Experimental Design

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Overview

Design of functional neuroimaging studies

- Categorical designs
- Factorial designs
- Parametric designs
- fMRI adaptation
- Control conditions
- Trial timing

Categorical Designs

Subtraction logic in psychophysics

Assumption of pure insertion:

⇒ you can insert a component process into a task without disrupting the other components

⇒ you can estimate duration of a cognitive process by comparing reaction times between different conditions

F.C. Donders

Categorical Designs

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

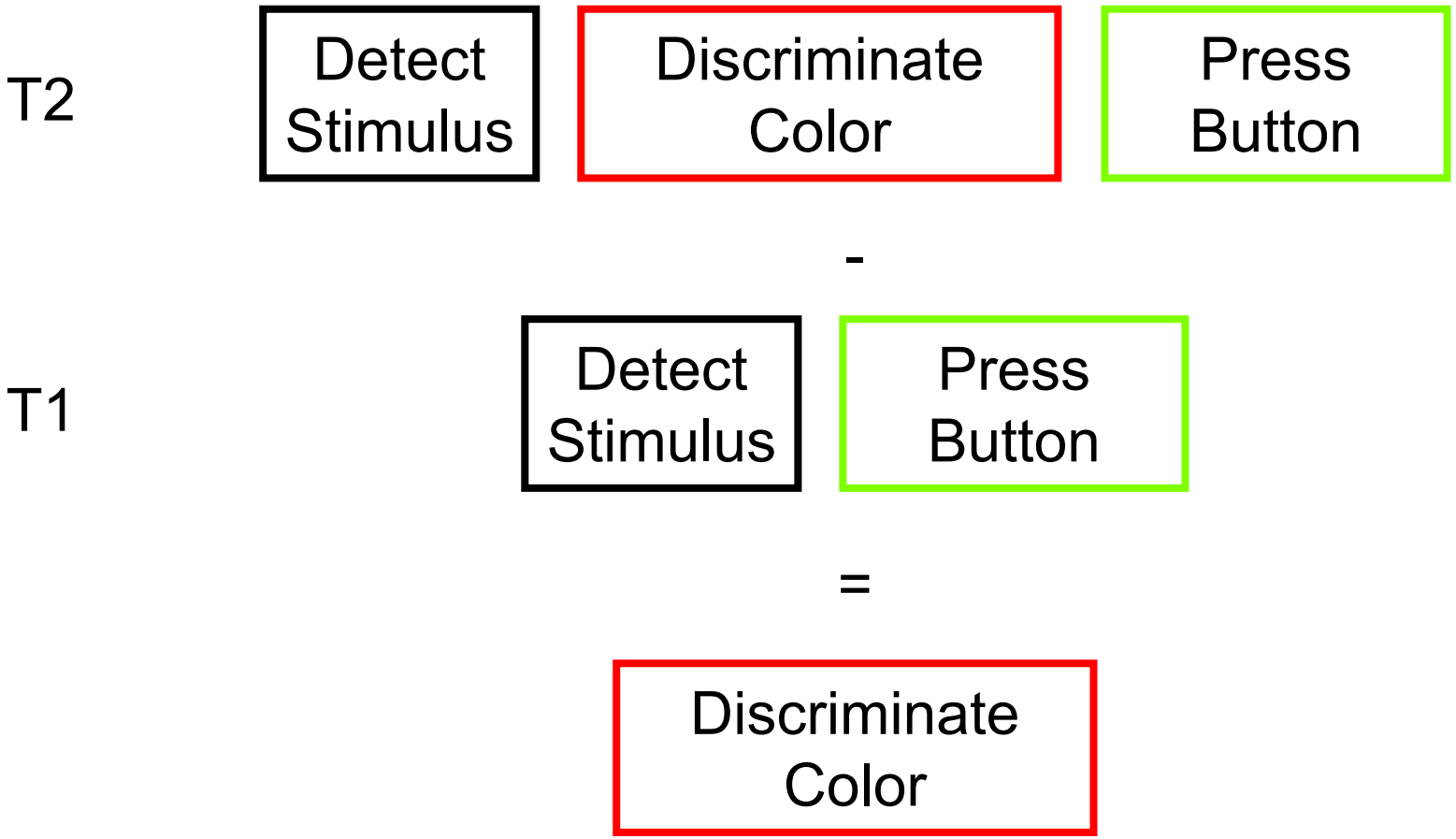
Detect Stimulus	Discriminate Color	Press Button

T3: Choice Reaction Time

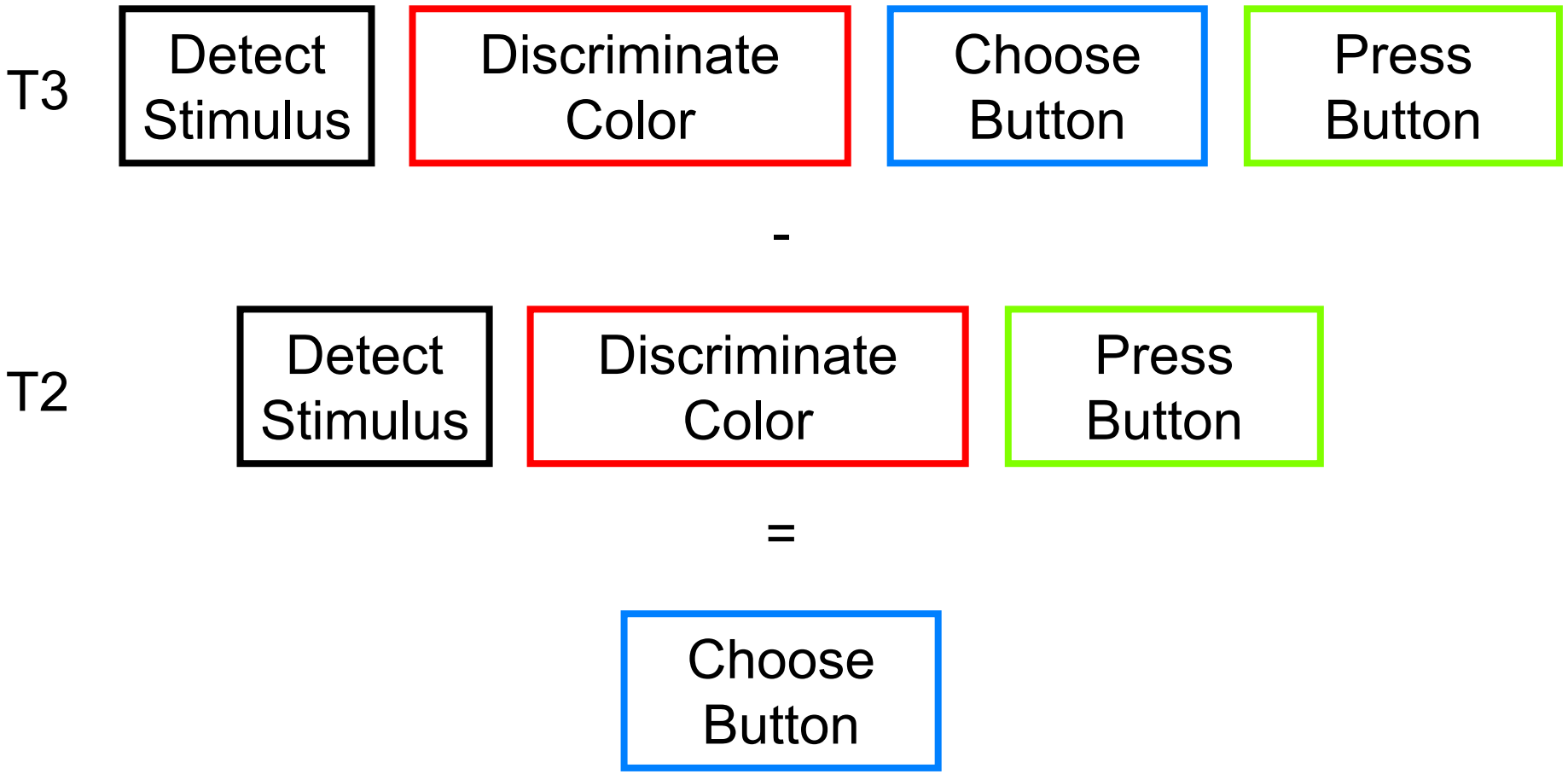
- Hit left button when light is green and right button when light is red

