Experimental design

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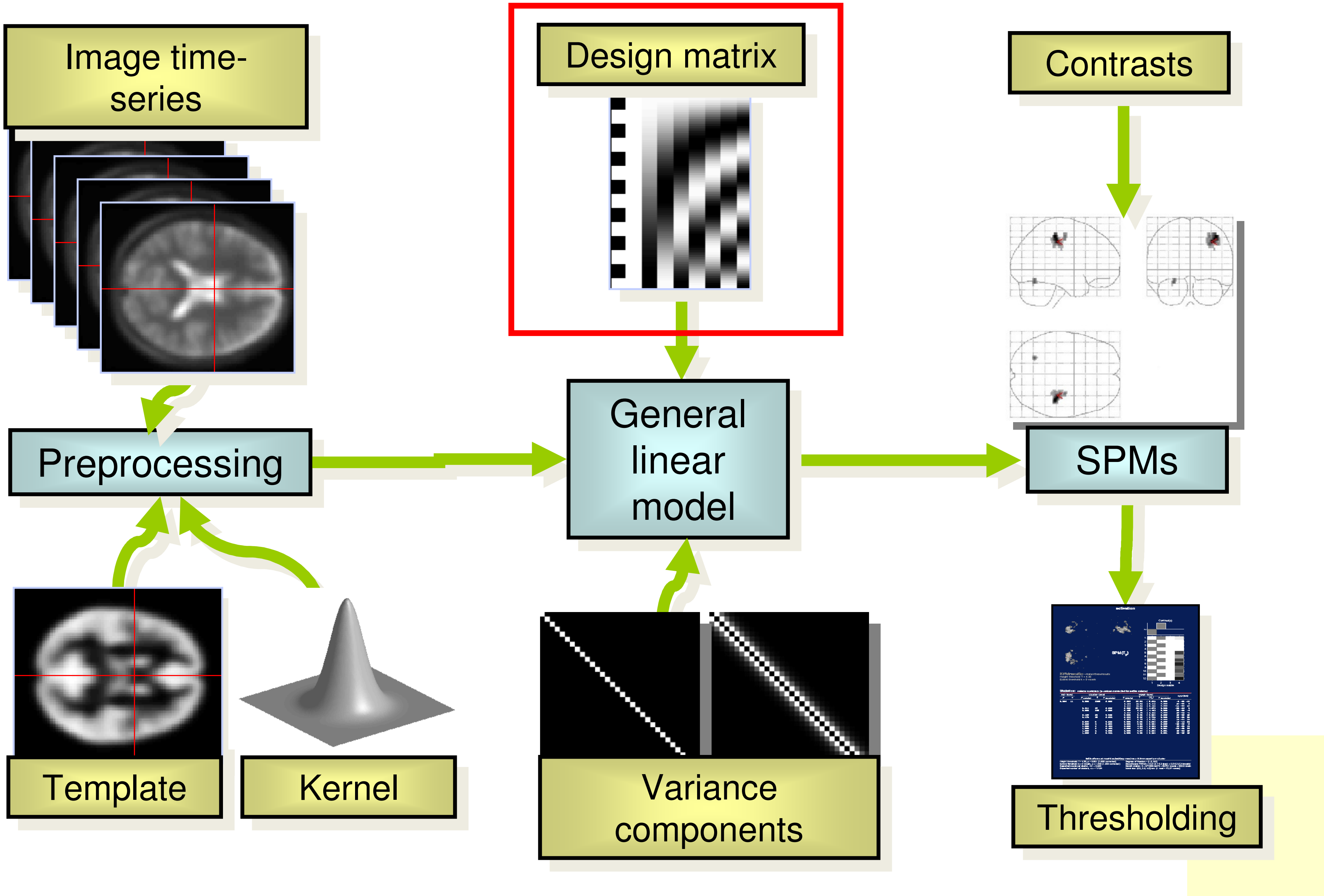
Edinburgh SPM course 2013

Thanks to Rik Henson, Thomas Wolbers, Jody Culham, and the SPM authors for slides

Overview of SPM



Overview

- Categorical designs
- Factorial designs
- Parametric designs

- fMRI adaptation
- Control condition
- Paradigm timing

Isolating a process

Subtraction logic and assumption of pure insertion

- Compare task conditions differing in a single process
- Measure the time the process takes
- Assume that addition of the component process does not alter other task components

Donders (1898-9)

Pure insertion

T1: Simple Reaction Time

- Hit button when you see a light

Detect Stimulus	Press Button

T2: Discrimination Reaction Time

- Hit button when light is green but not red

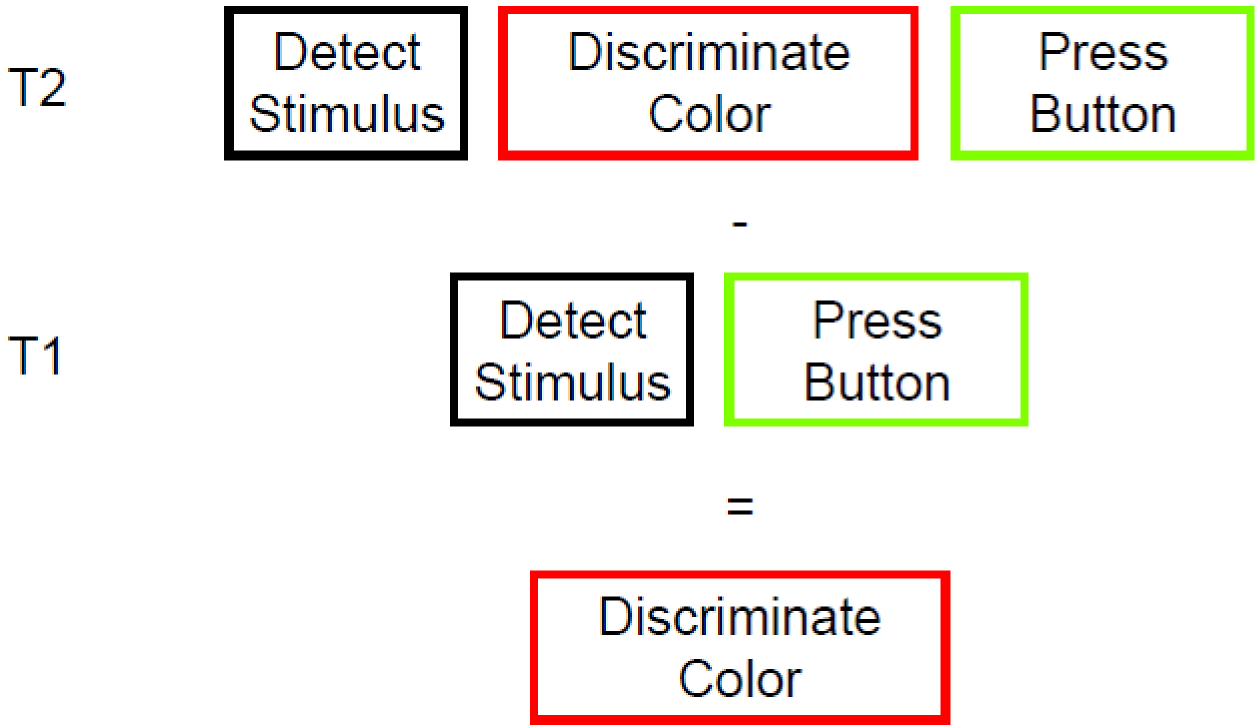
Detect Stimulus	Discriminate Color	Press Button

