Principles of task-evoked fMRI:
Overview for experimental design and analysis

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National Chiao Tung University

Today's task-evoked fMRI data

- http://is.gd/7YiKZn

心智科學大型研究設備共同使用服務計畫 —
身體、心靈與文化整合影像研究中心:

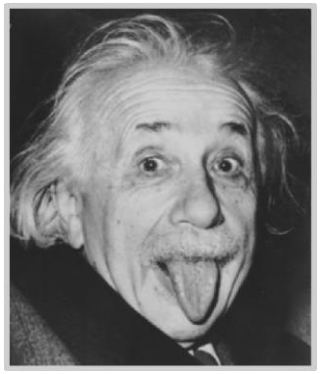
functional MRI 教育講習課程 II

2015/7/16 ~ 2015/7/17

	2014/07/16 (四) Task	2014/07/17(五) Resting
08:40-09:10	報到及入場	
09:10-09:20	主持人致詞	
09:20-10:40 Principles:	【Principles of Task-evoked fMRI: Overview for Exp. Design and Analysis】 黃植懋 教授 國立交通大學	【Principles of Resting-state fMRI: Analysis & Special Concerns】 吳昌衛 教授 國立中央大學
10:40-11:00	茶敘	
11:00-12:20 Hands-on:	【Task-fMRI Preprocessing】 黃植懋 教授 國立交通大學	【Rs-fMRI Quality Assurance & Functional Connectivity】 吳昌衛 教授 國立中央大學
12:20-13:40	休息(提供午餐便當)	
13:40-15:00 Hands-on:	【Data Modeling & Single-subject Analysis】 趙一平 教授 長庚大學	【Statistical Analysis for Group Comparison】 吳恩賜 教授 國立臺灣大學
15:00-15:20	茶敘	
15:20-16:40 Hands-on:	【Group Analysis, & Results Display】 趙一平 教授 長庚大學	【ROI analysis & Correlation with Behavior Measures】 吳恩賜 教授 國立臺灣大學
16:40-17:00	結語	

From behavior to the brain

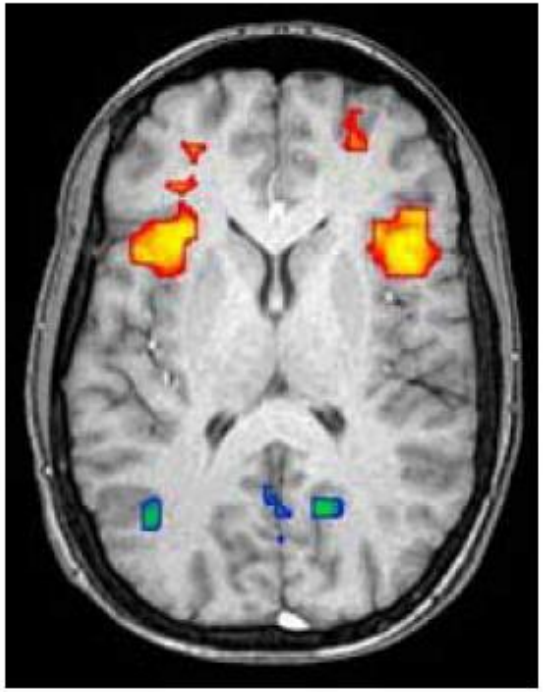
- Understanding behavior itself is complicated enough. Now we are trying to understand the brain and their linkage?



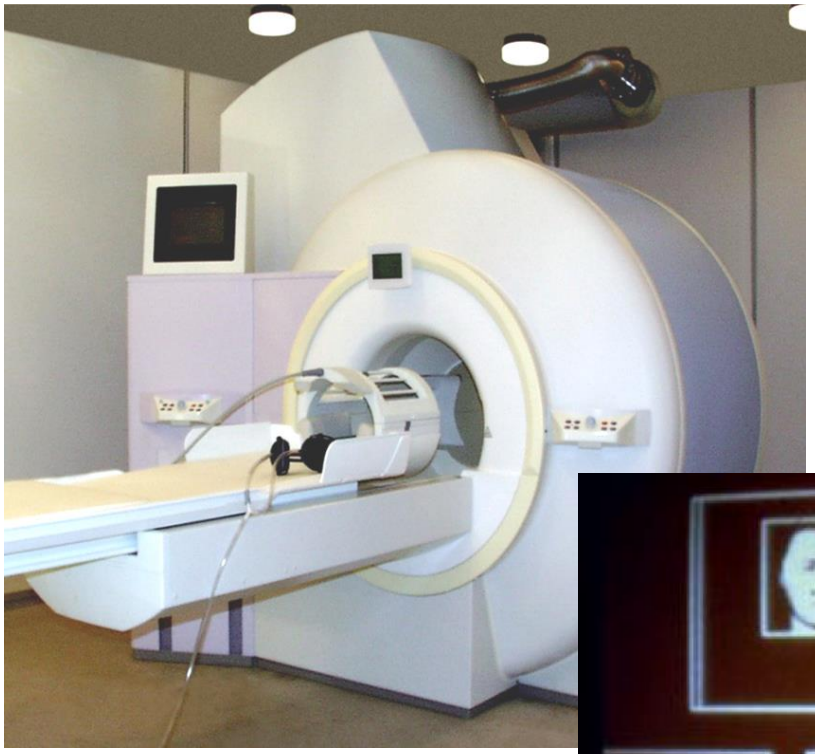
MRI and Functional MRI (fMRI)

