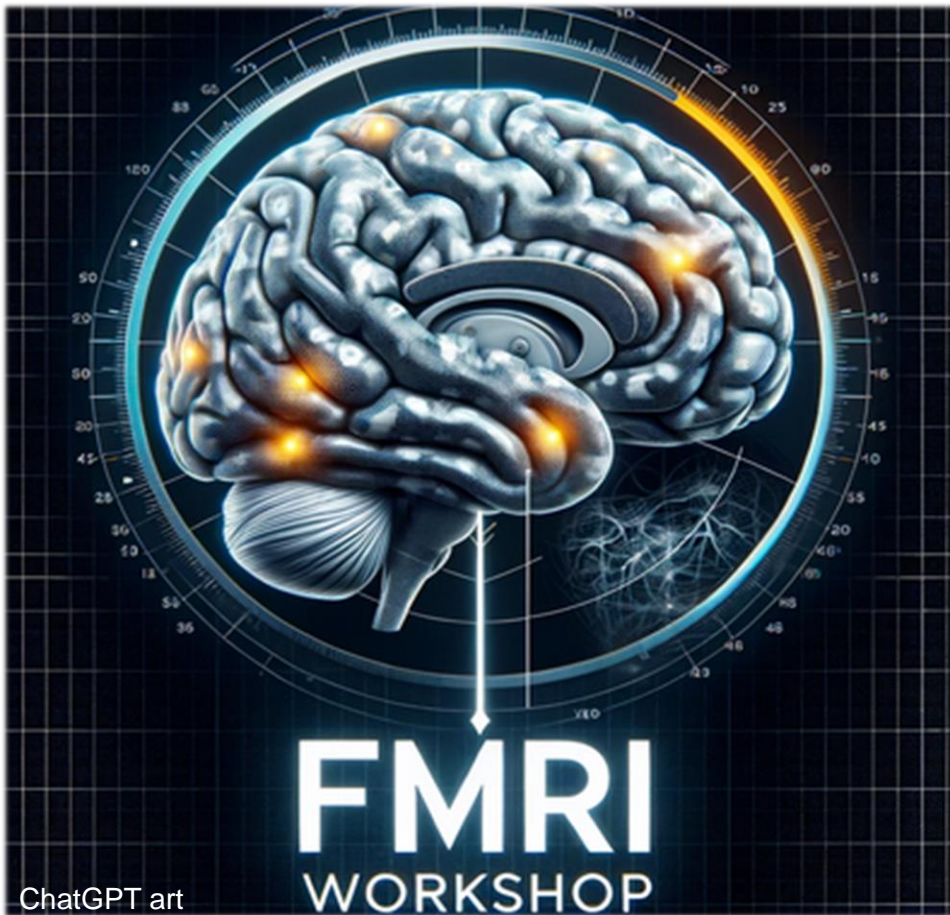




MRC Cognition
and Brain
Sciences Unit



UNIVERSITY OF
CAMBRIDGE



Functional Magnetic Resonance Imaging



GitHub

https://github.com/dcdace/fMRI_training

Dace Apšvalka

Winter, 2024

Outline

- Introduction
- Experimental design
- Data management
- Pre-processing
- Statistical analysis
- Practical demo

Experimental design

Experimental constraints

- **Physical constraints**

- Strong magnetic field
- Small space
- Loud
- Horizontal position

Some equipment won't work

Limited range of motion

Limited peripheral vision

Difficulty hearing

Uncomfortable



Experimental constraints

- **Physical constraints**

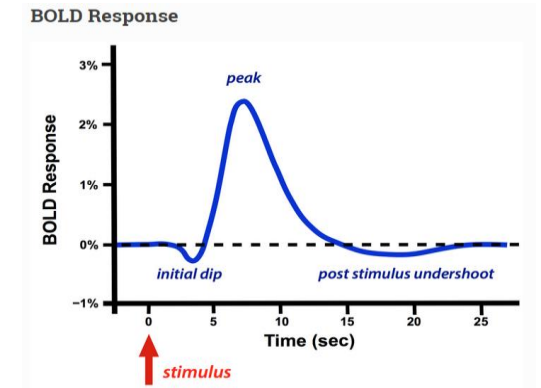
- Strong magnetic field
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- **Physiological constraints**