T3: Choice Reaction Time

- Hit left button when light is green and right button when light is red

Detect Stimulus	Discriminate Color	Choose Button	Press Button

Cognitive subtraction



Cognitive subtraction

T3	Detect Stimulus	Discriminate Color	Choose Button	Press Button
		-		
T2	Detect Stimulus	Discriminate Color		Press Button
		=		
			Choose Button	

Categorical designs

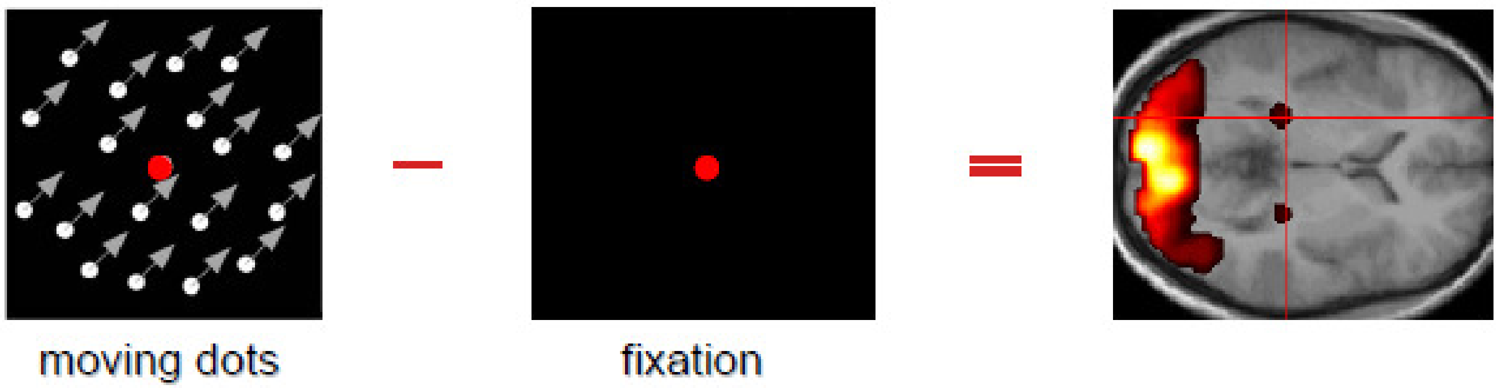
Principle

- Subtract two conditions to isolate a process
- Assume that addition of the component process does not alter other task components
- So adding the process into different tasks should produce the same change in activity
- (and: meaningful cognitive theory)

Categorical designs

Simple subtraction

- Detect regions specialised for a function by testing for activation difference



Categorical designs

Serial subtraction

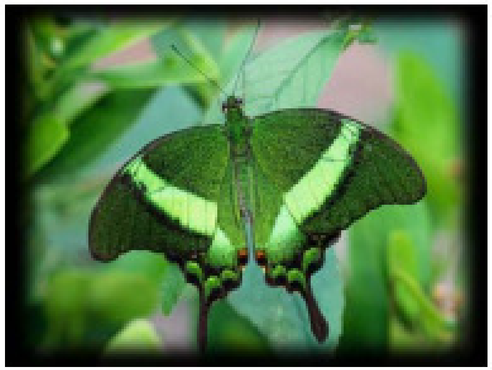
- Several cognitive processes in picture naming

⇒ visual analysis: occipital cortex

⇒ object recognition: ???

⇒ phonological retrieval: ???

⇒ verbal output: Broca's area

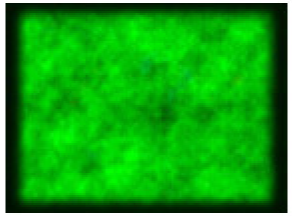


See Friston et al. chapter in Human Brain Function (I)

Categorical designs

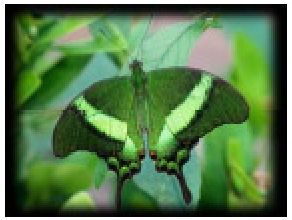
Experimental design

A say „yes“ when you see an abstract image
(*vis. analysis, verbal output*)



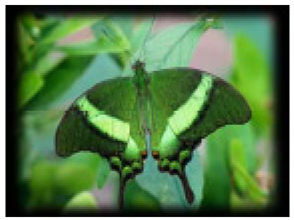
⇒ yes

B say „yes“ when you see a concrete object
(*vis. analysis, object recognition, verbal output*)



⇒ yes

C name concrete object
(*vis. analysis, object recognition, phonological retrieval, verbal output*)



⇒ butterfly

Categorical designs

A visual analysis verbal output	------------------
B visual analysis object recognition verbal output	**C** visual analysis object recognition phonological retrieval verbal output

B - A ⇒ significant IT activation ⇒ object recognition!

C - B ⇒ no significant IT activation ⇒ no evidence for IT involvement in phonological retrieval!

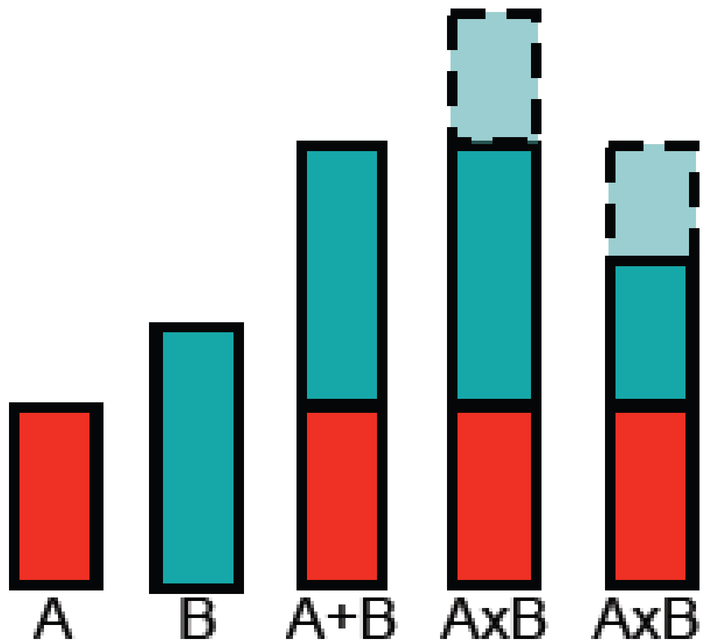
Problem: unjustified assumption that IT response to object recognition is <u>context independent</u>!

→ psychophysics ≠ neurophysiology

Factorial designs

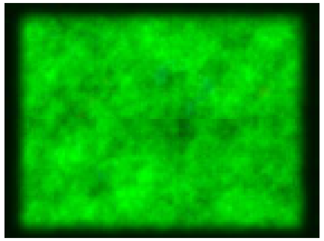
Interactions

- The whole (task) is more than the sum of its (interdependent) processes
- A modulates B
- Vary A and B independently



Factorial designs

D Name colour of abstract image
(*vis. analysis, phonological retrieval, verbal output*)



⇒ green

	no phonolog. retrieval		phonolog. retrieval	
no object recogn.	A	visual analysis verbal output	D	visual analysis phonological retrieval verbal output
object recognit.	B	visual analysis object recognition verbal output	C	visual analysis object recognition phonological retrieval verbal output

Interaction: (C - D) – (B - A) ⇒ significant IT activation

- phonological retrieval modulates IT response to object recognition

  ⇒ IT also involved in phonological retrieval!