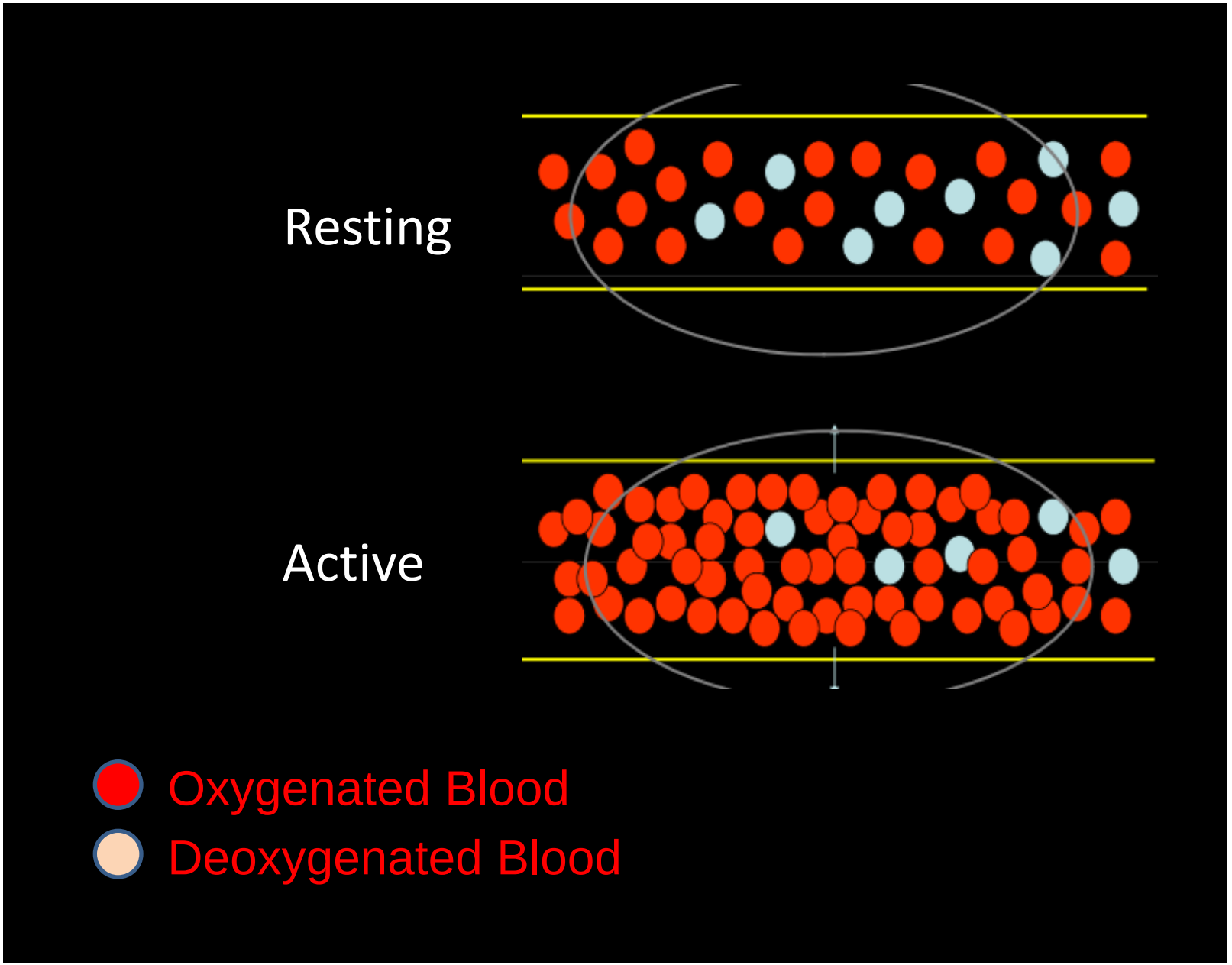
- MRI studies brain anatomy

- Functional MRI (fMRI) studies brain function

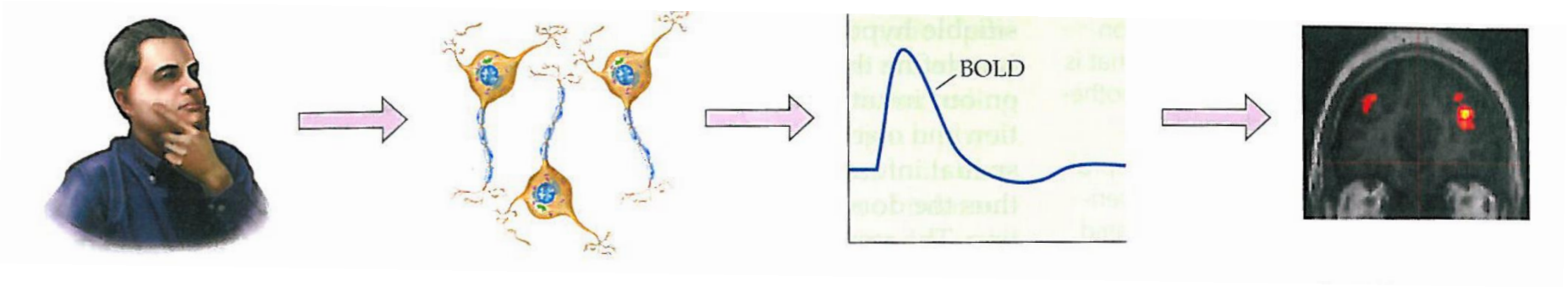


MRI scanner and task-evoked fMRI scan




Resting
Active
Oxygenated Blood
Deoxygenated Blood

Three distinct levels of research hypothesis in fMRI studies

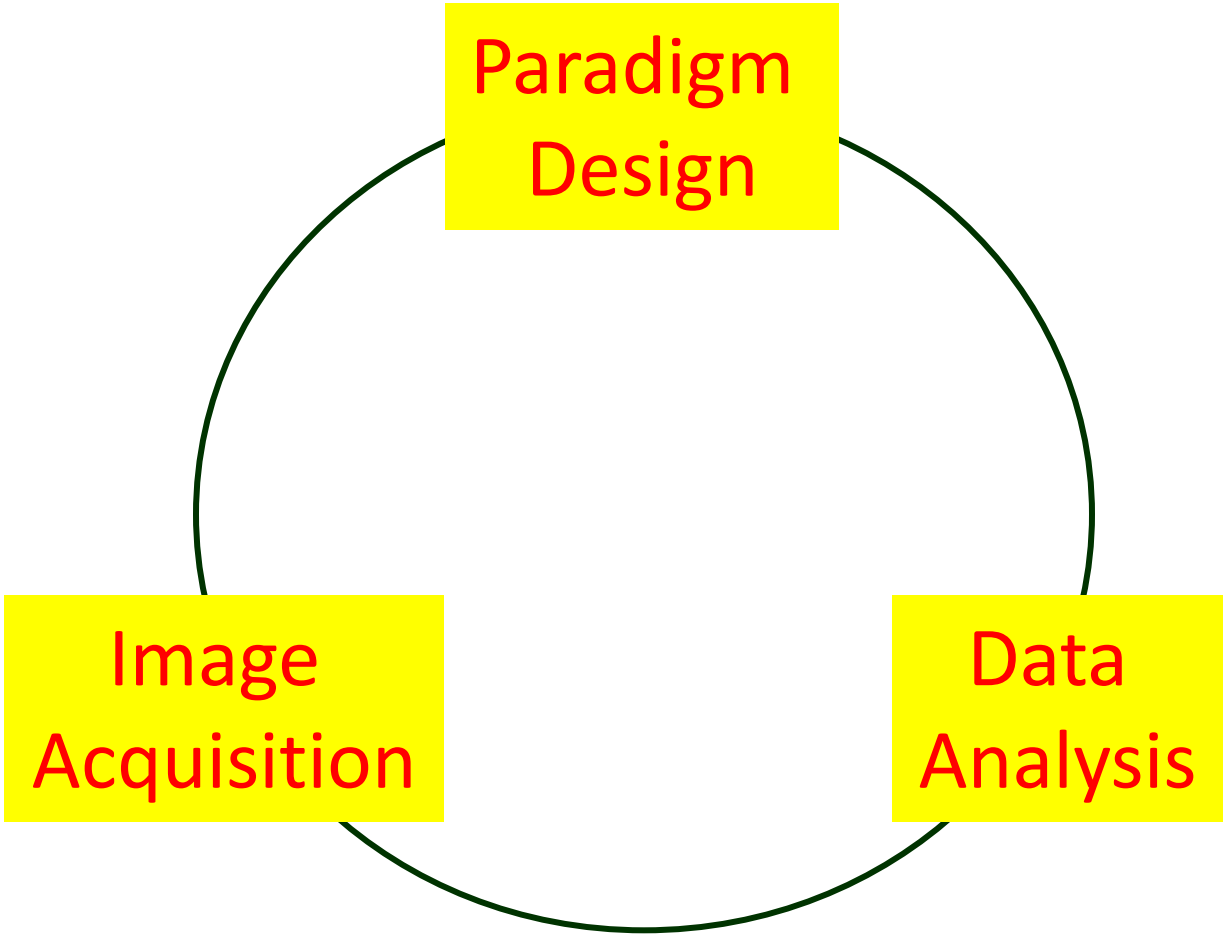


Hemodynamic

Neuronal

Psychological (Cognitive)

task-evoked fMRI Procedures



Outline for Today

- Overview: task-evoked fMRI experimental design
  - ✓ Essential components and Confounding factors
  - ✓ Jargons in an fMRI experiment
  - ✓ Experimental designs
    - Blocked design; Event-related design; Mixed design
  - ✓ Setting up a good research hypothesis

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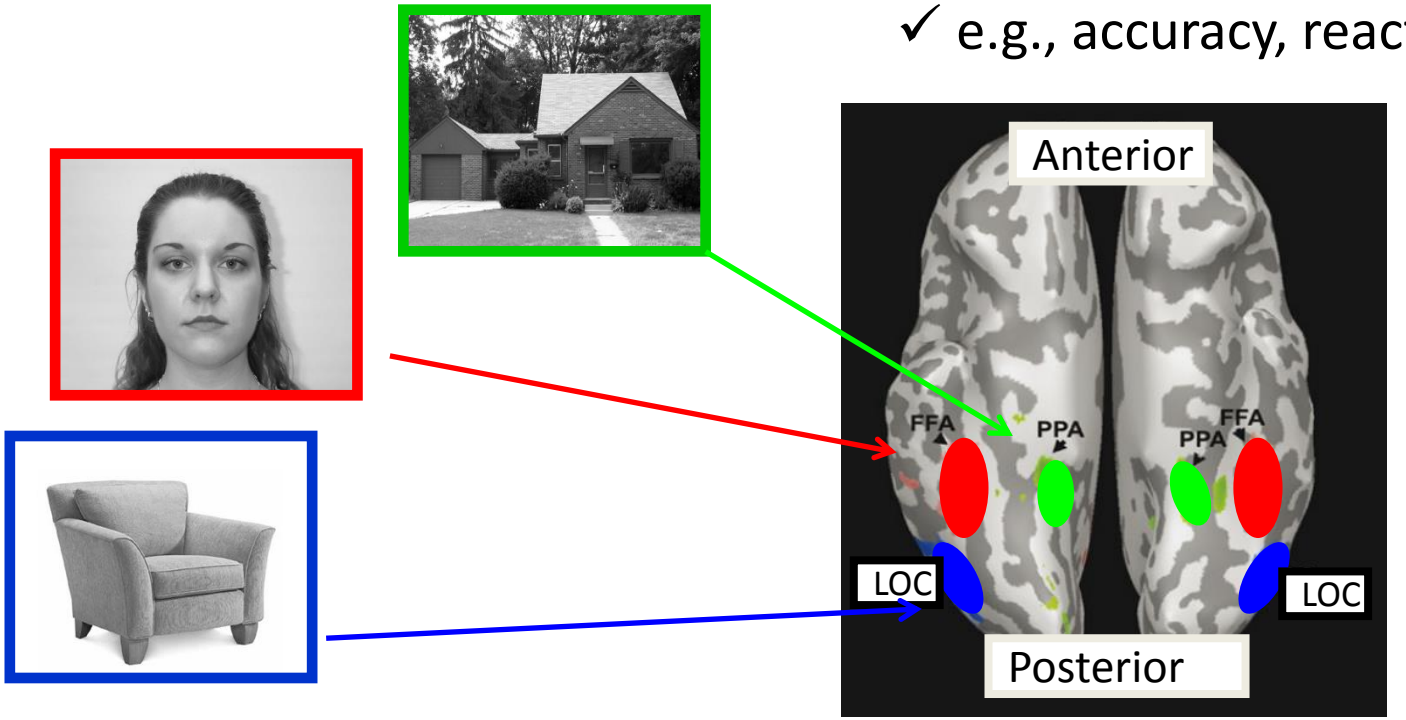
  - ✓ Visualization

Essential components in an experimental design

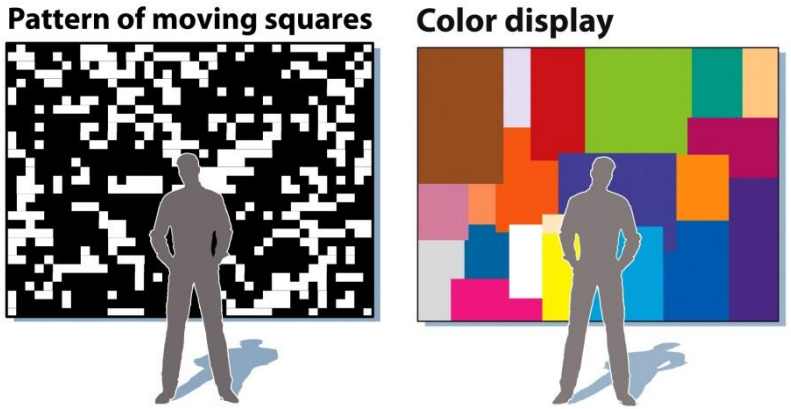
- Variables:
  - ➢ Independent variables
    - ✓ Manipulated by the experimenters
    - ✓ e.g. stimulus (face, words, pictures)
  - ➢ Dependent variable
    - ✓ Quantities that measured by experimenters
    - ✓ e.g., Heart rate, blood pressure, cortisol level, BOLD signal
    - ✓ e.g., accuracy, reaction times



Experimental designs

- Within-subject design
  - Each subject participants in all experimental conditions

- Between-subject design
  - Different conditions are assigned to different subject groups
  - e.g. male vs. female; drug abuser vs. abstainers; young vs. older adults.



Experimental designs

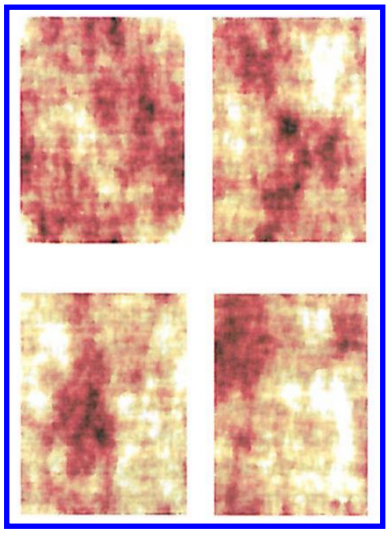
- **Experimental condition**
  - ✓ Contains the stimuli or task that is most relevant to research hypothesis
  - ✓ Task condition
- **Control condition**
  - ✓ Baseline condition
  - ✓ Non-task condition

	服藥前	服藥	服藥後
Experimental condition	發燒、 咳嗽、 流鼻水		症狀 消失
Control condition	發燒、 咳嗽、 流鼻水	多休息喝水	症狀 消失

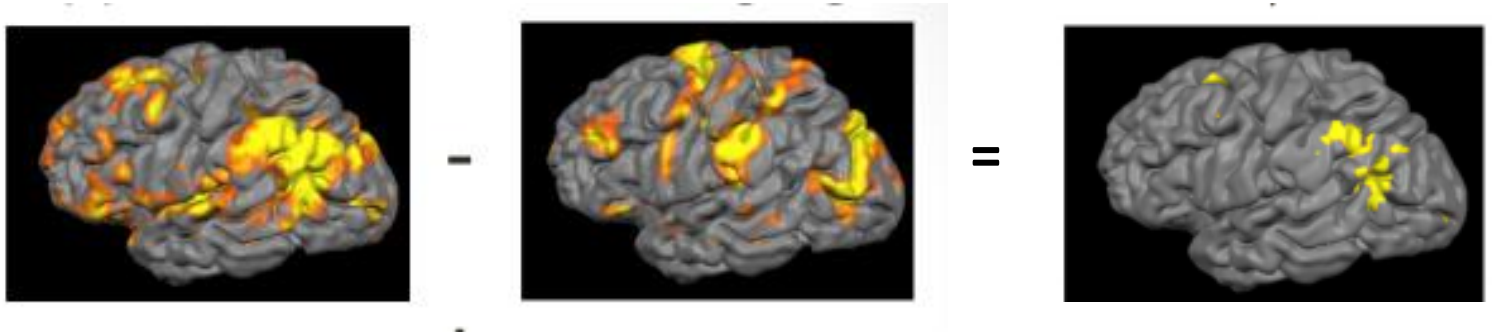
Experimental designs: task-evoked fMRI

- Experimental condition
- Control condition

faces



Scrambled pictures w/
same spatial frequency



Confounding factors

- Any property that co-varies with the independent variable within the conducted experiment
- Could be distinguished from the independent variables using a different experimental design

