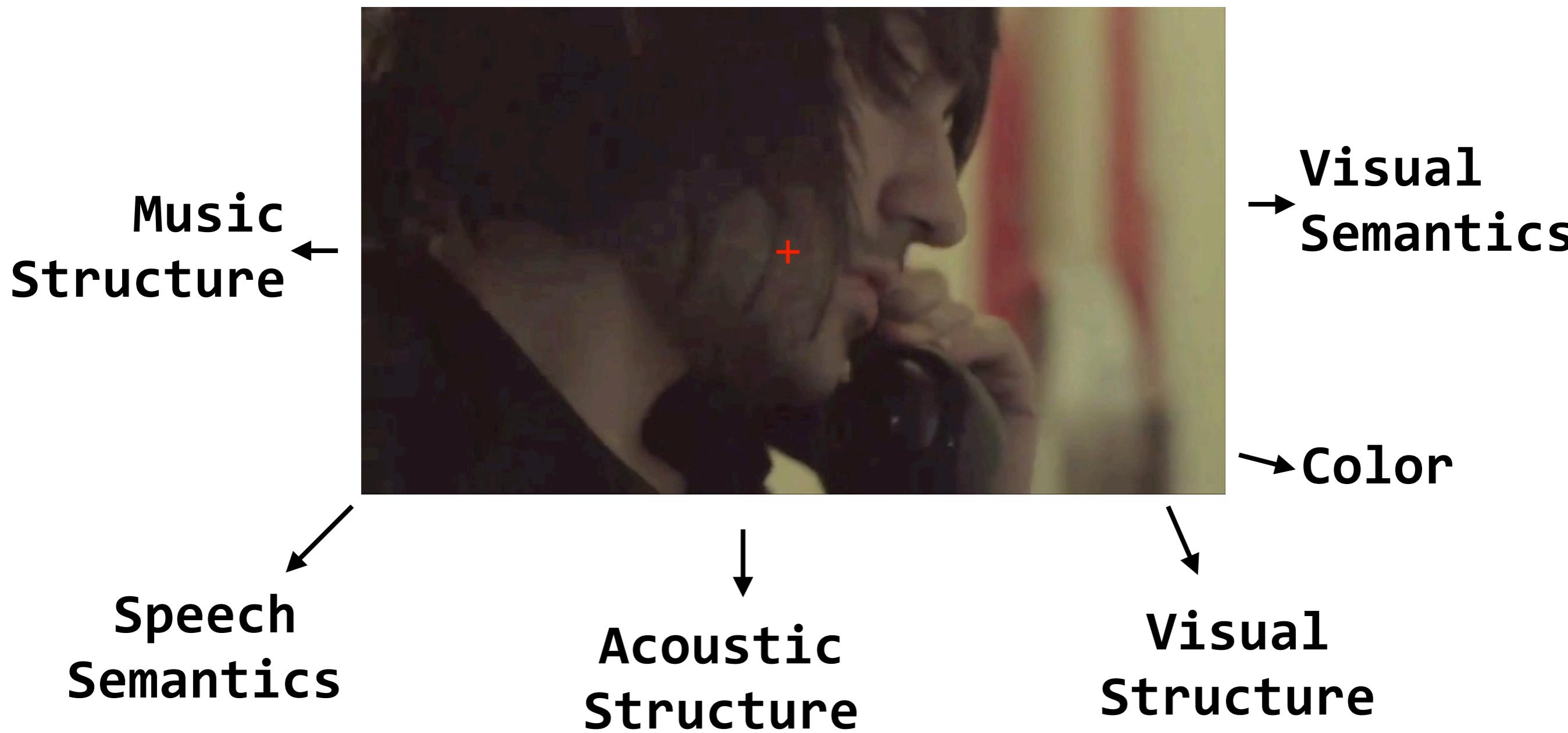


HYPOTHESIS-DRIVEN EXPERIMENTS

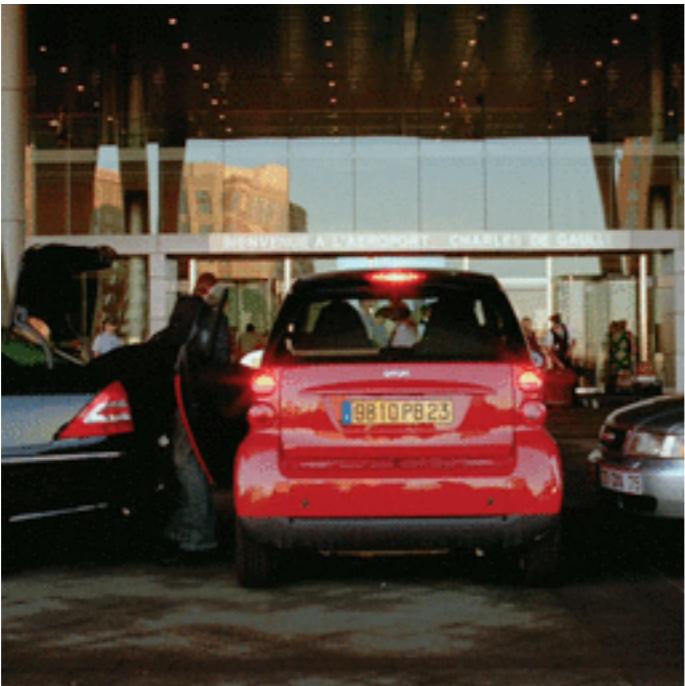
ANSWER ONE QUESTION

...better make sure it's the right question