Conjunction design

Two task pairs

- B – viewing concrete objects and saying "yes"
- C – naming concrete objects

Difference = phonological retrieval PLUS interaction with object recognition

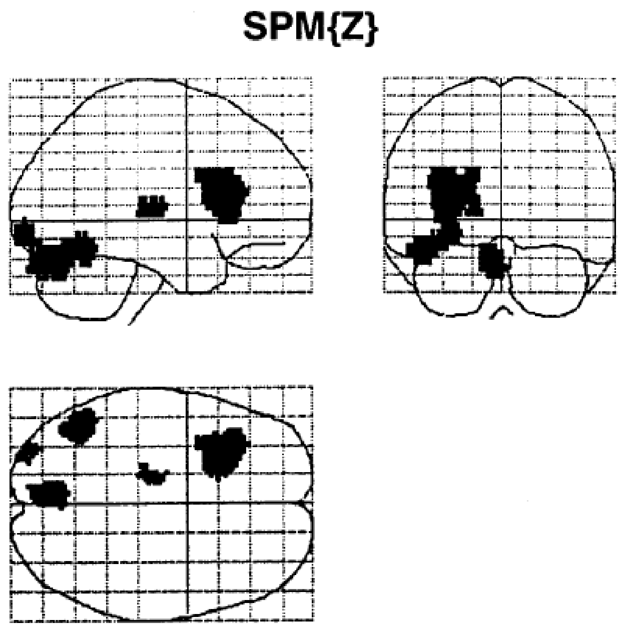
- B2 – viewing coloured shapes saying "yes"
- C2 – naming colour of coloured shapes

Diff = phonological retrieval PLUS interaction with visual analysis

Conjunction design

Overlap isolates the process of interest

- Phonological retrieval
- NOT its interactions with visual processing



Overlap of 4 subtractions

Price & Friston (1997)

Conjunction designs

Detecting overlapping processing

- Encoding faces, different objects
- Reactivation of same regions when face, object memories retrieved

MVPA recall study

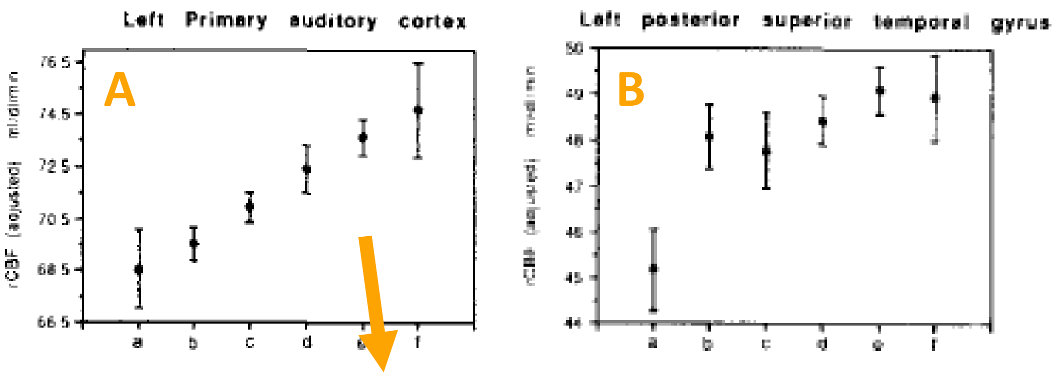
Polyn et al. (2005)

Parametric designs

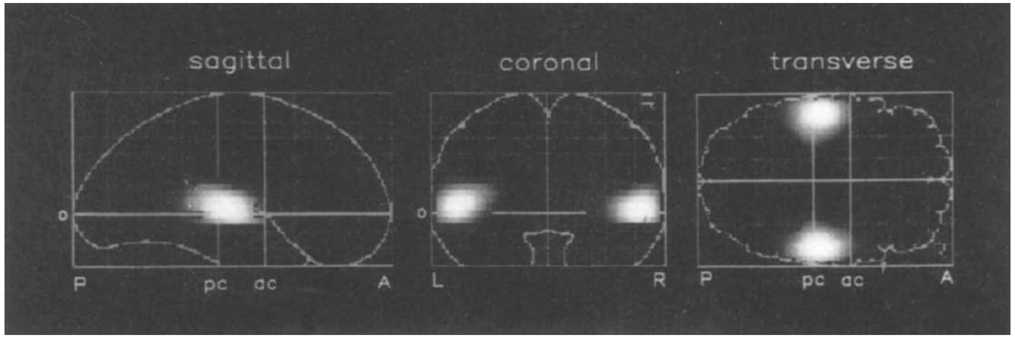
A continuously varying parameter

- Systematic variation in activity with process engaged to varying degrees
- Specific: e.g. Linear? Quadratic?
- Avoids pure insertion but does assume no qualitative change in processing
- Often less sensitive

Parametric designs



Rest + 5 rates of auditory word presentation



PET study

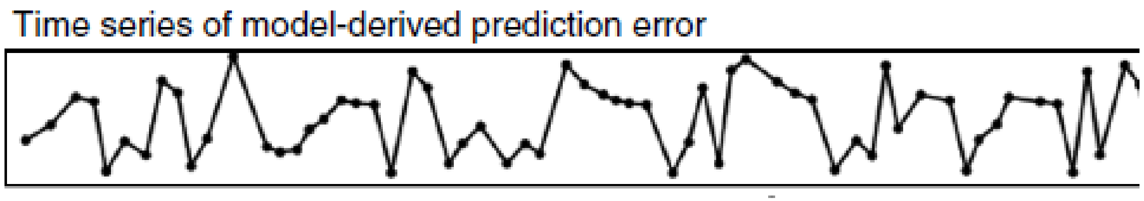
- Auditory words, varying rate
- Linear relationship of rate with activity in primary auditory cortex

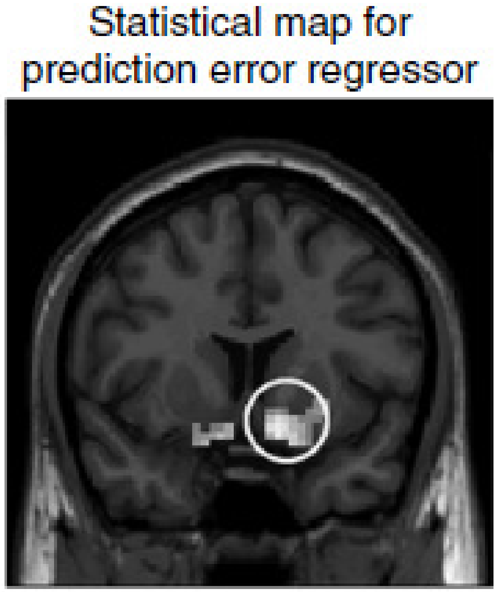
Price et al. (1992)

Parametric designs

Model based fMRI

- Computational model provides neurometric function e.g. Rescorla-Wagner prediction error
- Model comparison

