Experimental design

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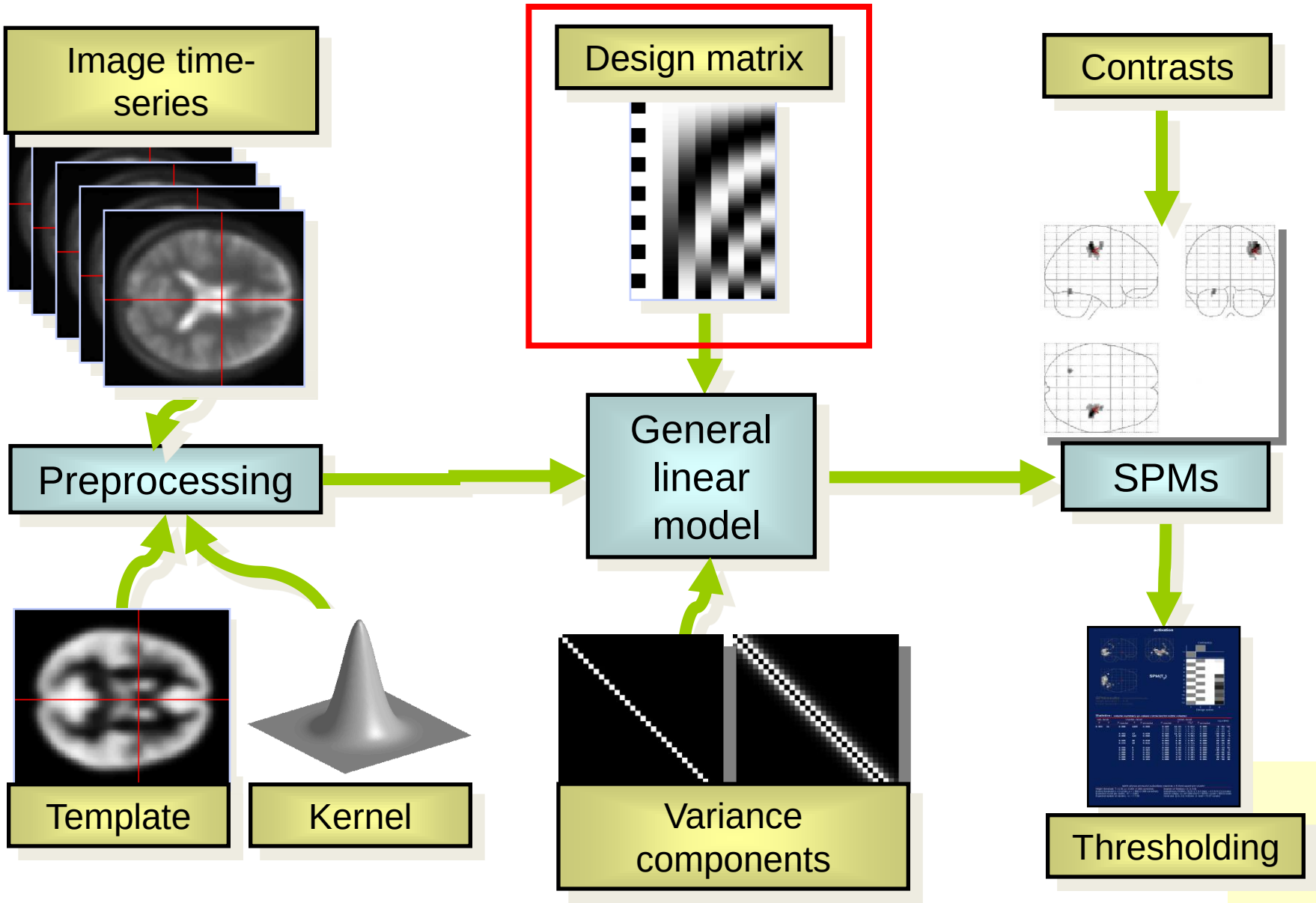
Edinburgh SPM course 2015

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

Overview of SPM



Overview

- Categorical designs
- Factorial designs
- Conjunction designs

- Parametric designs
- fMRI adaptation

- Paradigm timing

Isolating a process

- Basic aim: neural correlates of a single process
- Assume that addition of the component process does not alter other task components

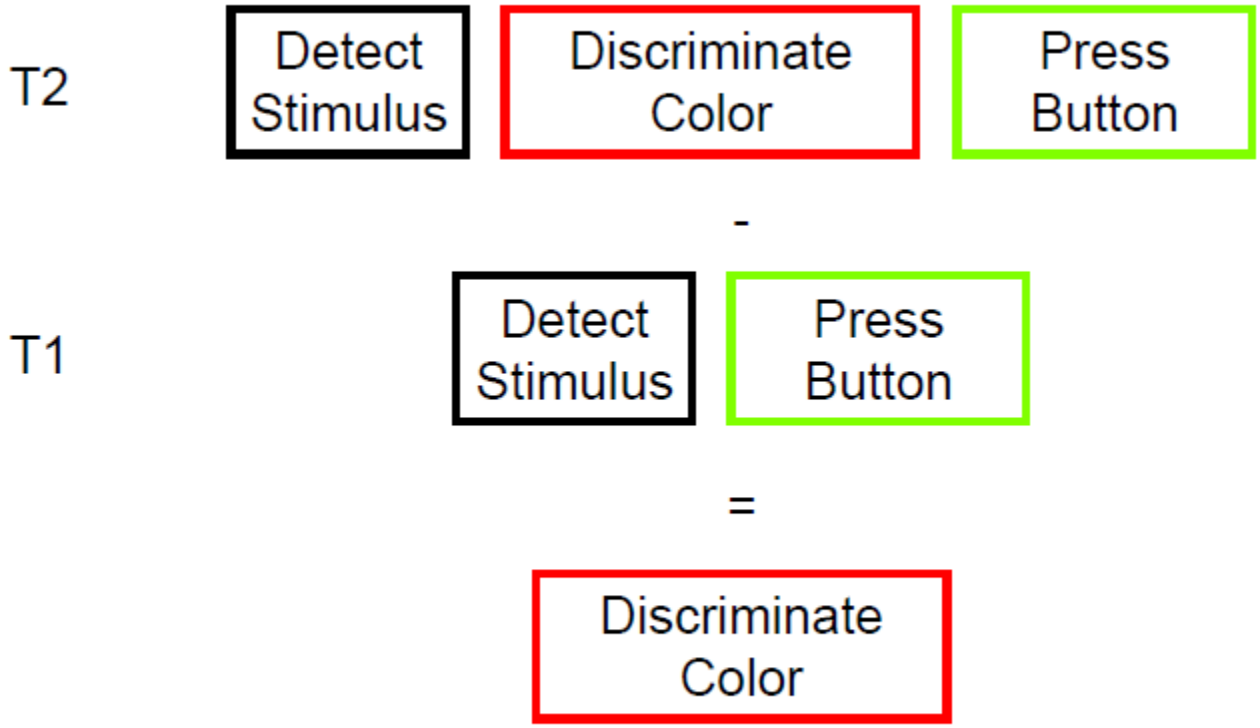
  "pure insertion"

- And: a meaningful cognitive ontology

Donders (1898-9)