Detect Stimulus	Discriminate Color	Choose Button	Press Button

Categorical Designs



Categorical Designs



Categorical Designs

Background

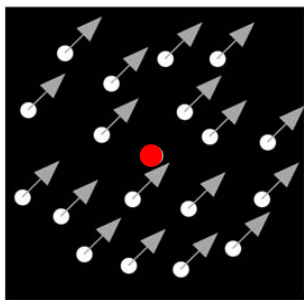
⇒ pure insertion: you can insert a component process into a task without disrupting the other components

⇒ addtional cognitive processes always evoke the same additional activation!

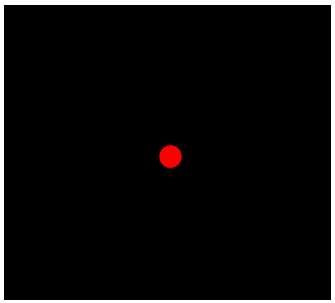
⇒ activation due to baseline task unaffected!

Simple subtraction

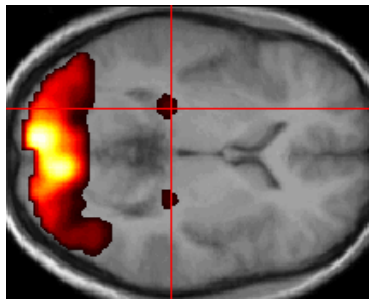
- you can identify functionally specialised regions with regionally specific activation differences



moving dots



fixation



Categorical Designs

Serial subtraction

Question: Is inferior temporal cortex (IT) involved in phonological retrieval during object recognition?

Cognitive processes

⇒ visual analysis: occipital cortex

⇒ object recognition: ???

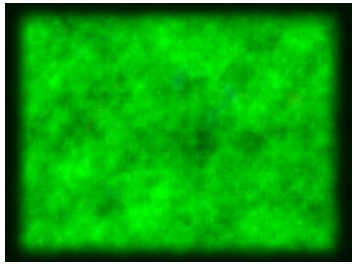
⇒ phonological retrieval: ???

⇒ verbal output: Broca‘s area

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!

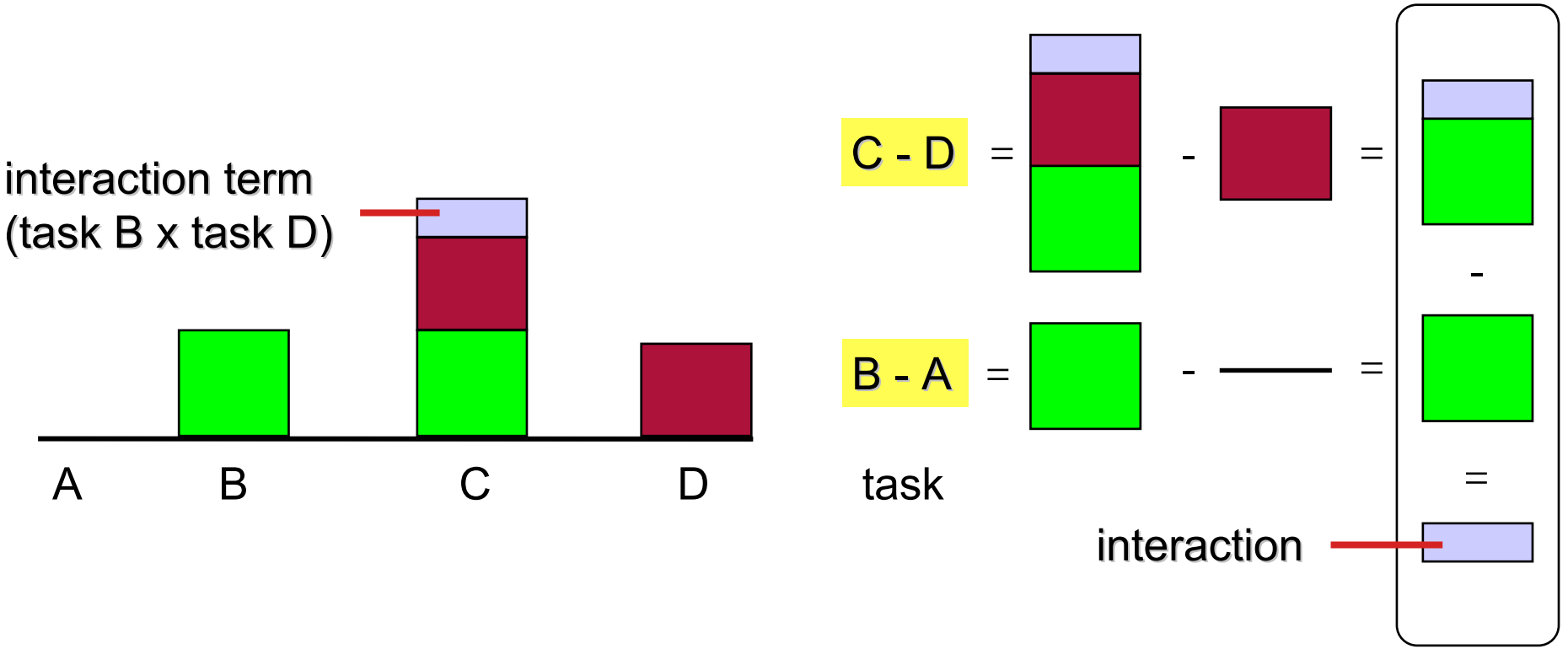
Problem: unjustified assumption that IT response to object recognition is context independent!

→ psychophysics ≠ neurophysiology

Factorial Designs

Background

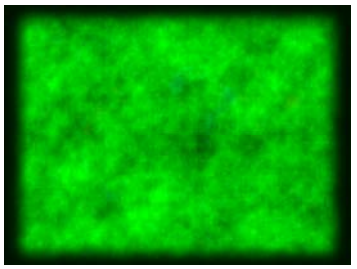
- "the whole is more than just the sum of its parts"
- cognitive processes are interdependent ⇒ task A interacts with task B, A modulates sensitivity to B ...



