STUDY DESIGN AND EFFICIENCY

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PART 1: STUDY DESIGN

BY: QUIN MASSEY
OVERVIEW

1. Main Design Goals
2. Types of Study Design
   - Subtraction
   - Conjunction
   - Factorial
   - Parametric
3. Stimulus Presentation Strategies
   - Blocked Design
   - Event Related Design
   - Mixed Design
We want to manipulate the participants experience & behaviour in some way that is likely to produce a functionally specific neural response, and then make an inference.

- Isolate functional processes of interest
- Measure Behaviour
- Collect as much data as possible
- Avoid confounding physiological and psychological artefacts
- Choose stimulus conditions and timing that maximise BOLD signal contrast

MAIN GOALS: TO TEST A SPECIFIC HYPOTHESIS

WHAT CAN WE MANIPULATE?
1. Stimulus Type and Properties
2. Stimulus Timing
3. Subject Instructions
SUBTRACTION: TESTS A SINGLE HYPOTHESIS PERTAINING TO THE ACTIVATION IN ONE TASK RELATIVE TO ANOTHER

Task condition 1: evokes process of interest

Task condition 2: evokes all but the process of interest

TWO TASK CONDITIONS DIFFERING IN THE PROCESS OF INTEREST

If the experiment is looking at the neuronal structures underlying a single process called “N”...

N = [Task with N] - [matched task without N]

ASSUMPTION OF ‘PURE INSERTION’: Two or more conditions can be cognitively added with no interactions among the cognitive components of a task (Amaro & Barker, 2006)
- Find a stimulation activity: “Look at the screen and when you see a word, repeat it.”

& a control activity: “When you see a word, do not repeat it.”

- You then subtract these two, and identify the difference, which would ideally be the cognitive process of interest (repetition).

- In order for subtraction to work, “pure insertion” is needed. Which is saying when a new cognitive component (repeating) is added to a task (reading), the implementation of the pre existing component (reading) remains unaffected.

- For example, we assume that reading to repeat and reading to read are the exact same thing.
CONJUNCTION: TESTS SEVERAL HYPOTHESES, DETERMINING THE SIGNIFICANCE BETWEEN THE TASK PAIRS

SEE SIMILARITIES BETWEEN AREAS

- Isolate process of interest by finding commonalities between task conditions
  Task Pair 1: Subtraction isolating A & B
  Task Pair 2: Subtraction isolating A & C

How does Conjunction differ to Subtraction?

- Subtraction looks for activation differences between a pair of tasks that share all but the component of interest, conjunction looks for the commonality in activation differences between two or more pairs of tasks that share only the component of interest.

- Cognitive components that are not common to all task pairs can include interaction terms, and because these effects are discounted, one does not need to depend on pure insertion.

Price & Friston (1997)
**NOTE: CONJUNCTION NULL HYPOTHESIS IS MORE STRICT THAN THE GLOBAL NULL HYPOTHESIS**

<table>
<thead>
<tr>
<th>Conjunction Null Hypothesis</th>
<th>Global Null Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>More strict analysis</td>
<td>Lenient numerical value &amp; analysis</td>
</tr>
<tr>
<td>$P = 0.05$</td>
<td>Allows researchers to indicate trends</td>
</tr>
<tr>
<td>Only activation over the p value threshold can reject the null hypothesis &amp; prove overlapping activation</td>
<td>Shows a more directional effect</td>
</tr>
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*CONJUNCTION NULL HYPOTHESIS IS IMPORTANT TO HAVE IN SITUATIONS WHEN A STRICT DESIGN & CONSERVATIVE NULL HYPOTHESIS IS NEEDED*

Friston et al. (1996)
PARAMETRIC: COGNITIVE DEMAND OF TASK VARIES SYSTEMATICALLY WITH **BOLD SIGNAL**

**LINEAR** - ADAPTATION, COGNITIVE DIMENSIONS

**NON LINEAR** - POLYNOMINAL EXPANSIONS, NEUROMETRIC FUNCTIONS, MODEL BASED REGRESSORS

- INCREMENTALLY INCREASES THE DIFFICULTY OF TASKS THROUGH A “STEP” INCREASE
- ALLOWS DISSOCIATION BETWEEN AREAS FUNCTIONALLY ASSOCIATED WITH TASKS AND OTHER ‘MAINTENANCE’ AREAS

EXAMPLE:

(Seidman et al., 1998)

**BASELINE:** RESPOND TO ALL LETTERS

**TASK 1:** RESPOND IF A IS PRECEDED BY Q (A, Q)

**TASK 2:** RESPOND IF A IS PRECEDED BY 3 LETTERS, THEN Q (ABCDQ)
FACTORIAL: TWO OR MORE FACTORS, AND THEIR DIFFERENT LEVELS ARE MATCHED

‘…perform a task where the cognitive components are intermingled in one moment, and separated in another instance…’ (Amaro & Barker, 2006)

Interactions:
When the effects of one factor depend on the levels of a second factor.