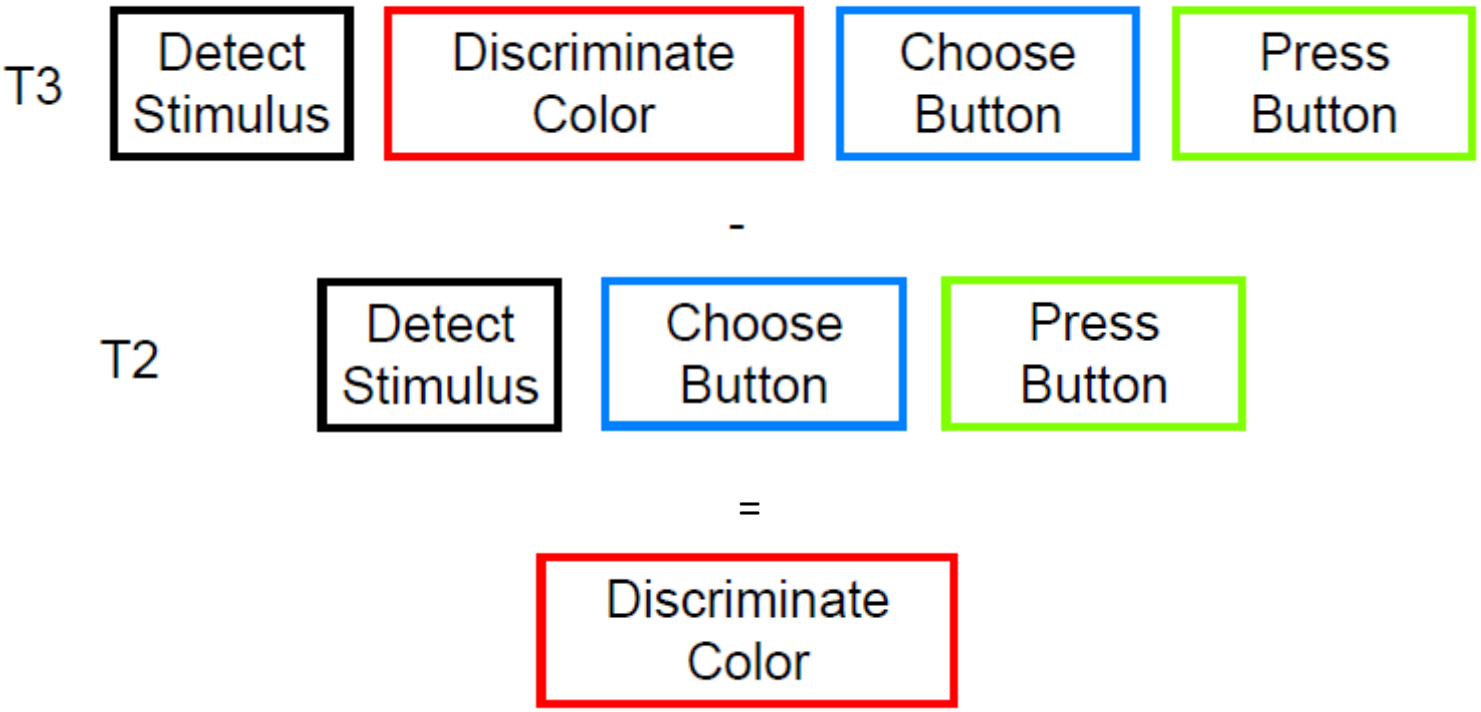
Cognitive subtraction

Use a simple reaction time task to isolate a process



Cognitive subtraction

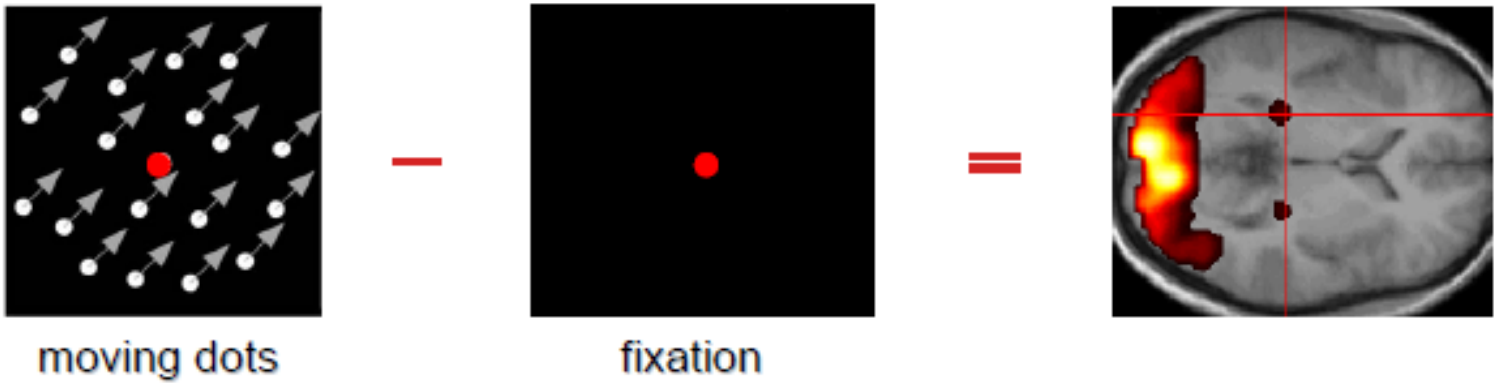
Use a choice reaction time task – get the same results



Categorical designs

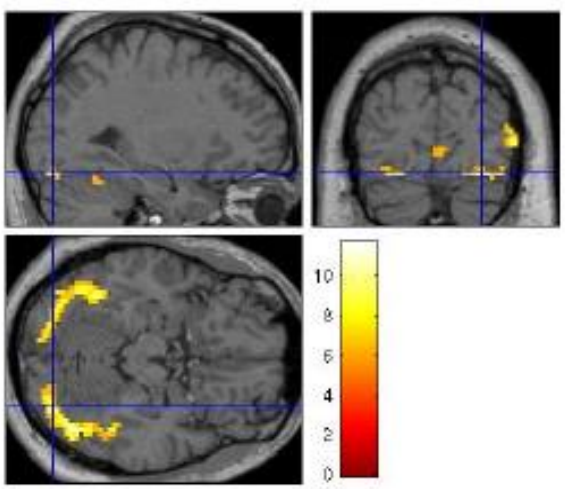
Simple subtraction

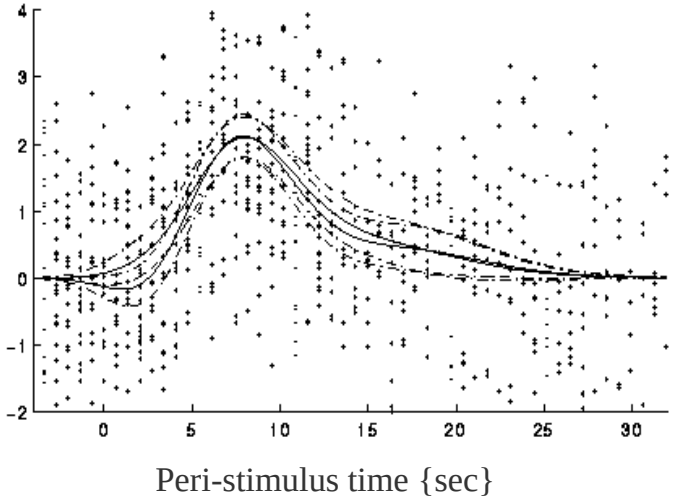
- Detect regions specialised for a function by testing for activation difference
- May also ask: do 2 tasks differ in processing?