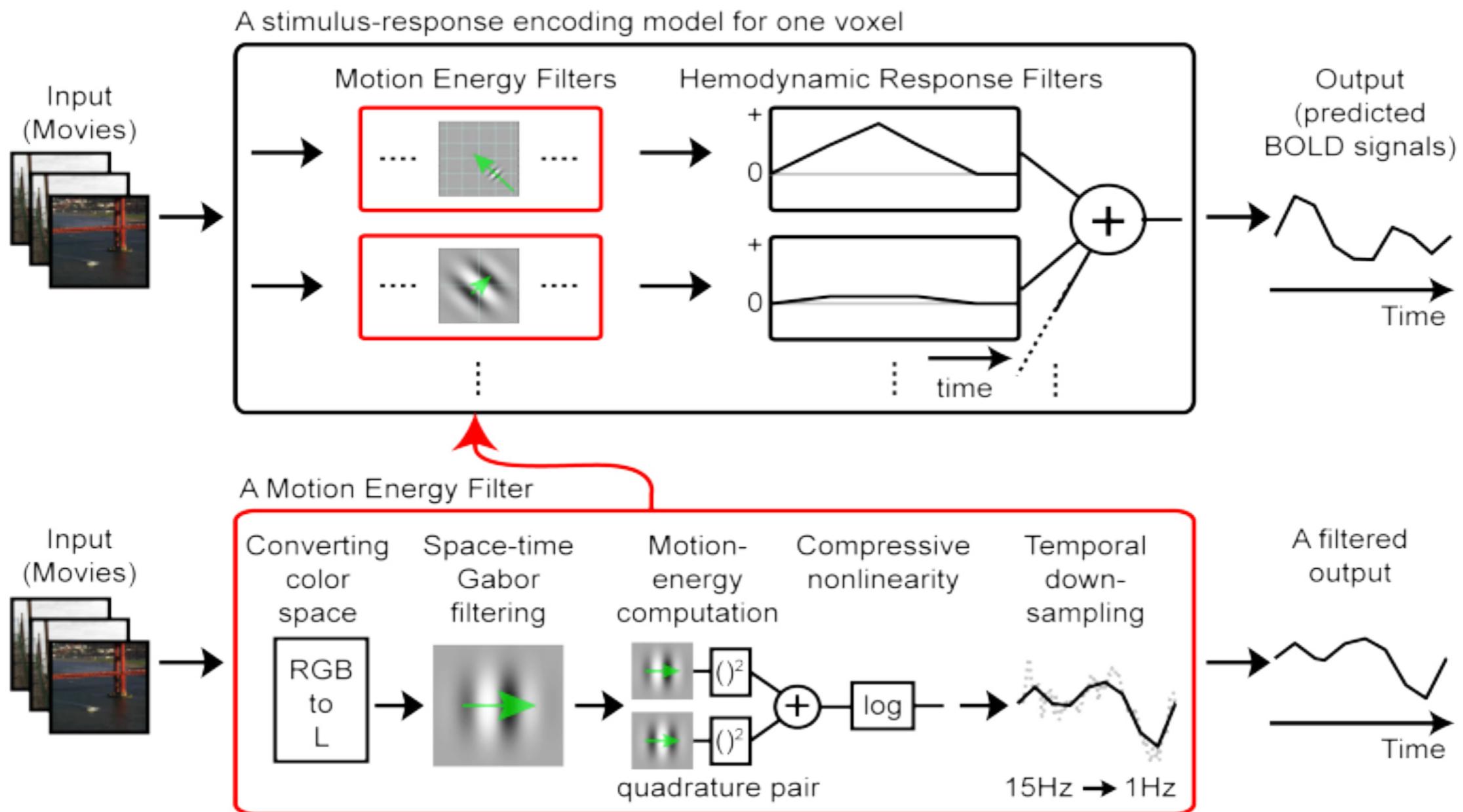
NATURAL STIMULI ANSWER MANY QUESTIONS



EXAMPLE: VIDEOS



EXAMPLE: VIDEOS



EXAMPLE: VIDEOS

Image

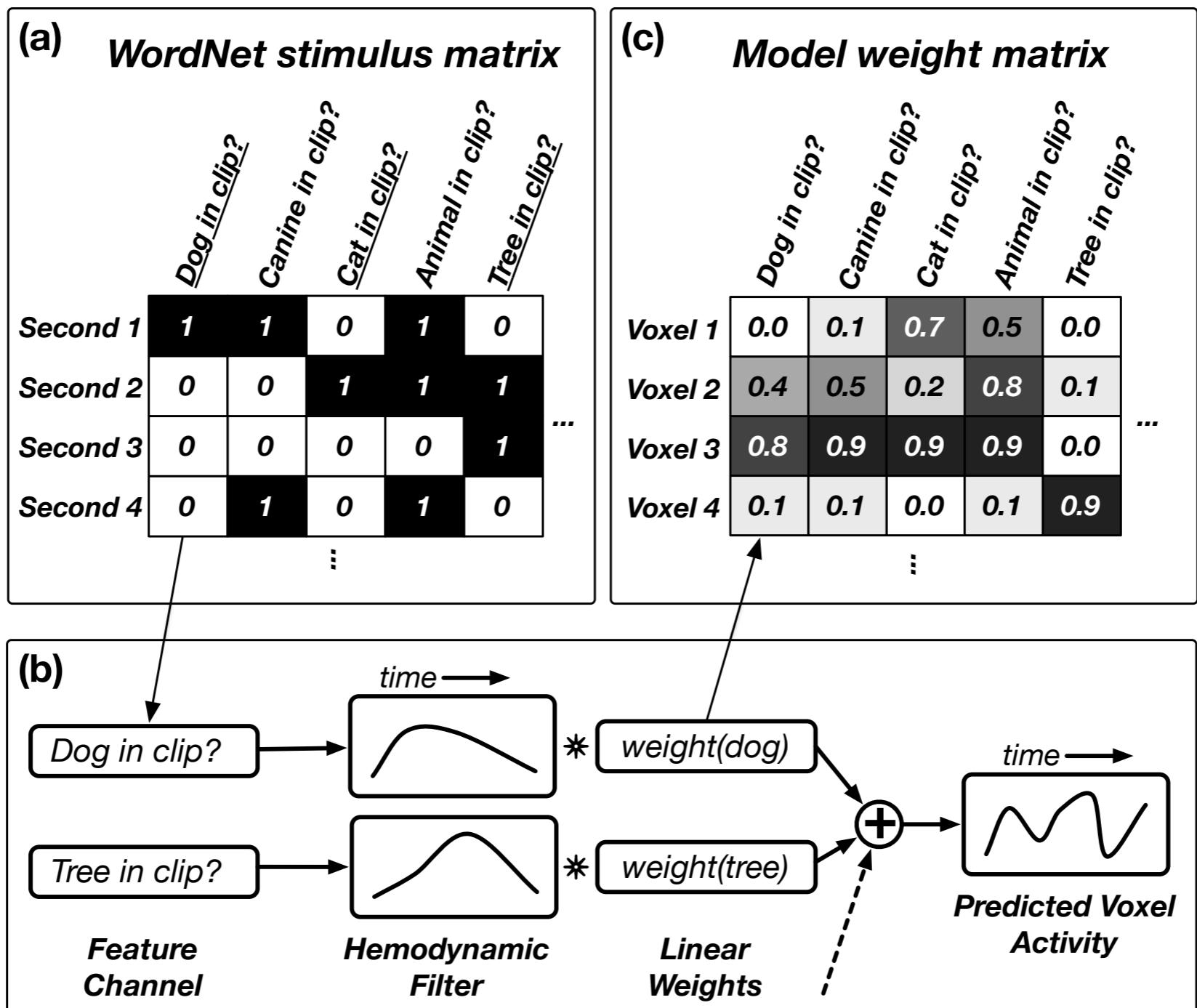


Presented movie

