MRC Cognition and Brain Sciences Unit

UNIVERSITY OF CAMBRIDGE

ChatGPT art

Functional Magnetic Resonance Imaging

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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

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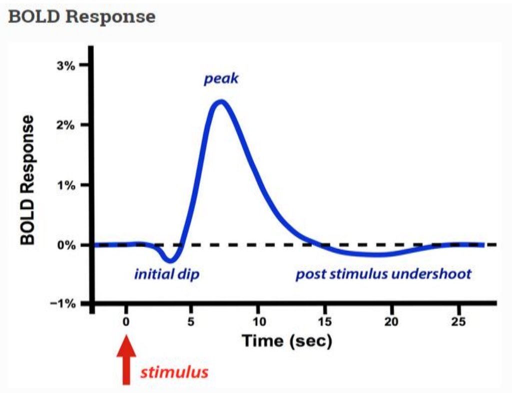
- **Physiological constraints**
  - BOLD is slow
  - BOLD is a relative measure – the absolute values are meaningless
  - The data are continuous time-series, not discrete events



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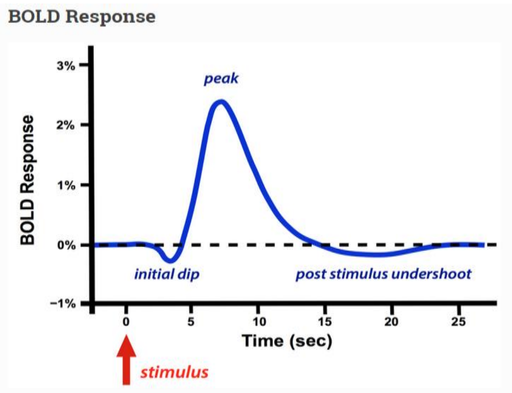


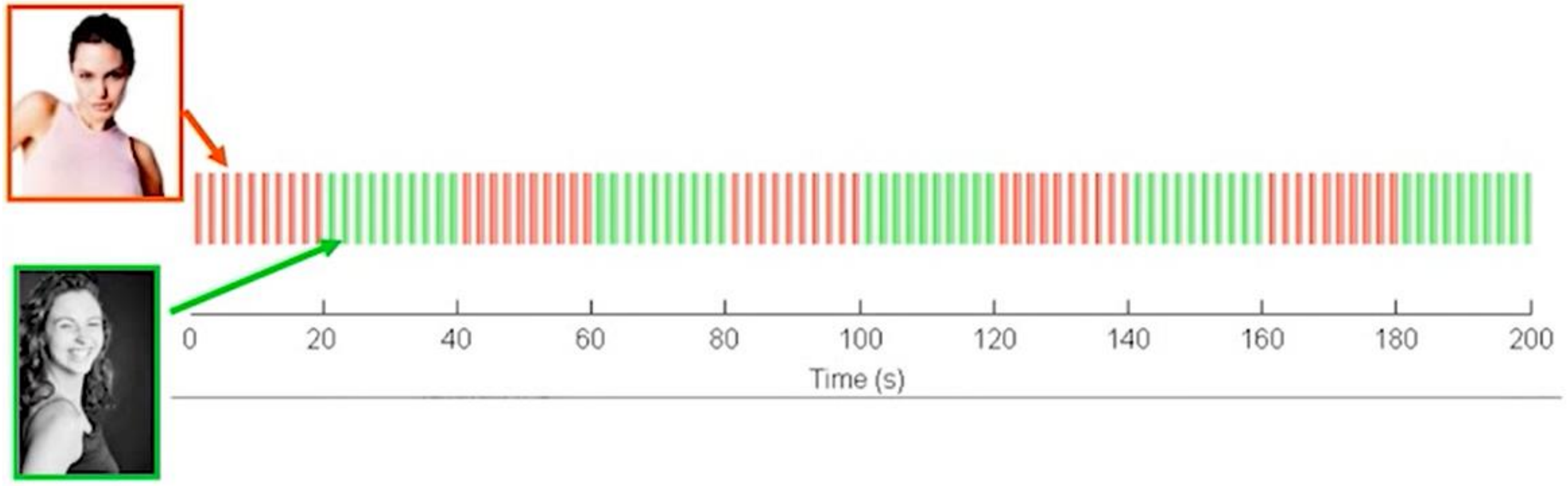
- **Psychological constraints**
  - Stimulus predictability
  - Time on task
  - Participant strategies
  - Temporal precision of the cognitive process
  - Unintended cognitive activity