- BOLD is slow
- BOLD is a relative measure – the absolute values are meaningless
- The data are continuous time-series, not discrete events



Experimental constraints

- **Physical constraints**

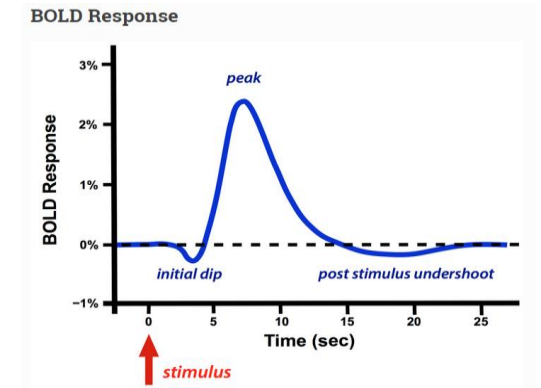
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- **Physiological constraints**

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- **Psychological constraints**

- Stimulus predictability
- Time on task
- Participant strategies
- Temporal precision of the cognitive process
- Unintended cognitive activity

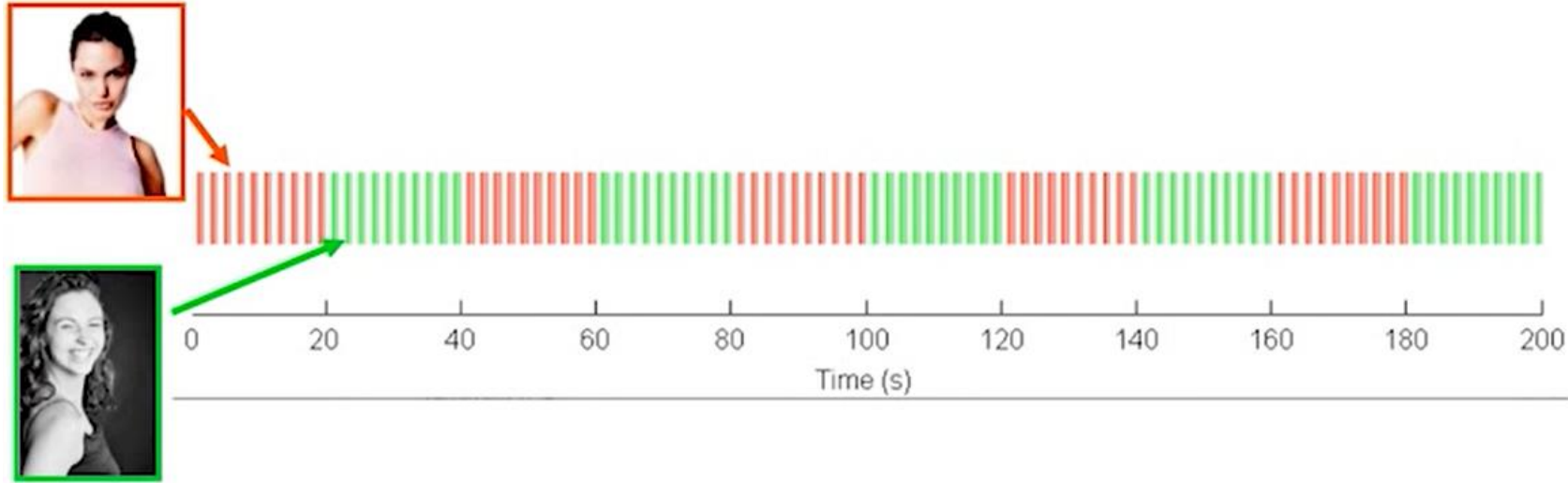


Good practices in fMRI experimental design (Huettel, Song & McCarthy, 2009)

