

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

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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：

fMRI 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 of Task-evoked fMRI:
Overview for Exp. Design and Analysis 】**

Principles:

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

【 Task-fMRI Preprocessing 】

Hands-on:

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

【 Data Modeling & Single-subject Analysis 】

Hands-on:

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

【 Group Analysis, & Results Display 】

Hands-on:

趙一平 教授 長庚大學

【 ROI analysis & Correlation with Behavior Measures 】

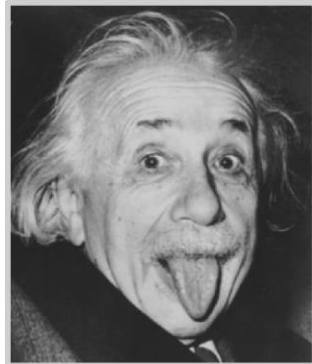
吳恩賜 教授 國立臺灣大學

16:40-17:00

結語

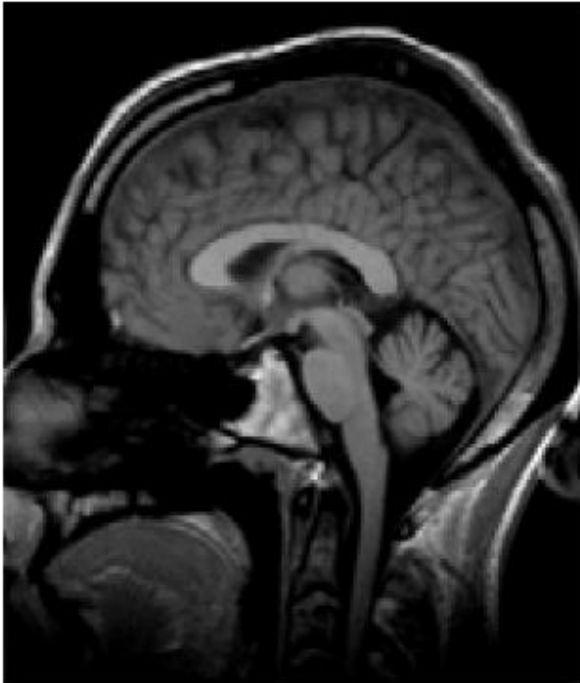
From behavior to the brain

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

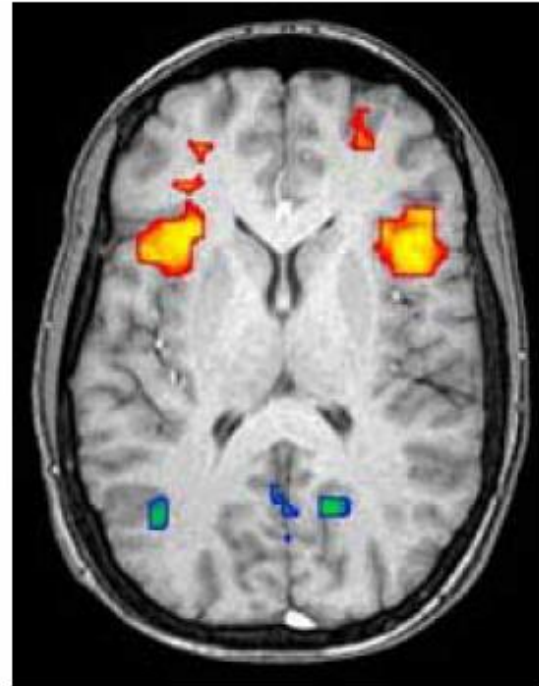


MRI and Functional MRI (fMRI)

- MRI studies brain anatomy



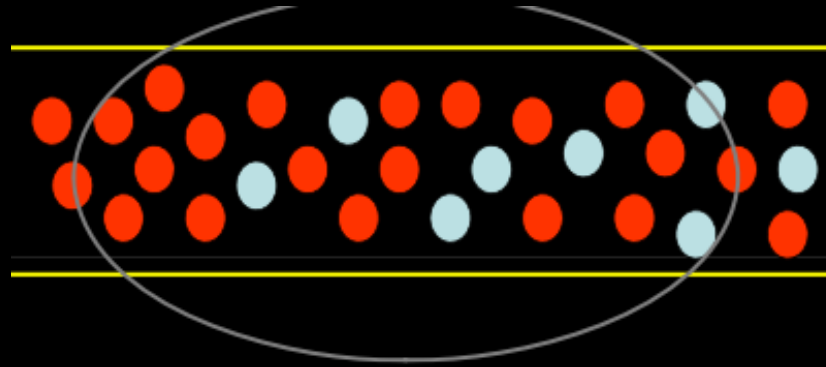
- Functional MRI (fMRI) studies brain function