Evidence of global warming

Example of confounding

“Clever” Hans

CLEVER HANS

(THE HORSE OF MR. VON OSTEN)

A CONTRIBUTION TO EXPERIMENTAL ANIMAL AND HUMAN PSYCHOLOGY

BY

OSKAR PFUNGST

WITH AN INTRODUCTION BY PROF. C. STUMPF, AND ONE ILLUSTRATION AND FIFTEEN FIGURES

TRANSLATED FROM THE GERMAN BY

CARL L. RAHN

Fellow in Psychology in the University of Chicago

WITH A PREFATORY NOTE BY

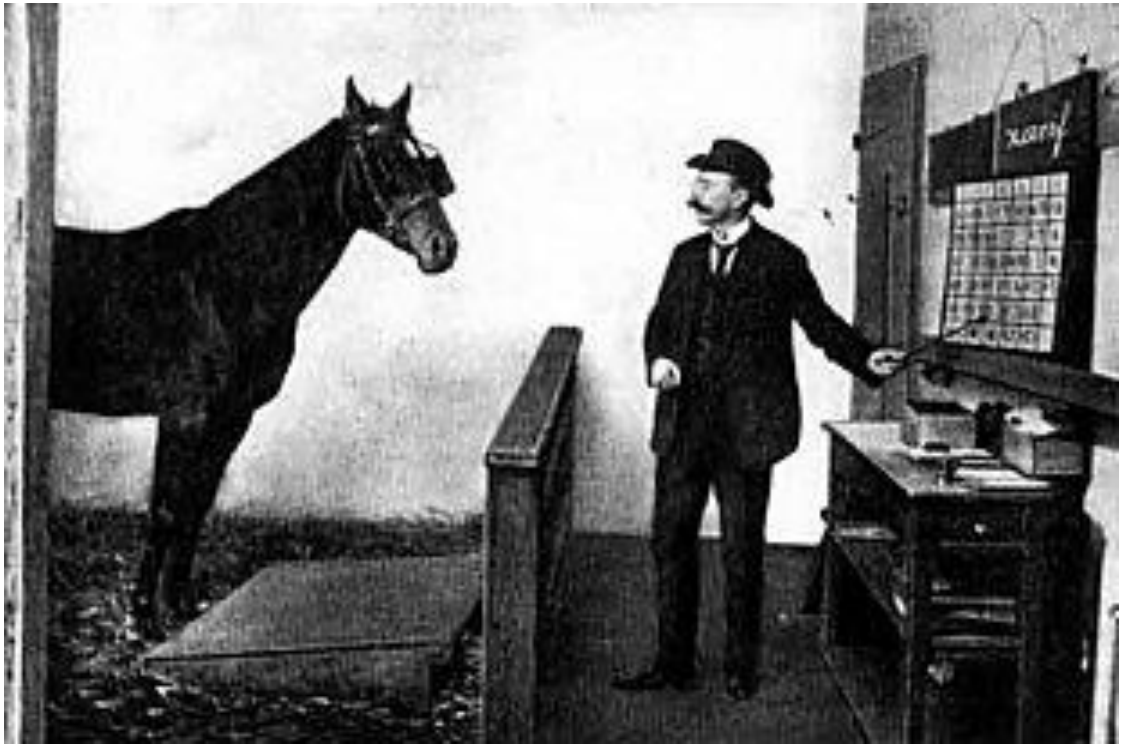
JAMES R. ANGELL

Professor of Psychology in the University of Chicago

NEW YORK

HENRY HOLT AND COMPANY

1911



Clever-Hans effect: Observer expectancy

When Hans is clever

When Hans is not clever

To prevent confounding factors

- Randomizing or Counterbalancing the order of the conditions makes sure that the potential effects are distributed equally across the conditions of the experiment.
  - Randomized: A-B-C, A-C-B, B-C-A, B-A-C, C-A-B, C-B-A (N!)
    - ✓ 4 conditions: 24; 5 conditions: 120; 6 conditions: 720
  - Counterbalancing: A-B-C, B-C-A, C-A-B
    - ✓ Ease of usage: don't have to switch instructions or equipment very often

A good way to identify confounding factors

- Participate in your own experiments as a pilot subject!

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Jargons in a task-evoked fMRI experiment

- Event
- Trial
- Block
- Condition
- Session

Color-word Stroop task
(史初普叫色作業)

- Slower response for incongruent trials (the color of a word is not the meaning of the word).
- Semantic process is automatic.
- You need to actively suppress the information processing of semantic knowledge: inhibition

紅

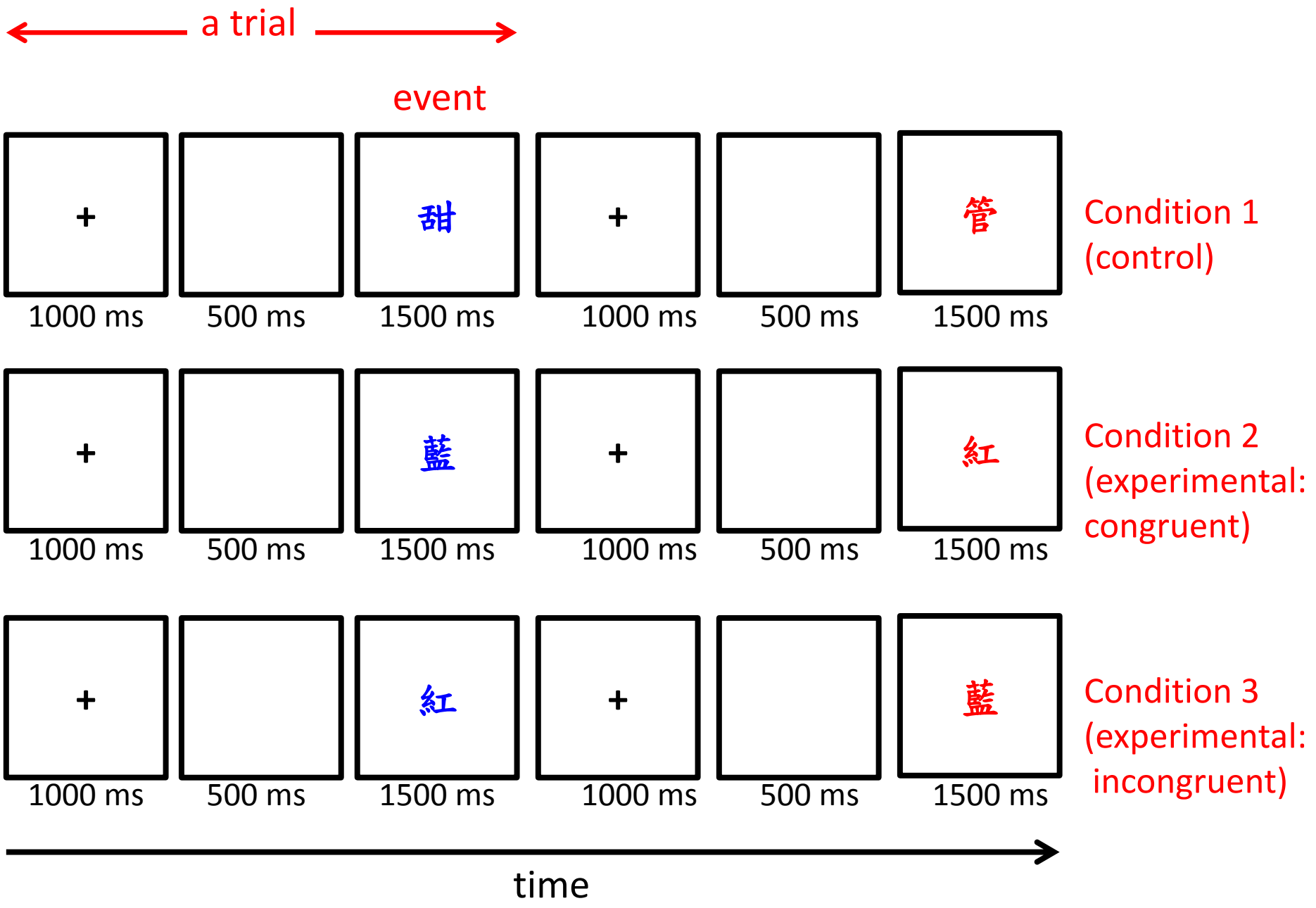
Congruent condition
(一致情境)

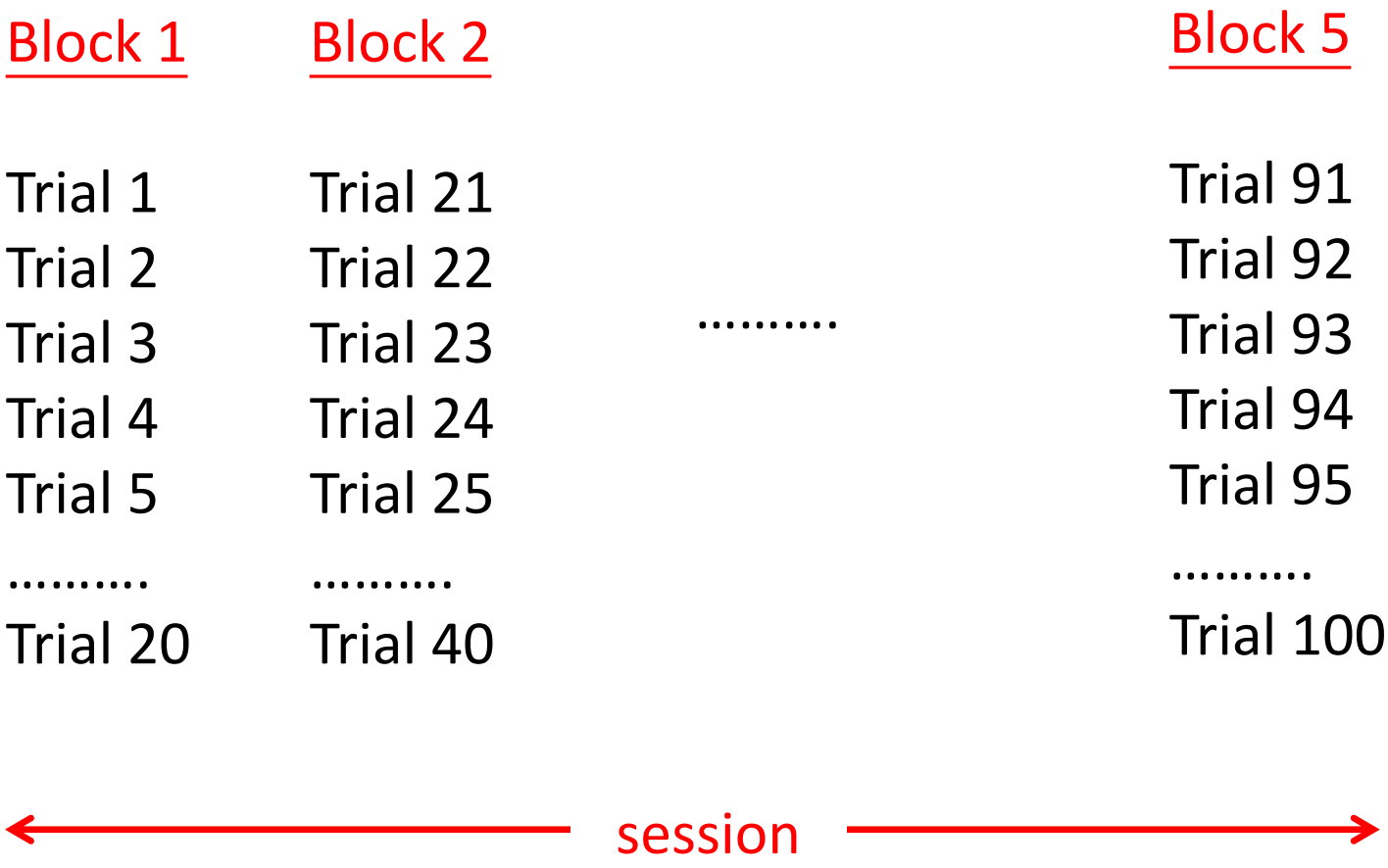
紅

Incongruent condition
(不一致情境)