Evoked responses

Faces vs. baseline ‘rest’





‘Null’ events or long SOAs essential for estimation of response vs. baseline

‘Implicit baseline’ in SPM is everything not specified in the model

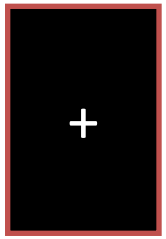
‘Cognitive’ interpretation hardly possible

Estimation of shape of the haemodynamic response

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’

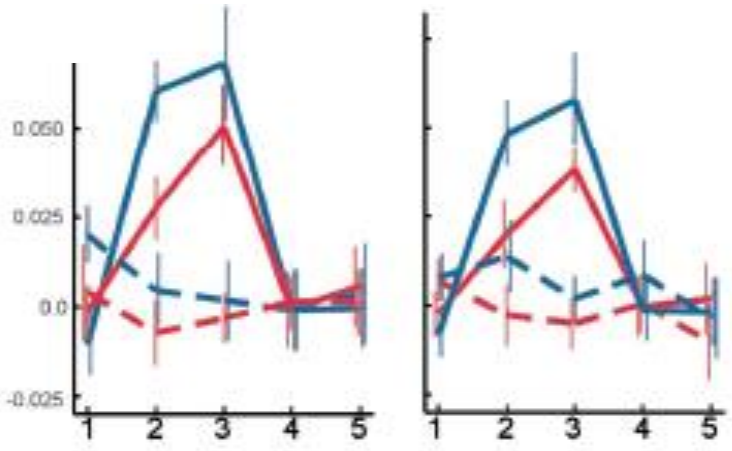
Similar stimuli same task

‘Female’

‘Female’

→ Choice of a baseline depends on your question!

Control condition



Novel vs. Odd/Even
Familiar vs. Odd/Even

Novel vs. Rest
Familiar vs. Rest

"Failure to activate" the hippocampus during episodic memory tasks?

…if we use fixation/ rest as the baseline

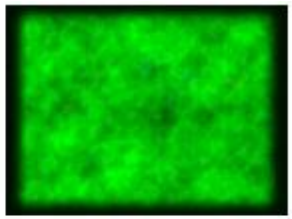
Stark & Squire (2001) PNAS

Categorical designs

Serial subtraction

- Is the inferiotemporal cortex sensitive to both object recognition and phonological retrieval of object names?

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

Friston et al. (1997)

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 context independent!

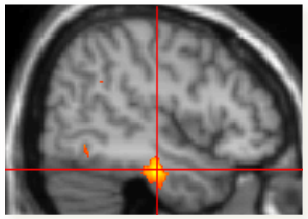
→ psychophysics ≠ neurophysiology

Overview

- Categorical designs
- Factorial designs
- Conjunction designs

- Parametric designs
- fMRI adaptation

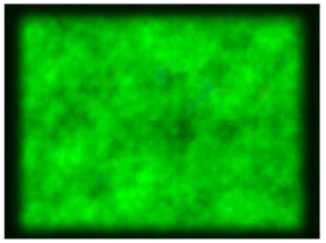
- Paradigm timing



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!

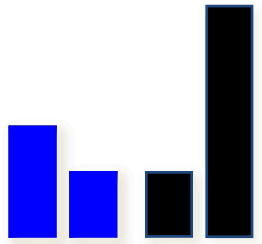
Friston et al. (1997)

Factorial designs

Interactions

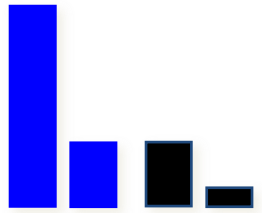
- The task is more than the sum of its (interdependent) processes
- A modulates B
- Vary A and B independently

cross-over



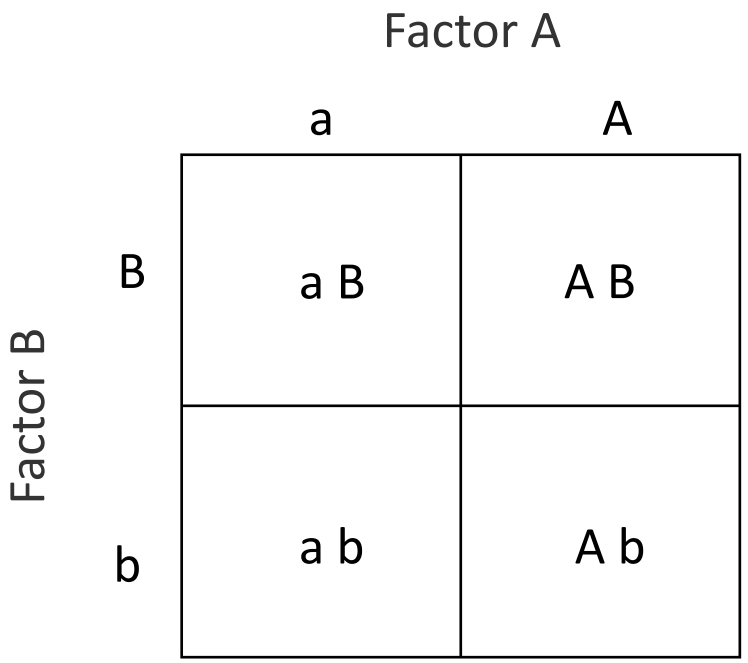
and

simple



We can selectively inspect our data for one or the other by masking during inference

Factorial designs



Main effect of B: B - b

(aB + AB) – (ab + Ab)

Main effect of A: A-a

(AB + Ab) – (aB + ab)

Interaction of A and B:

(AB + ab) – (Ab + aB)

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Conjunction design

One way to minimize ‘the baseline problem’ is to isolate
the same cognitive process by two or more separate contrasts,
and inspect the resulting simple effects for commonalities.

Conjunctions can be conducted across different contexts:

- tasks
- stimuli
- senses (vision, audition)

etc.

Note: The contrasts entering a conjunction have to be truly independent.

Conjunction design

Two task pairs

- B – viewing concrete objects and saying “yes”
- C – naming concrete objects

Difference = phonological retrieval PLUS interaction with object recognition

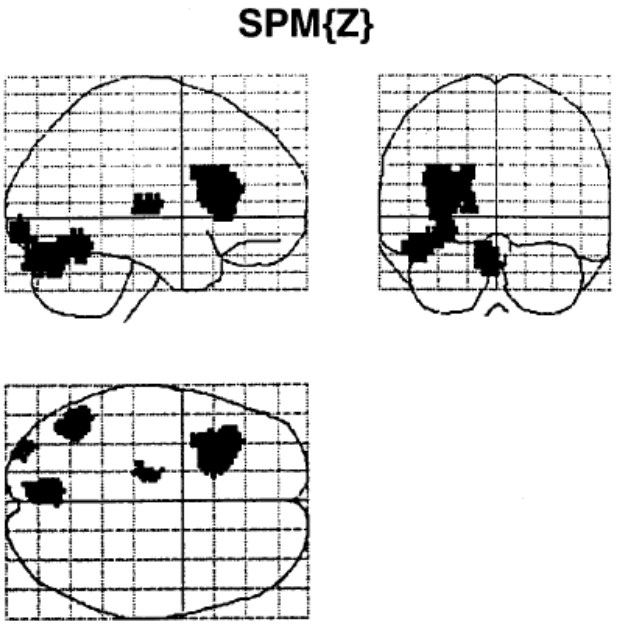
- B2 – viewing coloured shapes saying “yes”
- C2 – naming colour of coloured shapes