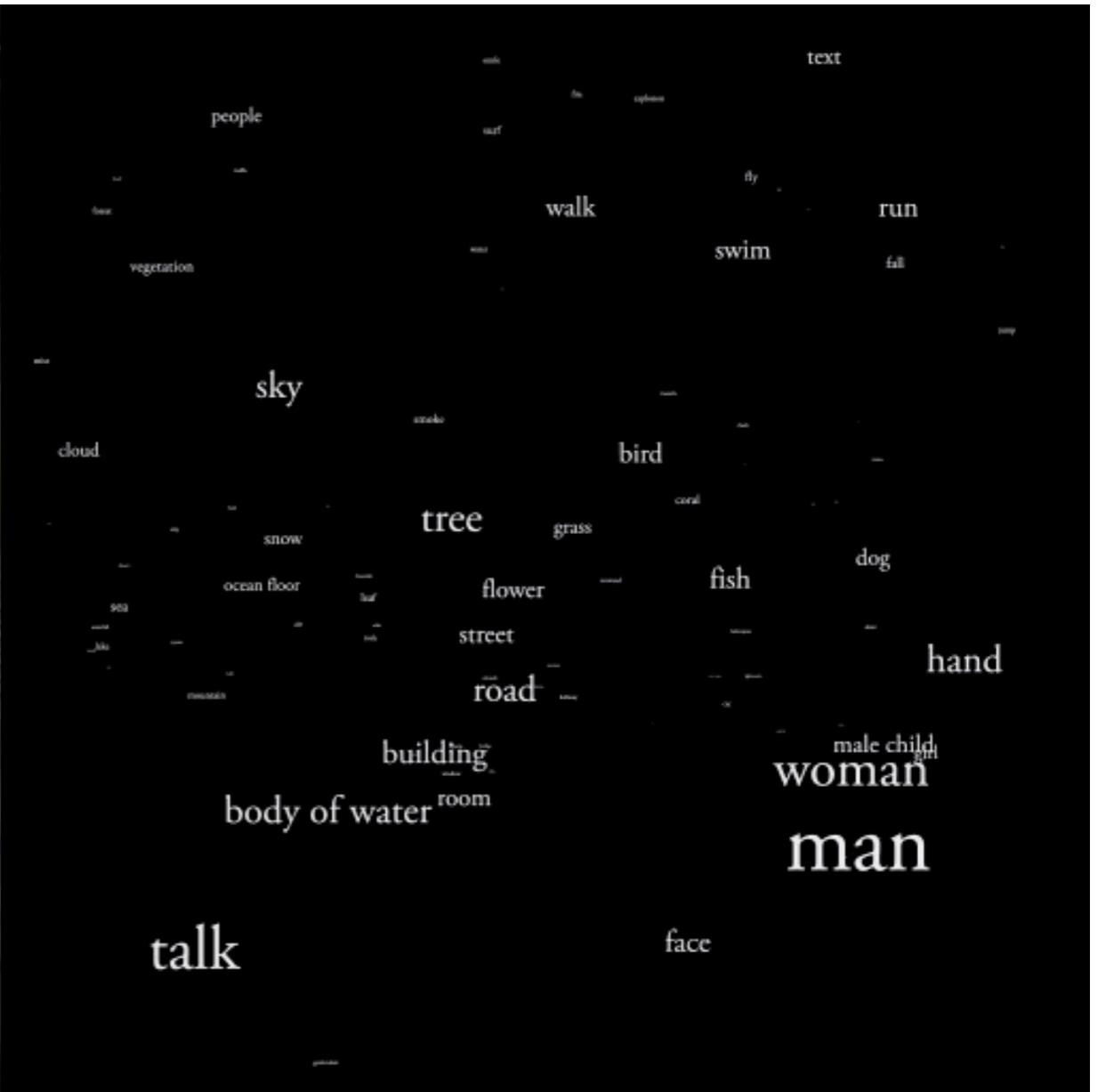
Decoded movie



EXAMPLE: VIDEOS 2



EXAMPLE: VIDEOS 2



**BE NOT AFRAID OF
NATURAL STIMULI**

NATURAL STIMULI: WHY NOT?

- variables of interest are *confounded* with other variables!