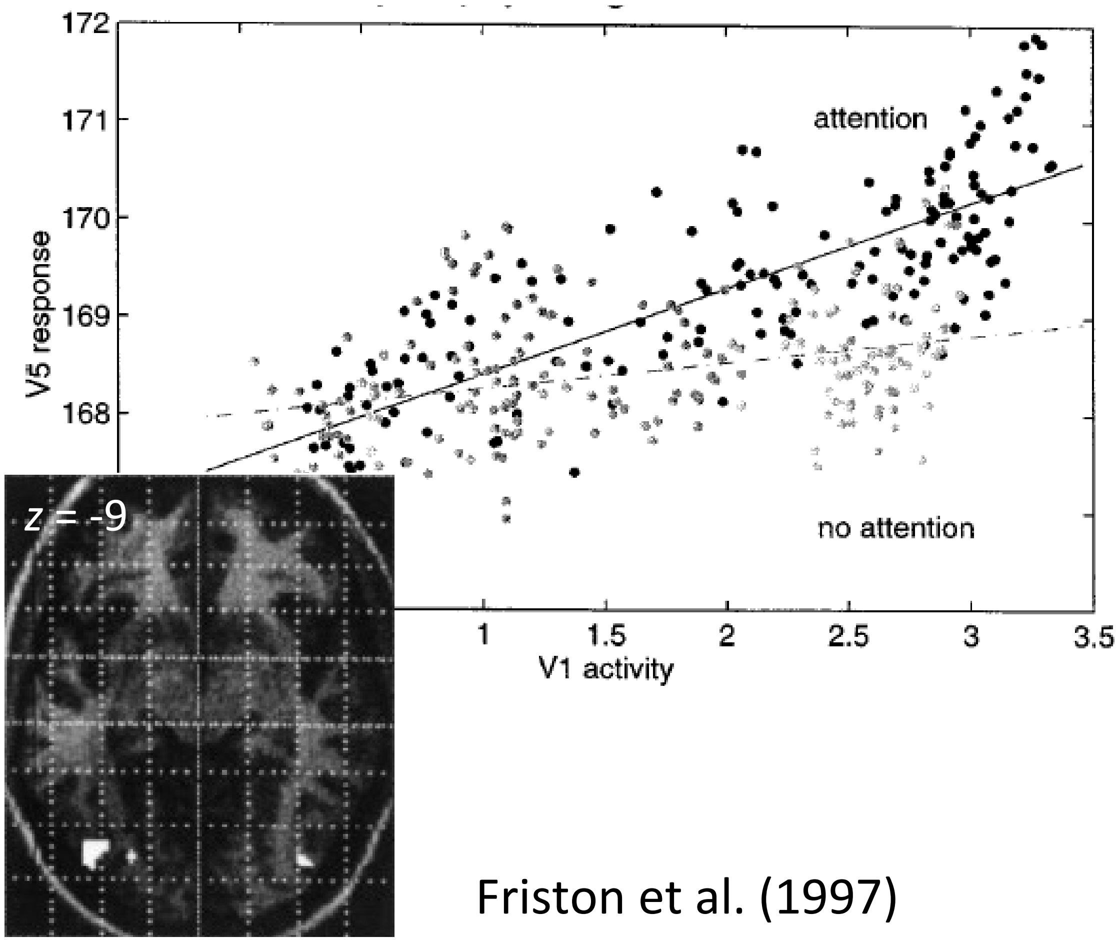




Glascher & O'Doherty (2010)

Parametric factorial designs

Psychophysiological interaction in V5

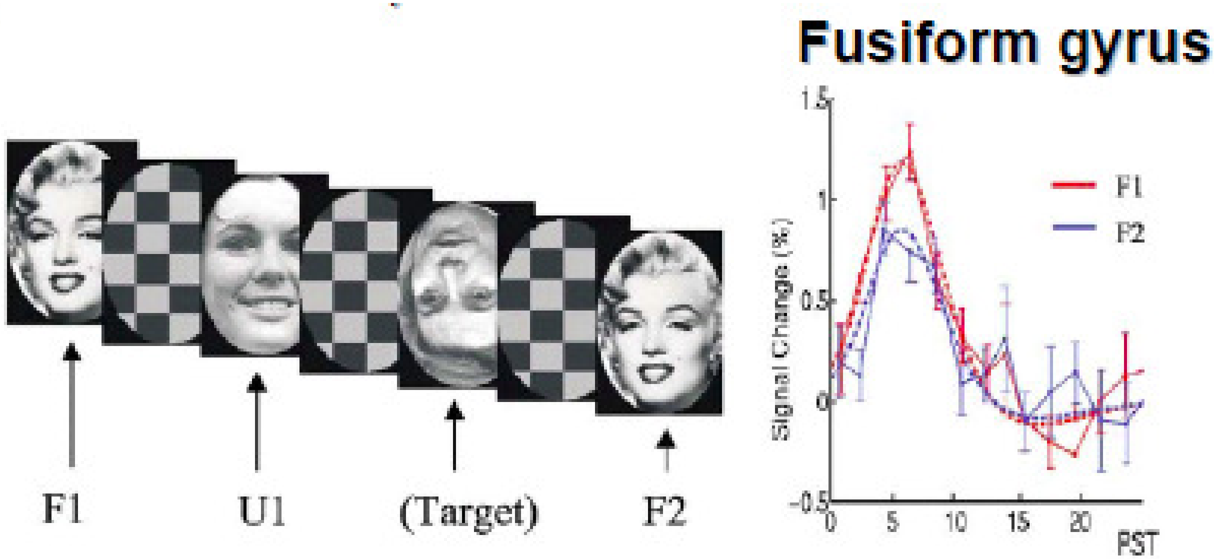


Friston et al. (1997)

- V1 activity = parametric (physiological) predictor
- Attention to motion = categorical (psychological) predictor

fMRI adaptation

- Repetition suppression
- = reduced BOLD response to repeated stimuli
- Accompanies priming (behavioural)