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!

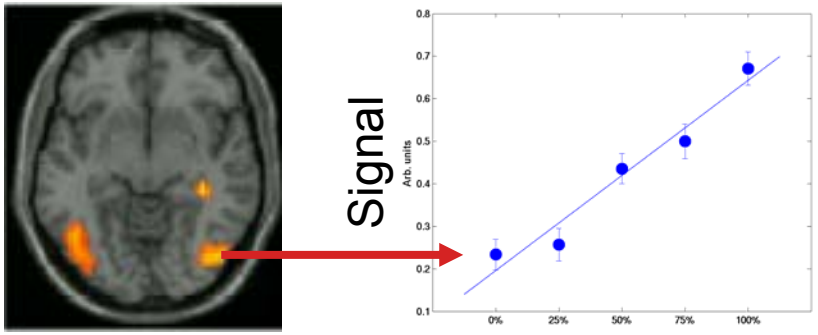
Parametric Designs

	cognitive processes
categorical/factorial designs	binary
parametric designs	continuous

Systematic variation of regional activation with endo-/exogenous parameters

⇒ task stays the same while the amount of processing varies; thus, changes to the nature of the task are less of a problem

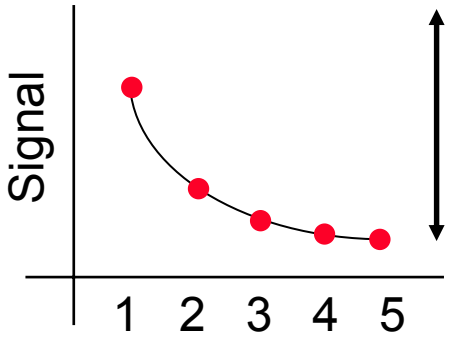
⇒ you can test for both linear (i.e.level of sensorimotor/cognitive processing) and non-linear effects (i.e. time effects)



Rose et al. (2005). *Cerebral Cortex*.

Example 1: linear activation increase in LOC with increasing object visibility!

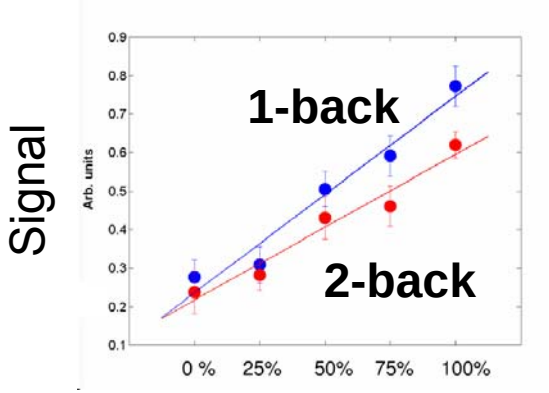
Parametric Designs



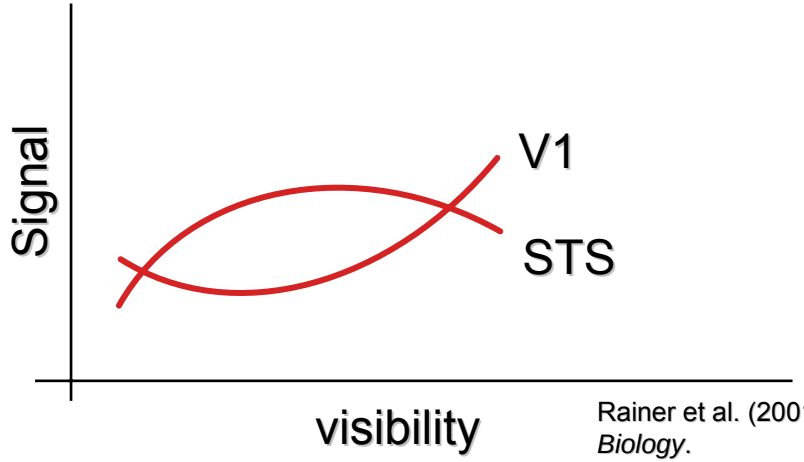
Example 2: Non-linear decrease of prefrontal activation over time during procedural learning!

Combining parametric and factorial designs

linear interaction



non-linear interaction

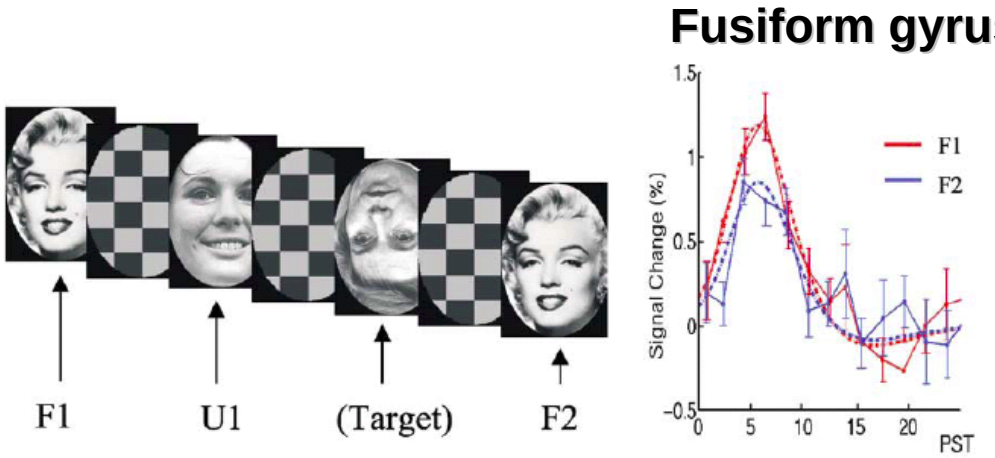


Rainer et al. (2001). *Current Biology*.

fMRI Adaptation

fMRI adaptation

- priming = reduced BOLD response to primed stimuli (i.e. repeated presentation)



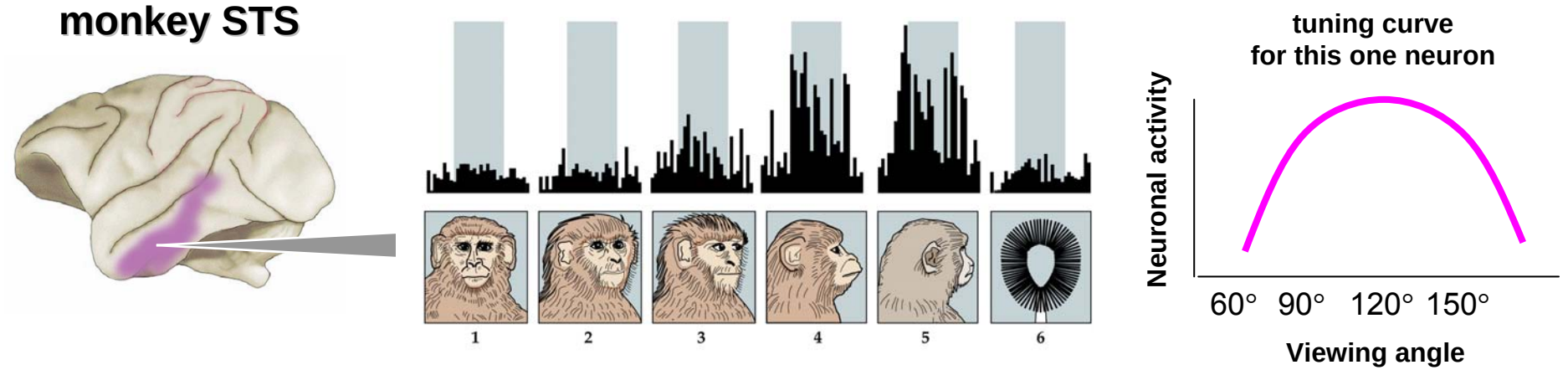
Henson et al. (2000)

repetition suppression / fMRI adaptation / priming

fMRI Adaptation

Priming as a tool

- increase in spatial resolution (hyperresolution)
- example: orientation tuning for face stimuli