Diff = phonological retrieval PLUS interaction with visual analysis

Conjunction design

Overlap isolates the process of interest

- Phonological retrieval
- NOT its interactions with visual processing



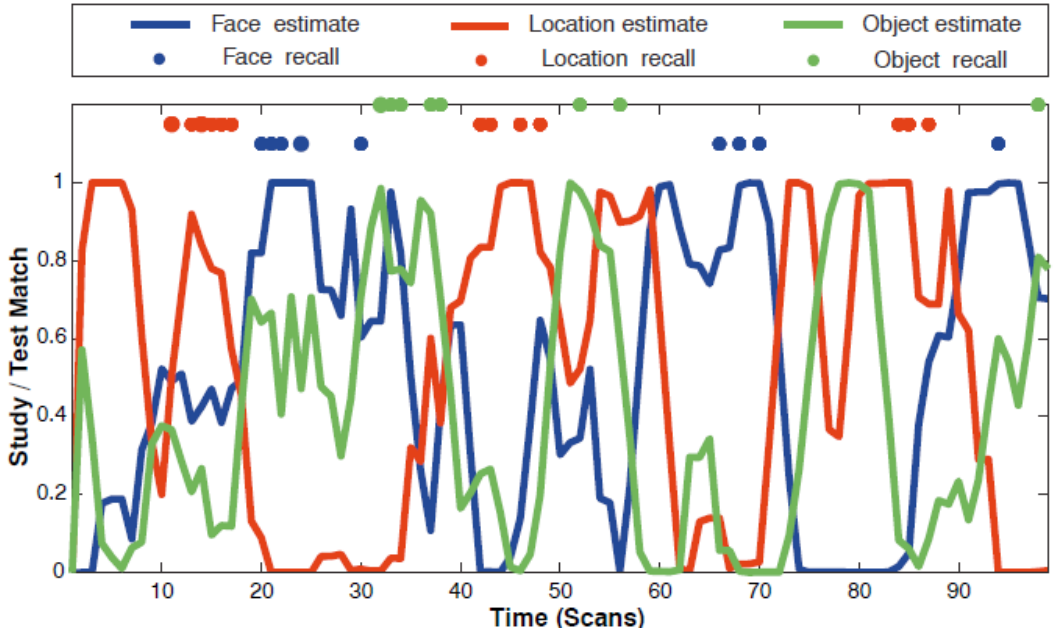
Overlap of 4 subtractions

Price & Friston (1997)

Conjunction design

Detecting overlapping processing

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



MVPA recall study

Polyn et al. (2005)

Conjunction statistical tests

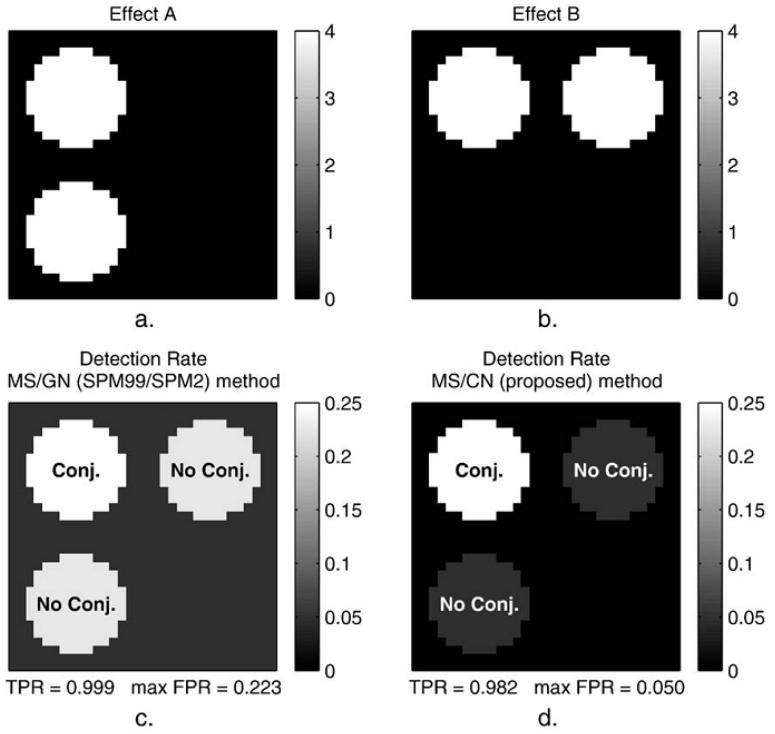
SPM12 offers two general ways to test the significance of conjunctions.

- Test of global null hypothesis (c): Significant set of consistent effects

"which voxels show effects of similar direction (but not necessarily individual significance) across contrasts?"

- Test of conjunction null hypothesis (d): Set of consistently significant effects

"which voxels show, for each specified contrast, effects > threshold?"



Friston et al., (2005). *Neuroimage*, 25:661-7.

Nichols et al., (2005). *Neuroimage*, 25:653-60.

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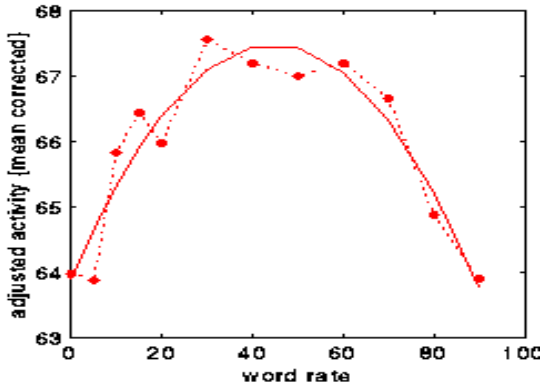
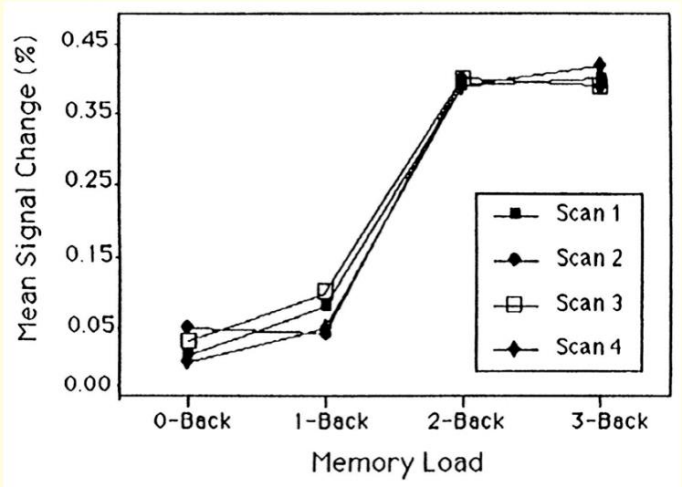
Parametric designs

A continuously varying parameter

- Systematic variation in activity with process engaged to varying degrees
- Avoids pure insertion but does assume no qualitative change in this processing over levels of the task
- To test, need to be more specific, e.g. Linear?
- Often less sensitive

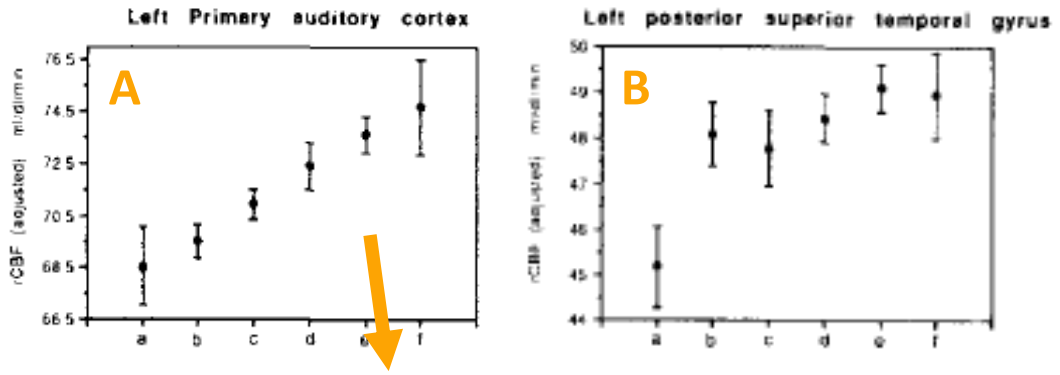
Buchel et al. (1996)