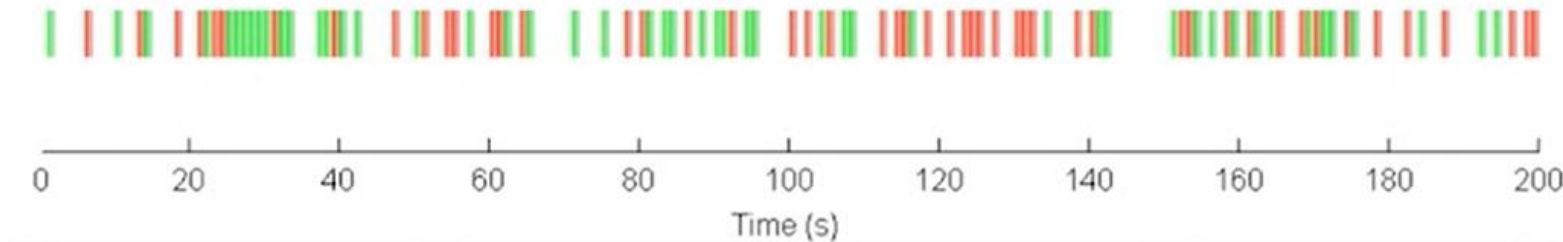
1. Evoke cognitive processes of interest
 - What will subjects do
2. Collect as much data as possible from each subject
 - How many trials do I need
3. Collect data from as many subjects as possible
 - What statistical power can I achieve
4. Choose your stimulus conditions and the timings of their presentations to evoke maximal changes in the cognitive processes of interest
 - How to increase the efficiency of the experiment
5. Organise the timings of experimental stimuli so that successively elicited processes of interest are minimally correlated with each other, over time
 - Variable intervals between successive events
6. Where possible, obtain measures of your subject's behaviour that can be related to the fMRI activation
 - task performance, memory effects, personality traits

Types of designs

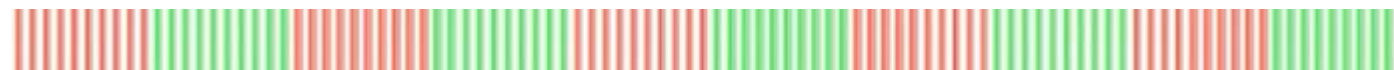
- **Block design:** similar events are grouped



- **Event-related design:** events are mixed



Block designs



- Advantages
 - Maximal efficiency
 - A 2-condition 16-20 second block design (\sim duration of HRF) is optimal for power
 - Reduced task-switching costs
 - Forgiving with respect to the exact form of the HRF
- Problems
 - Stimulus predictability (e.g., in Go/No-go task: N B M V X X X X)
 - Chance to apply strategy (e.g., in the Stroop task: blue, red, green; blue, red, green)
 - Cannot detect rapid/transient events
- Note
 - Too short blocks don't let HRF return to the baseline – the signal will be reduced
 - Too long blocks are confounded by low-frequency noise (MRI scanner drift)
 - Not recommended to have more than 4 conditions

Event-related designs



- Advantages
 - Avoid predictability and strategy
 - Can detect transient effects
 - More flexible - can accommodate more complex experimental designs and a wider variety of stimuli or tasks
- Problems
 - Lower detection power - requires more trials to achieve the same level of statistical power as block designs
 - Enhanced task-switching costs
 - Strong effect on presentation rate – requires design optimization (e.g. Optseq2 tool)
 - Sensitive to the exact form of the HRF
- Note
 - Each event is separated in time from the previous event with an inter-stimulus-interval (ISI)
 - Short 2-6 second jittered ISIs improve efficiency

Kinds of designs

- Subtractions designs
 - Basic contrast between task and control or between two task
- Individual differences
 - Correlations with behaviour or traits
- Process overlap/dissociation designs
 - Multiple subtractions
- Factorial designs
 - ANOVA designs
- Parametric modulation
 - Performance-related effects within subjects

Design trade-offs

- Fewer conditions and contrasts
 - + more power
 - - less generalizable
- Many comparisons
 - + high potential for specificity of inference
 - - low power