- variables of interest are *correlated* with each other!

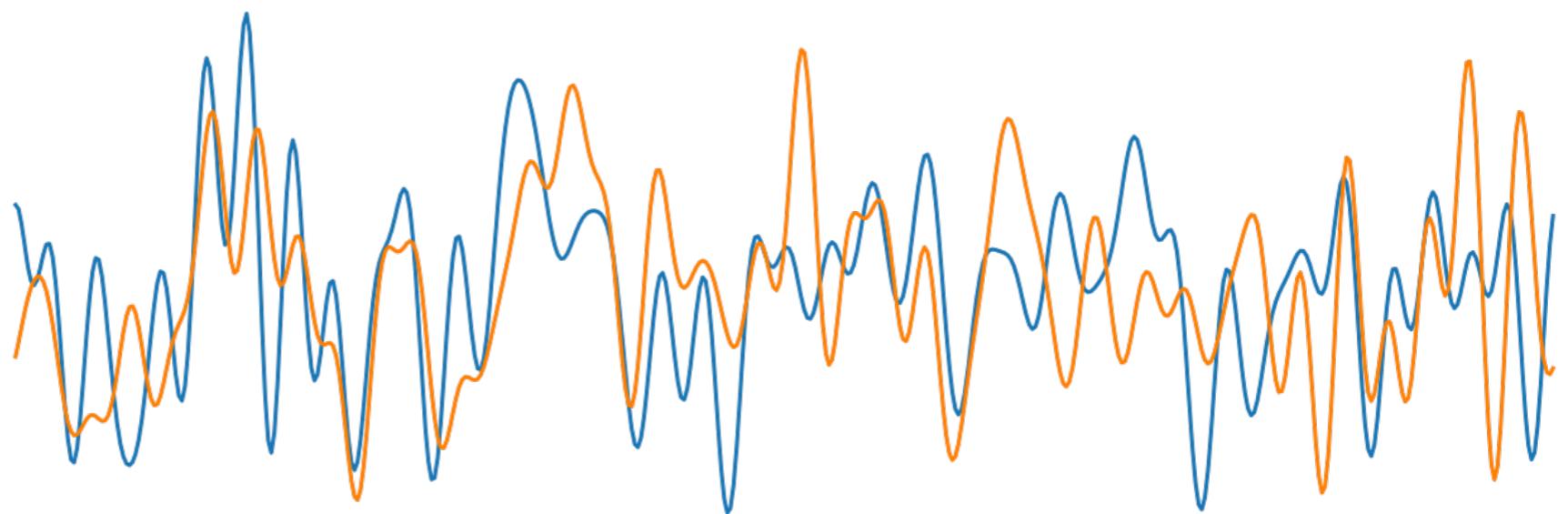
CONFOUNDS?

- *Traditional, controlled experiment:*
 - Confounds are baked into design
 - Confounds can be perfectly correlated with design
- *Natural stimuli:*
 - Confounds are just *other variables*
 - If confounds are perfectly correlated in natural stimuli...