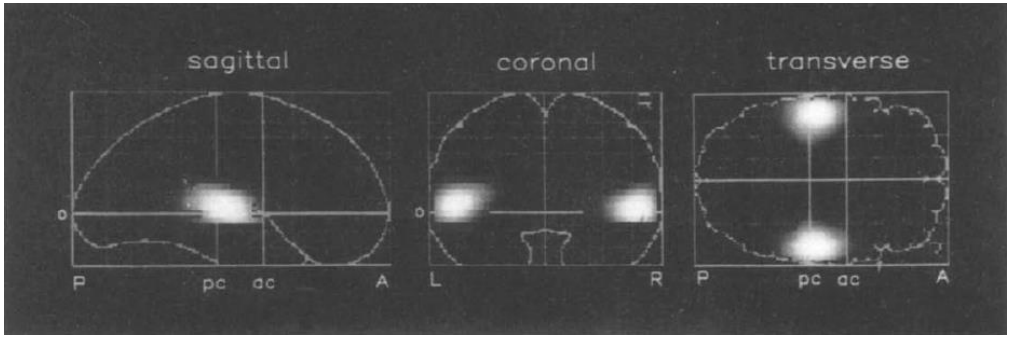


Cohen et al. (1996)

Parametric designs



Rest + 5 rates of auditory word presentation



Price et al. (1992)

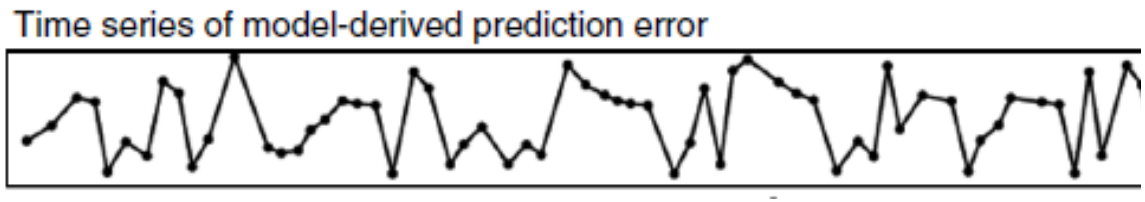
PET study

- Auditory words, varying rate
- Linear relationship of rate with activity in primary auditory cortex
- Can implement using contrasts
- In SPM12 the GUI supports parametric modulation regressors in design

Parametric designs

Model based fMRI

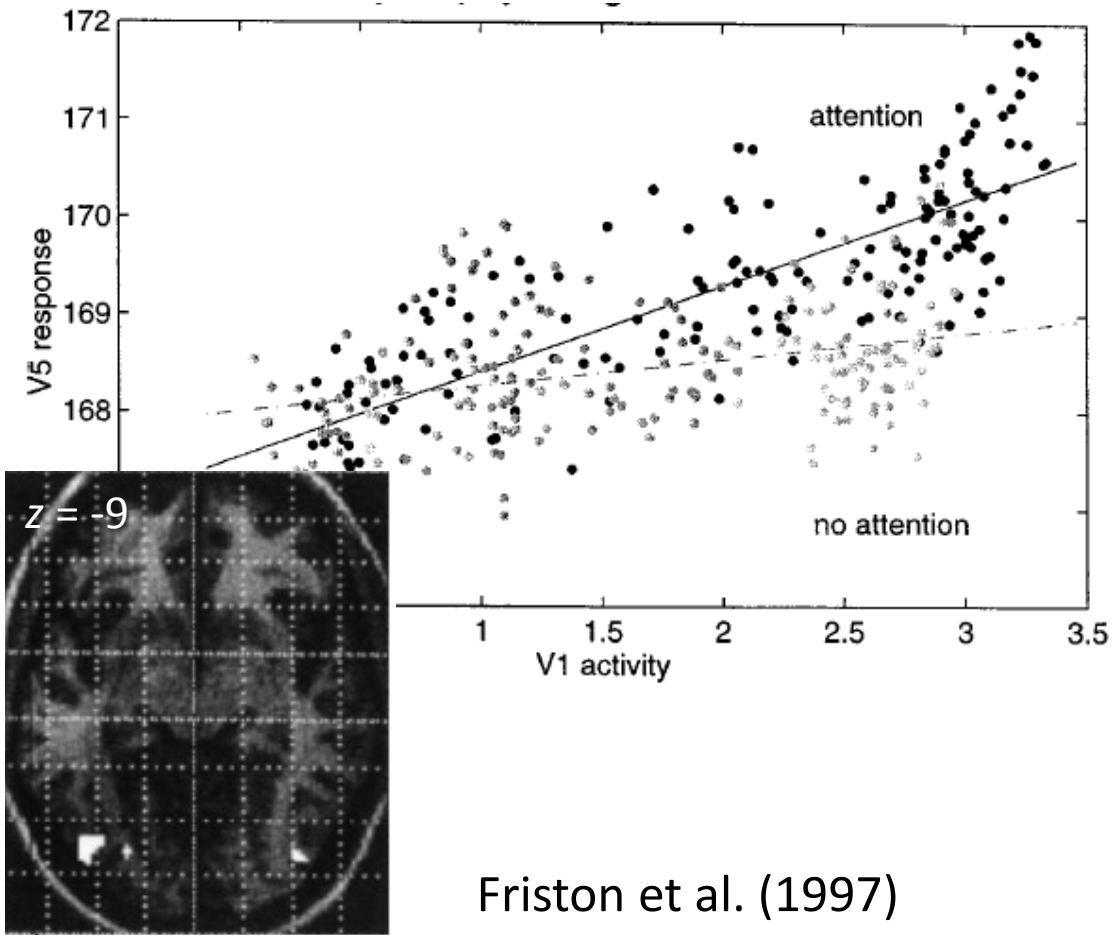
- Computational model provides neurometric function e.g. Rescorla-Wagner prediction error
- Can also do model comparison



Glascher & O'Doherty (2010)

Parametric factorial designs

Psychophysiological interaction (PPI) in V5



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

Friston et al. (1997)

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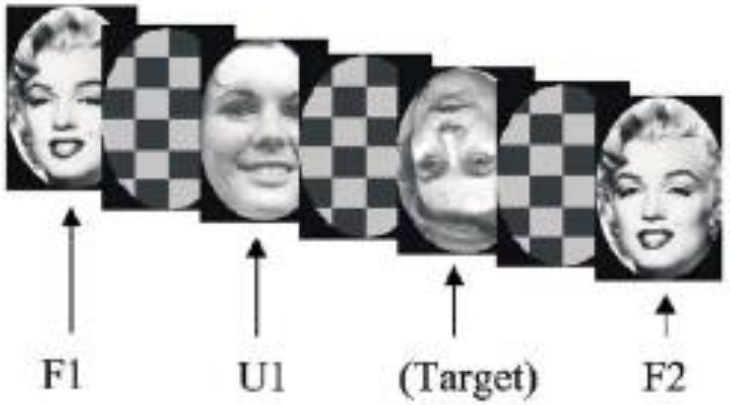
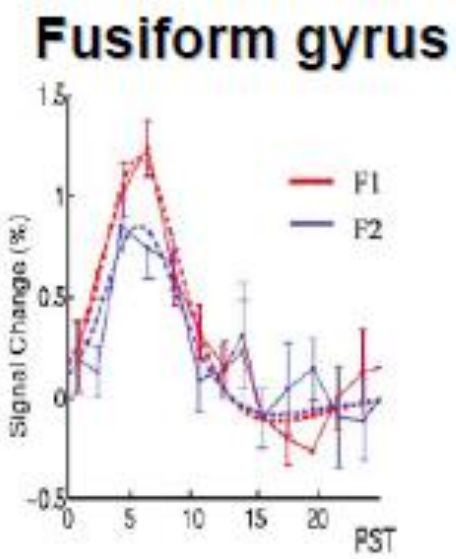
fMRI adaptation