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

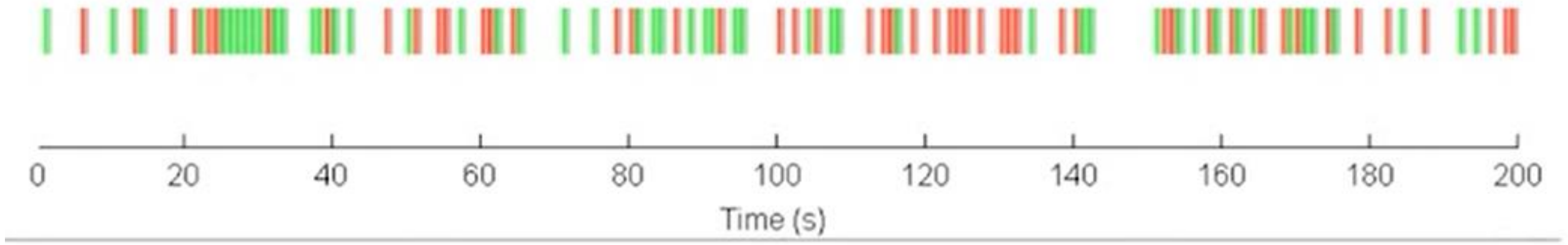
1. Evoke cognitive processes of interest
   - What will subjects do
2. Collect as much data as possible from each subject
   - How many trials do I need
3. Collect data from as many subjects as possible
   - What statistical power can I achieve
4. Choose your stimulus conditions and the timings of their 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

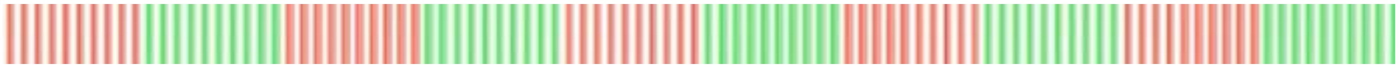
- **Block design**: similar events are grouped



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



Block designs



- Advantages
  - Maximal efficiency
    - A 2-condition 16-20 second block design (~ 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

https://youtu.be/ofl4p1Pyqes?si=UNQ1o8vd-BVcbfKV

Design trade-offs

- Fewer conditions and contrasts
  - + more power
  - - less generalizable

Good for the first studies in a new area of research

- Many comparisons
  - + high potential for specificity of inference
  - - low power

Good for the later studies with more complete information

https://youtu.be/ofl4p1Pyqes?si=UNQ1o8vd-BVcbfKV

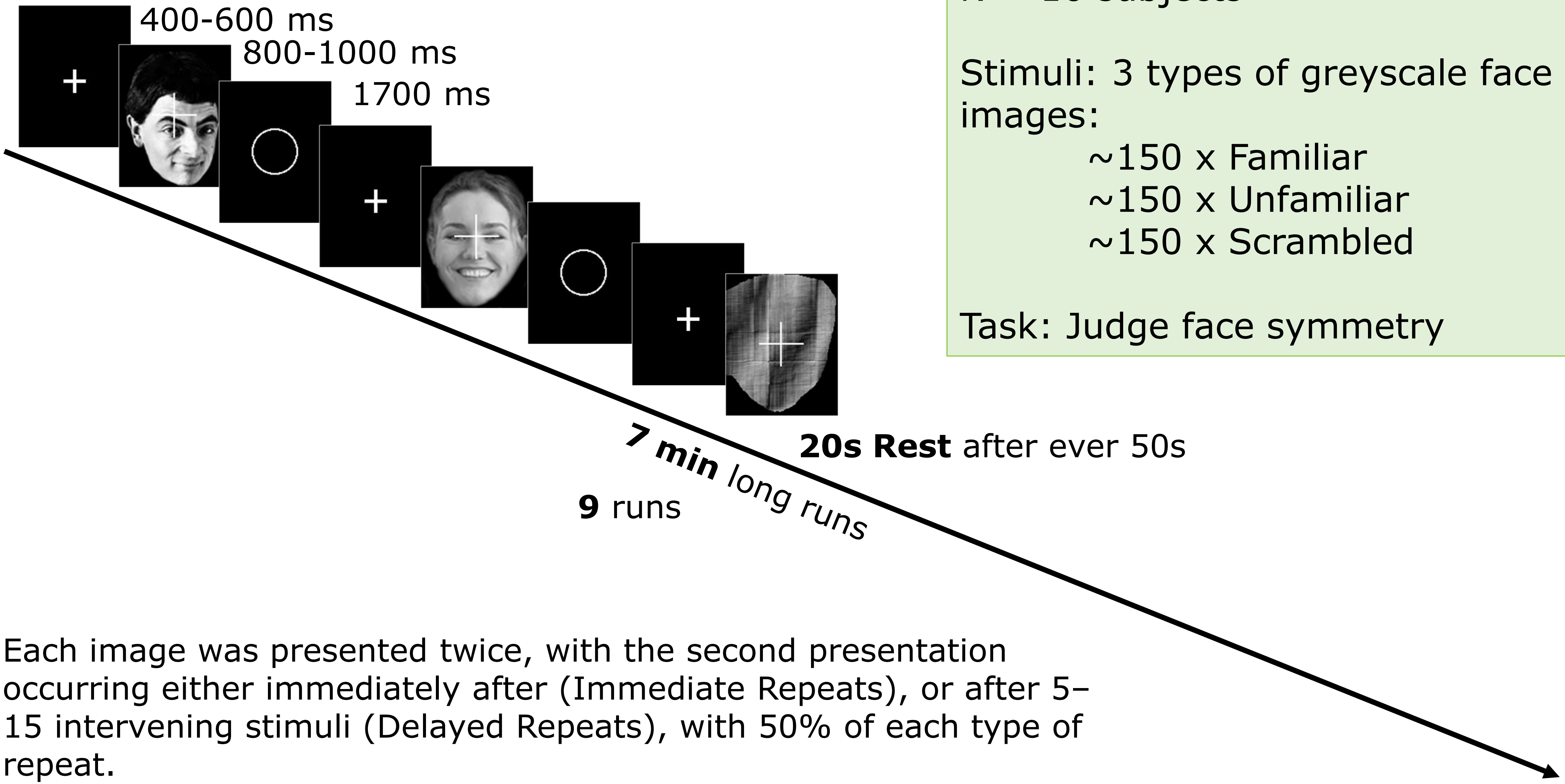
More information! https://imaging.mrc-cbu.cam.ac.uk/imaging/DesignEfficiency