Good for the first studies in a new area of research

Good for the later studies with more complete information

MRC

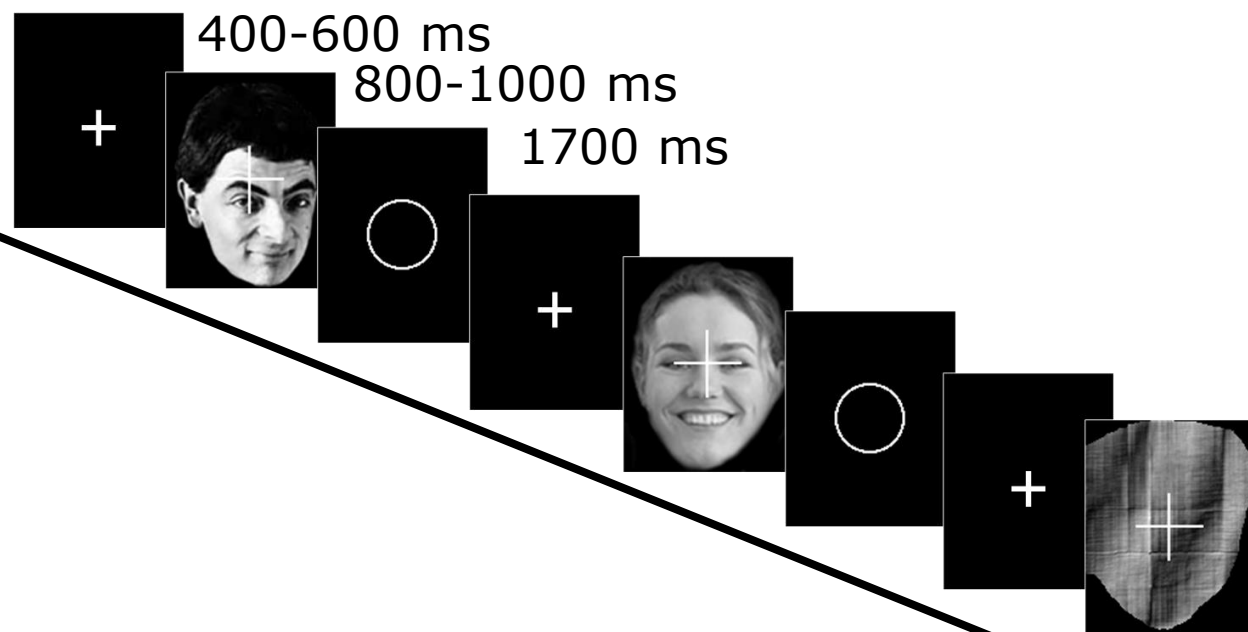
Cognition and
Brain Sciences Unit

Design efficiency in FMRI

Contents

1. Design efficiency in FMRI
 1. General Advice
 1. Scan for as long as possible.
 2. Keep the subject as busy as possible.
 3. Do not contrast trials that are far apart in time.
 4. Randomise the order, or SOA, of trials close together in time.
 2. Theoretical Background
 1. The BOLD impulse response (IR)
 3. Signal-processing
 4. Mathematics (statistics)
 1. Impact of nonlinearities on efficiency
 5. Correlation between regressors
 6. Common Questions
 1. I. What is the minimum number of events I need?
 2. II. Doesn't shorter SOAs mean more power simply because of more trials?
 3. III. What is the maximum number of conditions I can have?
 4. IV. Should I use null events?
 5. V. What is the difference between 'detection power' and 'estimation efficiency' ?
 6. VI. Should I generate multiple random designs and choose the most efficient one ?
 7. VII. Should I treat my trials as events or epochs ?
 7. Acknowledgements

Example Experiment: Face Recognition



N = 16 subjects

Stimuli: 3 types of greyscale face images:

- ~150 x Familiar
- ~150 x Unfamiliar
- ~150 x Scrambled

Task: Judge face symmetry

7 min long runs
9 runs
20s Rest after ever 50s

Each image was presented twice, with the second presentation occurring either immediately after (Immediate Repeats), or after 5–15 intervening stimuli (Delayed Repeats), with 50% of each type of repeat.