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



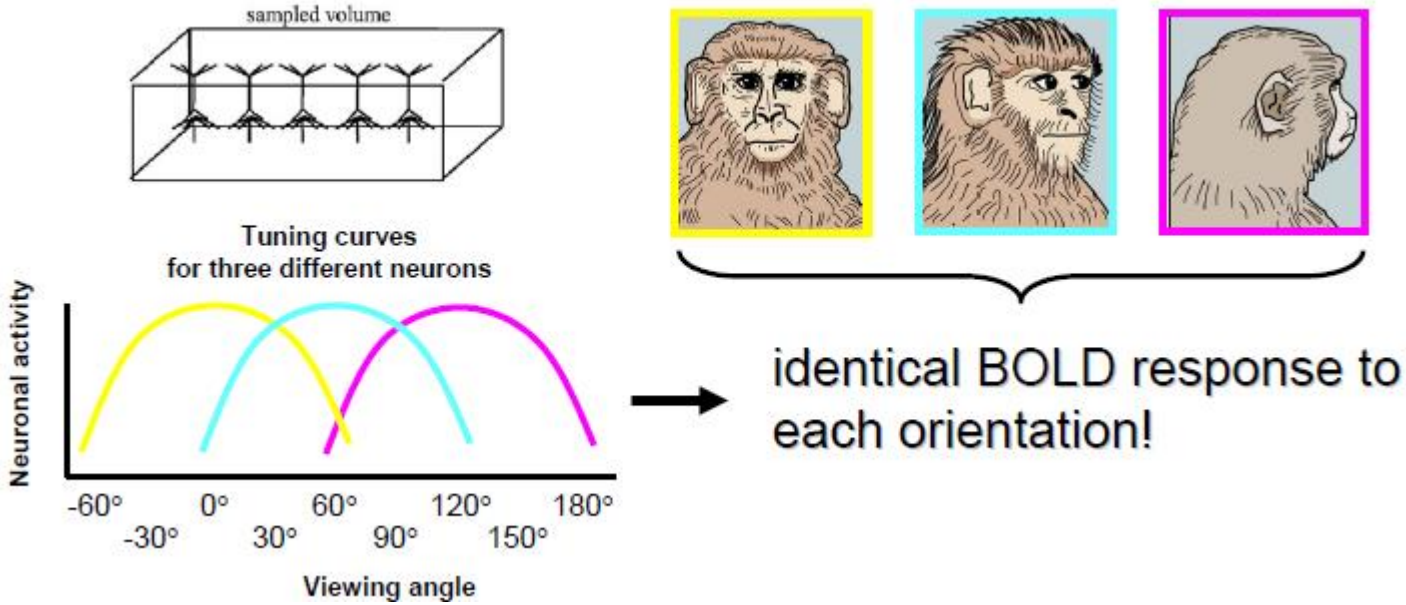


Henson et al. (2000)