Jargons in a task-evoked fMRI experiment

- Event
- Trial
- Block
- Condition
- Session


a trial
event
+
甜
+
管
1000 ms
500 ms
1500 ms
1000 ms
500 ms
1500 ms
Condition 1
(control)
+
藍
+
紅
1000 ms
500 ms
1500 ms
1000 ms
500 ms
1500 ms
Condition 2
(experimental:
congruent)
+
紅
+
藍
1000 ms
500 ms
1500 ms
1000 ms
500 ms
1500 ms
Condition 3
(experimental:
incongruent)
time


Block 1
Block 2
Block 5
Trial 1
Trial 2
Trial 3
Trial 4
Trial 5
……
Trial 20
Trial 21
Trial 22
Trial 23
Trial 24
Trial 25
……
Trial 40
……
Trial 91
Trial 92
Trial 93
Trial 94
Trial 95
……
Trial 100
session

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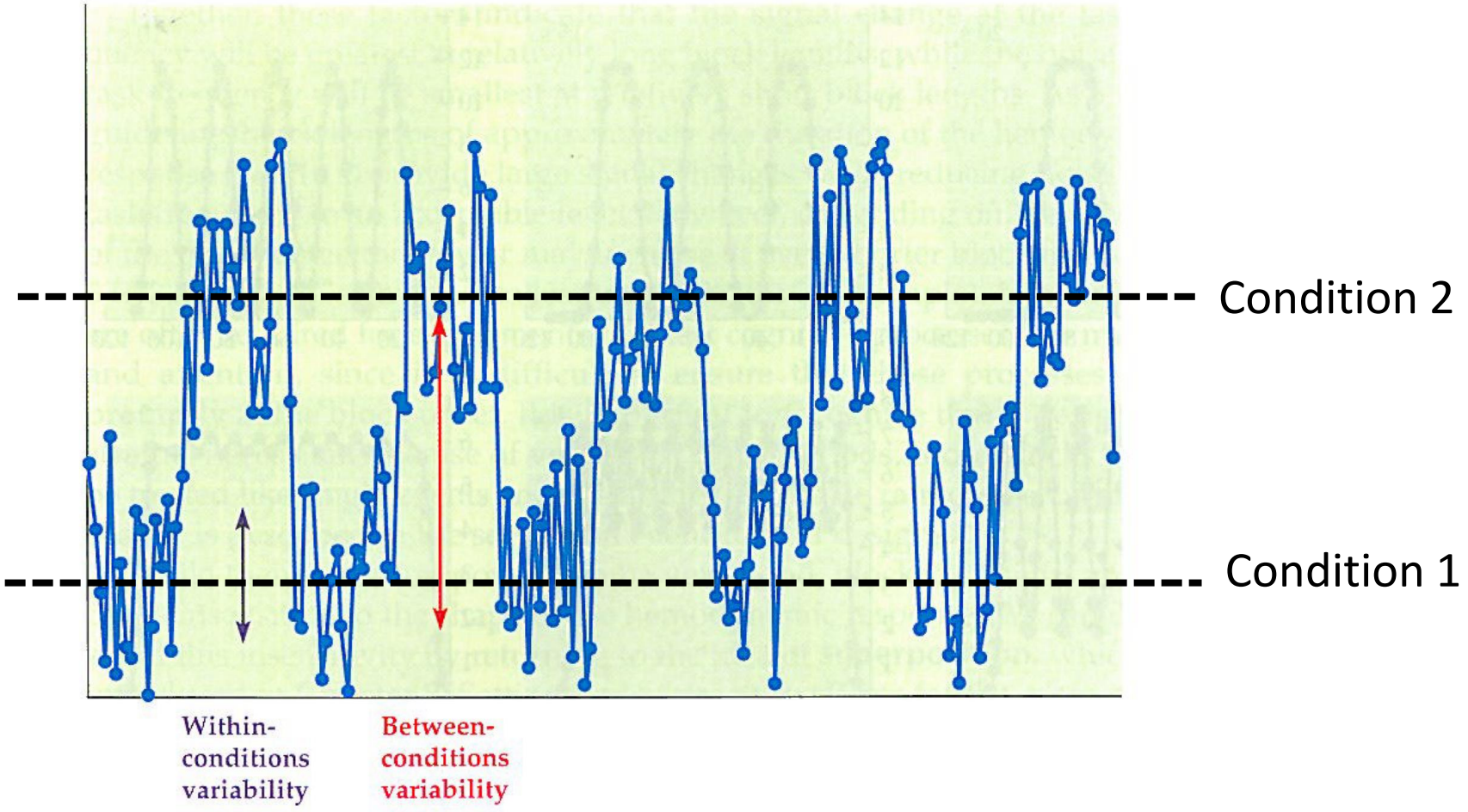
Experimental designs in task-evoked fMRI studies

- Blocked design
  - The separation of experimental conditions into distinct “blocks”
- Event-related design
  - The presentation of discrete, short duration “events” whose timing and order may be randomized
- Mixed design (blocked + event-related design)
  - Contains features of both blocked and event-related approaches

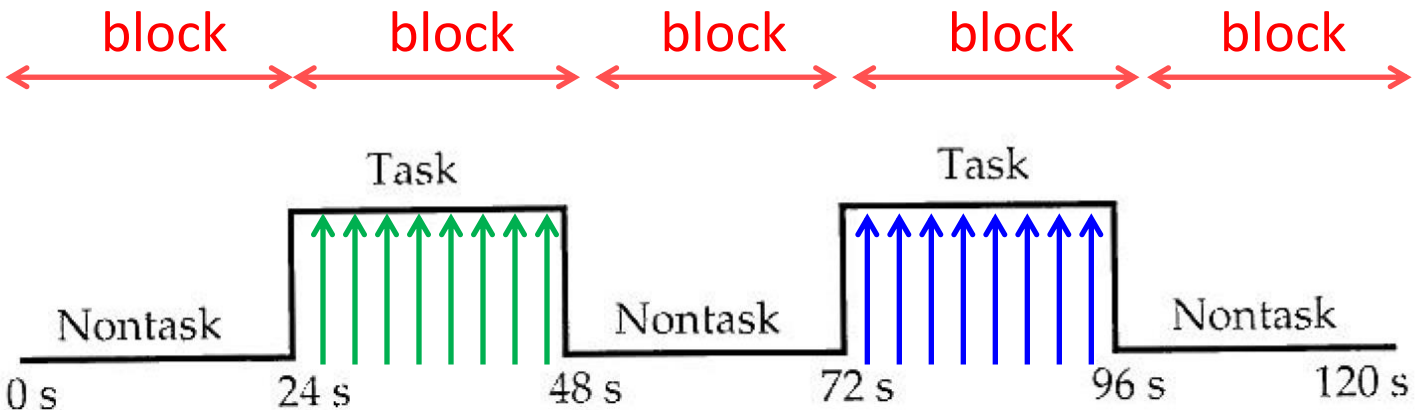
The goal of experimental design in task-evoked fMRI

- To maximize the between-conditions variability while minimizing within-conditions variability



Blocked design

- The separation of experimental conditions into distinct “blocks”, so that each condition is presented for an extended period of time.
  - Block: A time interval that contains trials from one condition



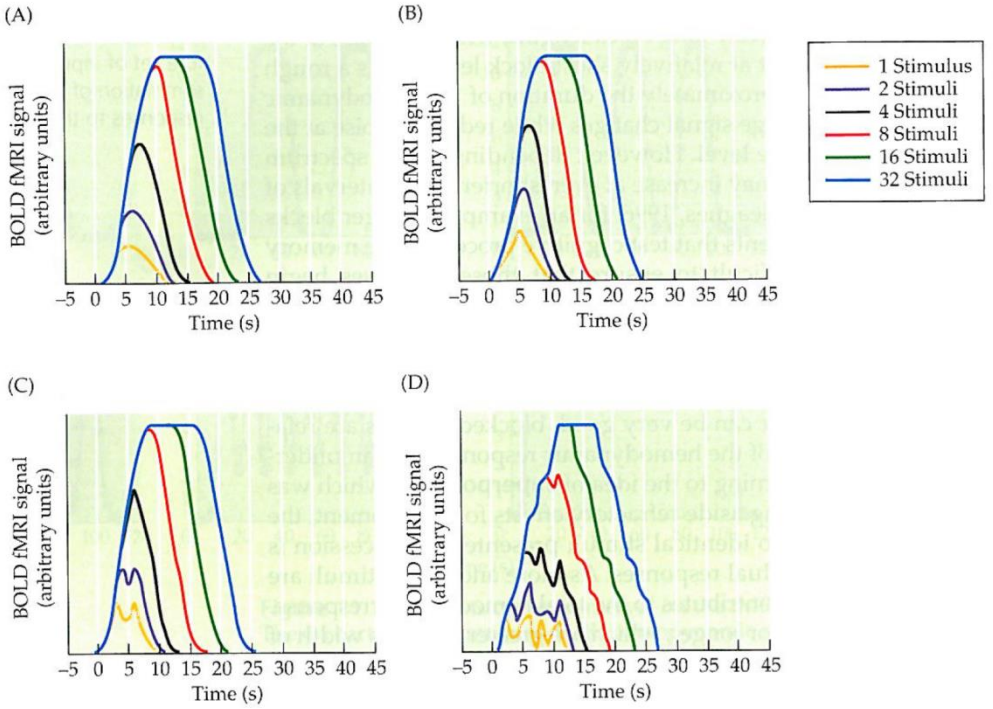
Blocked design

- Alternating design:
  - Blocked design alternates between two conditions
  - For optimal statistical power, the blocks in an alternating design should generally be of equal length