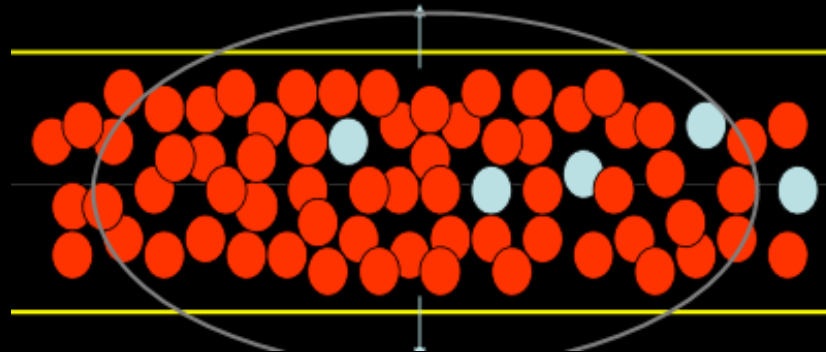
MRI scanner and task-evoked fMRI scan



Resting



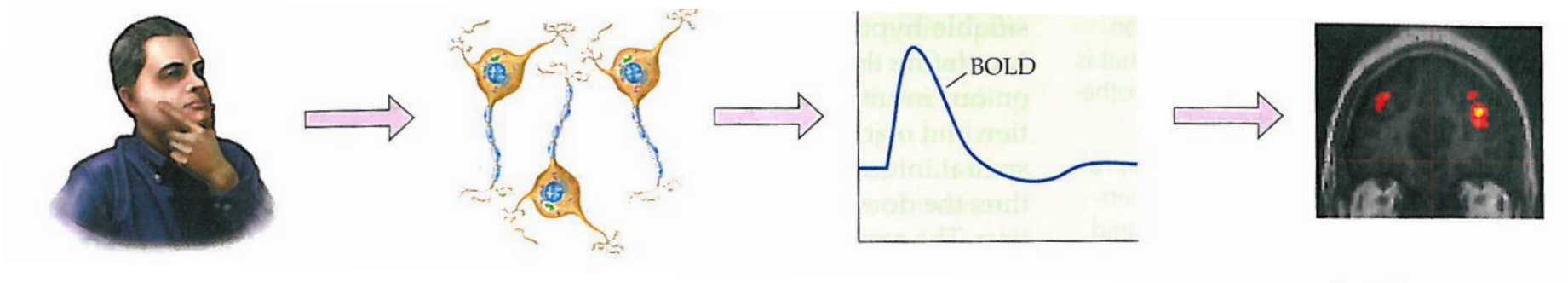
Active



 Oxygenated Blood

 Deoxygenated Blood

Three distinct levels of research hypothesis in fMRI studies



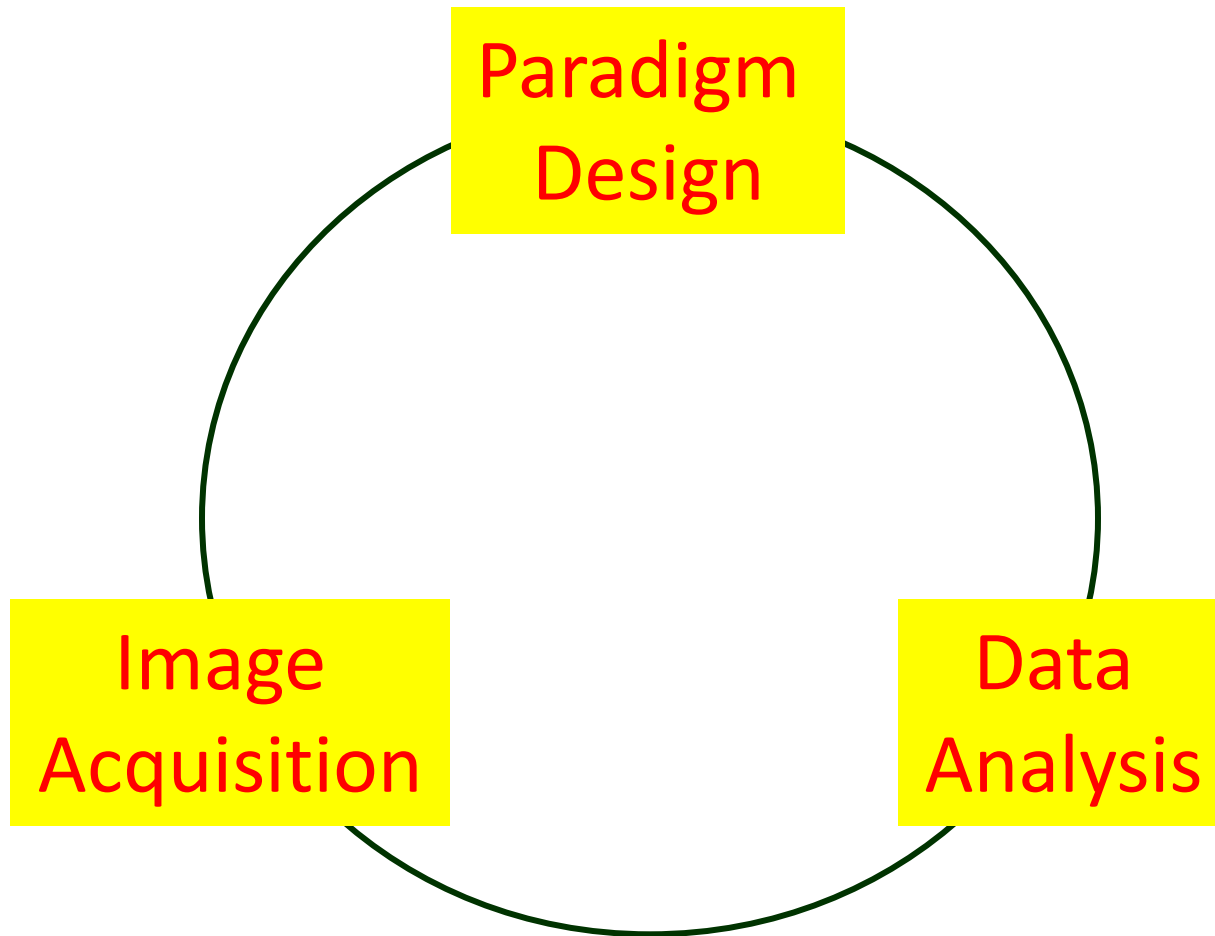
← Hemodynamic →

← 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
- **Overview: task-evoked fMRI data analysis**
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 - ✓ Statistical Analysis
 - ✓ Visualization

Essential components in an experimental design

- Variables:

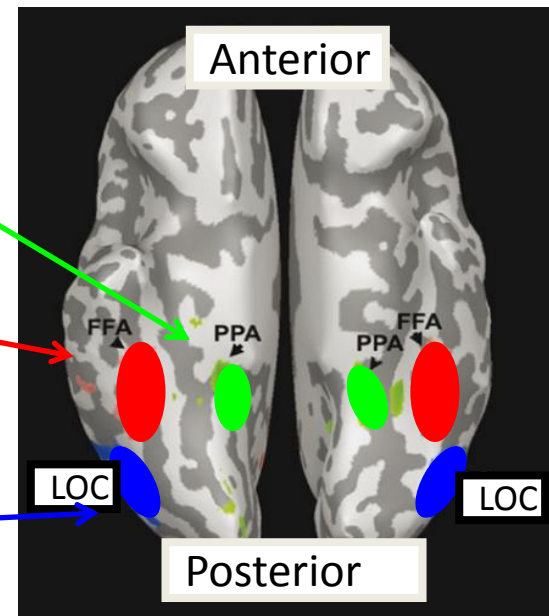
- **Independent variables**

- ✓ 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.

Pattern of moving squares



Color display



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

Experimental
condition

Control
condition

服藥前

發燒、
咳嗽、
流鼻水

服藥



服藥後

症狀
消失

發燒、
咳嗽、
流鼻水

多休息喝水

症狀
消失

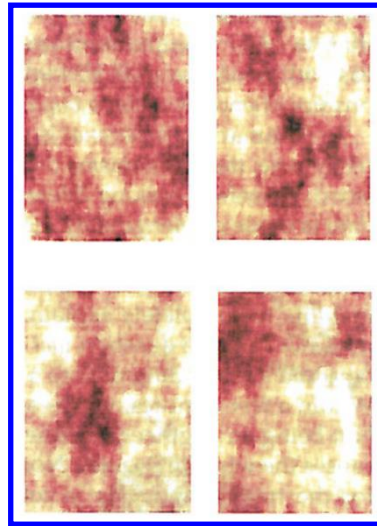
Experimental designs: task-evoked fMRI

➤ Experimental condition

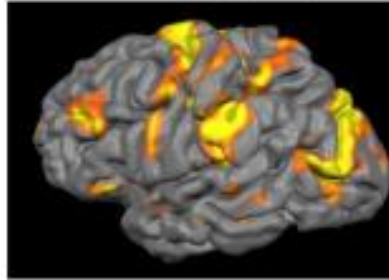
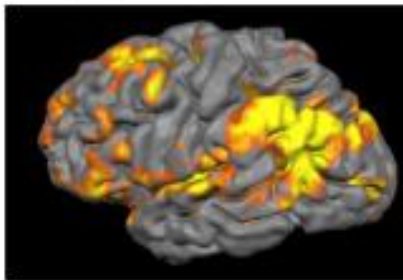


faces

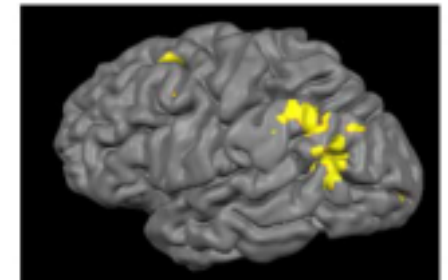
➤ Control condition



Scrambled pictures w/
same spatial frequency



=



Confounding factors

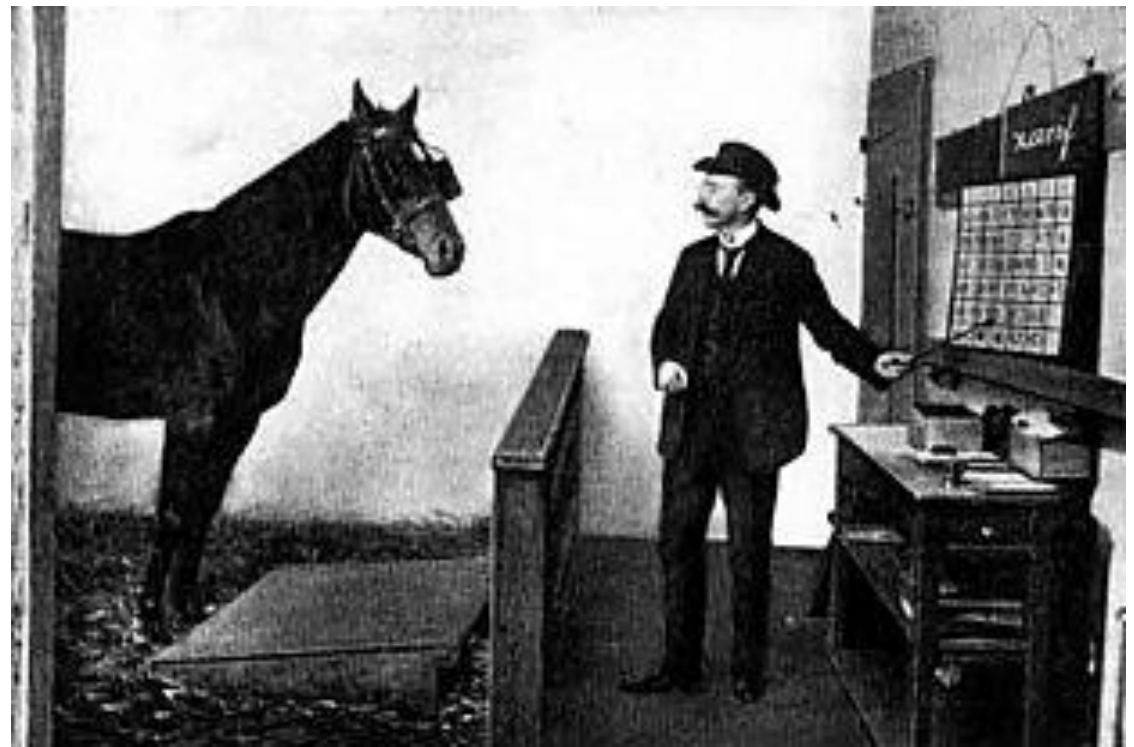
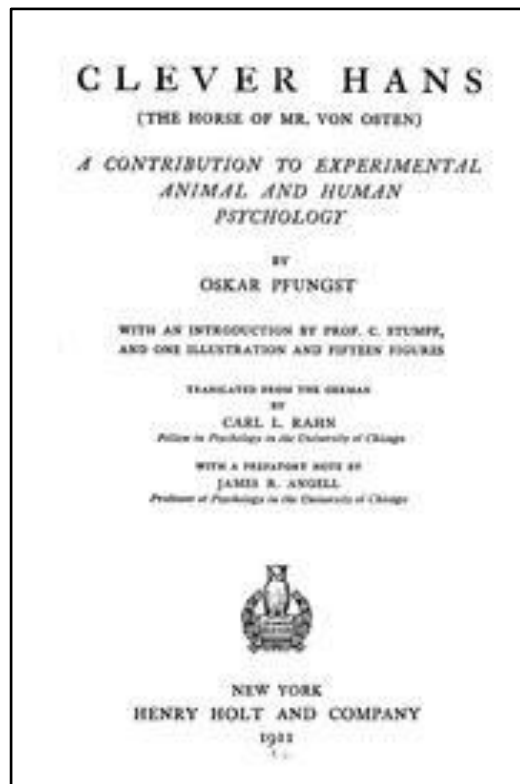
- Any property that co-varies with the independent variable within the conducted experiment
- Could be distinguished from the independent variables using a different experimental design

Evidence of global warming



Example of confounding

“Clever” Hans



Clever-Hans 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

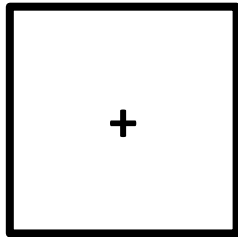
Incongruent condition
(不一致情境)

Jargons in a task-evoked fMRI experiment

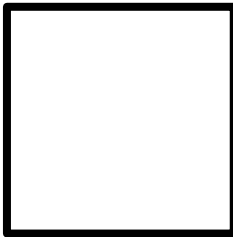
- Event
- Trial
- Block
- Condition
- Session