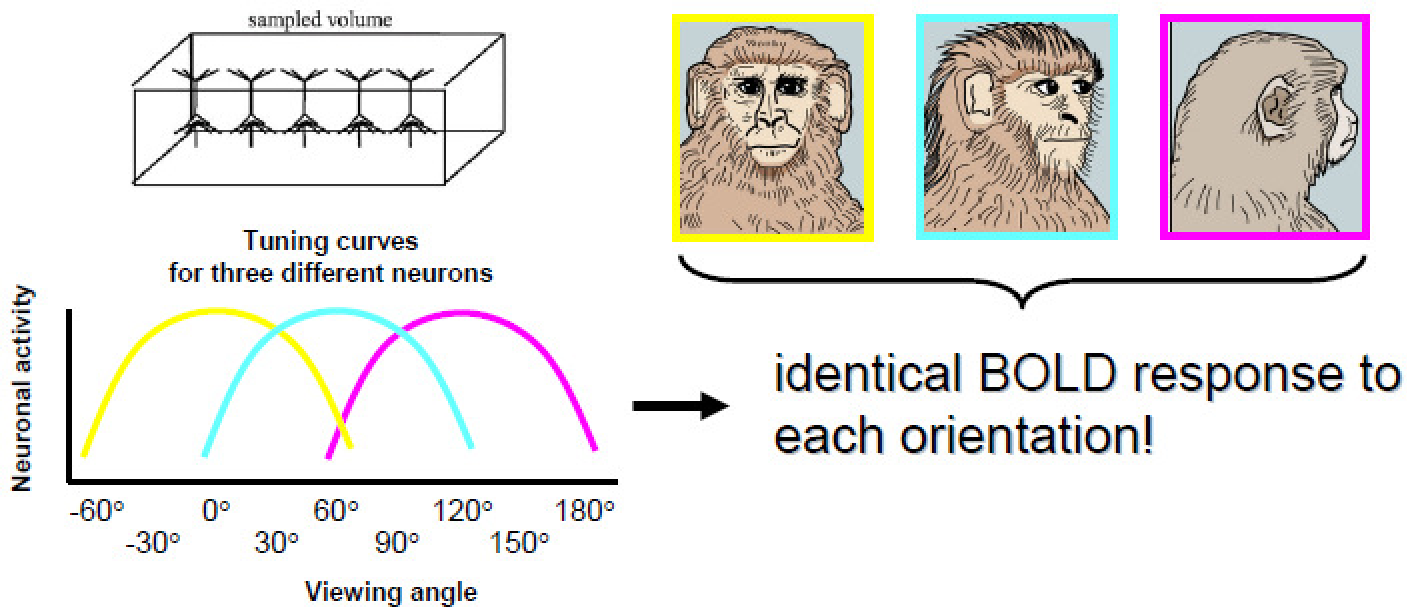


Henson et al. (2000)

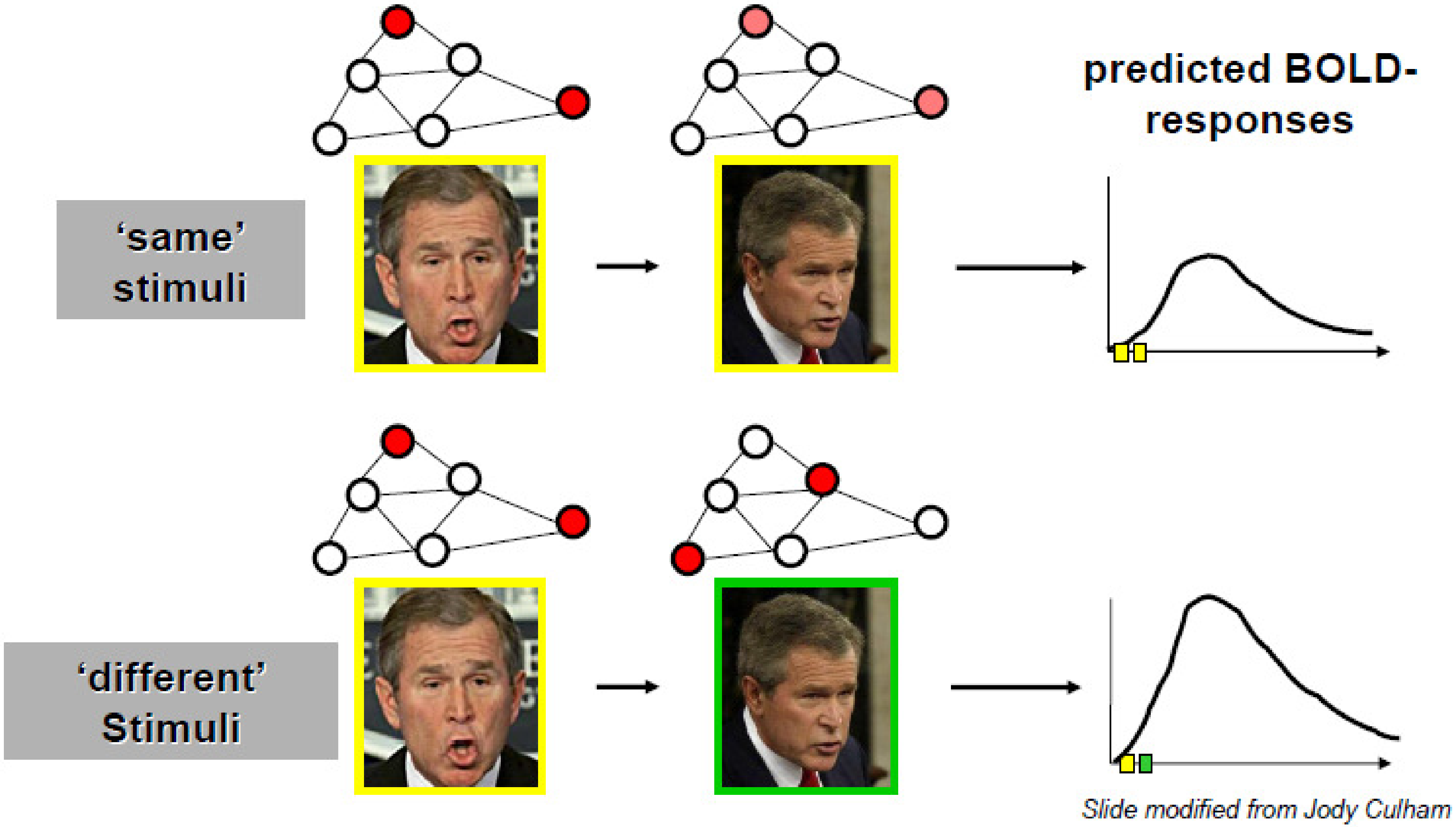
fMRI adaptation

Repetition suppression as a tool

- fMRI – typical voxel = 10,000s of neurons
- FFA – a mix, tuned to diff. face orientations?
- Or: all viewpoint-invariant?



