Overview

- Parametric designs in fMRI
- Parametric conditions: N-back task example
- Parametric modulation: Autobiographical memory study
- General conclusions about using parametric designs

Categorical subtractive designs

- Imaging studies typically designed to detect change in activation across task conditions
- Use of a subtractive design
  - Task 1 = $A + B + C$
  - Task 2 = $A + B + C + D$
  - Task 2 – Task 1 = D
- Categorical design $\Rightarrow$ D present or absent

Categorical subtractive designs

TASK A TASK B TASK B-A

(Petersen et al., 1989)

Problems with categorical subtractive designs

- Subtraction depends on accurate task analysis and decomposition
  - Are Task 1’s $A$, $B$, $C$ equal to Task 2’s $A$, $B$, $C$?
- Assumes a purely additive underlying model
  - Brain is likely to be interactive rather than additive
  - Are subtraction changes due to addition or interaction?
    - Task 1 = $A + B + C + AB + AC + BC + ABC$
    - Task 2 = $A + B + C + D + AB + AC + AD + BC + BD + CD + ABC + BCD + ABCD$
- Misleading inferences about engagement vs. modulation
  - Is D absent in Task 1, present in Task 2 or just changed in activity?
  - Continuum of activity might be more appropriate
Non-categorical designs

- Factorial designs
  - Explicitly test for interactions

- Parametric designs
  - Explicitly test for modulation of activity
  - E.g., Task 1: A + B₁ + C
    Task 2: A + B₂ + C
    Task 3: A + B₃ + C

Parametric designs: Variables studied

- Sensory
  - Visual: e.g., flicker frequency
  - Auditory, e.g., speech presentation rate
  - Somatic, e.g., stimulus intensity and pain

- Motor
  - Tapping rate, sequence complexity

- Cognitive
  - Attention load, working memory load, mental rotation

- Emotion
  - Trustworthiness, reward

- Behavioural performance
  - RT

Ways to design parametric studies

(1) Parametric conditions:
  - Creating conditions that differ in intensity of parameter of interest
  - Analysis:
    - correlation between condition and activity level
    - ANOVA – main effect of parametric variable
  - Example: N-Back tasks

Parametric conditions

- N-back task (Braver et al., 1997)
  - Conditions of increasing working memory load

Ways to design parametric studies

(2) Parametric modulation:
  - Collecting behavioral data for parameter of interest
  - Analysis: Enter behavioral data into a regression (linear or non-linear) using Parametric Modulation function of SPM
  - Identifies regions where activation varies with the behavioural rating
  - Example: Ratings for vividness of memories; age of memories
Parametric Modulation: Autobiographical memory

Retrieval of autobiographical memories – hippocampal activation
But what modulates this activation?

Factors thought to modulate hippocampal activation:
- Temporal specificity of the event
- Level of recollection (e.g., vividness, emotion, personal significance)
- Age of memory (more recent events = more hippocampal activation)

Participants
- 7 male and 7 female
- Aged between 20 and 40 yrs
- All right-handed

Pre-Scan Interview
- 20 specific events and 20 general events
  - General events = events repeated 10 times
  - All events more than 1 year old
  - Age of memory provided
  - Brief title devised for each memory

Autobiographical memory: Scanning Protocol

Autobio Tasks:
- Retrieve general OR specific event (6 sec)
- Rate for detail, personal significance OR emotion (4 sec)
- Rest (6 sec)

Two scans:
- Each scan includes 10 specific and 10 general autobiographical memory tasks
- Rating dimension constant over a scan; differs between scans

SHOVELING SNOW AT HOME
RATE DETAIL  1  2  3  4  5

Post-Scan Interview
• Immediately following the scan
• Rated each AM for
  – Level of detail
  – Emotionality
  – Personal significance
• Ratings based on AM retrieved in the scanner
• Highly correlated with in-scanner ratings (.80)

Analyses: SPM
• Univariate contrasts: Hippocampal active for retrieval of both specific and general memories

SPM Parametric Modulation
Reynolds of memory
- modulation of hippocampal activation only evident with specific AMs

Reynolds effect when recollective qualities covaried out:
Detail
Emotionality

• Note: When personal significance is taken into account, this recency effect disappears entirely
Recollective qualities of Specific AMs (recency covaried out)

- **Detail**
- **Personal Significance**

Recollective qualities of General AMs

- **Detail**
- **Emotionality**
- **Personal Significance**

**Conclusions**

- **Recency of autobiographic memories:**
  - For specific memories, recency modulates activity of the right hippocampus when detail and emotionality are taken into account, but dissipates when personal significance is accounted for.

- **Recollective qualities:**
  - **Specific memories** – detail and personal significance (and emotionality, subthreshold) modulate the left hippocampus
  - **General memories** – detail, emotionality and personal significance modulate the right hippocampus

**Limitations of parametric designs**

- **Minimum 3 levels**
  - The more the better
- **Variable manipulated must be at least ordinal**
  - E.g., 3-back > 2-back > 1-back
  - Or interval/ratio scales (e.g., stimulation rate, Hz)
- **Cannot use nominal scale,** e.g., living, non-living
Why go parametric?

- Avoiding conceptual fallacies
  - Additivity model

- Conceptual shift in hypothesis formation
  - “Modulated by” or “Sensitive to” vs. “Activated by”

- More sophisticated hypothesis testing
  - Stronger constraints
    - Categorical – step function
    - Linear vs. U-shaped: needs > 2 points