- Control-block design:
  - Baseline condition is introduced between two blocks

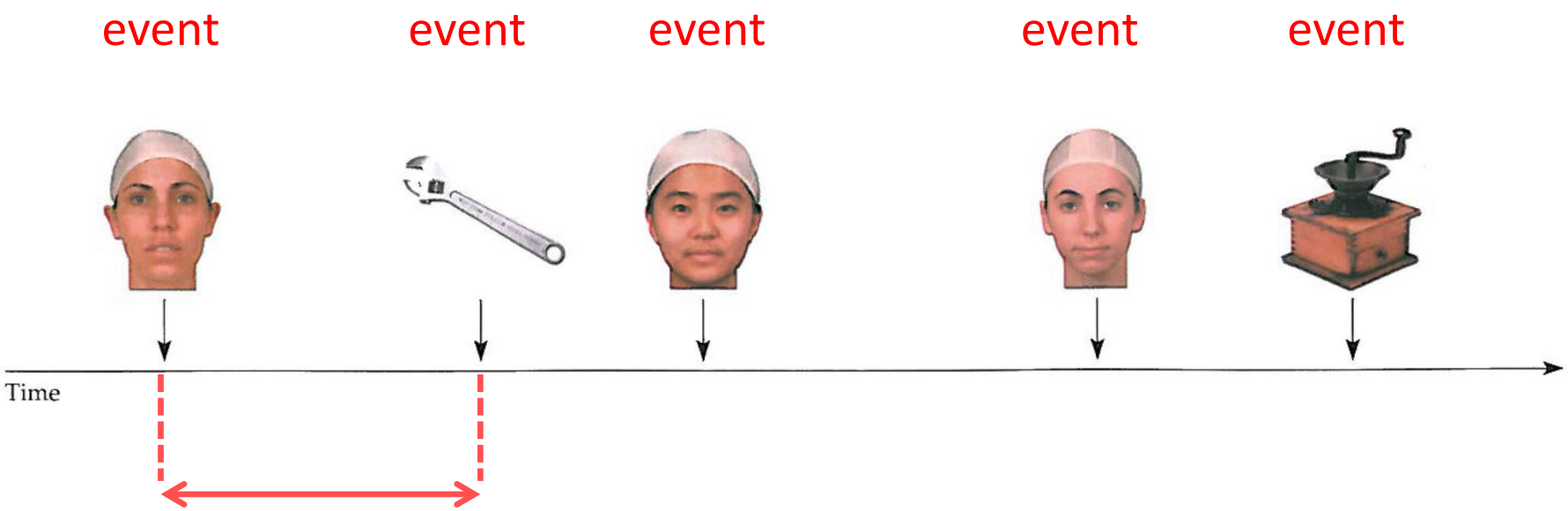
Advantages & disadvantages of blocked design

- Advantages:
  - Good for detecting significant fMRI activity (good detection power)
  - Simple analysis
- Disadvantages:
  - Insensitivity to the shape and timing of hemodynamic response
  - Potential problems with selection of conditions



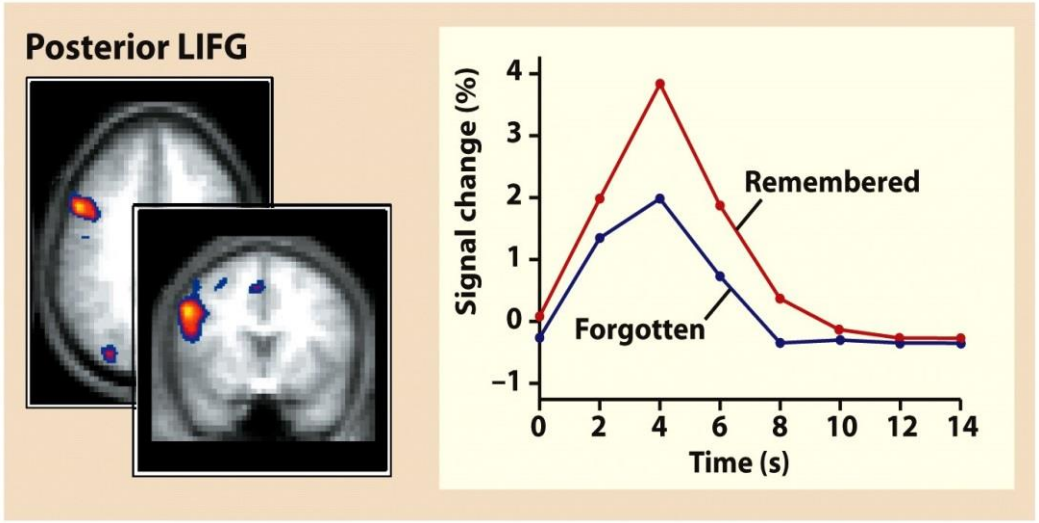
Event-related design

- The presentation of discrete, short duration “events” whose timing and order may be randomized

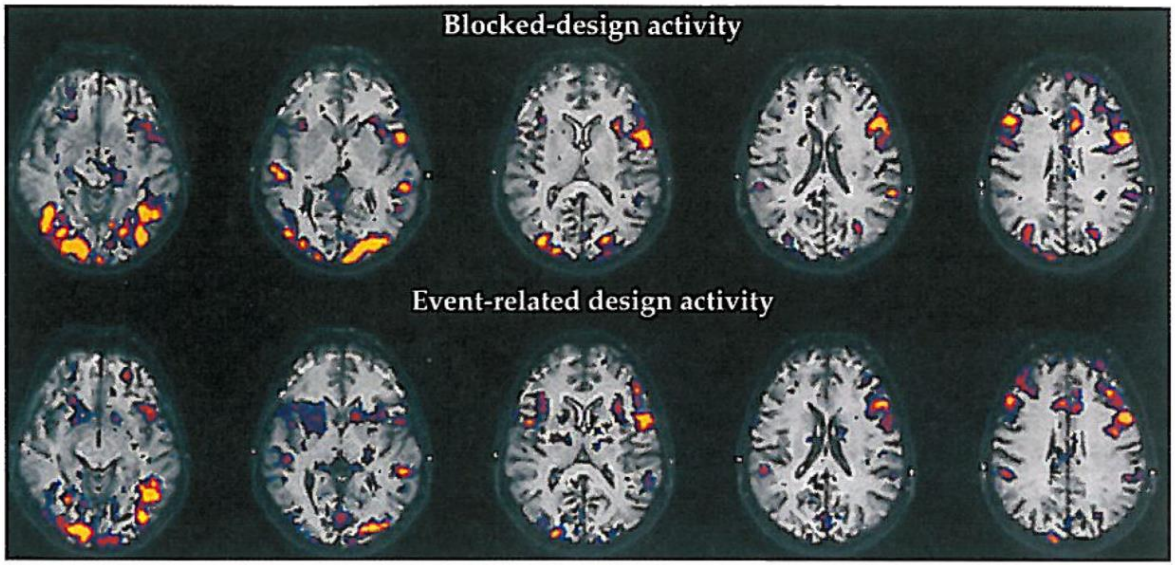


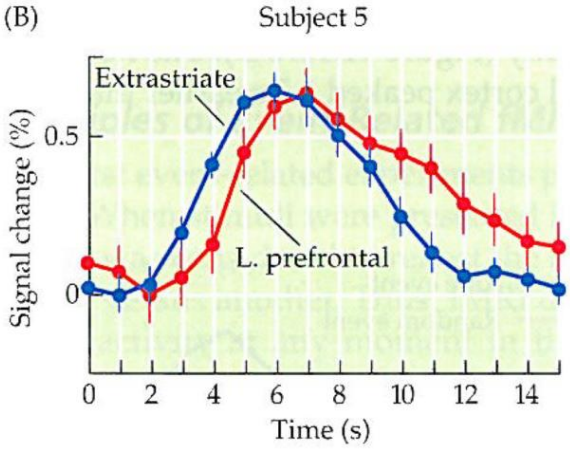
Advantages & disadvantages of event-related design

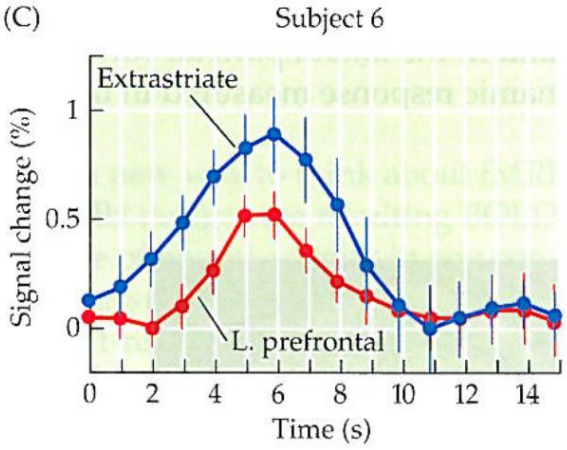
- Advantages:
  - Allow determination of change from baseline
  - Very flexible analysis strategies
  - Best for post-hoc trial sorting
- Disadvantages:
  - Reduced detection power