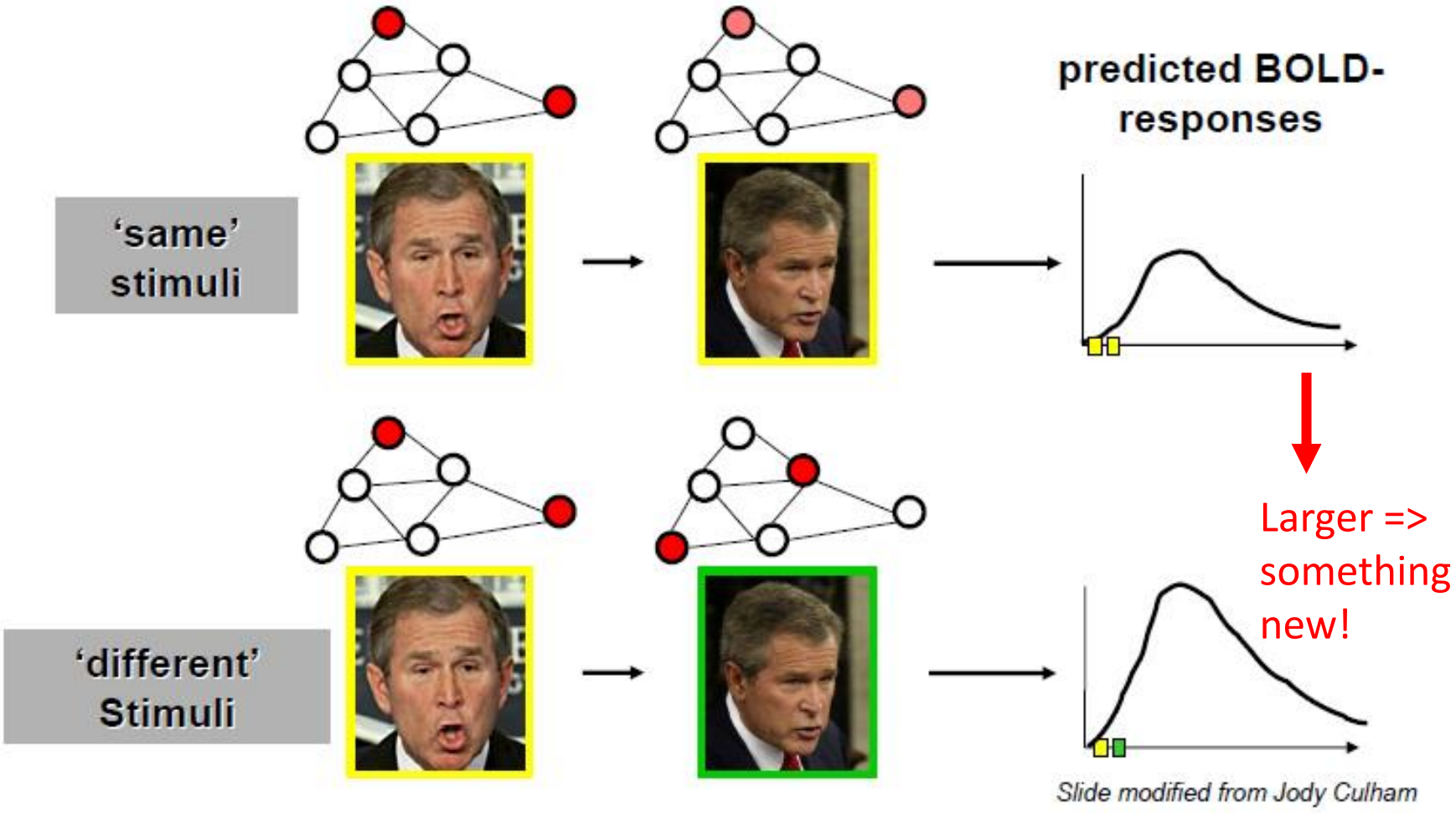
fMRI adaptation

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

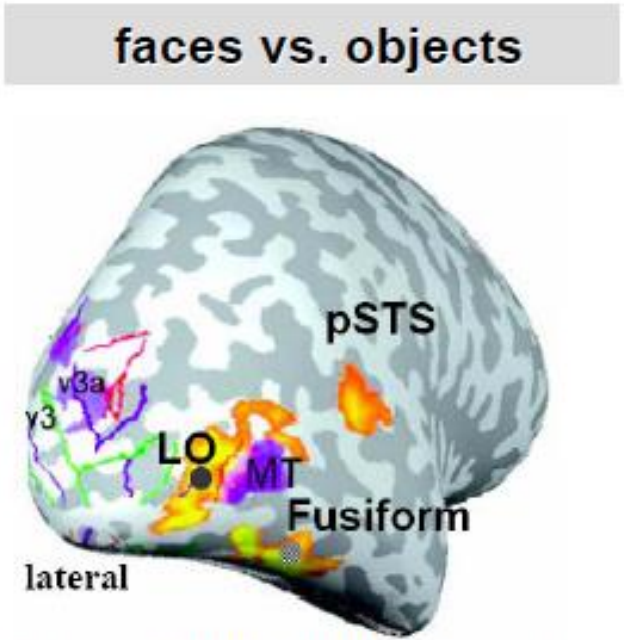


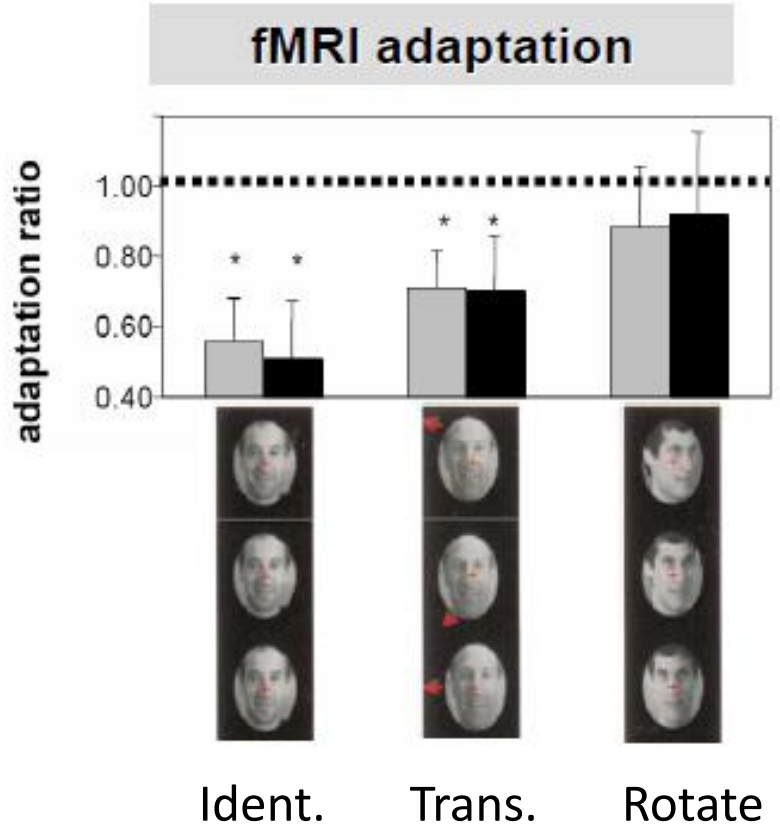
Release from adaptation => sensitivity to the changed feature

fMRI adaptation

Orientation tuning in human LOC (posterior Fusiform)

- Recovery from adaptation when rotate faces





Grill-Spector et al. (2001)

Design taxonomy

Categorical designs

Task A – Task B

- Subtraction
  - Pure insertion, evoked / differential responses
- Conjunction
  - Testing multiple hypotheses

Parametric designs

a A A A A

- Linear
  - Adaptation, cognitive dimensions
- Nonlinear
  - Polynomial expansions, neurometric functions
  - Model-based regressors

Factorial designs

- Categorical
  - Interactions and pure insertion
- Parametric
  - Linear and nonlinear interactions
  - Psychophysiological Interactions (PPI)

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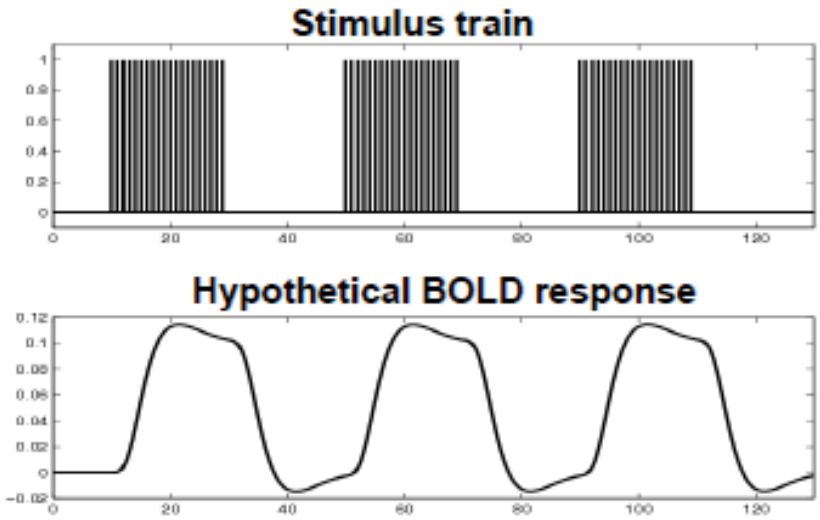
Paradigm timing

Block Design

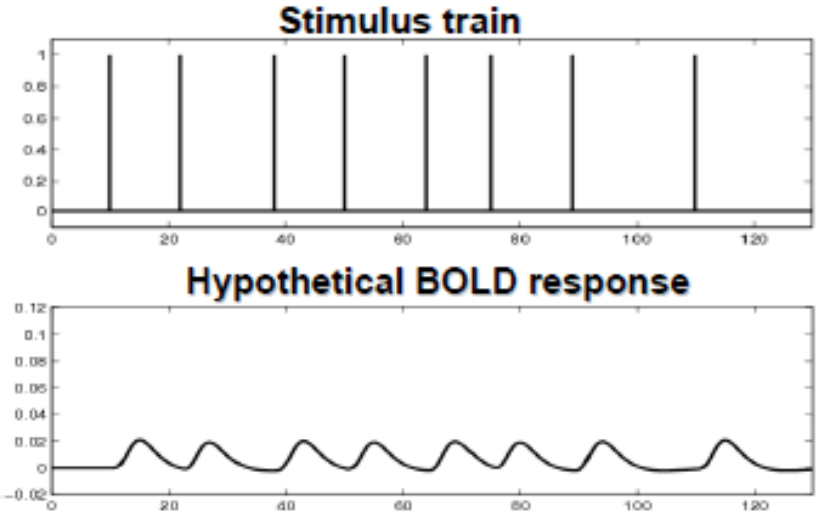


Analysis of whole block

Large effects (=efficient)