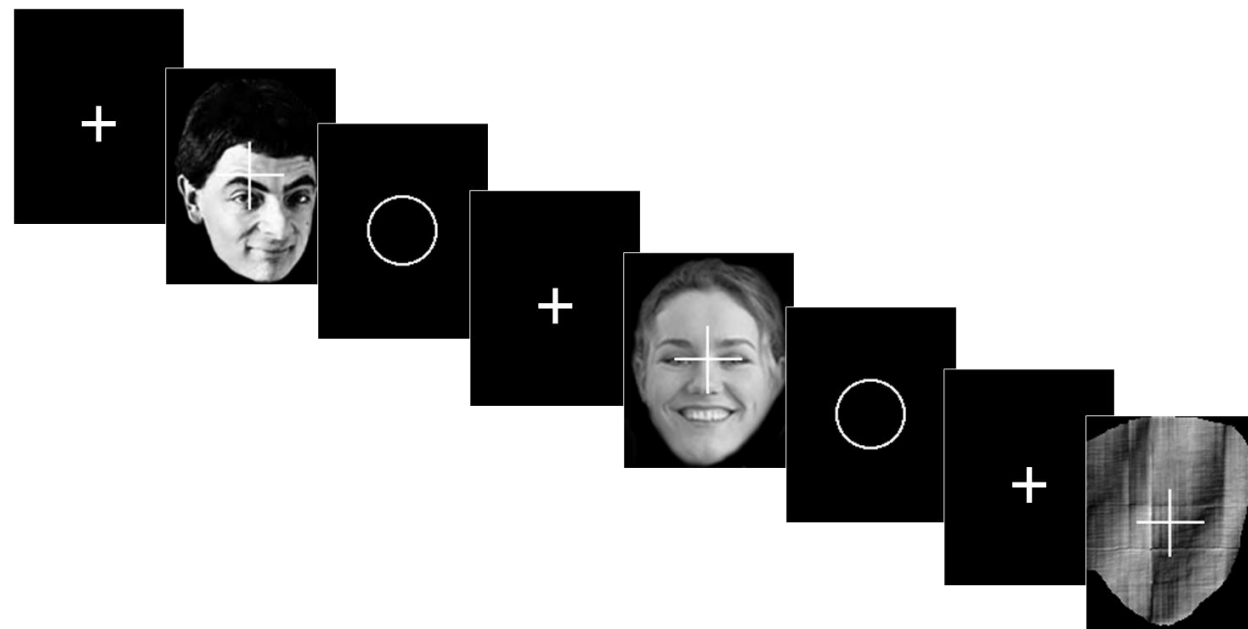
Example Experiment: Face Recognition

- Conditions

- Familiar faces
- Unfamiliar faces
- Scrambled faces
- Initial presentation
- Immediate repeat
- Delayed repeat

- Possible questions to investigate

- Brain areas for Faces
- Brain areas for Face Familiarity
- Response to Initial vs Repeated presentations
- Response to the Repetition of Familiar vs Repetition of Unfamiliar
- ...



SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES

- » Electroencephalography
-EEG
- » Brain imaging
- » Functional magnetic
resonance imaging
- » Cognitive neuroscience

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Published: 20 January 2015

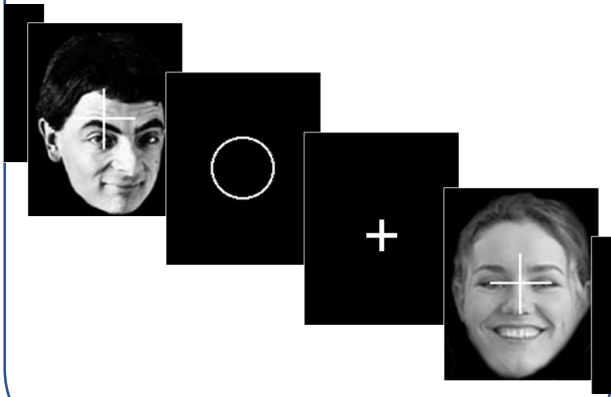
A multi-subject, multi-modal human neuroimaging dataset

Daniel G. Wakeman^{1,2} & Richard N. Henson²

We describe data acquired with multiple functional and structural neuroimaging modalities on the same nineteen healthy volunteers. The functional data include Electroencephalography (EEG), Magnetoencephalography (MEG) and functional Magnetic Resonance Imaging (fMRI) data, recorded while the volunteers performed multiple runs of hundreds of trials of a simple perceptual task on pictures of familiar, unfamiliar and scrambled faces during two visits to the laboratory. The structural data include T1-weighted MPRAGE, Multi-Echo FLASH and Diffusion-weighted MR sequences. Though only from a small sample of volunteers, these data can be used to develop methods for integrating multiple modalities from multiple runs on multiple participants, with the aim of increasing the spatial and temporal resolution above that of any one modality alone. They can also be used to integrate measures of functional and structural connectivity, and as a benchmark dataset to compare results across the many neuroimaging analysis packages. The data are freely available from <https://openfmri.org/>.