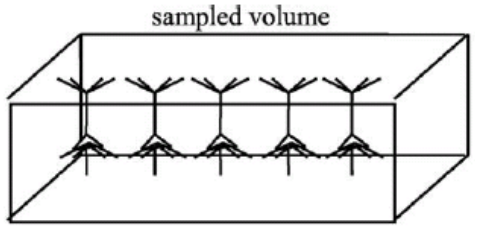


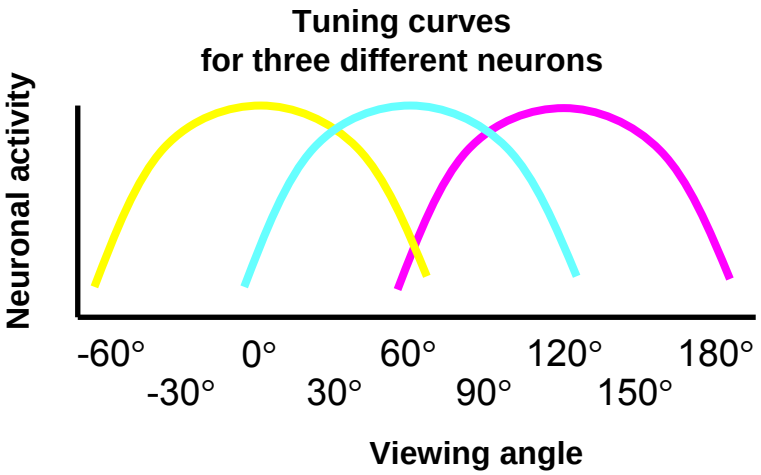
⇒ viewpoint selectivity in the human FFA?

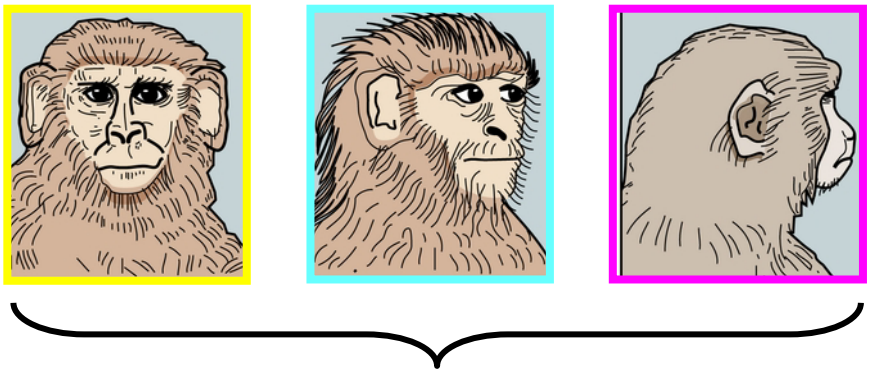
fMRI Adaptation

Priming as a tool

- fMRI – voxel typically contain ten thousands of neurons
- FFA: mixture of neurons tuned to different orientations?





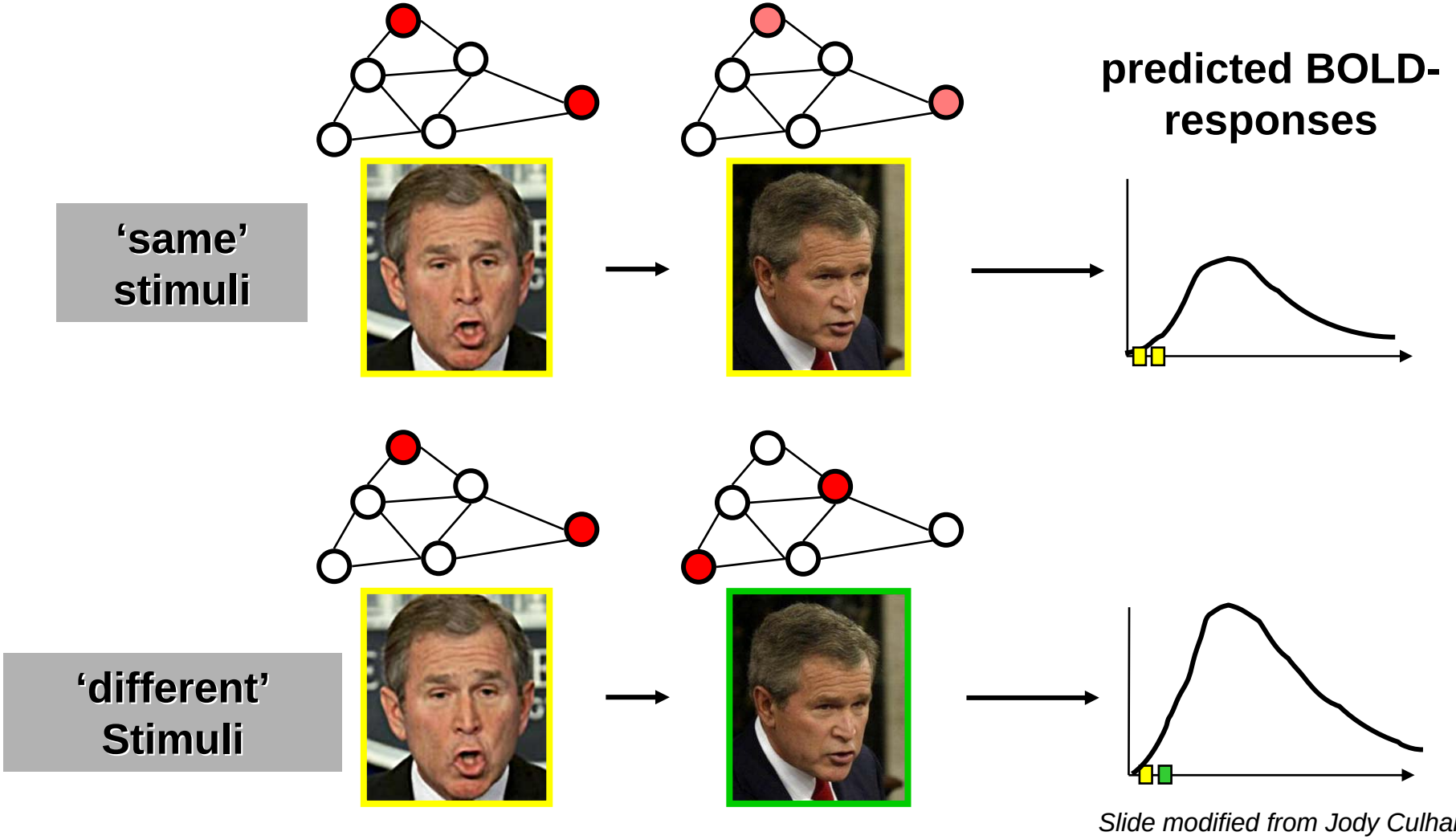


identical BOLD response to each orientation!