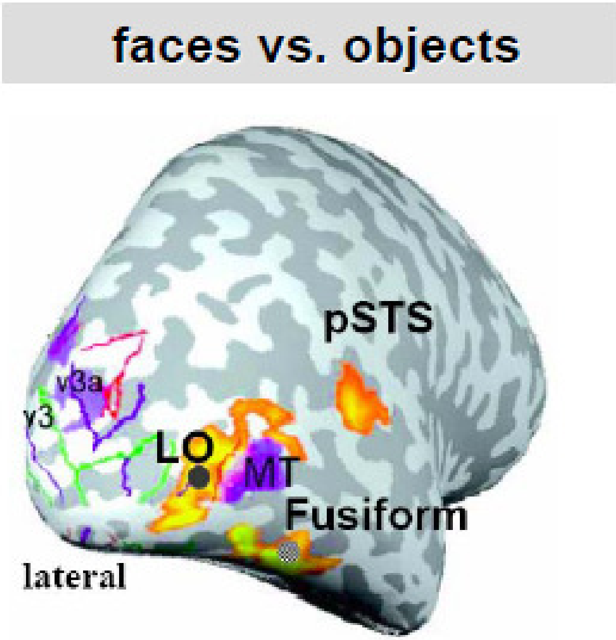
fMRI adaptation



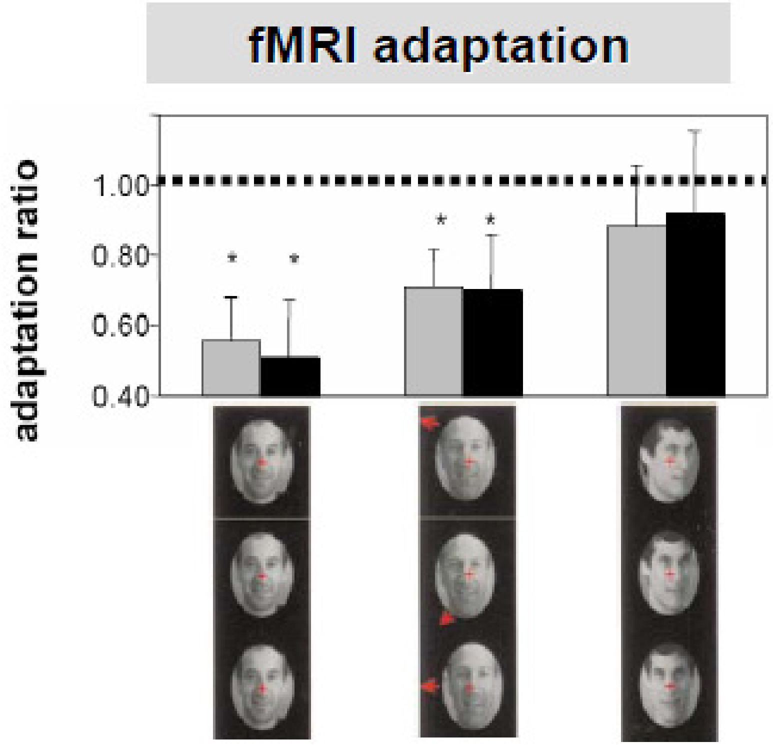
Release from adaptation => sensitivity to the changed feature

fMRI adaptation

Orientation tuning in human LOC



Grill-Spector & Malach (2001), Acta Psychol.



Ident. Trans. Rotate

Control condition

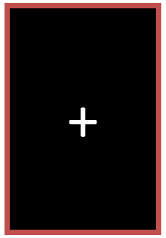
Problem

- fMRI is a contrastive method – for many designs, you need a control
- ‘Rest’ isn’t no processing in many areas

Control condition

Different stimuli and task

'Marilyn'



Wonder if I left the gas on…?

Different stimuli similar task

'Female'

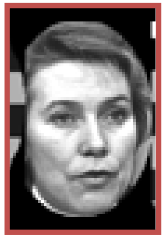
'Female'

Same stimuli different task

'Female'

'Seen before'

Similar stimuli same task

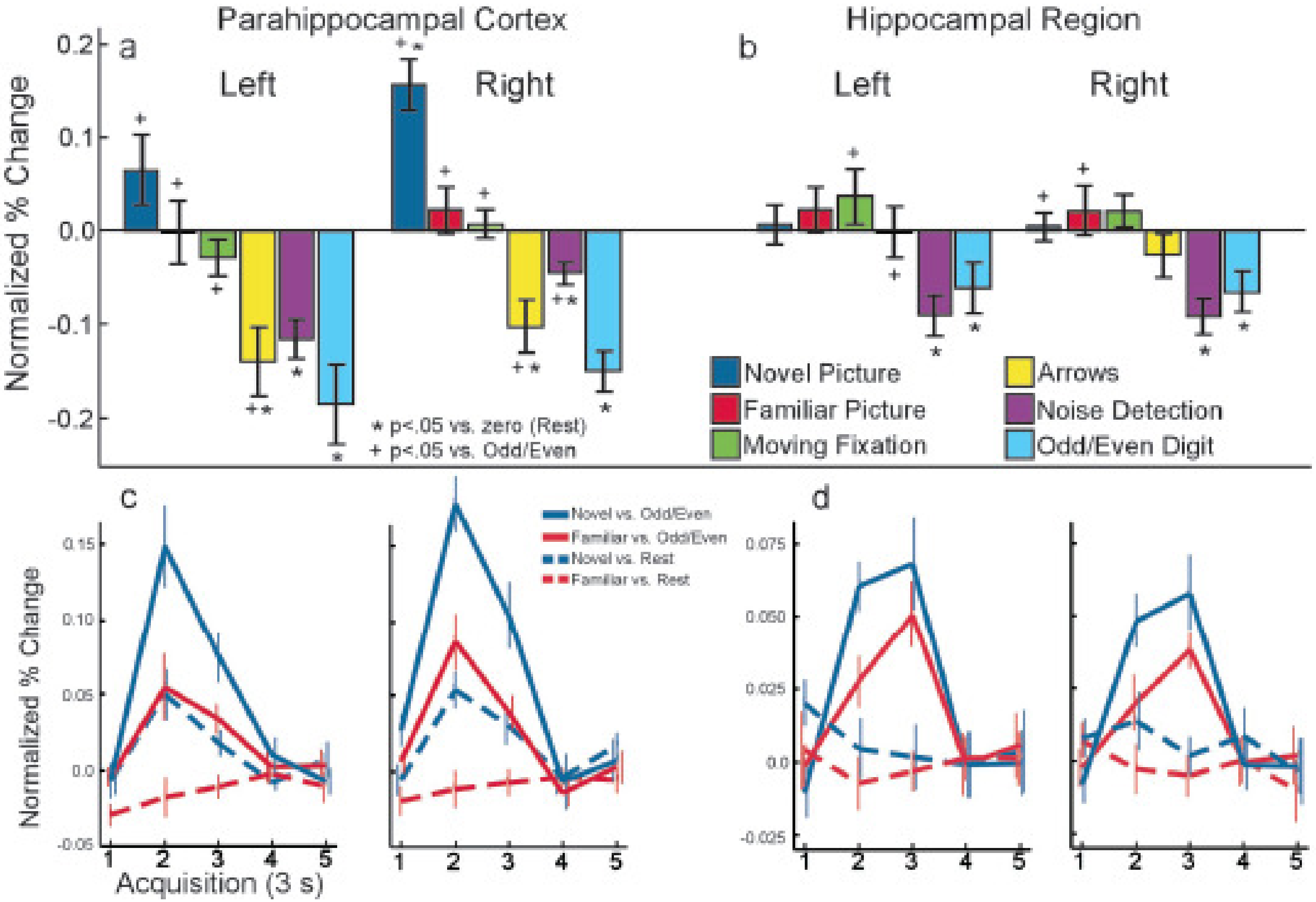


'Female'

'Female'

→ Choice of a baseline depends on your question!