← a trial →

event



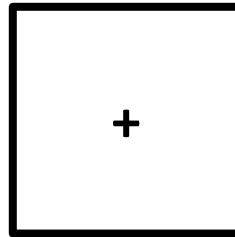
1000 ms



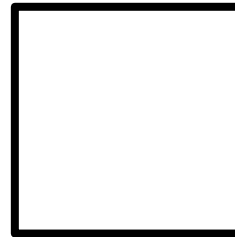
500 ms



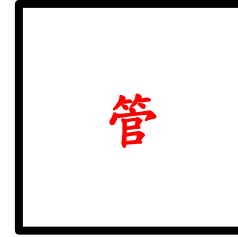
1500 ms



1000 ms

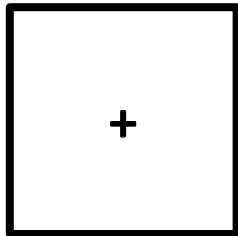


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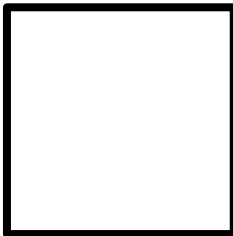


1500 ms

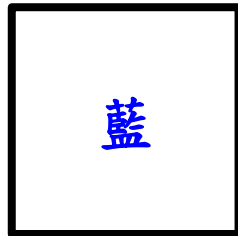
Condition 1
(control)



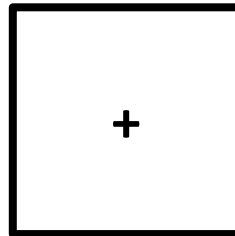
1000 ms



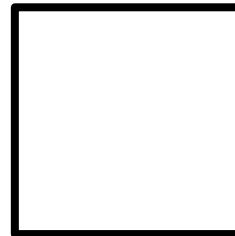
500 ms



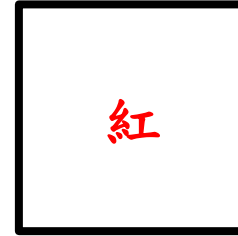
1500 ms



1000 ms

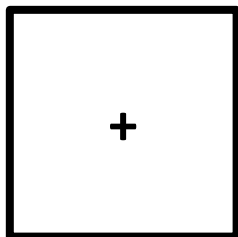


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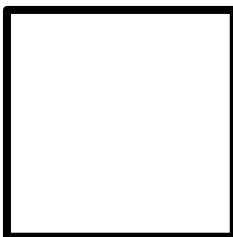


1500 ms

Condition 2
(experimental:
congruent)



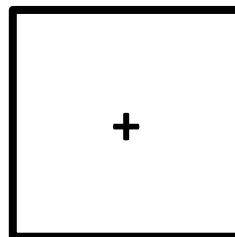
1000 ms



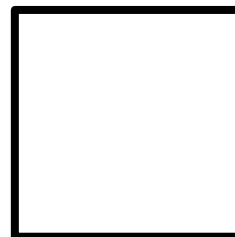
500 ms



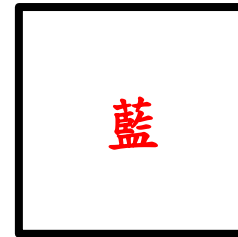
1500 ms



1000 ms



500 ms



1500 ms

Condition 3
(experimental:
incongruent)



time

Block 1

Block 2

Block 5

Trial 1

Trial 21

Trial 91

Trial 2

Trial 22

Trial 92

Trial 3

Trial 23

.....

Trial 93

Trial 4

Trial 24

Trial 94

Trial 5

Trial 25

Trial 95

.....

.....

.....

Trial 20

Trial 40

Trial 100



session

Outline for Today

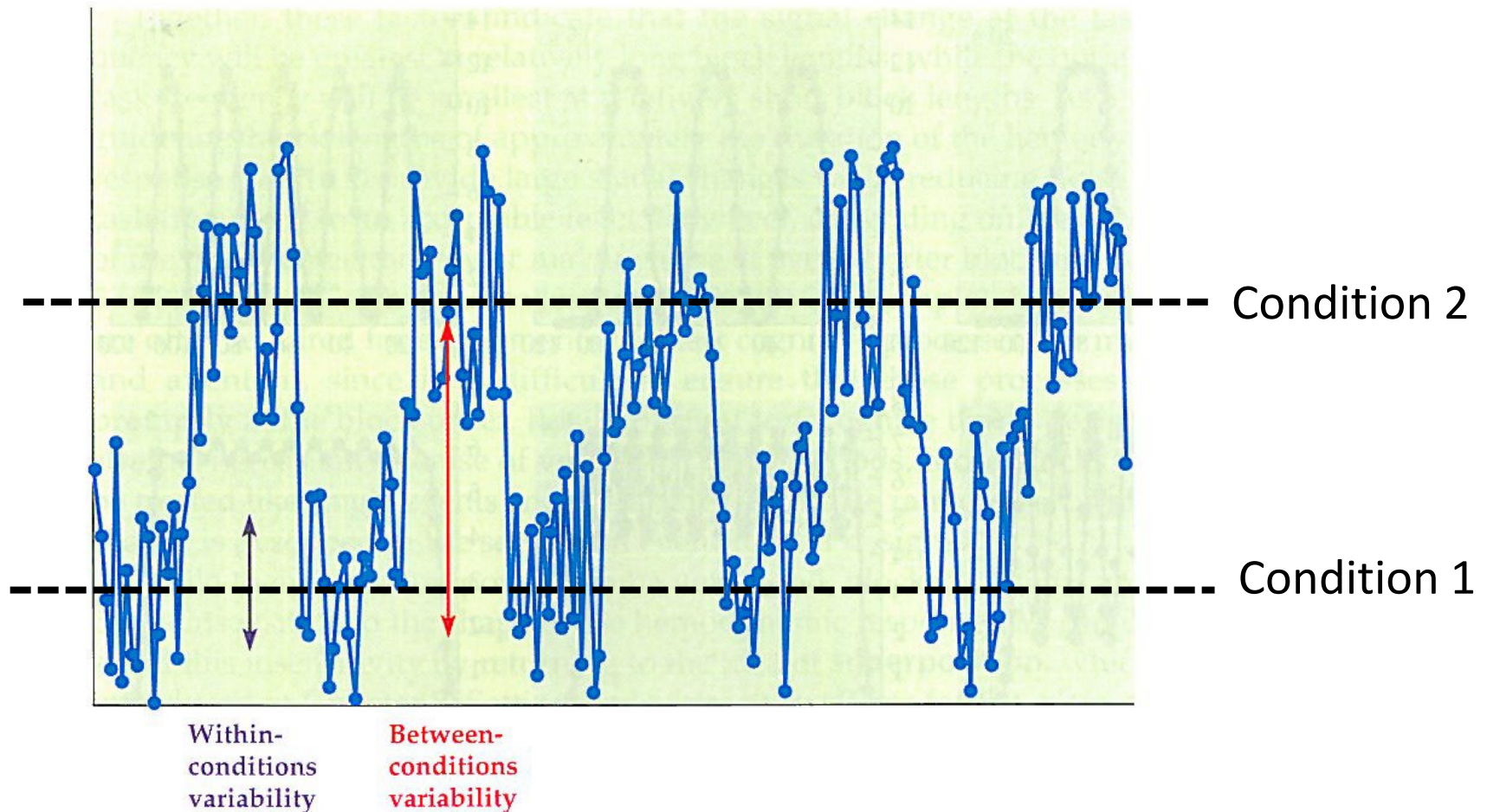
- **Overview: task-evoked fMRI experimental design**
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Experimental designs in task-evoked fMRI studies

- **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

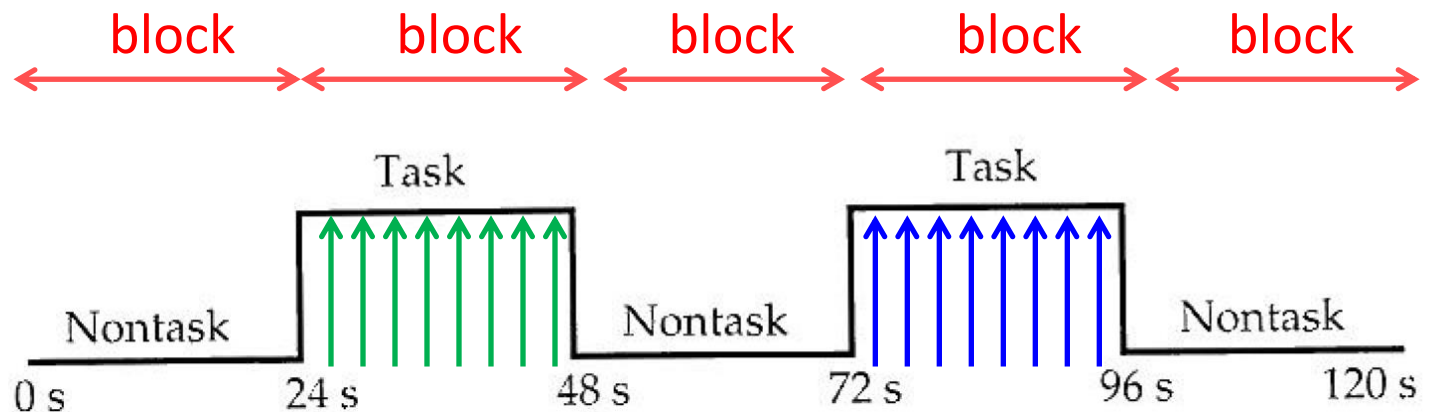
The goal of experimental design in task-evoked fMRI