Slide modified from Jody Culham

fMRI Adaptation

orientation tuning in the human FFA?



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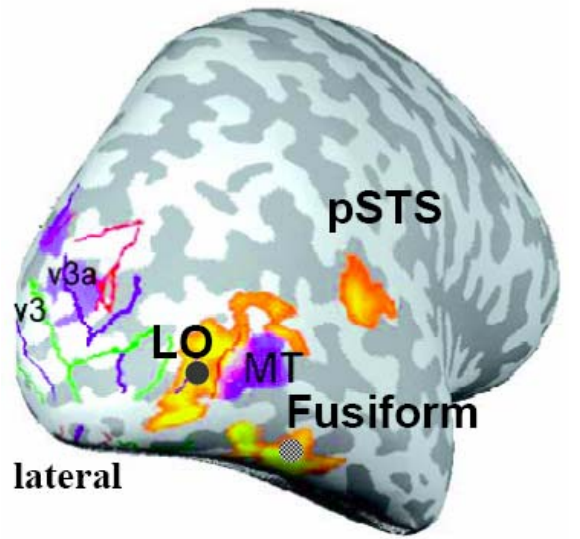
fMRI Adaptation

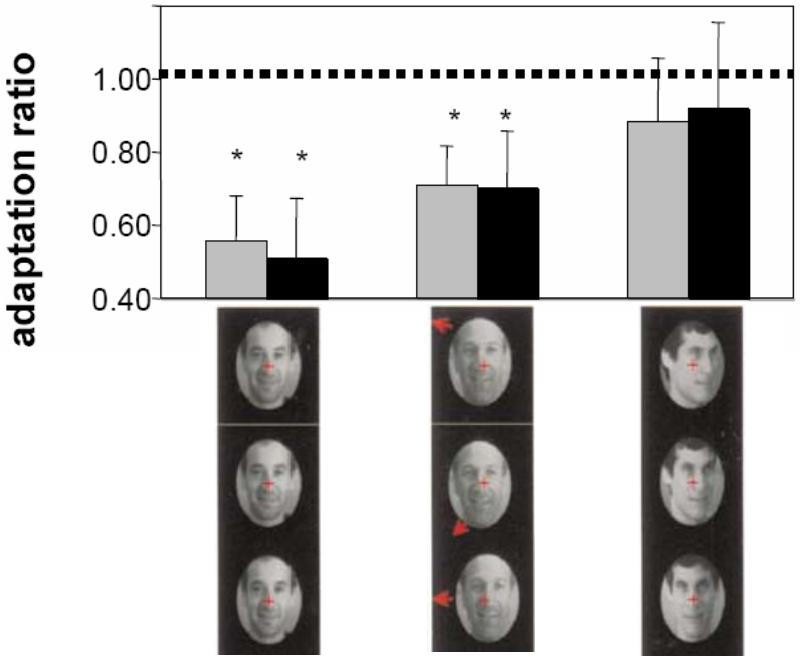
orientation tuning in the human FFA?

faces vs. objects



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

fMRI adaptation

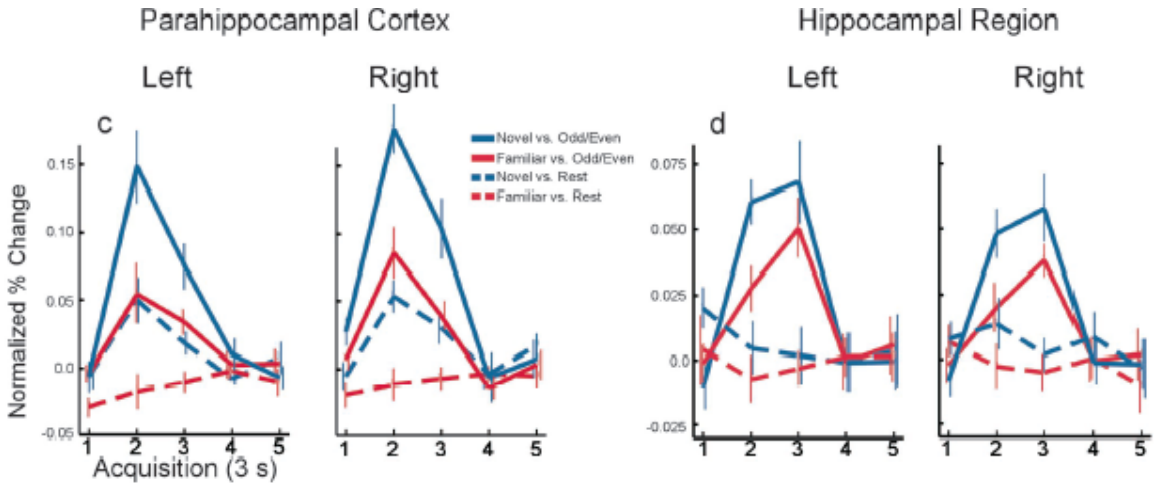


Control Condition

Problem

- fMRI = contrastive method

  ⇒ for many designs, you need to include adequate control conditions



Stark & Squire (2001) – When zero is not zero... *PNAS*, 98(22), 12760-12766.

„Rest" = often substantial activation in many areas!

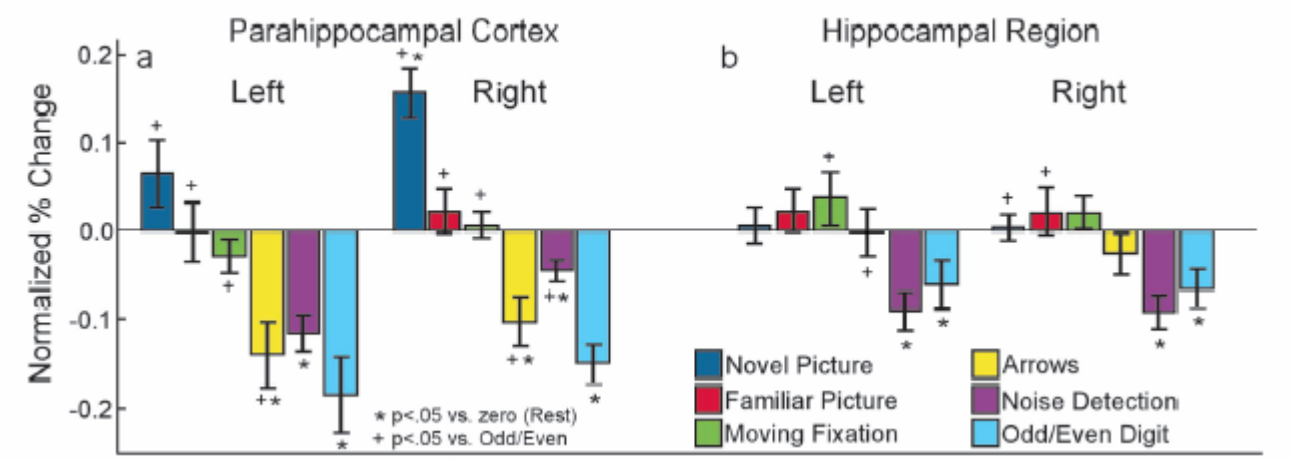
⇒ reason: mental imagery / rehearsal / eye movements…

⇒ loss of sensitivity!