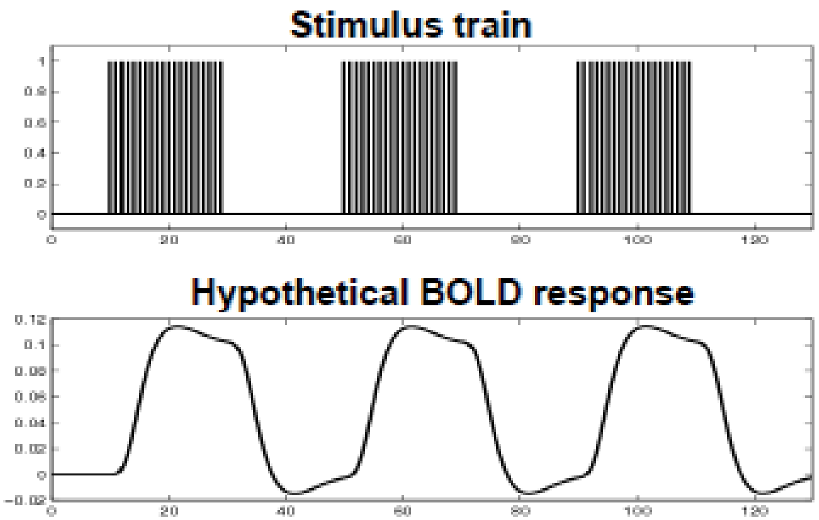
Control condition



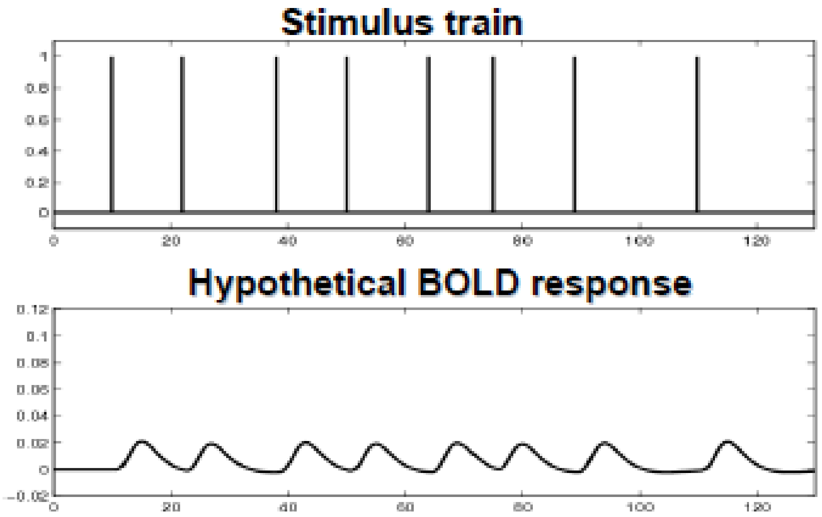
Stark & Squire (2001) PNAS

Paradigm timing

Block Design



Event-Related Design



Analysis of whole block

Large effects (=efficient)

Optimal length = 16 sec (sluggish BOLD vs. low frequency confounds)

Analysis of single items

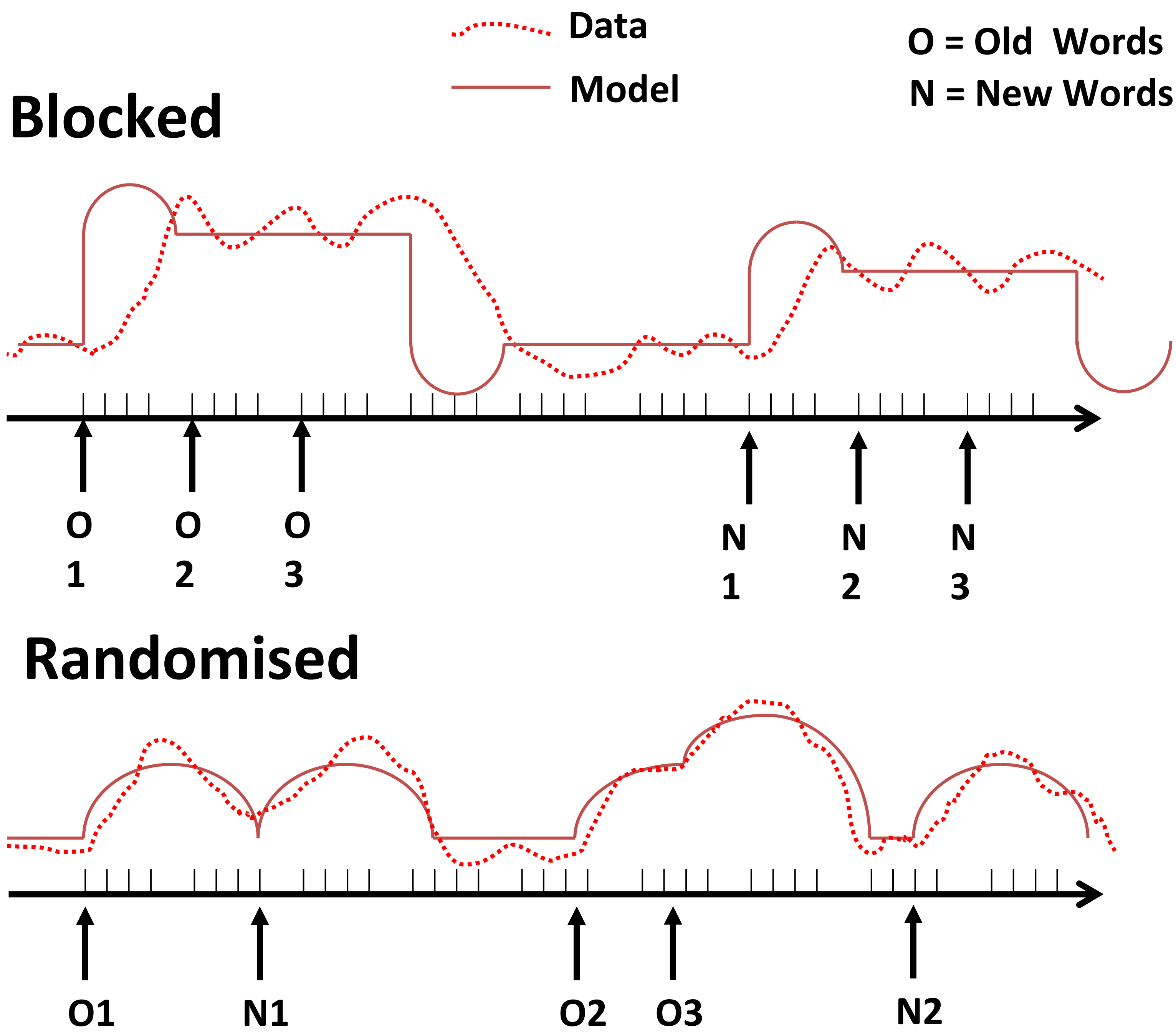
Smaller effects

SOA from min ~= 2 sec

Paradigm timing

Advantages of event-related design

- Intermixing of conditions avoids unwanted psychological effects e.g. habituation, expectancy, loss of concentration


Data
Model
O = Old Words
N = New Words
Blocked
O
1
O
2
O
3
N
1
N
2
N
3
Randomised
O1
N1
O2
O3
N2