- 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



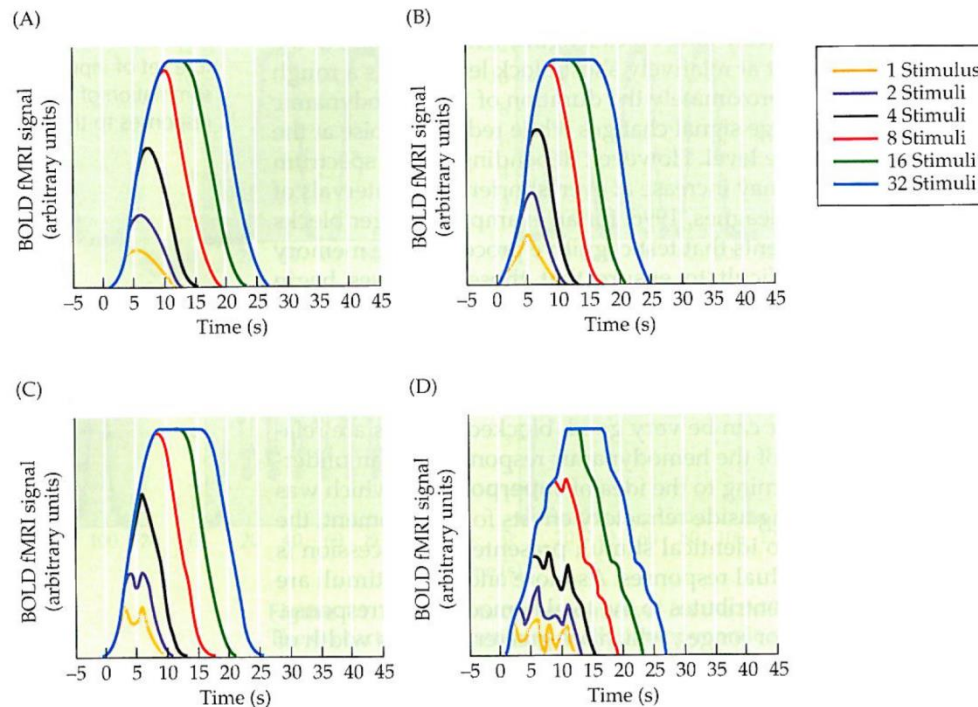
Advantages & disadvantages of blocked design

- Advantages:

- Good for detecting significant fMRI activity (good detection power)
- Simple analysis

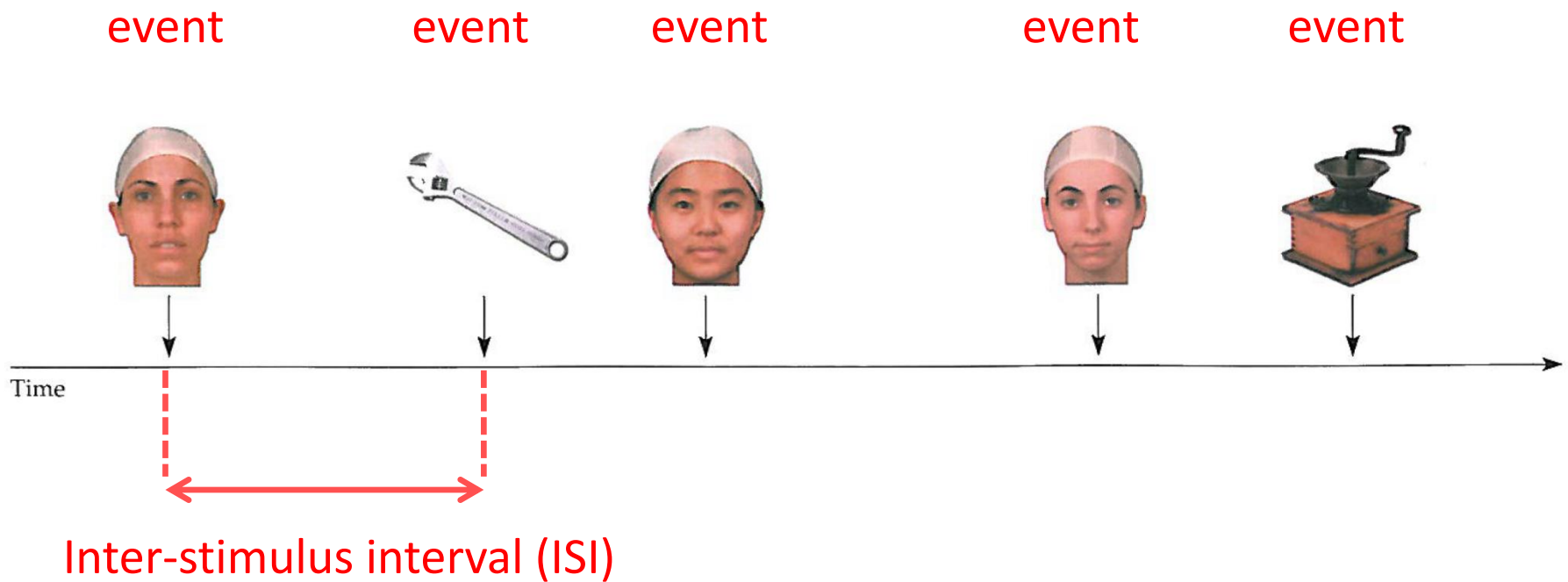
- Disadvantages:

- Insensitivity to the shape and timing of hemodynamic response
- Potential problems with selection of conditions



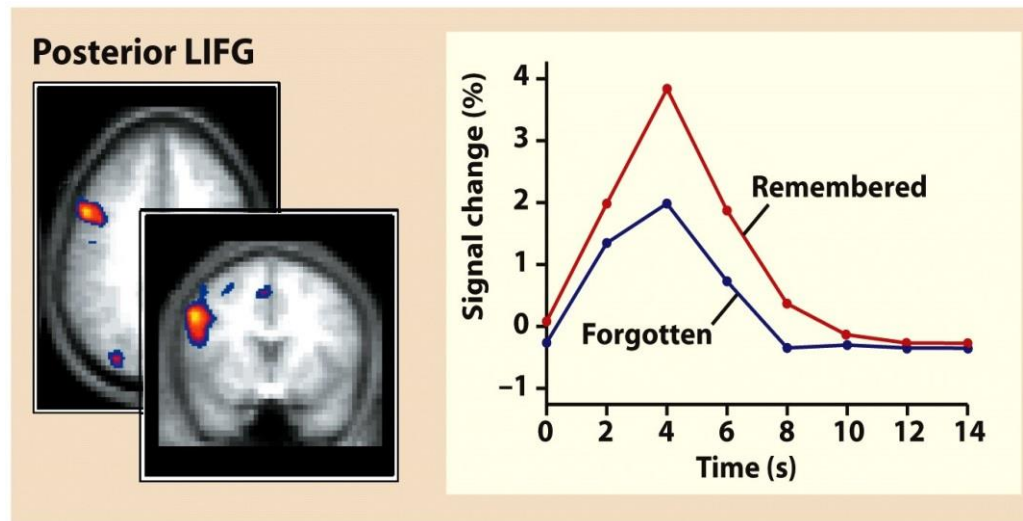
Event-related design

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

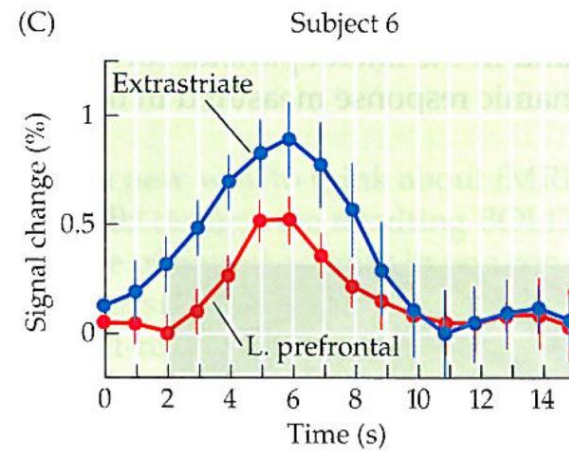
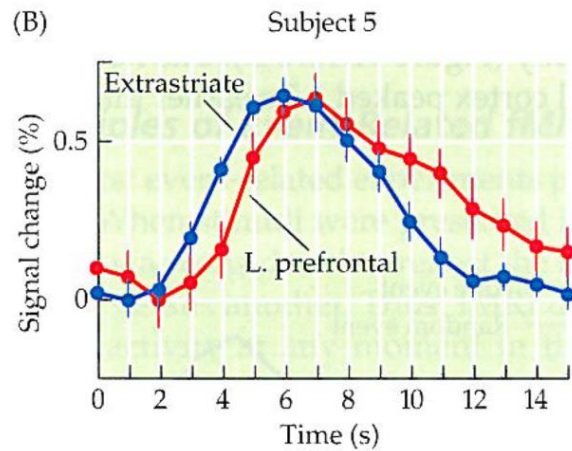
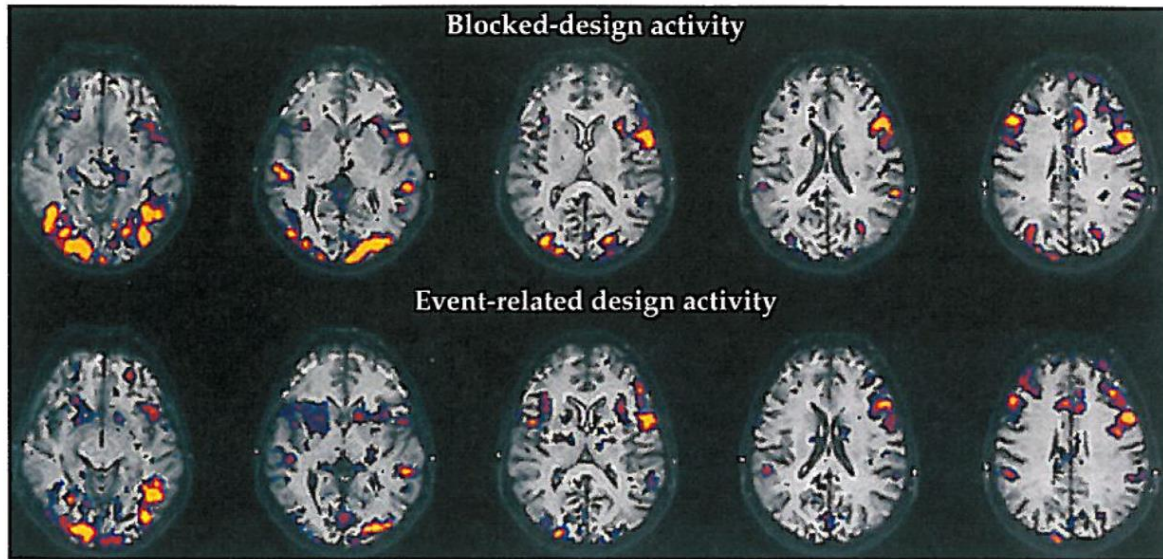