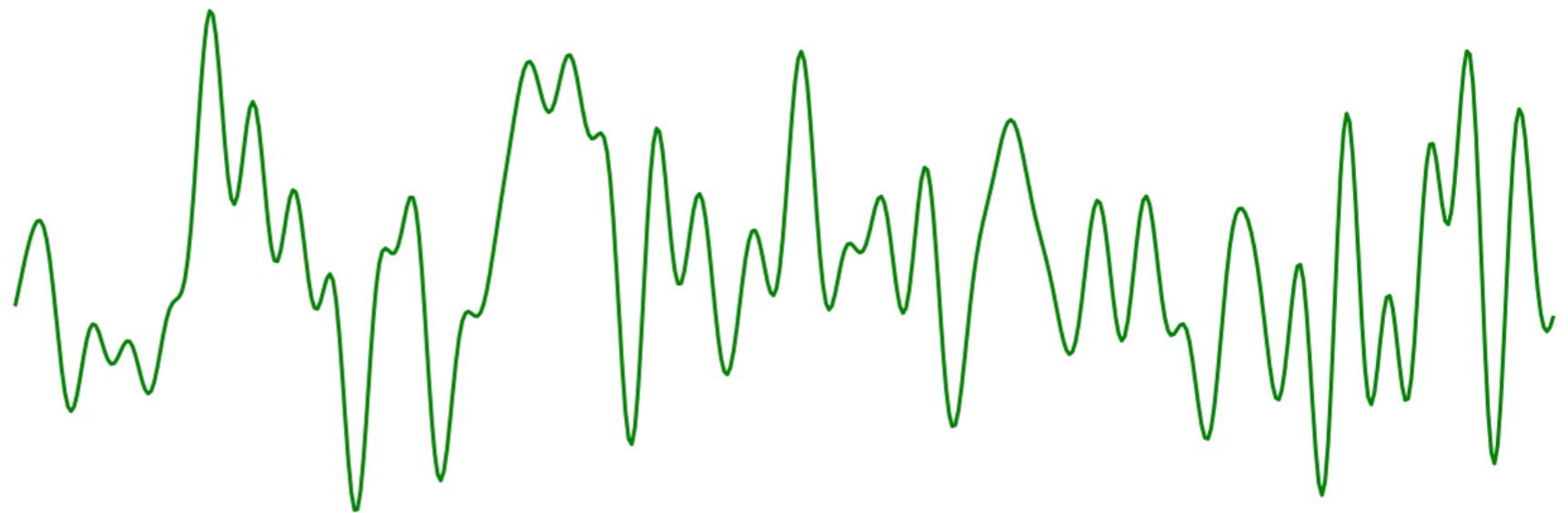
VARIABLES ARE CORRELATED?

VARIABLE 1

VARIABLE 2



RESPONSE



VARIABLES ARE CORRELATED?

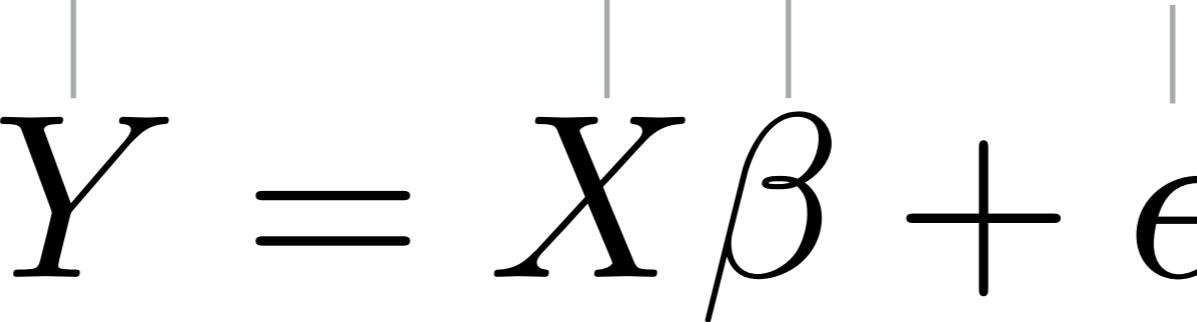
RESPONSE = A · (VARIABLE 1) + B · (VARIABLE 2) + E

A = ? B = ?