Main Effect:
Effect of one factor alone

2 X 2 DESIGN:
2 FACTORS X 2 LEVELS = 2 CONDITIONS
- EACH FACTOR HAS 2 LEVELS

Factors: X & Y
Levels: X1, X2, Y1, Y2
Conditions: X1Y1, X1Y2, X2Y1, X2Y2

Monti (2021)
Does a new drug decrease migraine attacks, is it more effective in males or females?

-Using the 2 x 2 chart, you can see all of the possible interactions between the two factors, dosage and gender. The interactions can also be seen on a graph, which is a combination of the individual factors main effects.

<table>
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<tr>
<th>Gender</th>
<th>Dosage</th>
<th>Male Low Dose</th>
<th>Male High Dose</th>
<th>Female Low Dose</th>
<th>Female High Dose</th>
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<tbody>
<tr>
<td>Male</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Female</td>
<td>Low</td>
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**Main Effects**

- **Gender**: Male and Female
- **Dosage**: Low and High

**Interactions**

- **Gender**: Male and Female
- **Dosage**: Low and High

Graph showing the number of migraine attacks for different combinations of gender and dosage.
PRESENTING STIMULUS:

Petersen & Dubis (2012)
**PROS:**
- Avoids rapid task switching (e.g. patients)
- Fast and easy to run
- Good signal to noise ratio
- Strong detection & statistical power

Maximises: data variability due to experimental manipulation (between-conditions variability)
Minimises: other sources of data variability (within-conditions variability)

**CONS:**
- Expectancy effect
- Habituation
- Signal drift
- Poor choice of baseline as many preclude meaningful conditions
- Can't have many tasks that cannot be conducted repeatedly

When the subjects expect a given result and unconsciously affects the outcome
**TASK A VS. NO TASK**

- **SQUEEZE RIGHT HAND** → **30 SEC REST** → **SQUEEZE LEFT HAND** → **30 SEC REST**

By resting, it shows more activity associated with the task, but may introduce unwanted results.

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**TASK A VS. TASK B**

- **SQUEEZE RIGHT HAND** → **SQUEEZE LEFT HAND** → **SQUEEZE RIGHT HAND** → **SQUEEZE LEFT HAND**

By continuously moving through tasks, you can distinguish differential activation between conditions. However, it does not allow identification of activity common in both tasks.
**Event Related Design:** Evoke process of interest transiently by brief presentation of individual stimuli

### Pros:
- Task order and spacing is randomised (as long as the hemodynamic response can reach baseline before the next trial)
- Allows real world testing & trial by trial sorting based on subject response
- Eliminates predictability
- Can look at novelty, priming & temporal dynamics of response

### Cons:
- Lower statistical power (small signal change)
- More complex design and analysis (e.g. timing/baseline issues)
- Evoke smaller changes in BOLD signal
- Possibly larger switching costs between tasks

[Huettel (chapter 9)]
The subject was presented with a picture of a house, and then a picture of a person. The participant was asked to tap his left index finger for the house, and tap his right for the person.

**EXAMPLE:**

The arrows indicate the “rest” in between tasks. The “rest” is just long enough for the hemodynamic response to fully move up, and return back to the baseline.
MIXED DESIGN: COMBINATION OF BLOCK AND EVENT RELATED DESIGN

Stimulus present in regular blocks: >1 type of event per block

EVENT: ITEM RELATED PROCESSES (BUTTON PRESS)

BLOCK: STATE RELATED PROCESSES (ATTENTION)

Donaldson et al. (2001)
Within task block, the subject is presented with a video of different numbers, with a letter appearing within the sequence. The subject is told to press the button when a letter is presented.

**EXAMPLE:**

BLOCK: VIDEO OF NUMBERS

EVENT: LETTERS PRESENTED

Donaldson et al. (2001)
Huettel (chapter 9)
Whichever study design you choose in both, design or stimulus presenting strategies, it all depends on your question.
Part 2: Efficiency and optimisation of fMRI designs
Good fMRI design requires **two criteria**

1. **Appropriate**  
   e.g. induces subject to do or experience the psychological state that you want to study (psychological)

2. **Efficient**  
   e.g. effectively detects brain signals related to those psychological states (statistical)

   *You can have a great psychological experiment with huge neuronal response, but be completely unable to identify this in fMRI-signal because you can’t disassociate the BOLD signal*
Content