MRC | Cognition and Brain Sciences Unit

Design efficiency in FMRI

Contents

Example Experiment: Face Recognition



N = 16 subjects

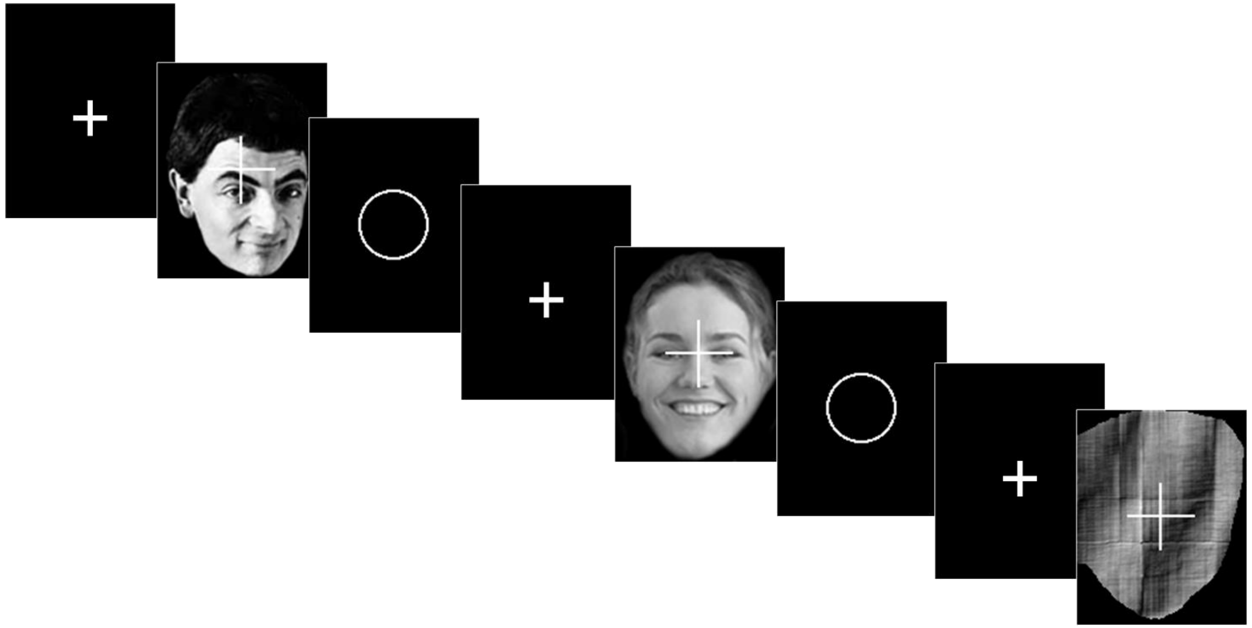
Stimuli: 3 types of greyscale face images:

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

Task: Judge face symmetry

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
  - …

Example Dataset

https://openneuro.org/datasets/ds000117/versions/1.0.5

www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES

» Electroencephalography -EEG

» Brain imaging

» Functional magnetic resonance imaging

» Cognitive neuroscience

Received: 07 April 2014

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Published: 2

A multi-subject, multi-modal human neuroimaging dataset

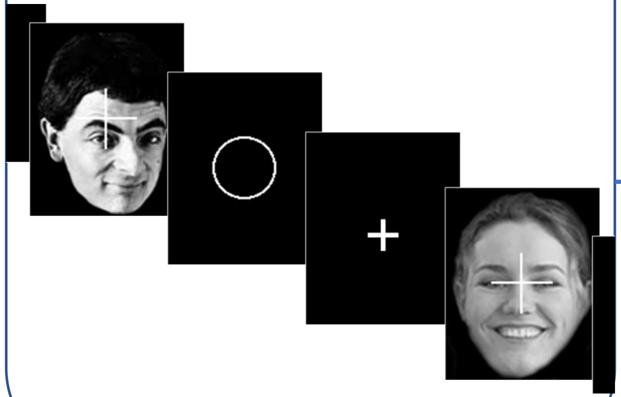
Daniel G. Wakeman[1,2] & Richard N. Henson[2]

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

Wakeman & Henson (2015), *Scientific Data*, http://www.nature.com/articles/sdata20151

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

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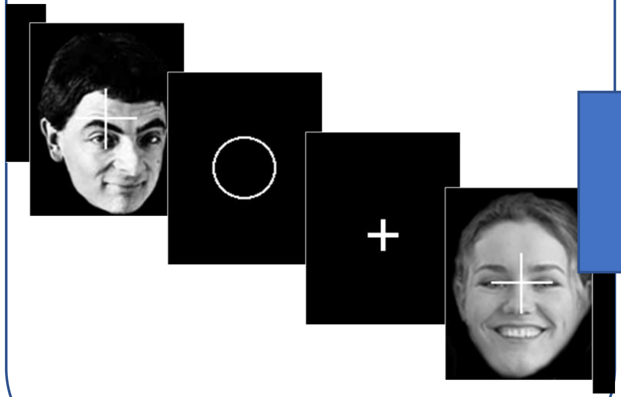


Data

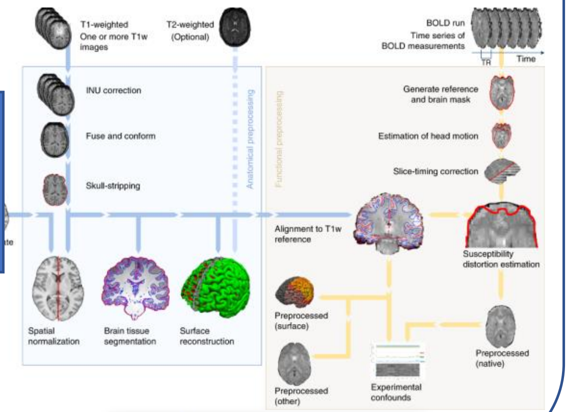
Stimuli
Timing

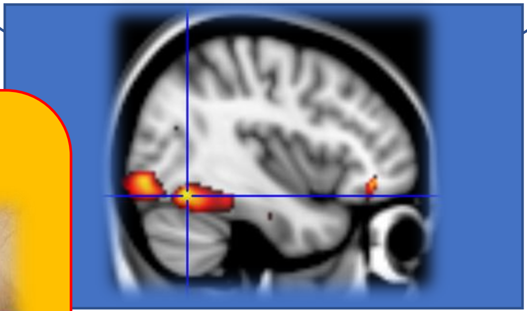
Collect the MRI data

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

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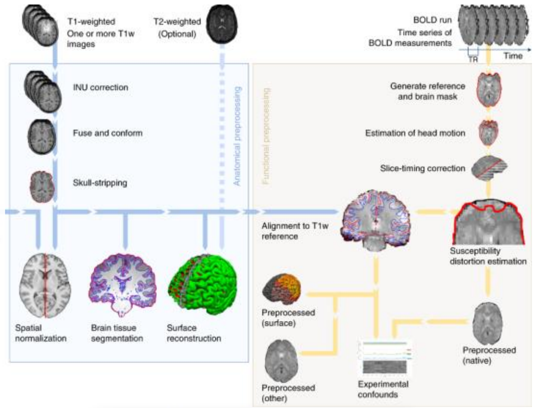
Stimuli Timing