Famous vs Unfamiliar
faces are processed
differently in the brain

Design an experiment



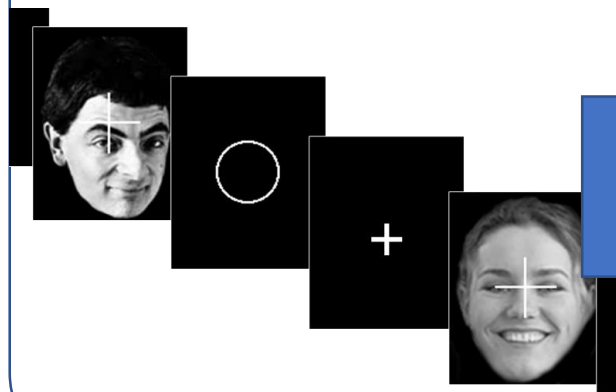
Collect the MRI data



What do we
do now?

Famous vs Unfamiliar
faces are processed
differently in the brain

Design an experiment



Data

Stimuli
Timing

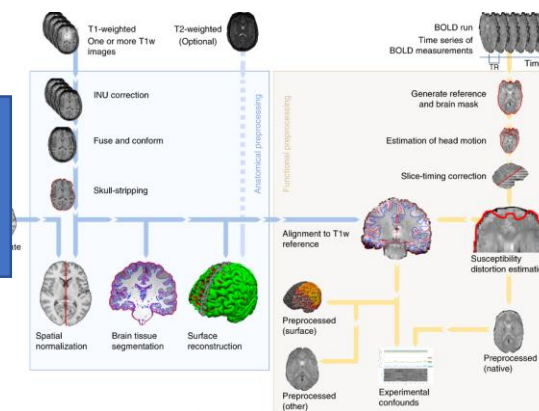
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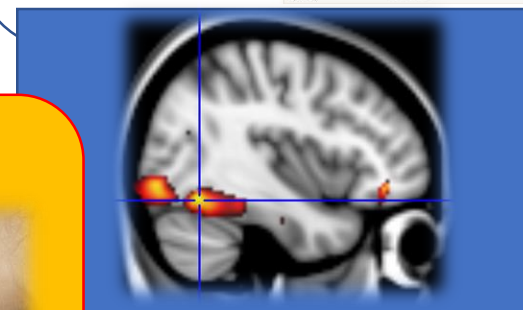
Data

Anatomical image
Functional images
Event details

Pre-process & Analyse



The final push



Famous vs
Unfamiliar faces
are processed
differently in the
brain

Design an
experiment

Collect the MRI data

Pre-process & Analyse

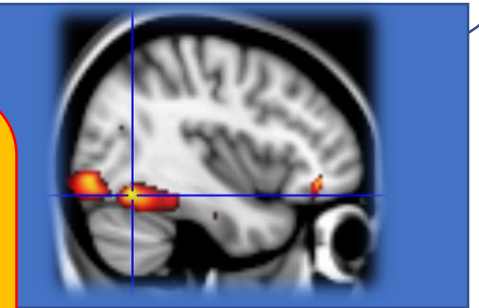
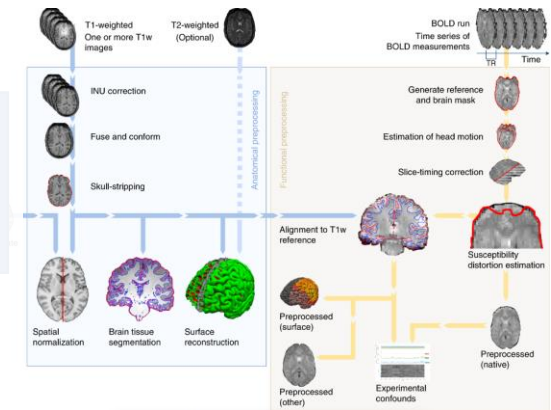
The final push

Data

Stimuli
Timing

Data

image
Functional
images



Environment

Data

Organise & Manage

Pre-process

Analyse

Report

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