• General advice
• Terminology
• Challenges with BOLD IR
• Stimulus timing: One condition
  • Fourier Transformation
  • High-pass filtering
• Stimulus timing: Two/more conditions
  • Different efficiencies for different contrasts
  • Correlation between regressors
General advice

1. Scan for as long as possible
   - Avoid fatigue, habituation and discomfort
   - Statistical power (40-60 mins)
   - Group analysis: number of subjects

2. Keep subject as busy as possible
   - Minimise the time subjects are not engaged in a task
   - Breaks in scanning
     - disrupts the spin equilibrium
     - reduce efficiency of any temporal filtering
   - "session" effects
Challenges with BOLD Impulse response

• BOLD impulse response (IR)
  o Haemodynamic Response Function (HRF): relation between burst of neuronal activity and BOLD signal
  o Typical response: peak at 4-6s, initial undershoot at 10-30s, returns to baseline at 25-32s (Malonek & Grinvald, 1996)

• Main challenges:
  1. Delayed and dispersed BOLD response
  2. Low frequency noise
Terminology

- **Trials**: replication of a condition
  - Components of a trial: bursts of neural activity, or periods of sustained neural activity
  - For example, a working memory trial can consist of a stimulus (event), a retention interval (epoch) and a response (event)

- **Stimulus Onset Asynchrony (SOA)**: time between onset of two different stimuli (Long vs short)

- **Inter-Trial Interval (ITI)**: time between the onset of successive trials

- **Inter-Stimulus Interval (ISI)**: time between the offset of one component and the onset of the next
Optimising efficiency: stimulus timing

• Temporal convolution model

  **Stimulus x IR = Predicted fMRI data**

  - The following examples will use this model

• Stimulus timing

  - You want trials to be temporally close to limit ITI
  - In order to be sensitive to differences between trials close together in time (i.e., <20 s), you can either
    - **Fix SOA** but vary the order of trials
    - Fix the order but **vary the SOA**

GLM: $Y(\text{data}) = X(\text{design matrix}) \cdot \beta(\text{parameters}) + \epsilon(\text{error})$
Stimulus timing: Single condition vs baseline
Fixed SOA

• SOA = 16s

Stimulus ("Neural")  IR  Predicted fMRI Data
0 16 32 48 64 80
0 5 10 15 20 25 30
0 16 32 48 64 80

○ **Not efficient** - Low variability of the signal

• SOA = 4s

Stimulus ("Neural")  IR  Predicted fMRI Data
0 16 32 48 64 80
0 5 10 15 20 25 30
0 16 32 48 64 80

○ **Even less efficient** – “raised baseline”
Varied SOA- Stochastic Design

- Minimal SOA of 4’s, but only a 50% probability of an event every 4s

Only half stimuli used compared to 4s SOA, but more efficient.

Reason:
- Larger variability in signal
- Good ability to estimate the shape of the BOLD IR
Varied SOA- Blocked design

- Blocked design: vary the SOA in a systematic fashion
  (block of 5 stimuli every 4s with 20s rest)

- Even more efficient than a stochastic design
- Why? – explained using the Fourier transform of each function
Fourier transform

Operation which converts functions from time to frequency domains

The Fourier transform (FT) process is like the musician hearing a tone (time domain signal) and determining what note (frequency) is being played.
Fourier transform

- FT plots magnitude as a function of frequency
- The BOLD IR acts as a low pass filter and attenuate higher frequencies
- Block design more efficient because the majority of signal is “passed” by the IR filter

https://www.youtube.com/watch?v=spUNpyF58BY
Sinusoidal modulation: Most efficient design

- Majority of signal passed by the IR, not filtered out.
- Stimulus frequency should be best aligned with the dominant frequency of the IR (.03 Hz) or 1 waveform in 32 seconds
- Issue: Practically, it would not be possible for most designs which have discrete events rather than modulated changes
Problem: low frequency noise

- Two main components of fMRI noise:
  - low-frequency "1/f" noise
  - background "white noise"

- Causes: scanner drift, gradual changes in physical parameters

- Solution: High-pass filter

- Goal: maximise the loss of noise and minimise the loss of signal
Consequences of high pass-filtering

• The high-pass filter would cause issues with design blocks that are too long
• Block designs are only efficient when the block length is short
• Issue with block design: subject may become aware of blocking and alter strategy/attention
• Compromise between efficiency and predictability
Revisiting the stochastic design

• The high-pass and low-pass filter discussed create a single band-pass filter or ‘efficient HRF’

• Minimal SOA of 4’s, but only a 50% probability of an event every 4s
  o randomised SOA "spreads" the signal energy across a range of frequencies
  o Majority of signal is passed → reasonably efficient design