REGRESSION

$$Y = X\beta + \epsilon$$

RESPONSE **VARIABLES** **WEIGHTS** **NOISE**



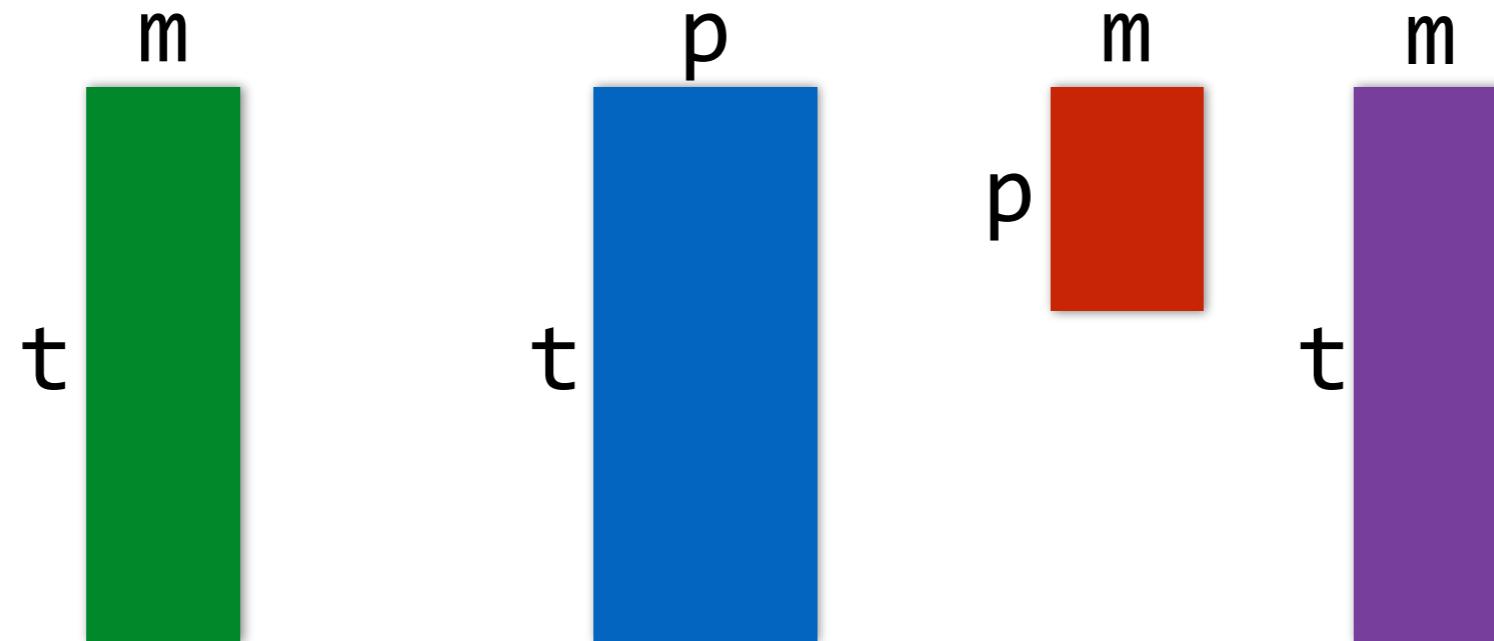
REGRESSION

$$Y = X\beta + \epsilon$$

RESPONSE VARIABLES WEIGHTS NOISE

The diagram illustrates the components of a regression equation $Y = X\beta + \epsilon$. The terms are labeled as follows:

- RESPONSE**: Y (green bar)
- VARIABLES**: X (blue bars)
- WEIGHTS**: β (orange bar)
- NOISE**: ϵ (purple bar)



REGRESSION

$$\hat{\beta} = (X^\top X)^{-1} X^\top Y$$

Moore-Penrose pseudoinverse

REGRESSION

$$\hat{\beta} = (X^\top X)^{-1} X^\top Y$$

~precision matrix

un-mixes the
variables

**“spike-triggered
average”**

correlation
between X & Y

IT'S OK FOR VARIABLES TO BE CORRELATED

- As long as we have enough samples to de-correlate them
- And we know what the variables are!

NEXT TIME

- * System identification & feature spaces