Control Condition

Alternatives

1. high congruency with experimental conditions
2. additional possibilities:

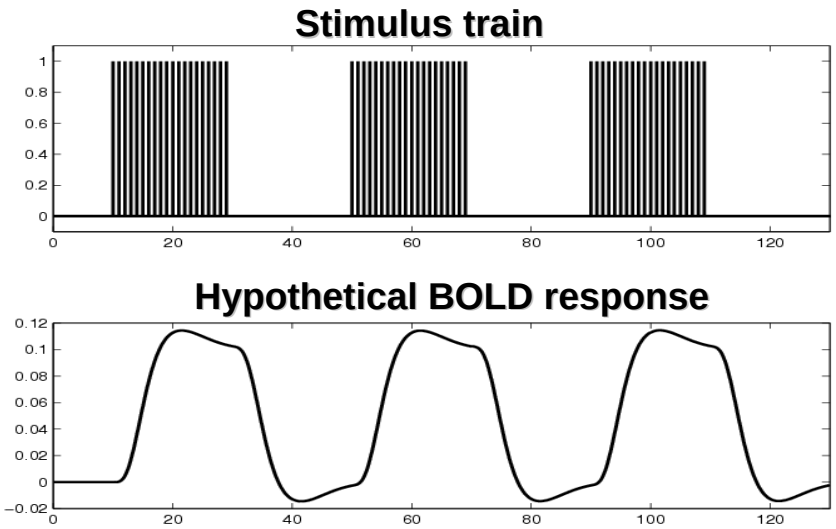


Stark & Squire (2001) – When zero is not zero... *PNAS*, 98(22), 12760-12766.

⇒ decision depends on experimental hypotheses!

Trial timing

Block Design

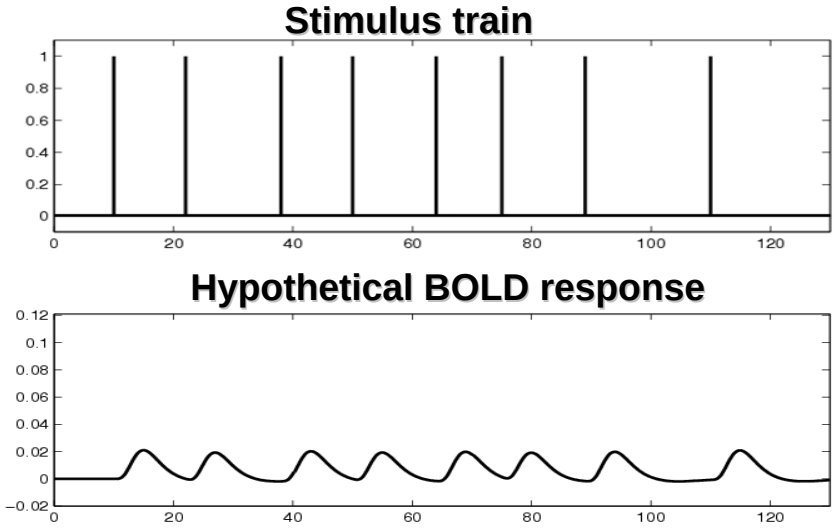


- analysis of entire block, not of single stimuli
- large effects
- Optimal block length: ~16sec