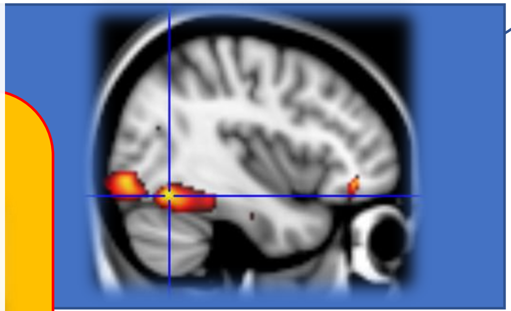
Collect the MRI data

Data

image Functional images

Pre-process & Analyse





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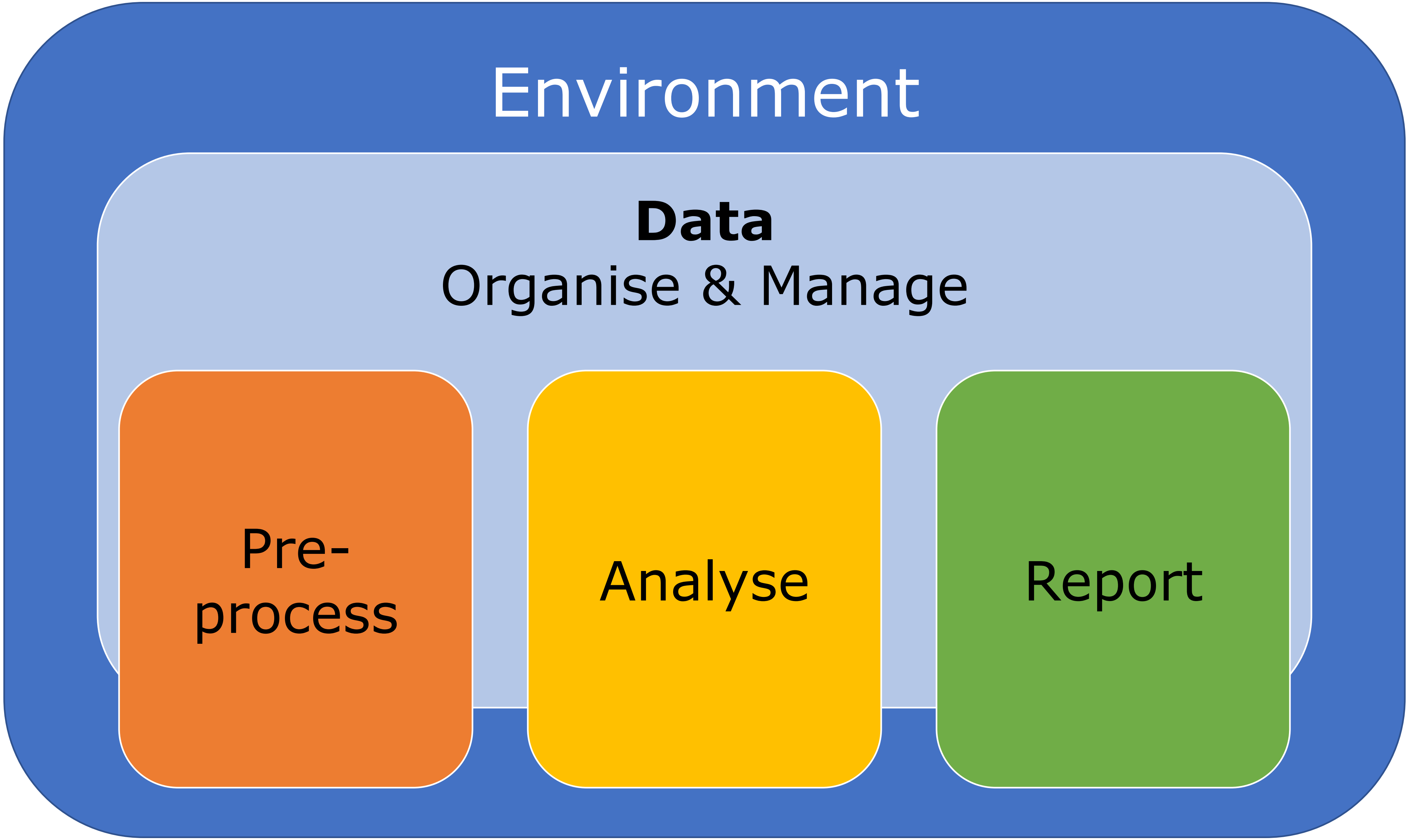

Environment
Data
Organise & Manage
Pre-process
Analyse
Report

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