Advantages & disadvantages of event-related design

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

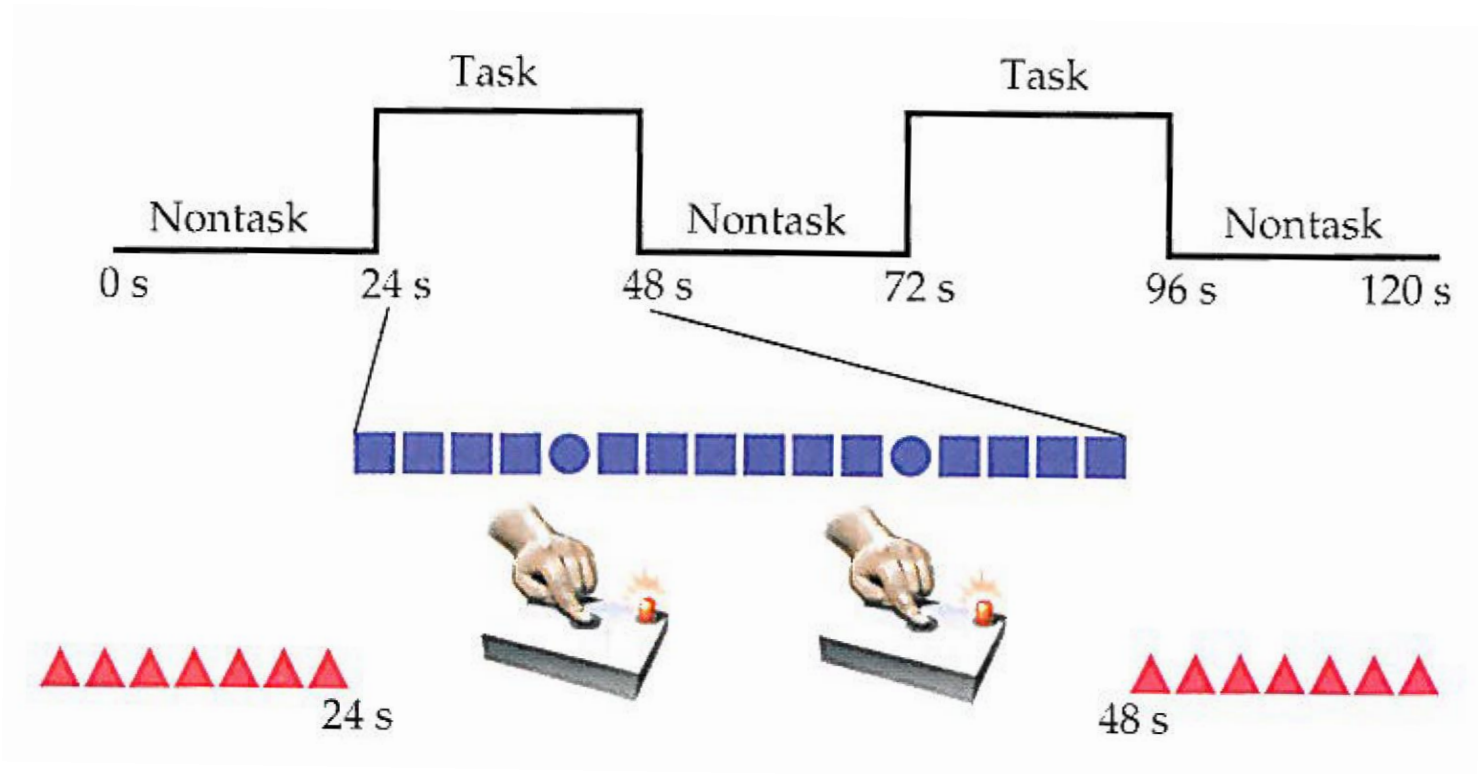


Blocked design vs. Event-related design



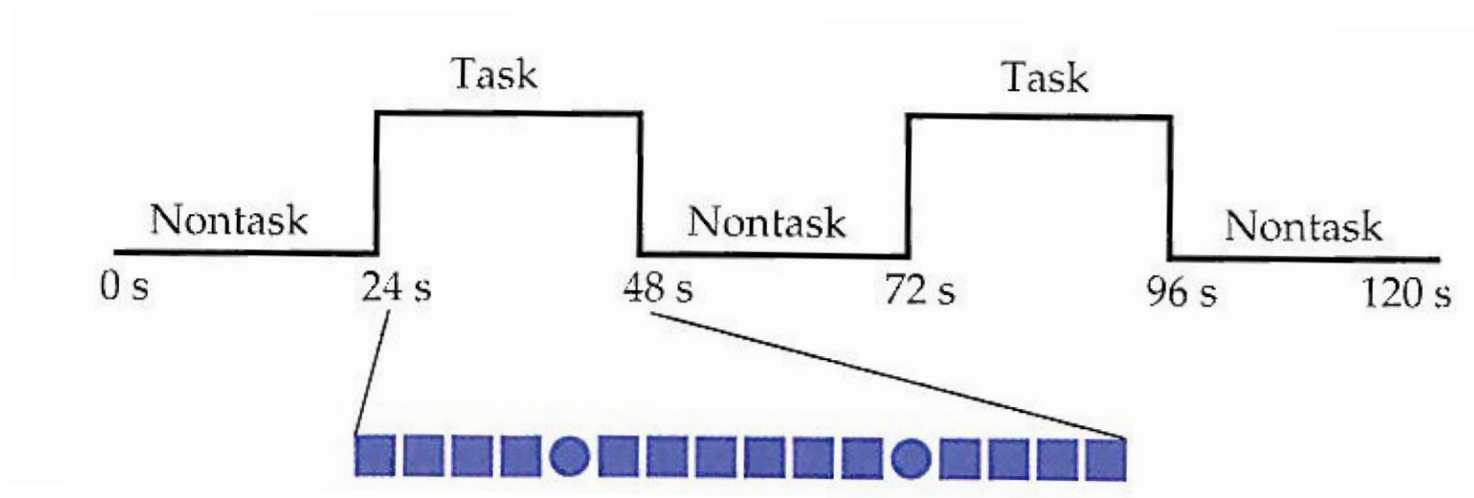
Mixed design

- 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...

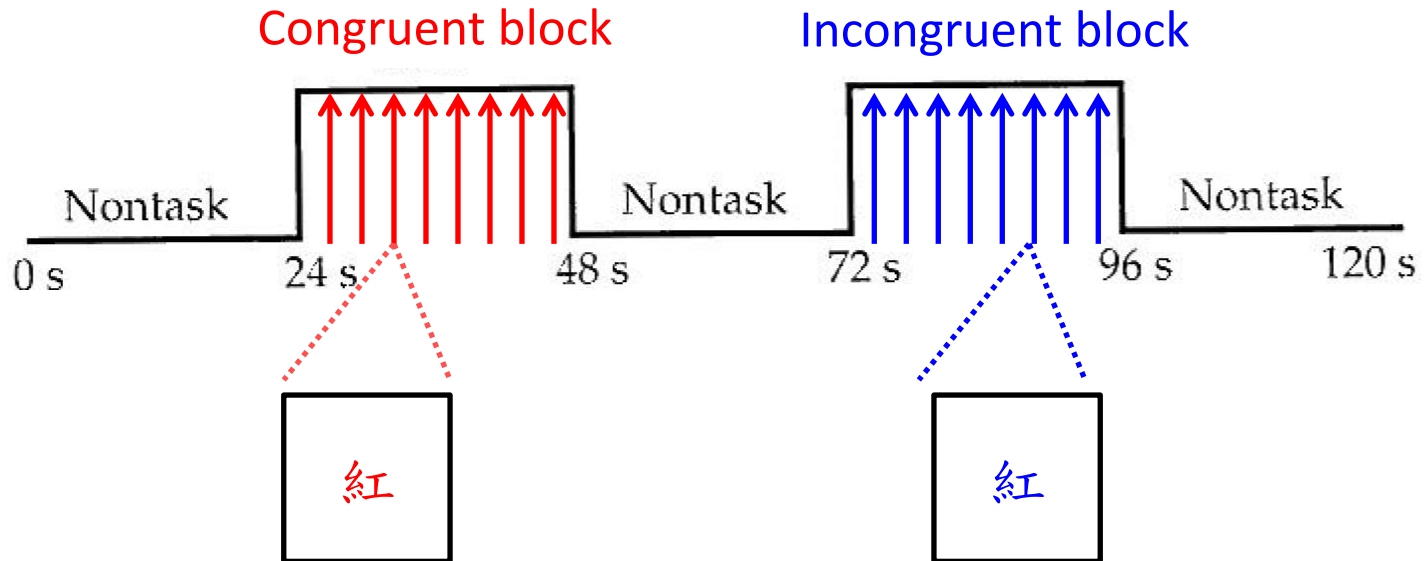
- In task-evoked fMRI studies, **there is no optimal experimental design**
- The fundamental rule: choose the design that best suits your experimental questions