• Best practice for event related designs
Stimulus timing:
2 or more conditions
Efficiency ($e$) is the ability to estimate $\beta$ (parameters), given the design matrix ($X$) for a particular contrast ($c$) and the given noise variance ($\sigma^2$)

$$e(\sigma^2, c, X) = \sigma^2 c^T(X^T X)^{-1} c^{-1}$$

- The efficiency for each contrast is different
- High covariance (correlation) between regressors can reduce efficiency.
Different efficiency for different contrasts

- A fully randomised design with two event-types (A and B, let’s say no mask/standard mask)
  - Long SOAs (16-20s) are optimal for common effect (A+B)
  - Short SOA’s are optimal for the differential effect (A-B)
- Trade off: The optimal SOA depends on the specific contrast of interest.
- What about when you want to be sensitive to both contrasts?

Marini et al., 2021
Reducing the trade off: null events

• Null events: “fixation trials” allow for selective averaging

• Purpose: buy us efficiency for detecting the common effect (A+B) even at short SOAs with a small reduction of efficiency for detecting the differential effect (A-B)

• This is equivalent to the stochastic design – randomises SOA between the events of interest
Correlation between regressors

• Efficiency can be considered in terms of the correlation between regressors.
  - Differential effect (A-B) has a high negative correlation
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• Corresponds to different efficiency for different contrast

\[ e(\sigma^2, c, X) = \{\sigma^2 c^T (X'X)^{-1} c\}^{-1} \]
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• Issue: High correlation between two regressors means that the parameter estimate for each one will be estimated inefficiently.

• Solution:
  - C -- Keep stimulus-response interval fixed at 4s, but only cue a response on a random half of trials.
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Conclusions

STUDY DESIGN:
• Subtraction : Task A – Task B
• Conjunction: Looks for commonality in activation differences
• Parametric: Task increases in difficulty
• Factorial: Test for interactions

STIMULUS PRESENTING DESIGN:
• Blocked design – sustained stimuli
• Event related – event related stimuli
• Mixed design – combination of the two.

1. Consider efficiency before experiment - prioritise study design being appropriate for the research question
2. Block design (short block length ~20sec) are most efficient
3. Stochastic designs are also useful in specific contexts - For specific inferences linked to particular events at particular times
4. Different contrasts have different efficiencies – bridge the gap with null events
5. Correlation between regressors should be considered and minimised to improve efficiency
References

• Rik Henson’s SPM guide: http://imaging.mrc-cbu.cam.ac.uk/imaging/DesignEfficiency
• Dougherty D., Rauch S., Rosenbaum JF. (2004). Essentials of Neuroimaging for Clinical Practice
References


• [https://mediacentral.ucl.ac.uk/Player/2897](https://mediacentral.ucl.ac.uk/Player/2897)


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• Previous MfD slides

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• **Thank you: Dr Sara Bengtsson**
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STUDY DESIGN:
• Factorial: Subtraction : Task A – Task B
  → can look at multiple factors in an experiment
• Parametric: Task increases in difficulty
• Conjunction: Looking for similarities in brain activation for multiple different regions.

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5. Correlation between regressors should be considered and minimised to improve efficiency
What is the main difference between Subtraction and Conjunction designs?

A. Conjunction looks for activation differences between a pair of tasks that share all but the component of interest, and Subtraction looks for the commonality in activation differences between two or more pairs of tasks that share only the component of interest.

B. Pure insertion is not required for subtraction but is for conjunction.

C. Nothing, they are the same.

D. Subtraction looks for activation differences between a pair of tasks that share all but the component of interest, and Conjunction looks for the commonality in activation differences between two or more pairs of tasks that share only the component of interest.
What two designs make up the "mixed design"

A Factorial and Block

B Factorial and Parametric

C Block and Event-Related

D Event-Related and Conjunction
Stimulus Onset Asynchrony (SOA) is

A Time between onset of two different stimuli
B Time between the offset of one component and the onset of the next
C Time between the onset of successive trials
D Frequency between onset of two different stimuli
Which is the most efficient design from the following?

A Blocked design with fixed SOA
B Stochastic design with varied SOA
C Blocked design with varied SOA
None of the above
References

- Rik Henson’s SPM guide: http://imaging.mrc-cbu.cam.ac.uk/imaging/DesignEfficiency
- Dougherty D., Rauch S., Rosenbaum JF. (2004). Essentials of Neuroimaging for Clinical Practice
References


• https://mediacentral.ucl.ac.uk/Player/2897

• https://www.coursera.org/learn/functional-mri-2/lecture/zVWBb/module-7a-advanced-experimental-design-i-fundamentals-of-design-efficiency

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