Blocked design vs. Event-related design

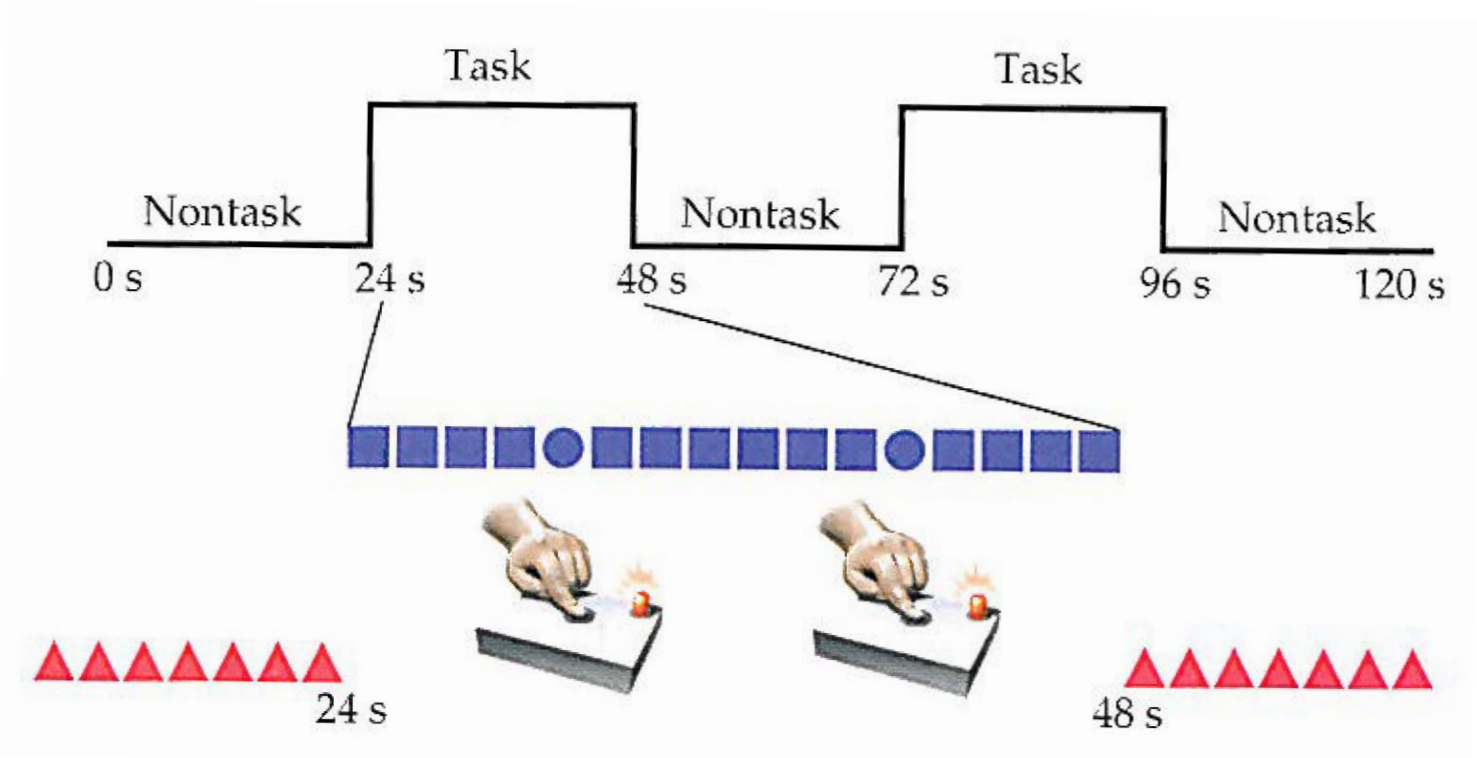






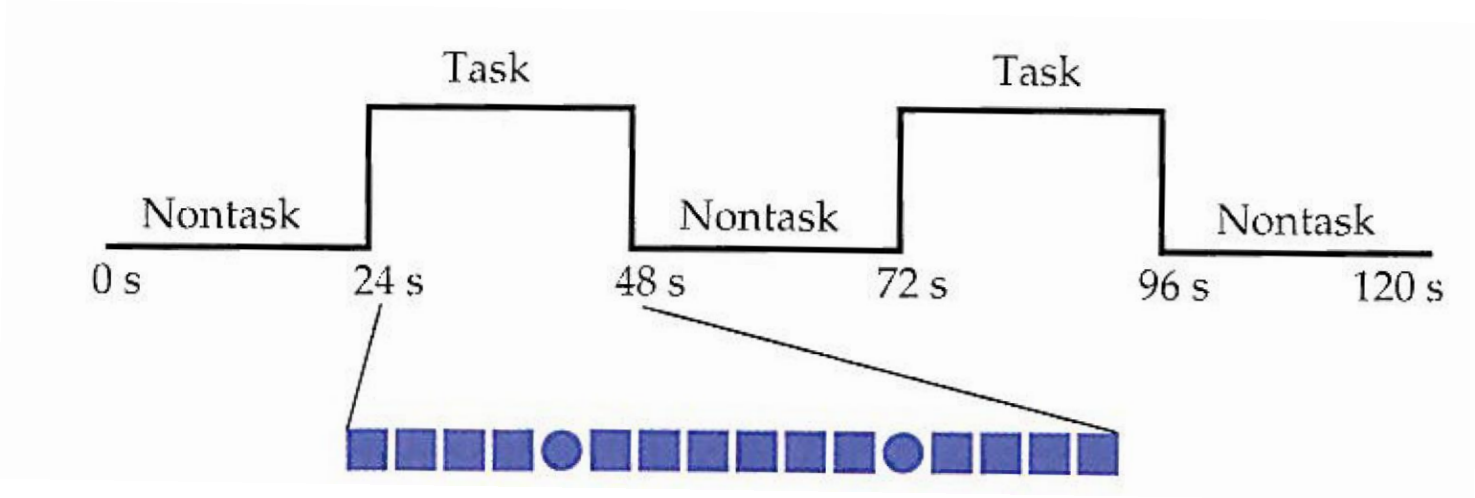
Mixed design

- A design that contains features of both blocked and event-related approaches



Advantages & disadvantages of mixed design

- Advantages:
  - Combination of blocked and event-related design
  - Can dissociate transient and sustained component of activity
- Disadvantages:
  - Most complicated analyses



However…

- In task-evoked fMRI studies, there is no optimal experimental design

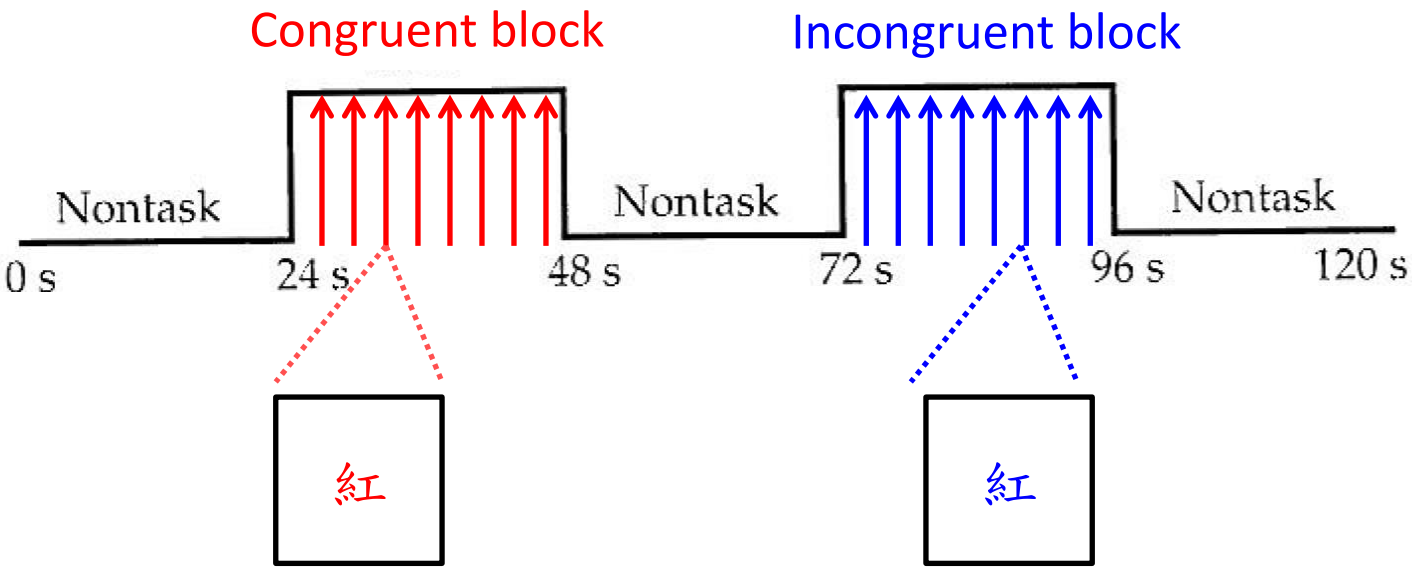
- The fundamental rule: choose the design that best suits your experimental questions

Example 1

- 63 year-old stroke patients, only 10 minutes available for functional MRI scan
- To explore the effects of stroke on inhibitory-control function
- Color-word Stroop task

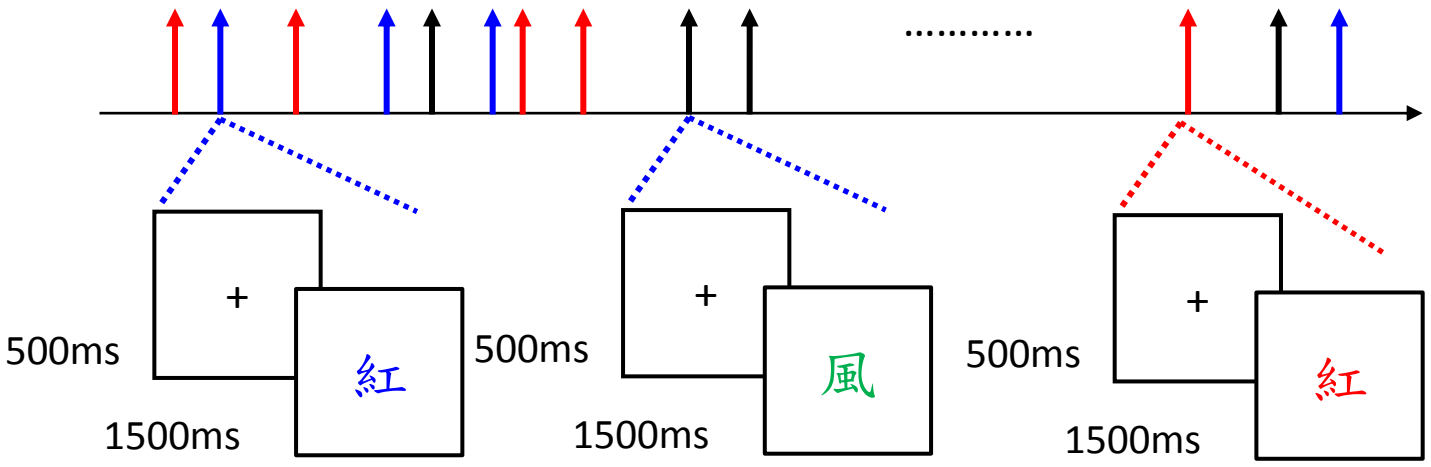
Example 1

- 63 year-old stroke patients, only 10 minutes available for functional MRI scan
- To explore the effects of stroke on executive-control function (i.e. Color-word Stroop task)



Example 2

- 22 year-old healthy young adults, 30 minutes available for functional MRI scan
- To investigate the influences of brain activation associated with errors executive-control processing (e.g. Color-word Stroop task)



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THE ROYAL SOCIETY

If neuroimaging is the answer, what is the question?

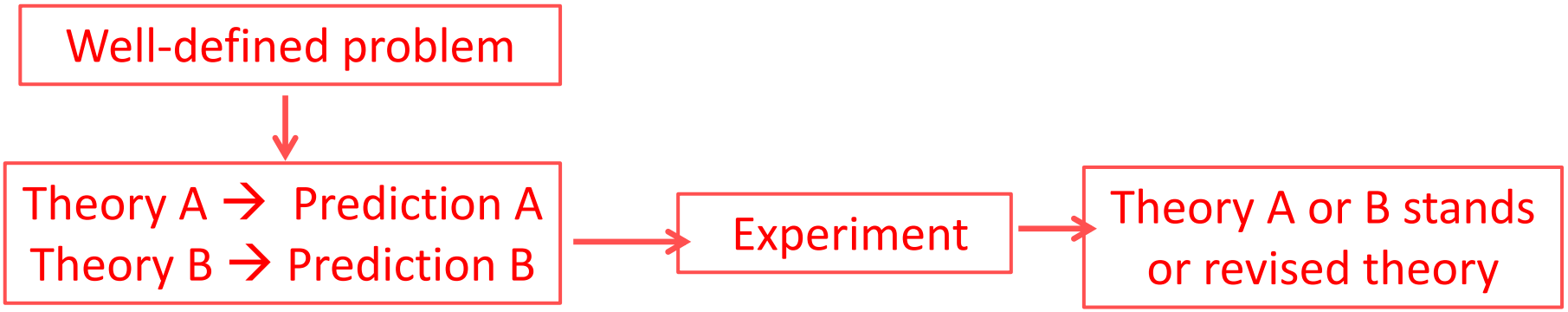
S. M. Kosslyn

832 William James Hall, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA (smk@wjh.harvard.edu)

"Attending a poster session at a recent meeting, I was reminded of the old adage '**To the man who has only a hammer, the whole world looks like a nail.**' In this case, however, instead of a hammer we had a magnetic resonance imaging (MRI) machine and instead of nails we had a study. Many of the studies summarized in the posters did not seem to be designed to answer questions about the functioning of the brain; neither did they seem to bear on specific questions about the roles of particular brain regions. Rather, they could best be described as 'exploratory'. People were asked to engage in some task while the activity in their brains was monitored, and this activity was then interpreted post hoc."