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

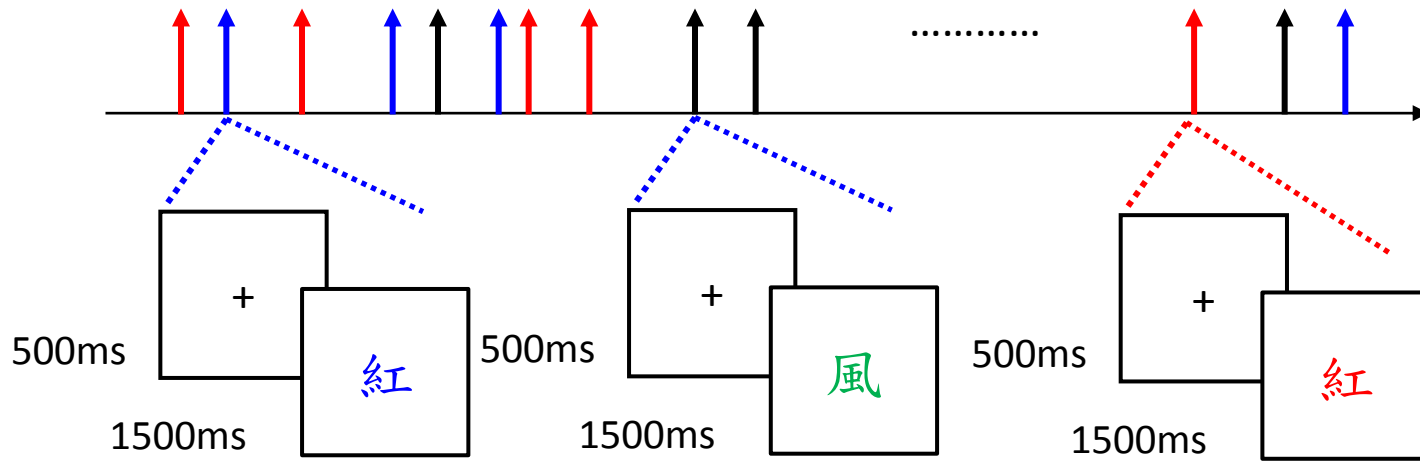
Example 1

- 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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If neuroimaging is the answer, what is the question?

S. M. Kosslyn

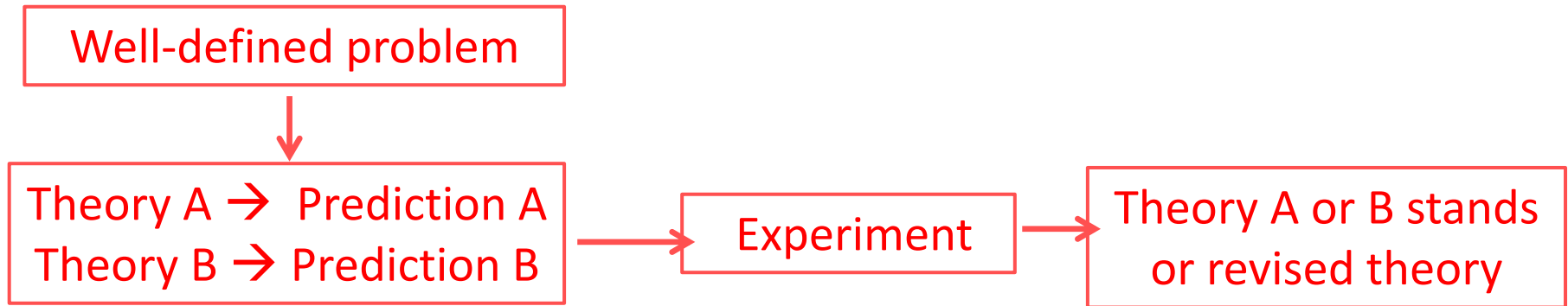
832 William James Hall, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA (smk@wjh.harvard.edu)

“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.”

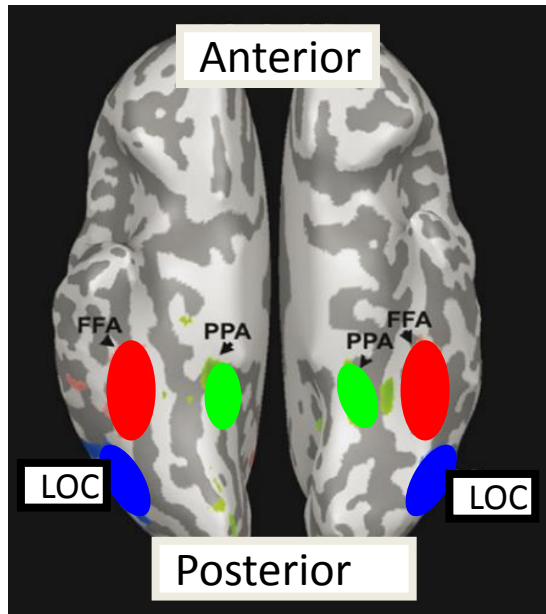
Stephen M. Kosslyn (1999). If neuroimaging is the answer, what is the question?
Phil Trans R. Soc Lond B, 354, 1283-1294

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)

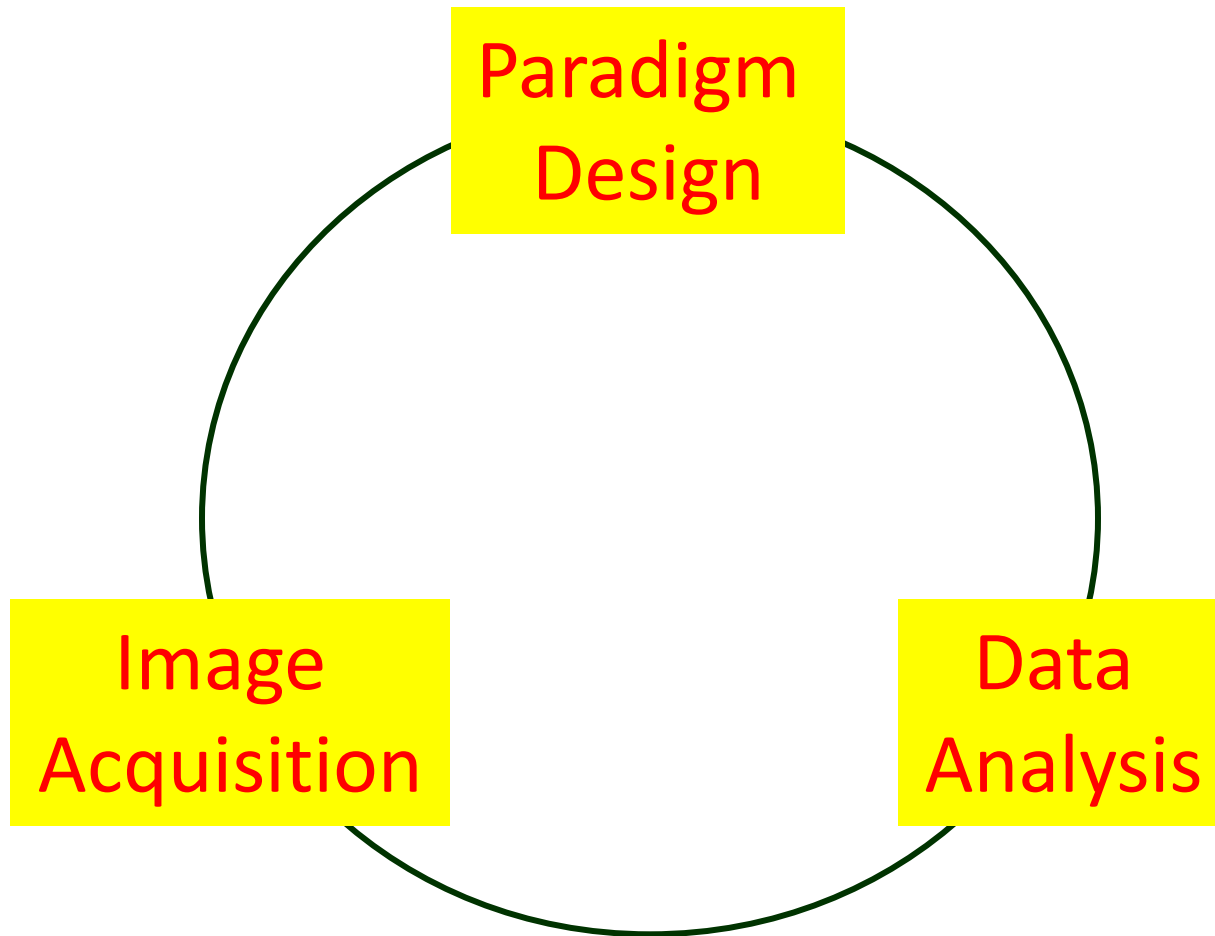
fMRI studies: data driven



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

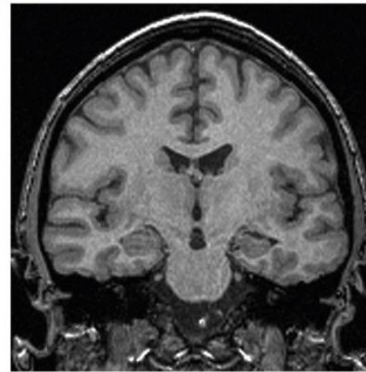
task-evoked fMRI Procedures



fMRI basic: orientation

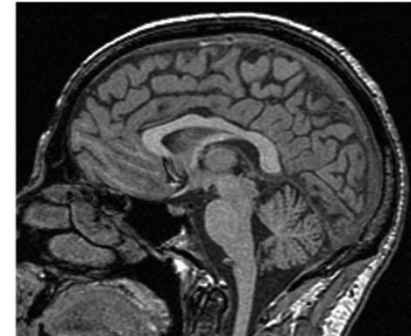
- Slice orientation:
 - Axial
 - Coronal
 - Sagittal

