MEG in Cognitive Neuroscience

Reading words and nonwords

Source localization (evoked responses)

Multiple experimental conditions

Individual subject

Group-level analysis

Mouth movements and MEG

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Dual-Route Model of Reading

FAMILIAR WORDS

'BRAIN'

visual features

single letters (pre-lexical)

whole word (lexical)

meaning (semantics) ➔ sound form (phonology)

adapted from Coltheart et al. Psychol Rev 1993
Reading Words and Nonwords

- TALO
- LAUTANEN
- short word
- long word

- Lexical route dominates, length has little effect

- ROKI
- SOIJINTO
- short nonword
- long nonword

- Grapheme-to-phoneme, length has strong effect

100 different stimuli of each type, in randomized order
Stimulus duration 400 ms, interstimulus interval 2600 ms
Silent reading, prompt to read aloud ("?") in 4% of trials
→ preparation for pronunciation but no movement artefacts

Data filtered at 0.03-200 Hz, sampled at 600 Hz
Online averaging -200...+1000 ms with respect to stimulus onset
Minimum of 90 artefact-free epochs per condition

Wydell et al. JOCN 2003
Data Analysis

4 experimental conditions (typically 2-6)
8 subjects (typically 8-12)

1. Single-subject analysis
   one condition at a time: source model
   multiple conditions: single, combined model that
   works for all conditions
   significant differences between conditions

2. Group analysis
   grouping of sources by...
   function, location, direction of current flow, timing
   significant effects
Reading Words and Nonwords: Signals

One subject

Short words
Long words
Short nonwords
Long nonwords

100 fT/cm
-200...+800 ms
Low-pass filtered at 40 Hz

Wydell et al. JOCN 2003

Start with something simpler...
MEG Responses to Auditory Stimulation

One subject, average of 80-100 trials

VectorView™

Current flow

-50...250 ms

0.100 ft/cm

RS/Oct03
Auditory Responses: Finding Source Areas

Current flow

100 µf/cm
-50...250 ms

Original model
Auditory Responses: Multiple Sources

Left

[10 nAm]

80%

goodness-of-fit

Time (ms)

RS/May05
Auditory Responses: Multiple Sources

- Left
- Right
- 80%
- 10 nAm
- Time (ms)
- RS/May05
Auditory Responses: Multiple Sources

Left

Right

N100m

P200m

Time (ms)

0 100 200

80%

2 sources

4 sources

10 nAm
Somatosensory Responses: Signals

Current flow

Right median nerve stimulation

100 ft/cm²
-50...250 ms
Somatosensory Responses: Field Patterns

50 ms

30 ms

20 ms

105 ms

95 ms

75 ms
Somatosensory Responses: Source Waveforms
Localization of Source Currents: Models

Appearance is determined by the choice of model, not by the structure of active areas in the brain.

MEG (or EEG) gives an estimate of the centre of an active area but NO direct information about its spatial extent.
Reading Words and Nonwords: Signals

Wydell et al. JOCN 2003
Analysis of Multiple Data Sets: Approaches

1. Analyze each condition independently and COMBINE
   Start from the most prominent / earliest response pattern
   For the combined model, choose REPRESENTATIVE sources:
   clearest field patterns / best confidence values

2. Start from one experimental condition, use these sources for the other conditions, and ADD and MODIFY sources

Separate sets of sources for each experimental condition:
   Compare LOCATIONS and ORIENTATIONS of current flow

A single set of sources for all conditions – as few as possible:
   Compare ACTIVATION STRENGTHS and TIMING

RS/May05
Reading Words and Nonwords: Signals vs. Model

Short words
Long words
Short nonwords
Long nonwords

Current flow

Wydell et al. JOCN 2003
Reading Words and Nonwords: Signals vs. Model

Wydell et al. JOCN 2003
Within-Subject Test for Significant Differences

Behaviourally, naming latencies are shorter for short than long words; length effect stronger for nonwords (Weekes, Q J Exp Psychol LMC 1997)

Comparison *Short words ≠ Long nonwords* should encompass both length and lexicality effects and their interaction

Wydell et al. JOCN 2003
Tarkiainen et al. Brain 1999
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Standard deviation of prestimulus baseline taken as measure of noise level

Difference exceeding $2.58 \times \text{SD} \ (p < 0.01)$ considered significant

Wydell et al. JOCN 2003
Tarkiainen et al. Brain 1999
Grouping of Sources across Subjects

Maximum signal < 200 ms after stimulus onset

Short words
Long words
Short nonwords
Long nonwords

Wydell et al. JOCN 2003
Grouping of Sources across Subjects

Maximum signal ≥ 200 ms after stimulus onset

Wydell et al. JOCN 2003
Group-Level Test for Significant Effects

Grouping by function, timing, and location

Strength

nAm

Length 100-150 ms

40

20

0

0

200 ms

100

0

Visual feature analysis in occ cortex < 200 ms (Tarkiainen et al. Brain 1999)
Phonological analysis in left superior temporal cortex > 250 ms
... if we accept the dual-route model

Wydell et al. JOCN 2003
Reading Words Aloud: Paradigm

Perception

Eingang

Vocalization

Kontakt

+ Mouth EMG + Microphone

300 ms

500 ms

2000 ms

2000 ms

4.8 s

9 developmental stutterers
10 fluent speakers

Salmelin et al. Brain 2000
Reading Words Aloud: Triggers for Averaging

EMG onset

Speech onset

Stimulus

Trial 1
Trial 2
Trial 3
Trial 4
Trial 5

200 ms

Intertrial variation typically 100-200 ms

Salmelin et al., Brain 2000
Reading Words Aloud: Mouth Movement Artefact

Salmelin et al., Brain 2000

Speech onset

-1000...1000 ms
Reading Words Aloud: Stimulus Onset

Salmelin et al., Brain 2000

-200...1800 ms

0 300 800 ms

speech

word

480 ms
Reading Aloud: Stutterers vs. Fluent Speakers

Fluent speakers
Stutterers

Timing

Strength

Salmelin et al. Brain 2000
Source Modelling in Practice

MEG data are usually NOT ambiguous – "inverse problem"
Identification of clear field patterns → well-behaved models

Put effort in experimental design and data quality
Decide what you need to resolve & choose the paradigm

Parametric variation of stimuli is essential for functional localization
and helpful in source modelling

Learn to read your signals! KNOW your data throughout!

The proposed solution should be obvious also in the original signals
Analysis tool must provide visual control of model and what it explains

Caution in interpretation – true for all imaging techniques
References