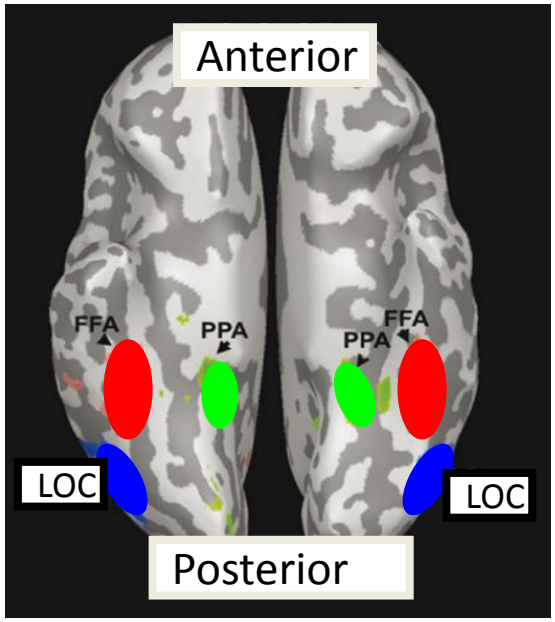
Stephen M. Kosslyn (1999). If neuroimaging is the answer, what is the question?
Phil Trans R. Soc Lond B, 354, 1283-1294

fMRI studies: theoretically driven



fMRI studies: theoretically driven

- Different stimulus categories elicit different patterns of activity in ventral visual cortex.
- Predictions:
  - Face recognition task lead to activation in fusiform face area
  - Animacy judgment task lead to activation in lateral occipital complex



Place/House Areas
(Parahippocampal gyrus)

Face Areas
(Fusiform Face Area)

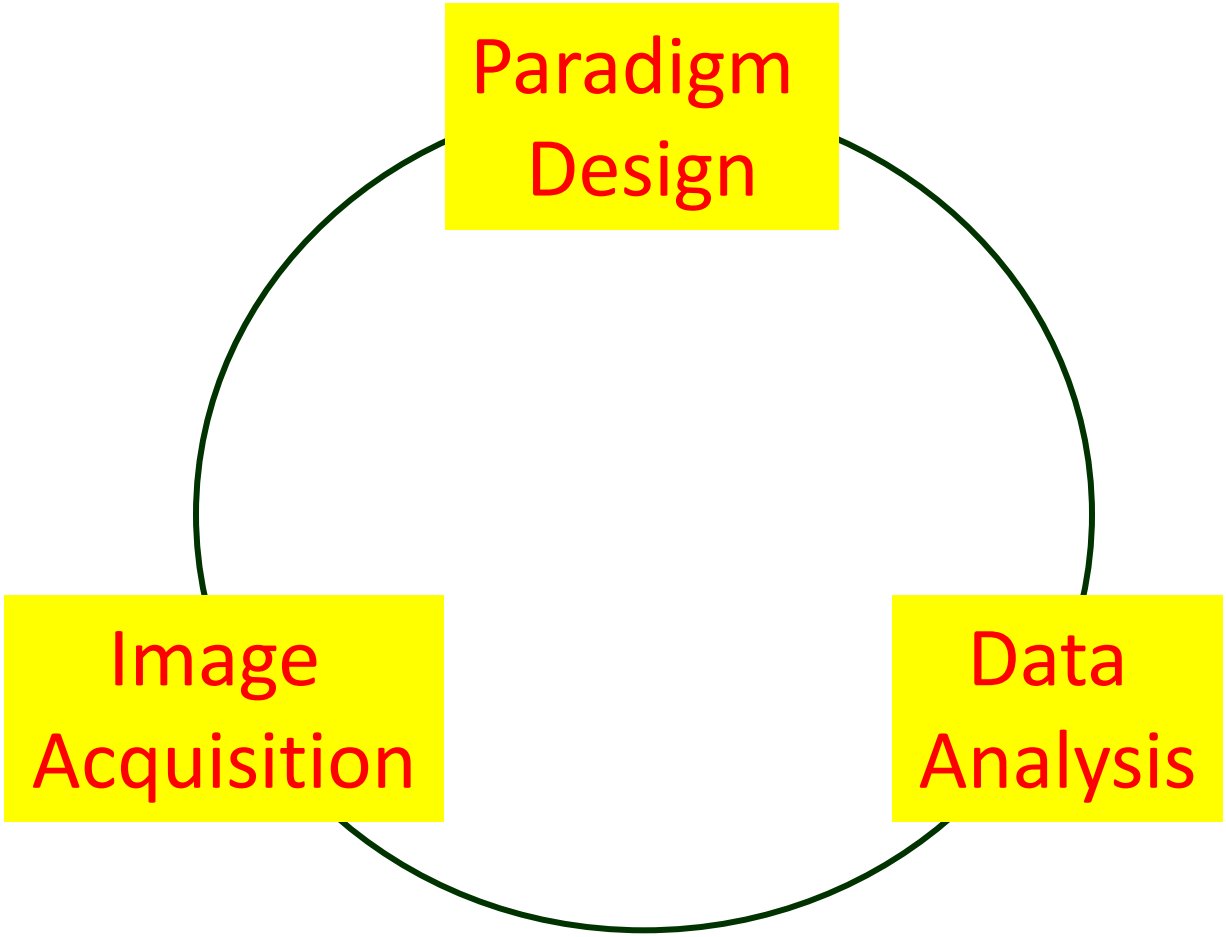
Object Areas
(Lateral occipital complex)

fMRI studies: data driven

Setting up a good research hypothesis

- In general:
  - “manipulating the independent variable will cause changes in the dependent variable”
- More precise:
  - “increasing the independent variable should cause a decrease in the dependent variable”
  - By specifying how independent and dependent variables should relate to each other

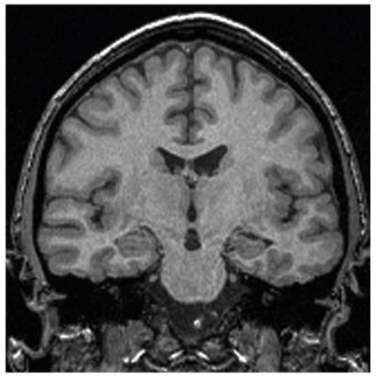
task-evoked fMRI Procedures



fMRI basic: orientation

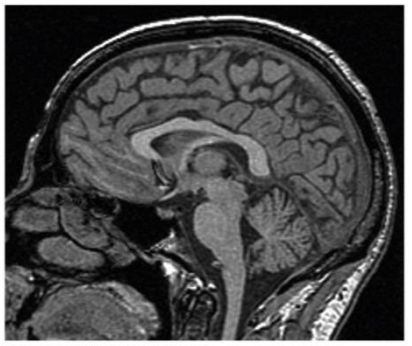
- Slice orientation:
  - Axial
  - Coronal
  - Sagittal

Coronal view

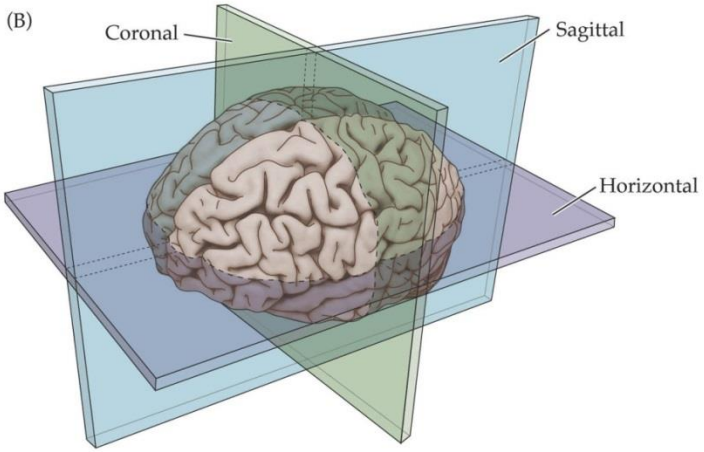


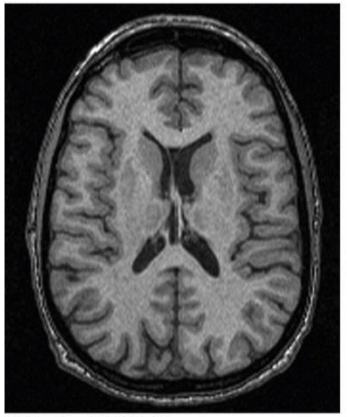
ICE, Fourth Edition, Atlas, Plate 2 (Part 3)

Sagittal view



CIENCE, Fourth Edition, Atlas, Plate 4 (Part 4)



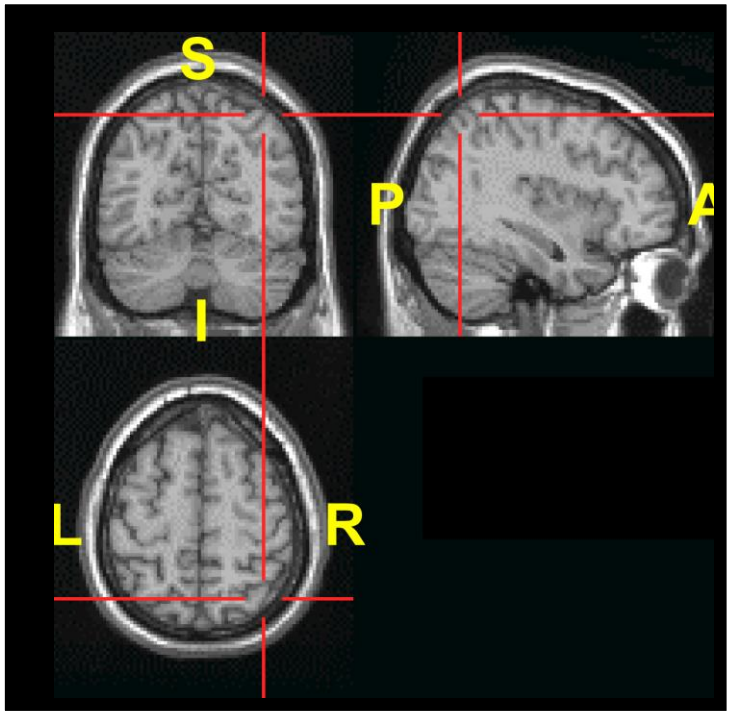


Edition, Atlas, Plate 3 (Part 4)

Horizontal view

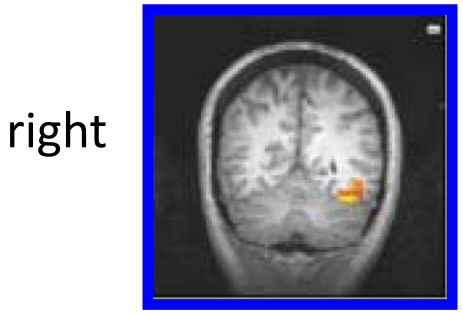
fMRI basic: orientation

- Slice orientation:
  - A-P: anterior-posterior (前後)
  - S-I: superior-inferior (上下)
  - L-R: left-right (左右)



fMRI basic: orientation

- Neurological convention
  - Left is left, right is right
- Radiological convention
  - Left is right, right is left