  ⇒ allows enough time for signal to oscillate fully

  ⇒ not near artifact frequencies

Event-Related Design



- analysis of single stimuli
- smaller effects
- minimal SOA: ~2sec

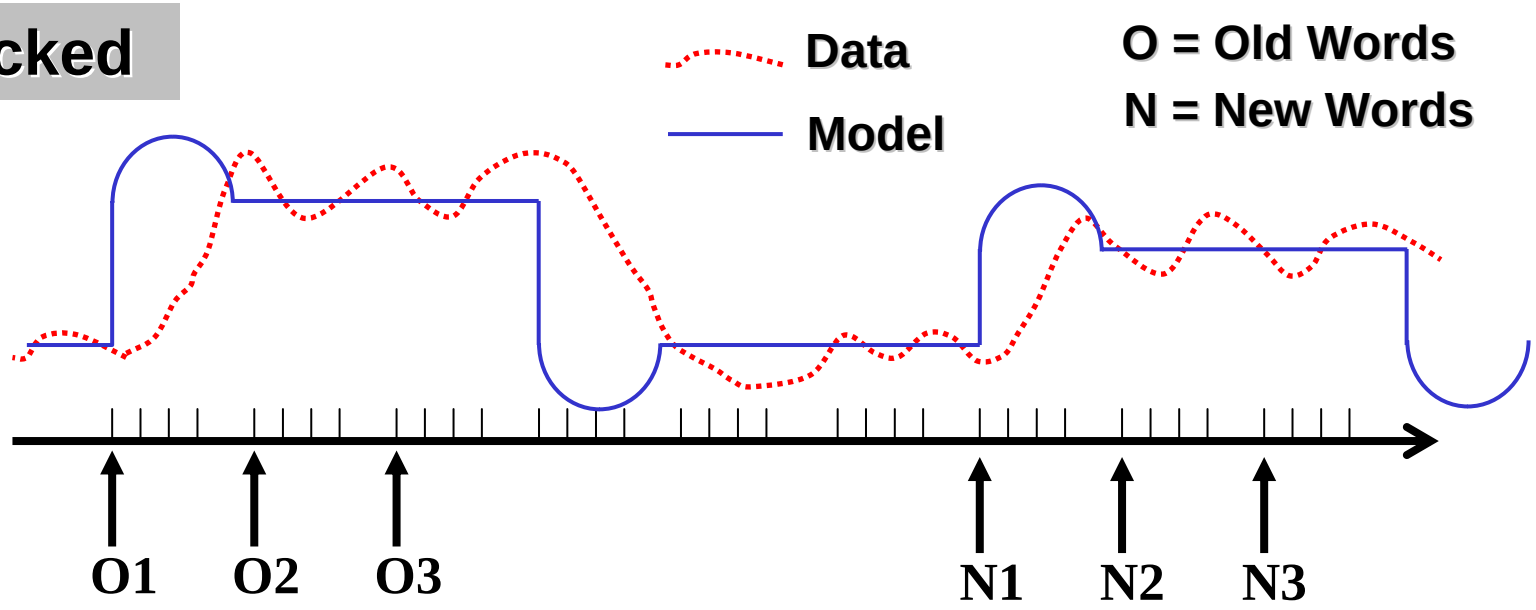
Trial timing

Advantages of event-related design

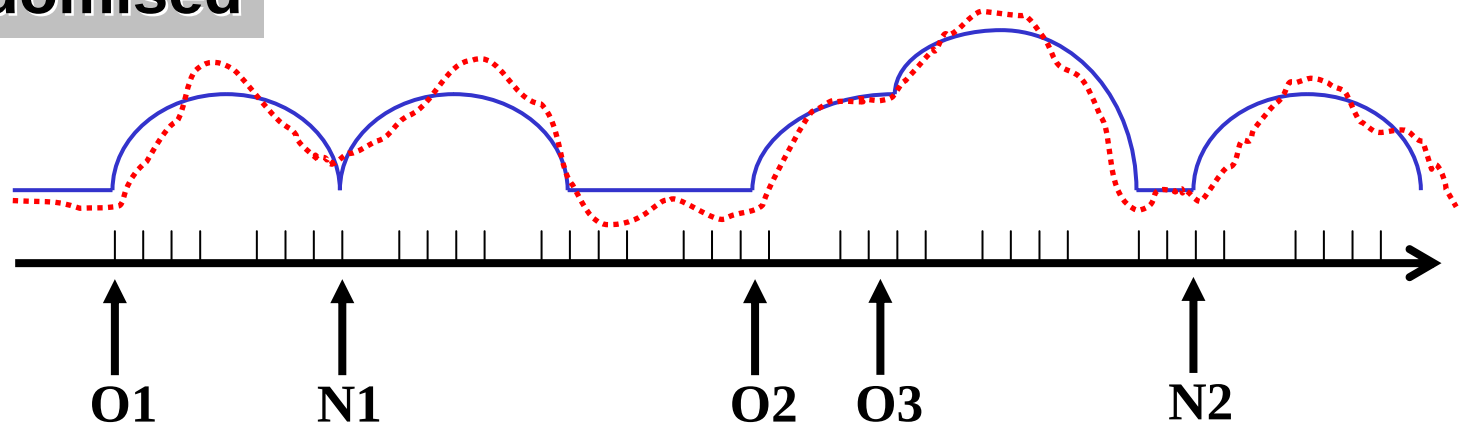
- randomised order avoids unwanted psychological effects
  e.g. habituation / expectancy effects, attentional decline

Trial timing

Blocked



Randomised



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Trial timing

Advantages of event-related design

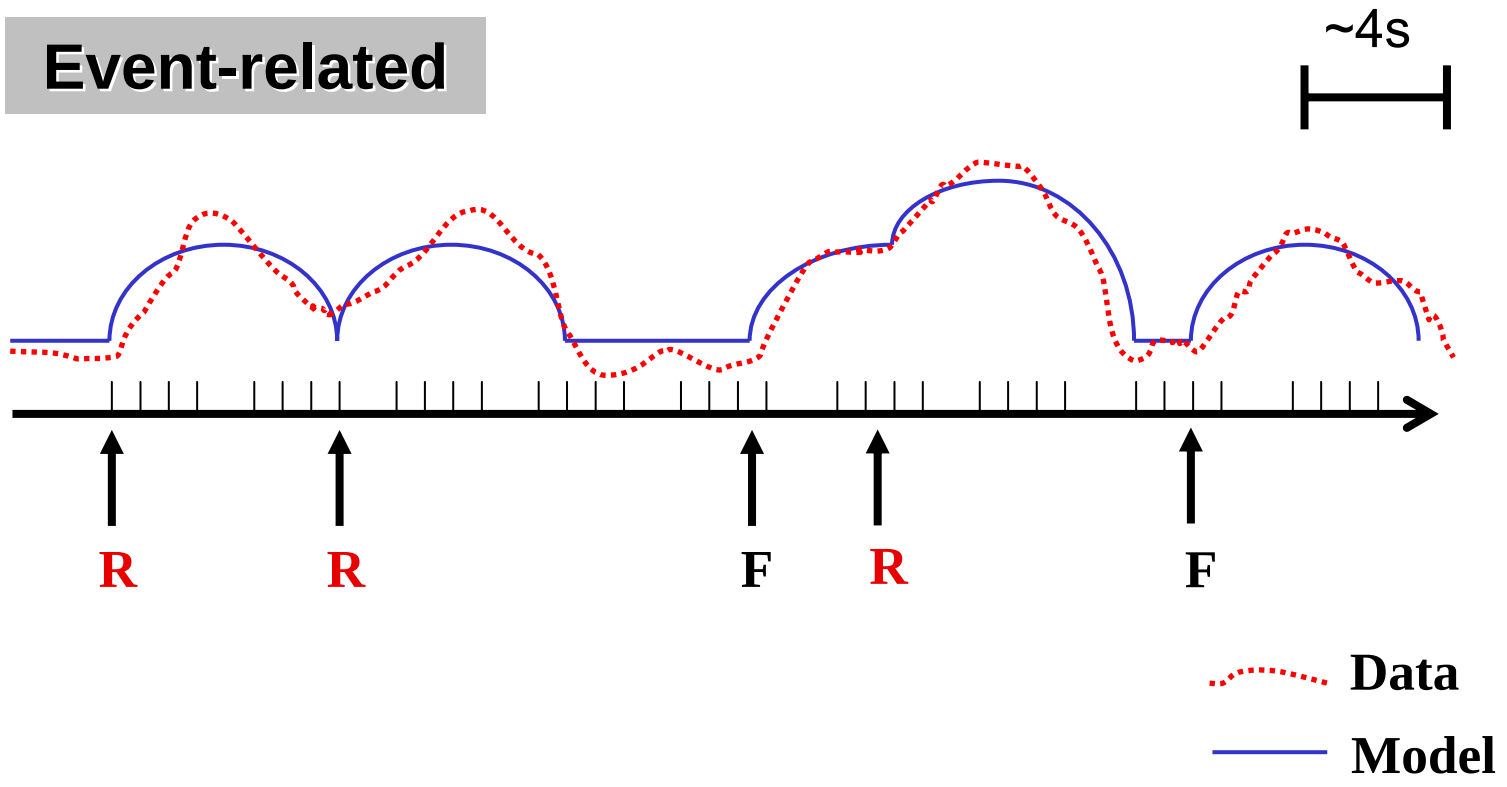
- randomised order avoids unwanted psychological effects
  e.g. habituation / expectancy effects, attentional decline
- post-hoc/subjective classification of trials
  e.g. subsequent memory effect