Coronal view

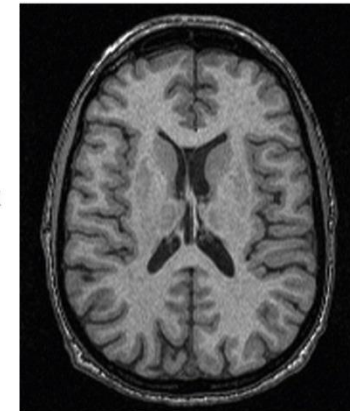
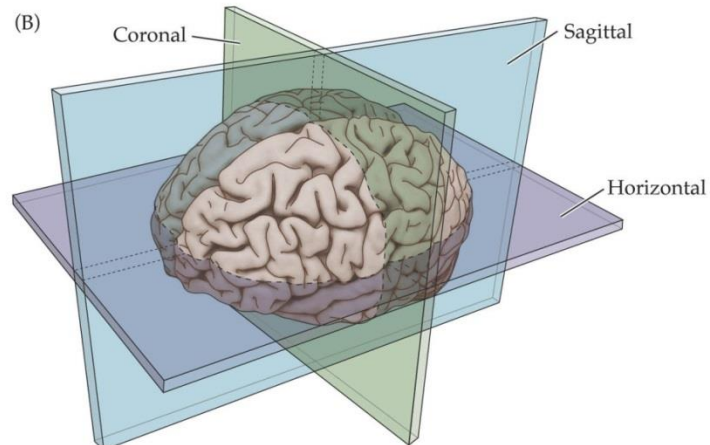


ICE, Fourth Edition, Atlas, Plate 2 (Part 3)

Sagittal view



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

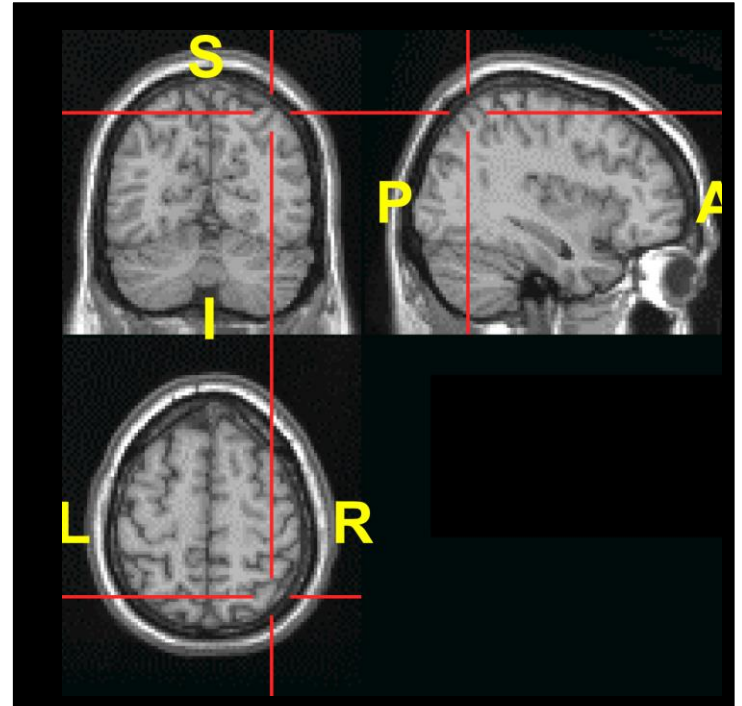


Edition, Atlas, Plate 3 (Part 4)

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

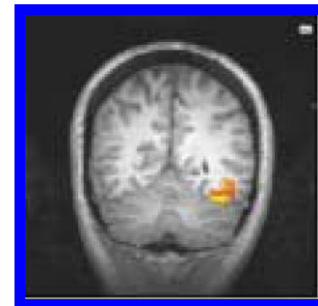
left



right

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

right



left

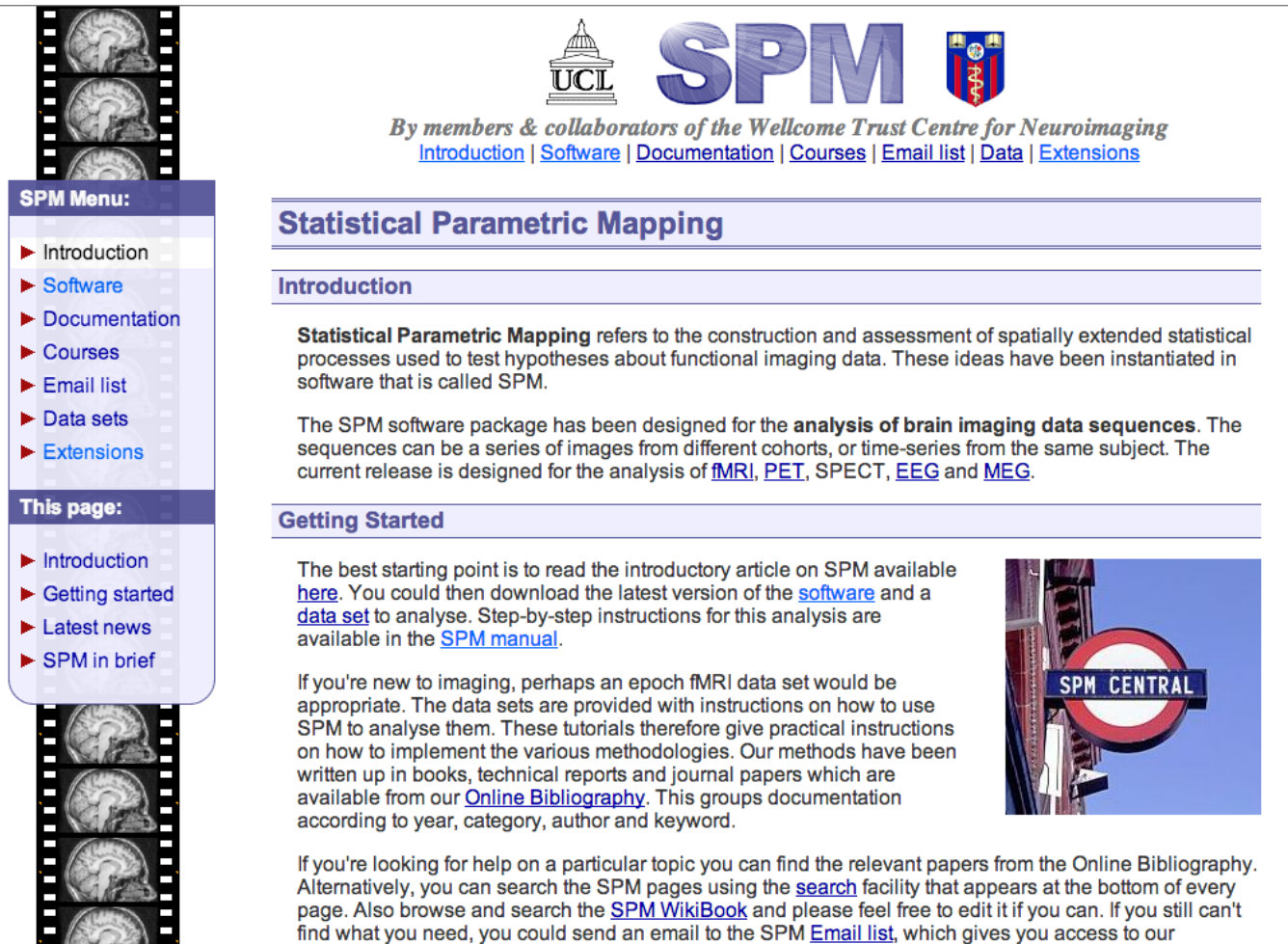
- Make sure how your software doing with left/right
 - If you're really unsure, tape a vitamin E or oil capsule to the one side of the subject's head. It will show up on the anatomical image

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



The screenshot shows the SPM website interface. On the left is a vertical filmstrip containing three brain scan images. Below it is a navigation menu with two sections: 'SPM Menu:' and 'This page:'. The 'SPM Menu:' section lists: Introduction, Software, Documentation, Courses, Email list, Data sets, and Extensions. The 'This page:' section lists: Introduction, Getting started, Latest news, and SPM in brief. The main content area has a header with the UCL logo, the text 'SPM', and the Wellcome Trust logo. Below this is the text 'By members & collaborators of the Wellcome Trust Centre for Neuroimaging' and a list of links: Introduction, Software, Documentation, Courses, Email list, Data, and Extensions. The main heading is 'Statistical Parametric Mapping'. Below it is the 'Introduction' section, which defines SPM as a process for testing hypotheses about functional imaging data. It mentions that the software is designed for the analysis of brain imaging data sequences, such as fMRI, PET, SPECT, EEG, and MEG. The 'Getting Started' section provides a starting point, recommending reading an introductory article, downloading the software and data set, and following the SPM manual. It also offers resources for new users, including data sets with instructions, practical tutorials, books, technical reports, and journal papers. A final note suggests using the Online Bibliography, the search facility, the SPM WikiBook, or the Email list for help.

