**Overview**

1. A Taxonomy of Designs
2. Epoch vs Event-related
3. Mixed Epoch/Event Designs

**A taxonomy of design**

- **Categorical designs**
  - Subtraction: Additive factors and pure insertion
  - Conjunction: Testing multiple hypotheses

- **Parametric designs**
  - Linear: Cognitive components and dimensions
  - Nonlinear: Polynomial expansions

- **Factorial designs**
  - Categorical: Interactions and pure insertion
  - Parametric: Linear and nonlinear interactions

**A categorical analysis**

Experimental design

Word generation G

Word repetition R

R G R G R G R G R G

G - R = Intrinsic word generation

…under assumption of pure insertion, ie, that G and R do not differ in other ways
Cognitive Conjunctions

• One way to minimise problem of pure insertion is to isolate same process in several different ways (i.e., multiple subtractions of different conditions)

Task (1/2)
Viewing Naming

Visual Processing
Object Recognition
Phonological Retrieval

Object viewing
Colour viewing
Object naming
Colour naming

<table>
<thead>
<tr>
<th>V</th>
<th>R</th>
<th>P</th>
<th>V</th>
<th>P</th>
<th>V</th>
</tr>
</thead>
</table>

- Object - Colour viewing: \[1 \times 0 \times 0\]
- Object - Colour naming: \[0 \times 0 \times 1\]

\[[R \cdot V] \& [P \cdot R \cdot V] \Rightarrow R \& R = R\]

Price et al, 1997

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A (linear) parametric contrast

Linear effect of time

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Nonlinear parametric design matrix

Inverted ‘U’ response to increasing word presentation rate in the DLPFC

Polynomial expansion:
\[ f(x) = \beta_1 x + \beta_2 x^2 + \ldots \]
\( \ldots (N-1)\text{th order for } N \text{ levels} \)

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Interactions and pure insertion

- Presence of an interaction can show a failure of pure insertion (using earlier example)

\[ [1 -1 0 0] \otimes [-1 -1] = [1 1] = [1 -1 1 -1] \]

Task (1/2)

- Visual Processing: V
- Object Recognition: R
- Phonological Retrieval: P
- Object viewing: RV
- Colour viewing: V
- Object naming: PRVP
- Colour naming: PV

Stimuli (A/B)

- Object: O
- Colour: C

Arithmetic (Object – Colour) \times (Viewing – Naming)

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(Linear) Parametric Interaction

A (Linear) Time-by-Condition Interaction

(“Generation strategy”?)

Contrast: [5 3 1 -1 -3 -5] \otimes [-1 1]
Nonlinear Parametric Interaction

F-contrast tests for nonlinear Generation-by-Time interaction (including both linear and Quadratic components)

Factorial Design with 2 factors:
1. Gen/Rep (Categorical, 2 levels)
2. Time (Parametric, 6 levels)

Time effects modelled with both linear and quadratic components...

Psycho-physiological Interaction (PPI)

Parametric, factorial design, in which one factor is psychological (eg attention) ...and other is physiological (rec. activity extracted from a brain region of interest)

Attentional modulation of V1 - V5 contribution

Psycho-physiological Interaction (PPI)

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  - Categorical
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Epoch vs Events

- Epochs are periods of sustained stimulation (e.g., box-car functions)
- Events are impulses (delta-functions)
- In SPM99, epochs and events are distinct (e.g., in choice of basis functions)
- In SPM2, all conditions are specified in terms of their 1) onset and 2) duration...
  — events simply have zero duration
- Near-identical regressors can be created by: 1) sustained epochs, 2) rapid series of events (SOAs<~3s)
- i.e., designs can be blocked or intermixed...models can be either epoch-related or event-related

Advantages of Event-related fMRI

1. Randomised (intermixed) trial order
   c.f. confounds of blocked designs (Johnson et al 1997)
2. Post hoc / subjective classification of trials
   e.g., according to subsequent memory (Wagner et al 1998)
3. Some events can only be indicated by subject (in time)
   e.g., spontaneous perceptual changes (Kleinschmidt et al 1998)

Data

Model

O = Old Words
N = New Words

R = Words Later Remembered
F = Words Later Forgotten

R F R F

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4. Some trials cannot be blocked
e.g., “oddball” designs (Clark et al., 2000)

5. More accurate models even for blocked designs?
e.g., “state, state-item” interactions (Chawla et al., 1999)

Advantages of Event-related fMRI

“Oddball”

Consider an experiment presenting words at different rates in different blocks:

An “epoch” model may estimate the parameter that increases with rate, because the parameter reflects response per block.

An “event” model may estimate the parameter that decreases with rate, because the parameter reflects response per word.

Epoch vs Events

Though blocks of trials can be modelled as either epochs (mean) or runs of events,

interpretation of parameters differs:

• An “epoch” model may estimate the parameter that increases with rate, because the parameter reflects response per block.

• An “event” model may estimate the parameter that decreases with rate, because the parameter reflects response per word.
Disadvantages of Intermixed Designs

1. Less efficient for detecting effects than are blocked designs
2. Some psychological processes may be better blocked (e.g., switching, attentional instructions)

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Mixed Designs

- Recent interest in simultaneously measuring effects that are:
  - transient (“item-related”)
  - sustained (“state-related”)

- What is the best design to estimate both…?

A bit more formally... “Efficiency”

- Sensitivity, or “efficiency”, e (see later):
  \[ e = \frac{1}{\text{regressors}} \]

- High covariance increases elements of \( (X^TX)^{-1} \)

- So, when correlation between regressors is high, sensitivity to each regressor alone is low

Item effect only...

Blocks = 40s, Fixed SOA = 4s

Efficiency = 565 (Item Effect)

Item and State effects

Blocks = 40s, Fixed SOA = 4s

Efficiency = 16 (Item Effect)

Correlation = .97

Not good...
**Item and State effects**

Blocks = 40s, Randomised SOA_{min} = 2s

Efficiency = 54 (Item Effect)

Correlation = .78

Design Matrix (X)

Better!

**Mixed Designs (Chawla et al 1999)**

- Visual stimulus = dots periodically changing in colour or motion
- Epochs of attention to: 1) motion, or 2) colour
- Events are target stimuli differing in motion or colour
- Randomised, long SOAs between events (targets) to decorrelate epoch and event-related covariates

**Attention modulation DET**:
- 1) baseline activity (state-effect, additive)
- 2) evoked response (item-effect, multiplicative)

Mixed Designs (Chawla et al 1999)

V5 Motion change under attention to motion (red) or color (blue)

V4 Color change under attention to motion (red) or color (blue)

State Effect (Baseline)

Item Effect (Evoked)