Trial timing

R = Words Later Remembered

F = Words Later Forgotten

Event-related



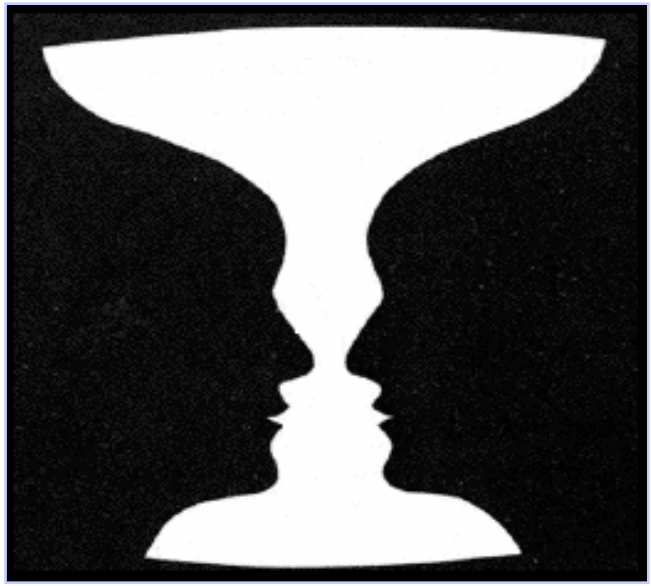
Slide modified from Rik Henson

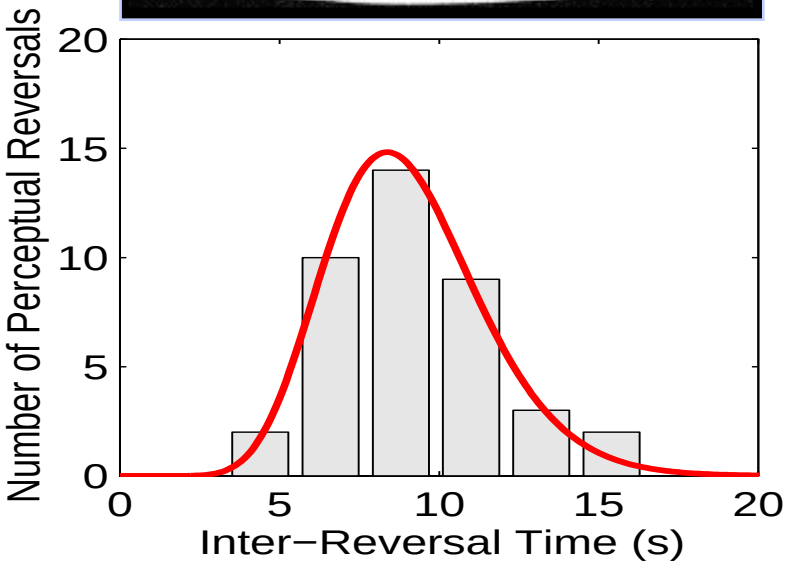
Trial timing

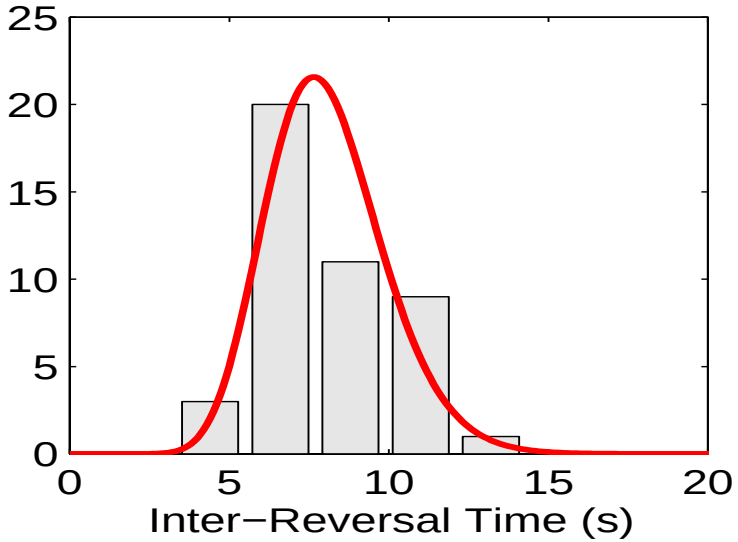
Advantages of event-related design

- randomised order avoids unwanted psychological effects
  e.g. habituation and expectancy effects, attentional decline
- post-hoc/subjective classification of trials
  e.g. subsequent memory effect
- some events can only be indicated by subject (in time)
  e.g. spontaneous perceptual changes

Trial timing







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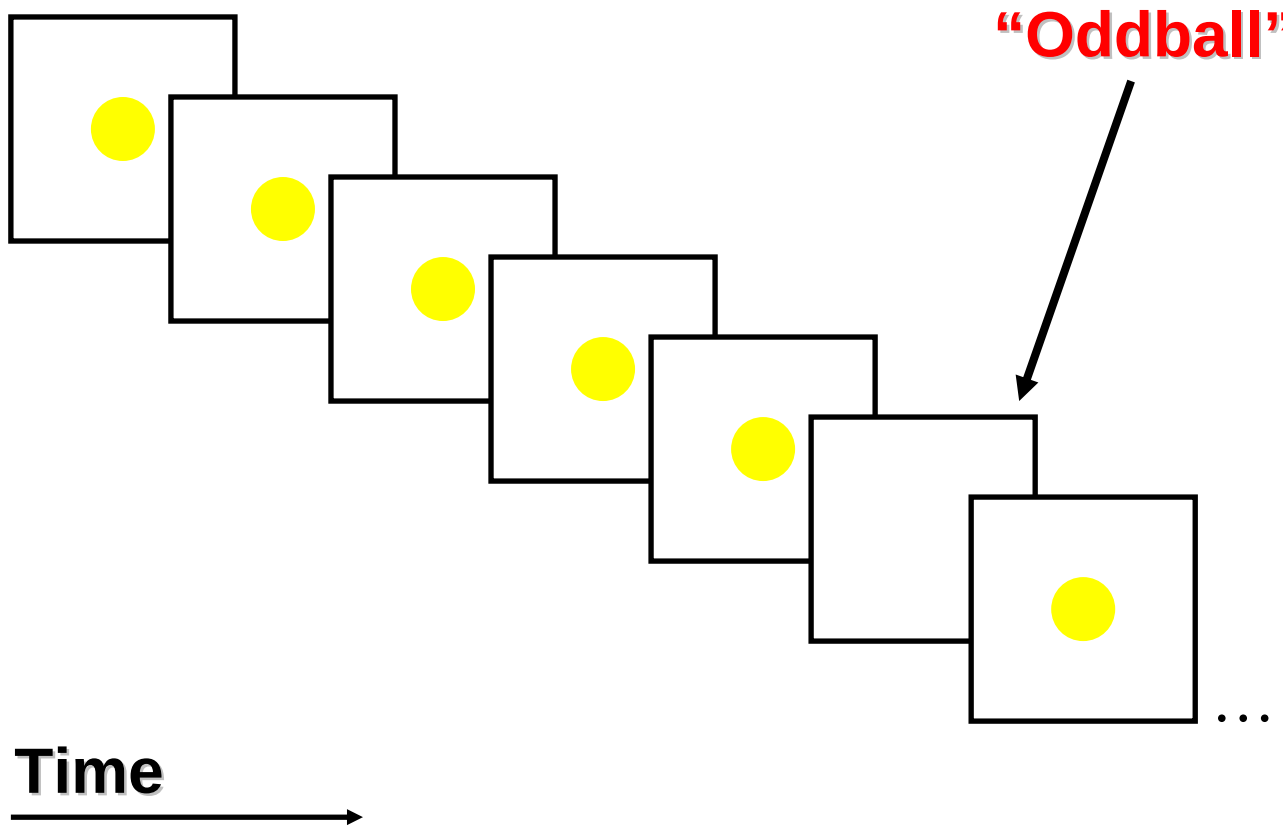
Trial timing

Advantages of event-related design

- randomised order avoids unwanted psychological effects
  e.g. habituation and expectancy effects, attentional decline
- post-hoc/subjective classification of trials
  e.g. subsequent memory effect
- some events can only be indicated by subject (in time)
  e.g. spontaneous perceptual changes
- some trials cannot be blocked
  e.g. „oddball“ paradigms

Trial timing



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