CNL

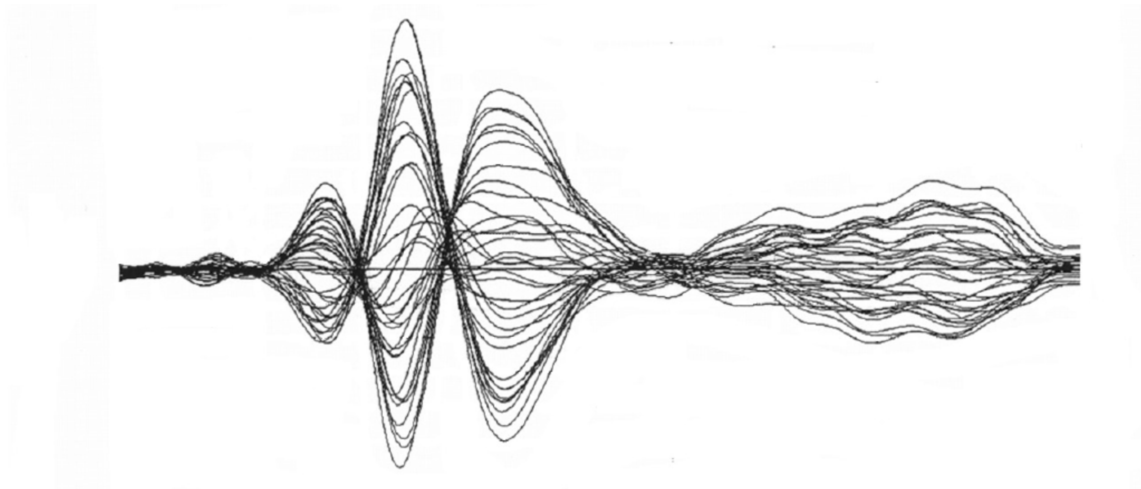
MEG

Behavioral

Psychophysics

Genetics

MEG Investigations of Spectral and Temporal Resolution Properties of Human Auditory Cortex



Nicole M. Gage, PhD
Department of Cognitive Sciences
University of California, Irvine

cognitive
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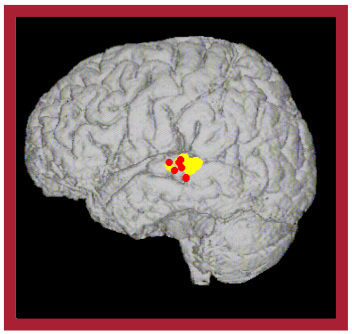

MEG
Behavioral
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Genetics

•Speech perception and hemispheric asymmetries in speech processing

•Auditory perception and cortical sound processing

•Cortical language function and mapping in healthy adults and pre-surgical patients

•Neurobiology of language dysfunction in developmental disorder

•History of neuroscience: Carl Wernicke’s model for language and his theory of conceptual representation in cortex

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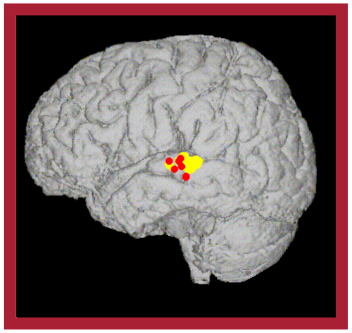

MEG
Behavioral
Psychophysics
Genetics

Research Goals:

To understand neural mechanisms that underlie speech and language processing in healthy adults and typically developing children

To elucidate neural processes that underlie language dysfunction in developmental disorder, such as autism

To understand the correspondence between genetics, brain, and behavior in the language domain

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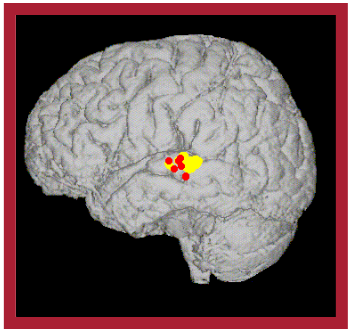

MEG
Behavioral
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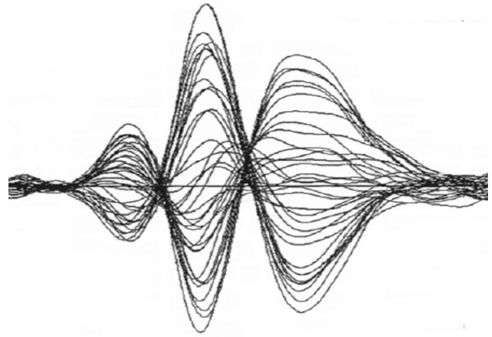
- Speech perception and hemispheric asymmetries in speech processing
- Auditory perception and cortical sound processing
- Cortical language function and mapping in healthy adults and pre-surgical patients
- Neurobiology of language dysfunction in developmental disorder
- History of neuroscience: Carl Wernicke's model for language and his theory of conceptual representation in cortex

Plan of the Talk



Studies of cortical sound processing in adults

Spectral resolution properties of auditory cortex
Integrative processes underlying cortical evoked components
Temporal resolution properties of auditory cortex