Paradigm timing

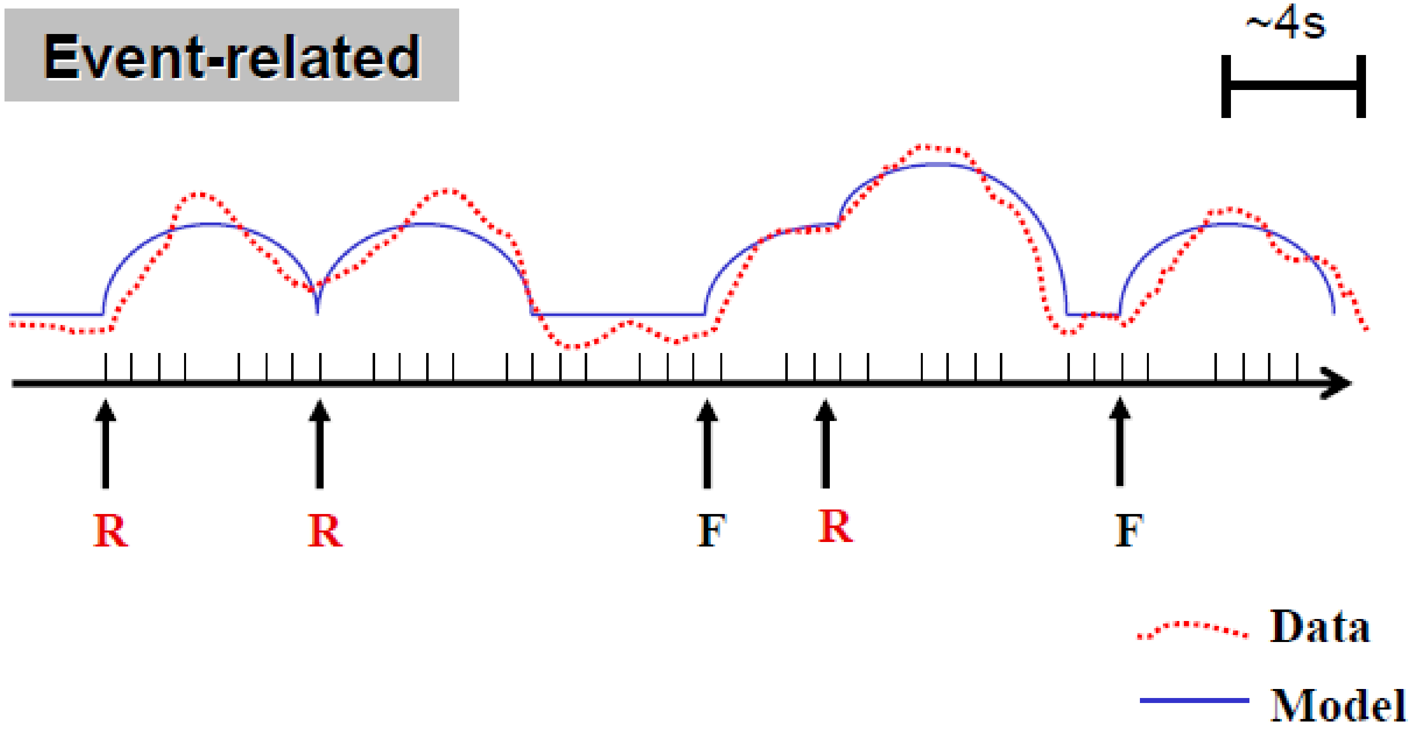
Advantages of event-related design

- Intermixing of conditions avoids unwanted psychological effects e.g. habituation, expectancy, loss of concentration
- Post-hoc classification of trials, e.g. Subsequent memory effect

Paradigm timing

R = Words Later Remembered

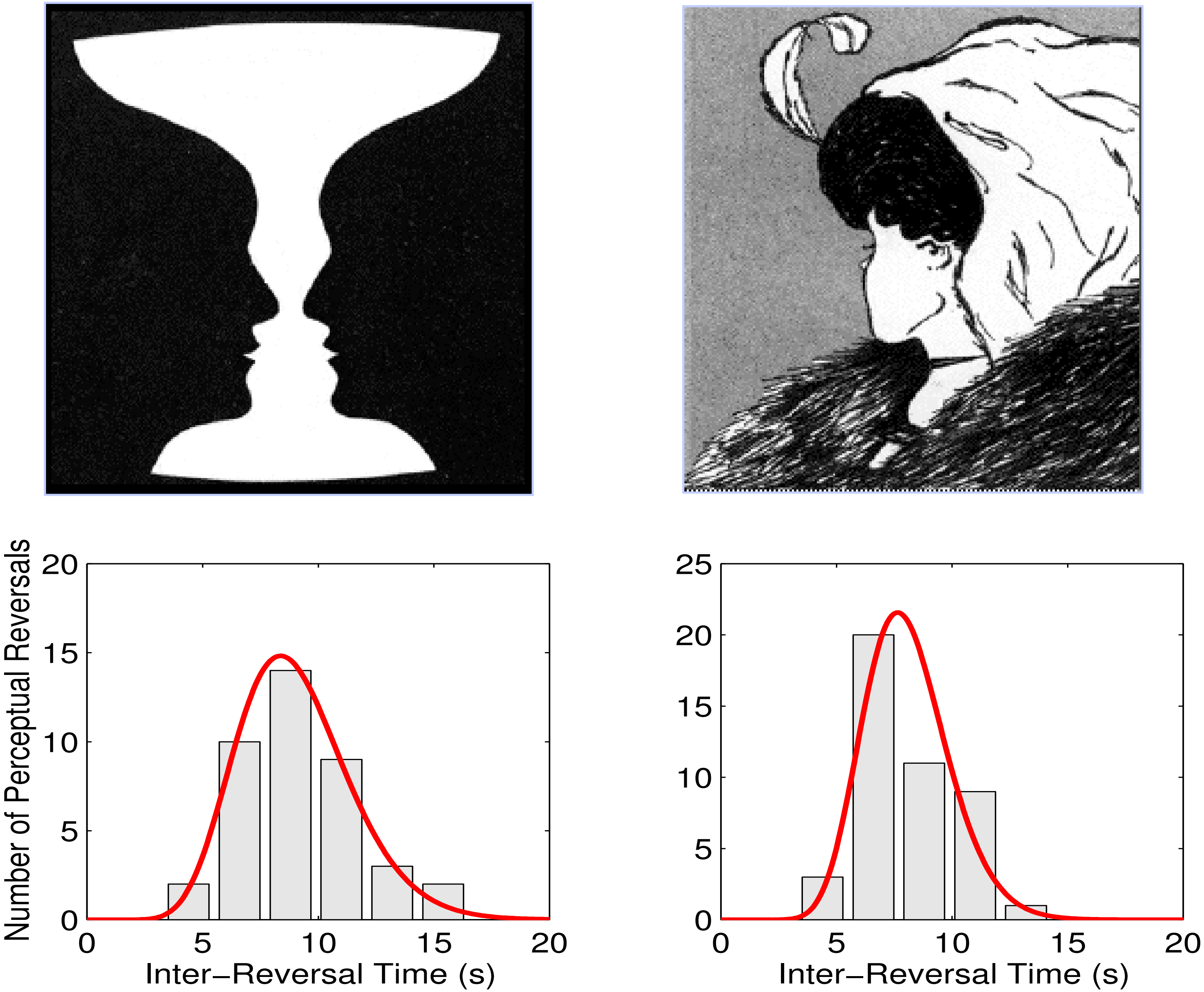
F = Words Later Forgotten



Paradigm timing

Advantages of event-related design

- Intermixing of conditions avoids unwanted psychological effects e.g. habituation, expectancy, loss of concentration
- Post-hoc classification of trials, e.g. Subsequent memory effect
- Some events can only be indicated by subject at particular time e.g. Spontaneous perceptual changes


Number of Perceptual Reversals
0
5
10
15
20
0
5
10
15
20
Inter−Reversal Time (s)
0
5
10
15
20
25
0
5
10
15
20
Inter−Reversal Time (s)

Paradigm timing

Advantages of event-related design

- Intermixing of conditions avoids unwanted psychological effects e.g. habituation, expectancy, loss of concentration
- Post-hoc classification of trials, e.g. Subsequent memory effect
- Some events can only be indicated by subject at particular time e.g. Spontaneous perceptual changes
- Some events cannot be blocked, e.g. oddball

Summary

A few principles, one main take-home message

- Different designs for different questions

Want to know more?

- Temporal design efficiency
- Design optimisation

→ Advanced course (Wednesday)