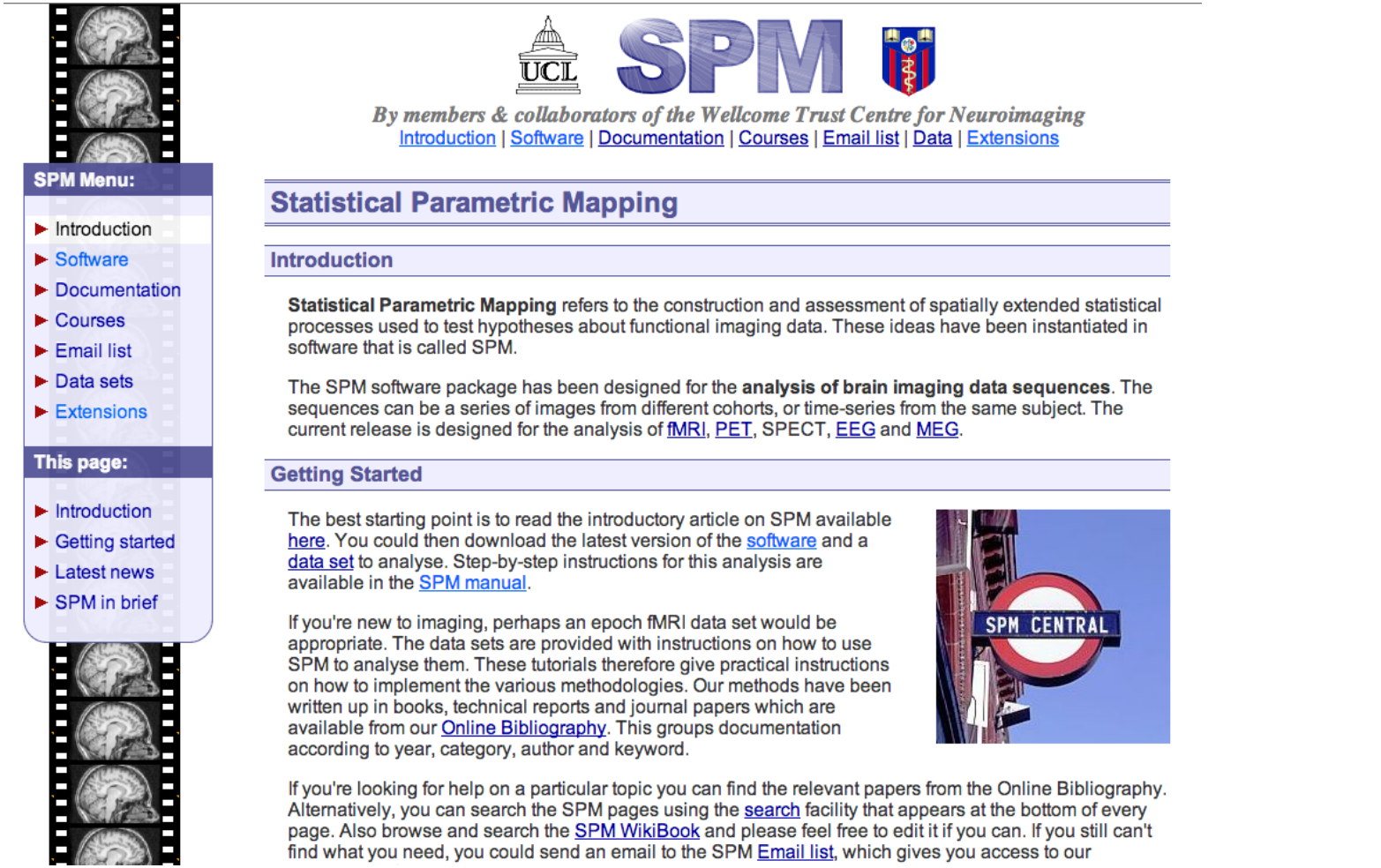
- Make sure how your software doing with left/right
  - If you're really unsure, tape a vitamin E or oil capsule to the one side of the subject's head. It will show up on the anatomical image

fMRI分析軟體

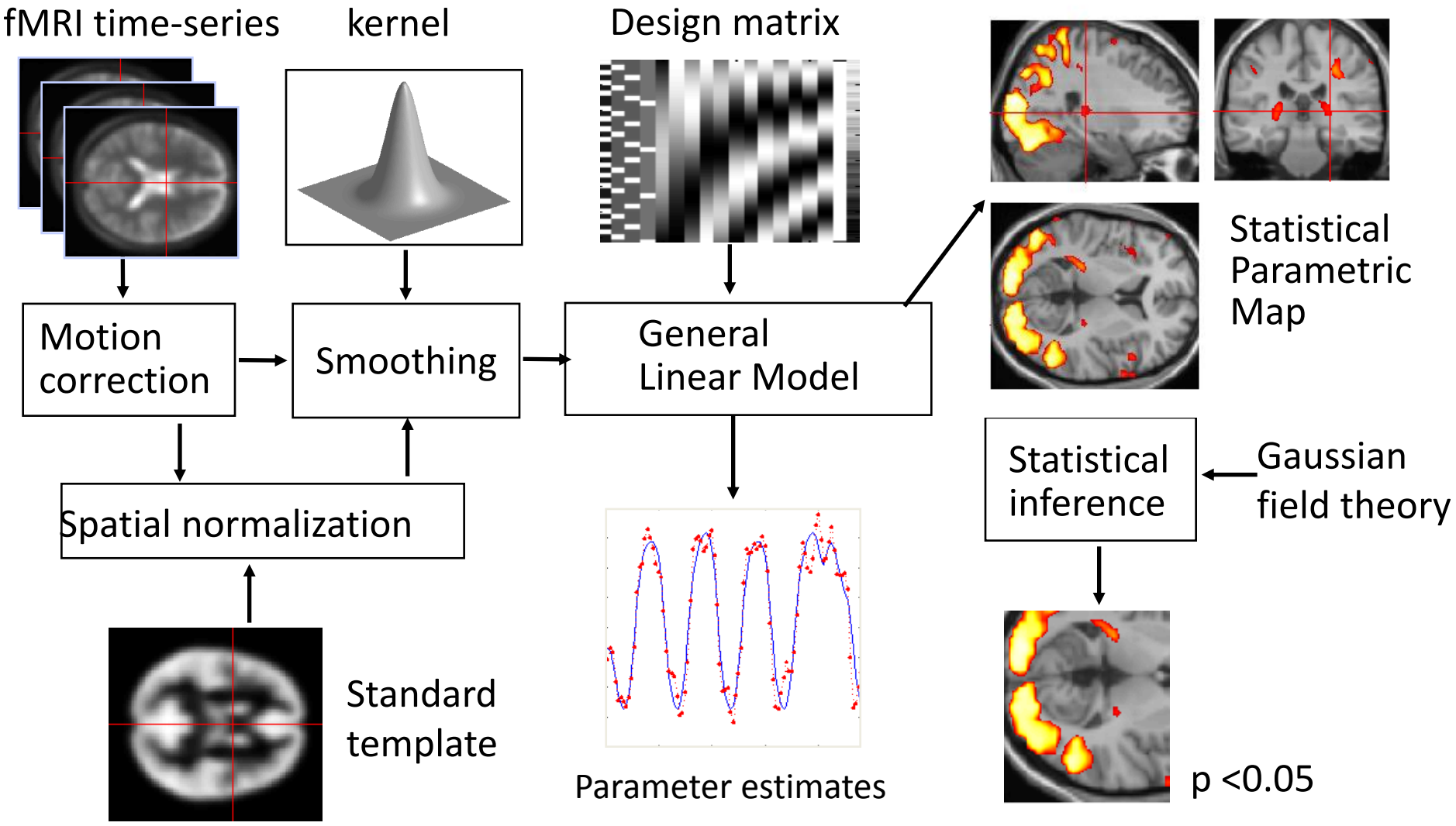
- Task-evoked fMRI data analysis
  - ✓ SPM, http://www.fil.ion.ucl.ac.uk/spm/software/
  - ✓ FSL, http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/
  - ✓ BrainVoyager, http://www.brainvoyager.com/downloads/downloads.htm
  - ✓ AFNI http://afni.nimh.nih.gov/afni/download
- Resting-state fMRI data analysis
  - ✓ SPM (based on extensions)
  - ✓ FSL
  - ✓ REST, http://restfmri.net/forum/index.php
  - ✓ AFNI

SPM(Statistical Parametric Mapping)

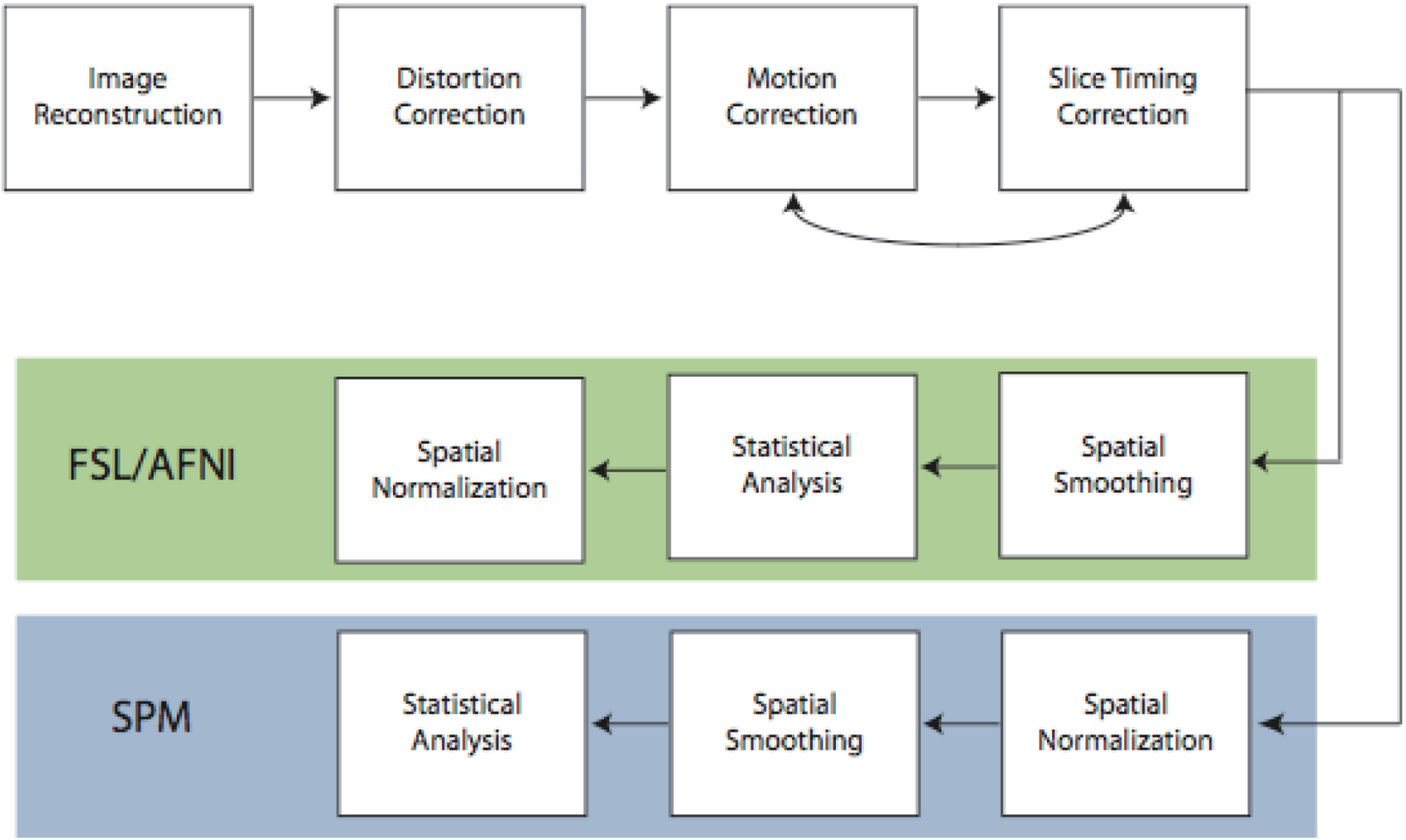
- Based on MATLAB



fMRI Data transformations



Overview of task-evoked fMRI data analysis



task-evoked fMRI data analysis

- Data pre-processing
  - motion correction
  - slice timing correction
  - spatial normalization
  - spatial smoothing
- Statistical analysis I: Activation maps
  - t-test
  - thresholding (intensity / cluster size)
- Statistical analysis II: Group analysis
- Visualization