SPM Menu:

- ▶ Introduction
- ▶ Software
- ▶ Documentation
- ▶ Courses
- ▶ Email list
- ▶ Data sets
- ▶ Extensions

This page:

- ▶ Introduction
- ▶ Getting started
- ▶ Latest news
- ▶ SPM in brief

Statistical Parametric Mapping

Introduction

Statistical Parametric Mapping refers to the construction and assessment of spatially extended statistical processes used to test hypotheses about functional imaging data. These ideas have been instantiated in software that is called SPM.


The SPM software package has been designed for the **analysis of brain imaging data sequences**. The sequences can be a series of images from different cohorts, or time-series from the same subject. The current release is designed for the analysis of [fMRI](#), [PET](#), SPECT, [EEG](#) and [MEG](#).

Getting Started

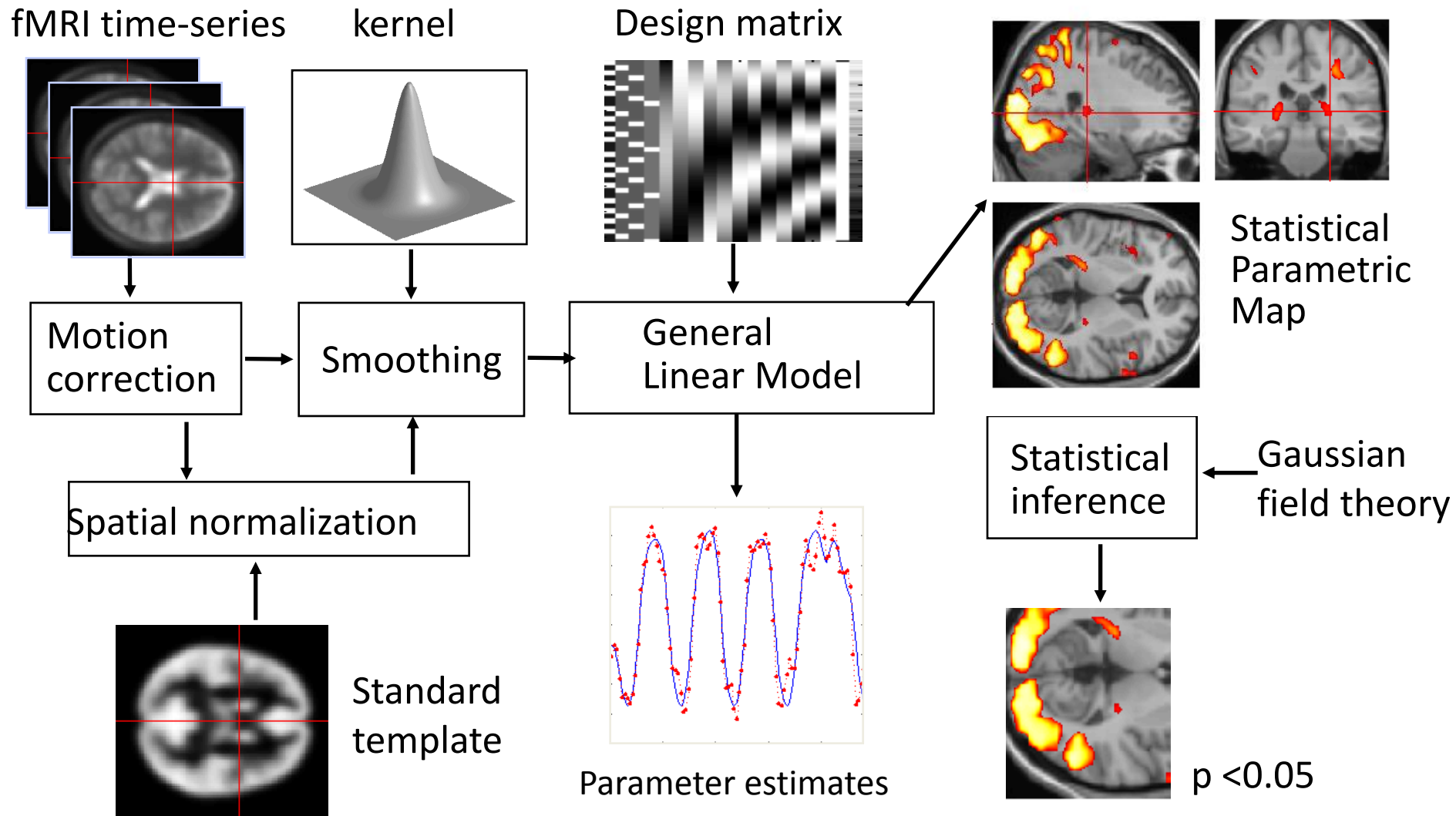
The best starting point is to read the introductory article on SPM available [here](#). You could then download the latest version of the [software](#) and a [data set](#) to analyse. Step-by-step instructions for this analysis are available in the [SPM manual](#).

If you're new to imaging, perhaps an epoch fMRI data set would be appropriate. The data sets are provided with instructions on how to use SPM to analyse them. These tutorials therefore give practical instructions on how to implement the various methodologies. Our methods have been written up in books, technical reports and journal papers which are available from our [Online Bibliography](#). This groups documentation according to year, category, author and keyword.

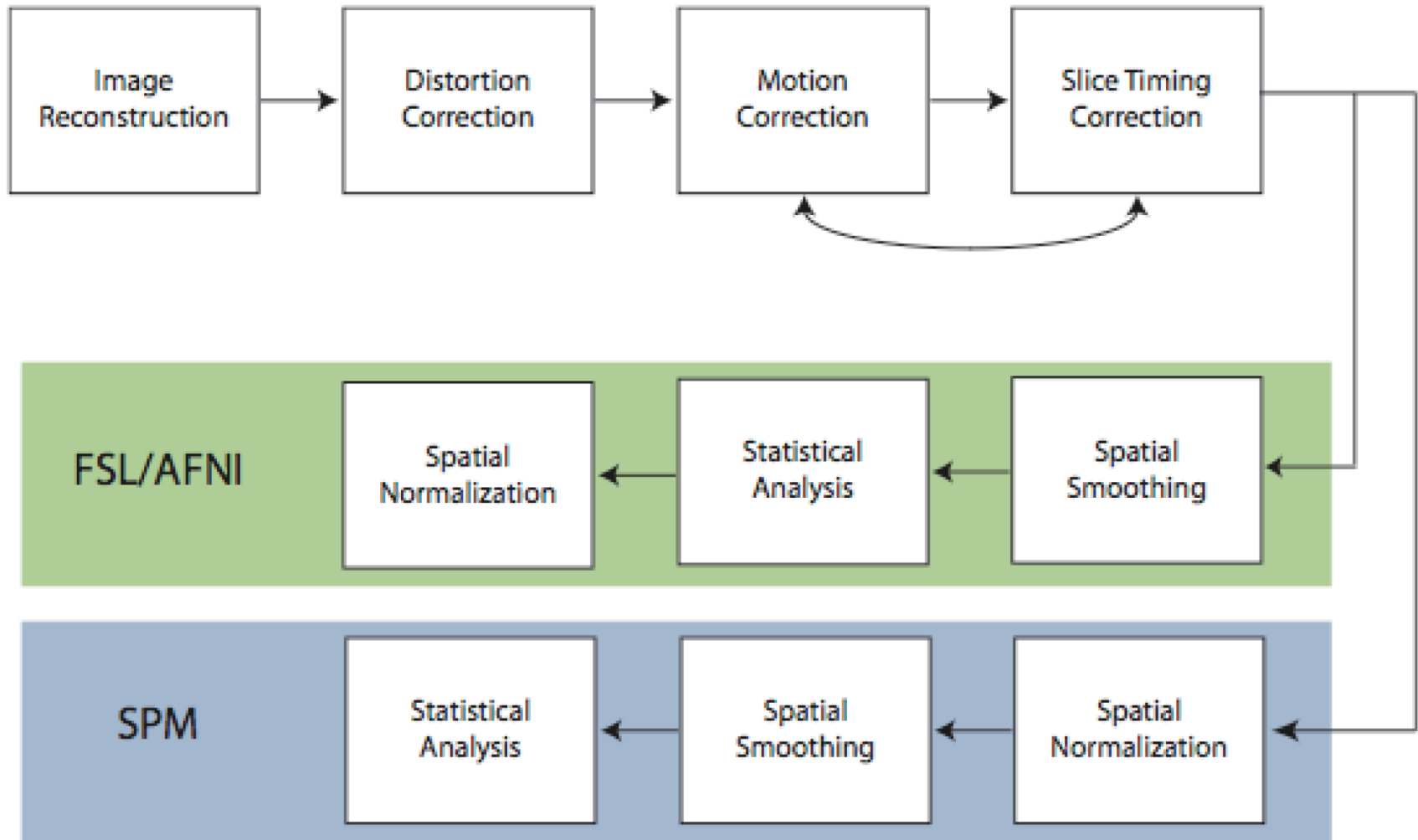
If you're looking for help on a particular topic you can find the relevant papers from the Online Bibliography. Alternatively, you can search the SPM pages using the [search](#) facility that appears at the bottom of every page. Also browse and search the [SPM WikiBook](#) and please feel free to edit it if you can. If you still can't find what you need, you could send an email to the SPM [Email list](#), which gives you access to our



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