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

Event-Related Design



Analysis of single items

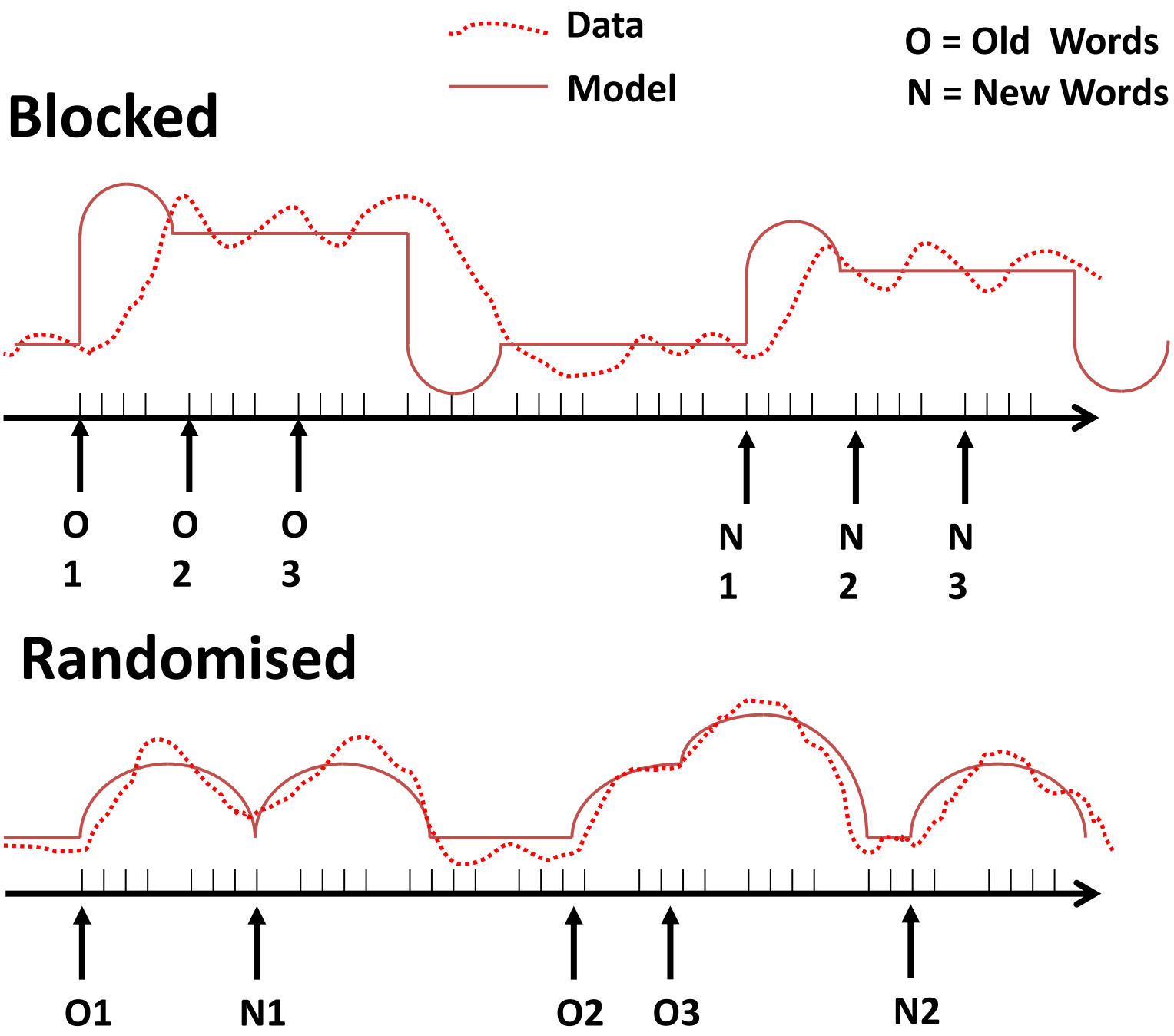
Smaller effects

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

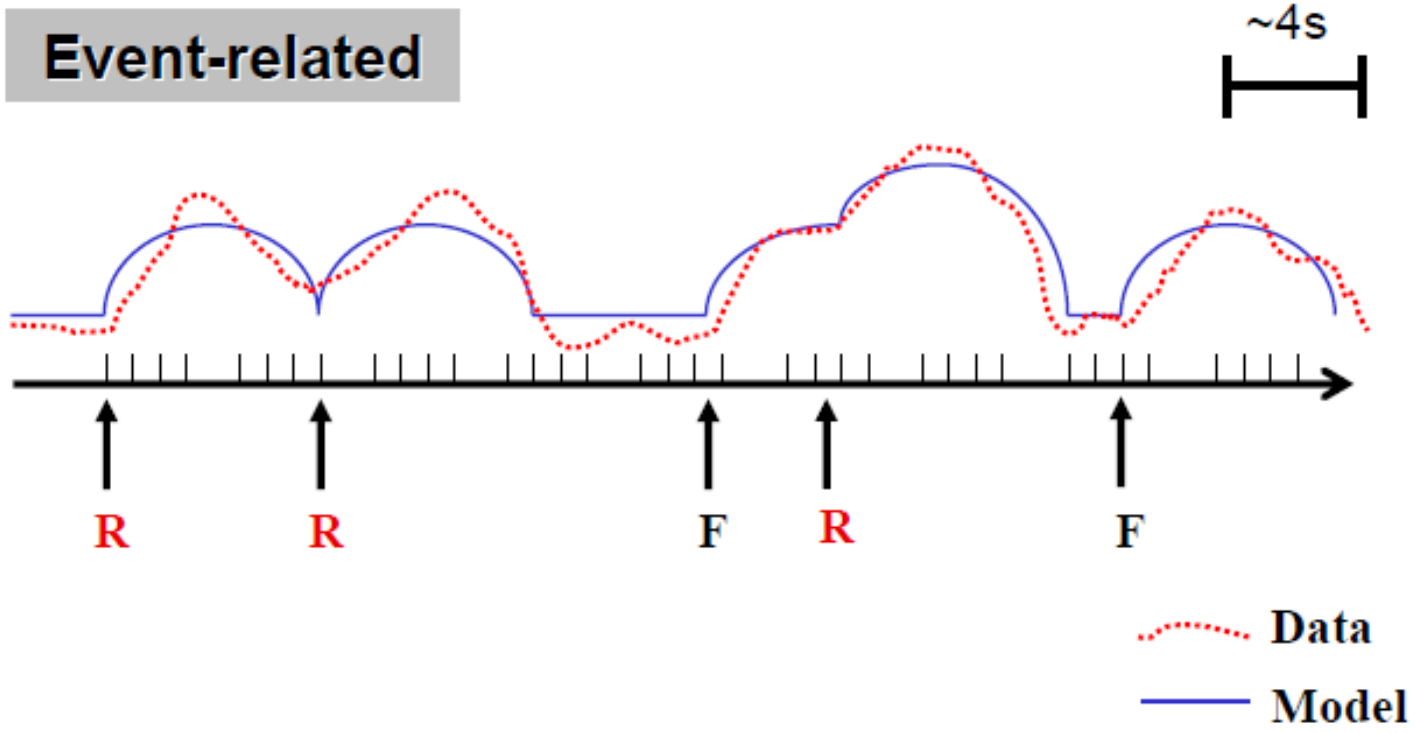
Advantages of event-related design

- 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

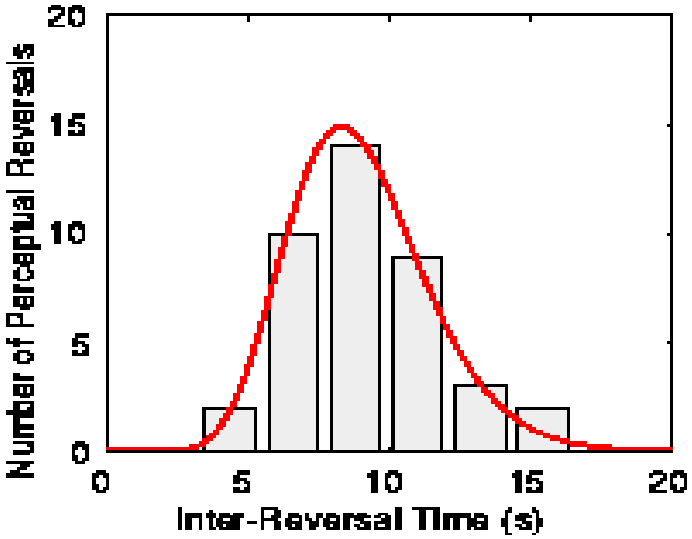
F = Words Later Forgotten

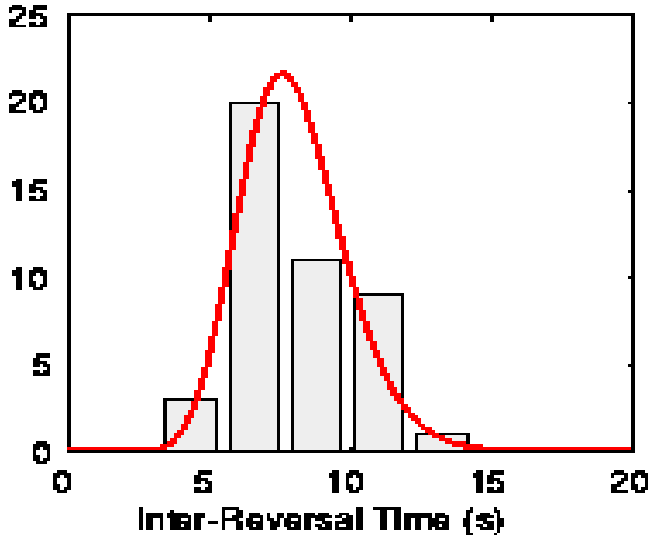


Paradigm timing

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
Inter-Reversal Time (s)
0
5
10
15
20


Inter-Reversal Time (s)
0
5
10
15
20
25

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 (Friday)