Cortical sound processing in typically developing children and children with autism

Spectral resolution for speech and non-speech sounds
Maturational changes in cortical evoked components
Temporal resolution properties of auditory cortex

A case study:

Child with autism and language impairment, a rare chromosome deletion on a region implicated in language, and extreme sensory reactivity

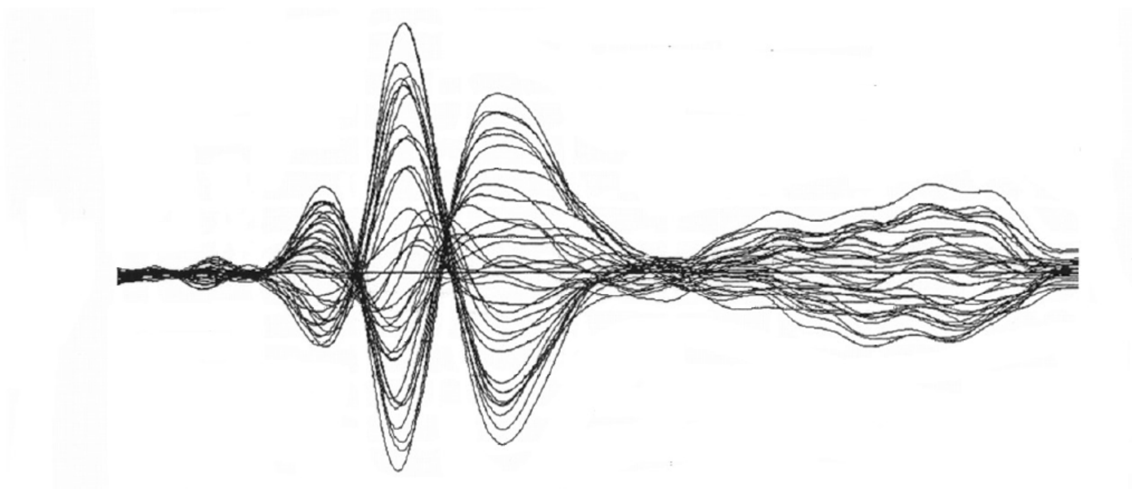
Temporal Resolution of Auditory Cortical Systems

The temporal resolution of the auditory system is exquisite, with neural systems that decode features in the acoustic signal capable of submillisecond resolution.

The high level of resolution in auditory cortical systems provides the capability for decoding fine-grained fluctuations in sounds, critical to the accurate perception of speech.

Magnetoencephalography (MEG)

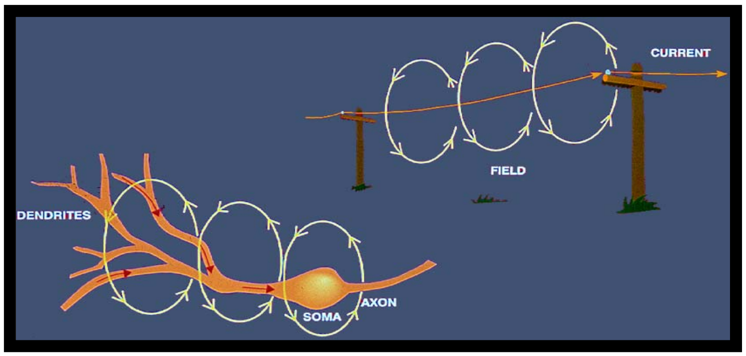
- Millisecond temporal resolution
- Post-synaptic, dendritic flow
- Synchronized response of populations of neurons
- Time-locked to a stimulus event
- Modeled by a single equivalent current dipole



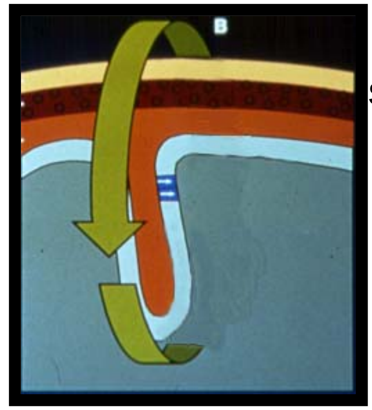
Neuromagnetic Auditory Evoked Field

Basic Principles of MEG

Magnetic Fields Sources



Orientation of Neurons

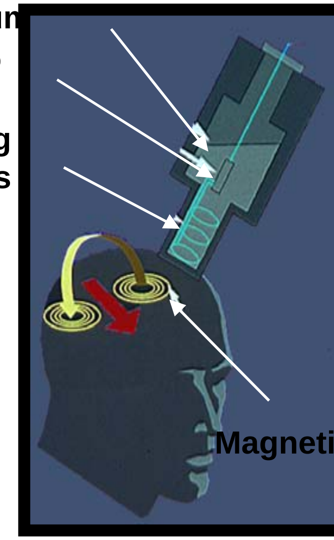


Detection Device

Liquid Helium

SQUID

Superconducting Coils

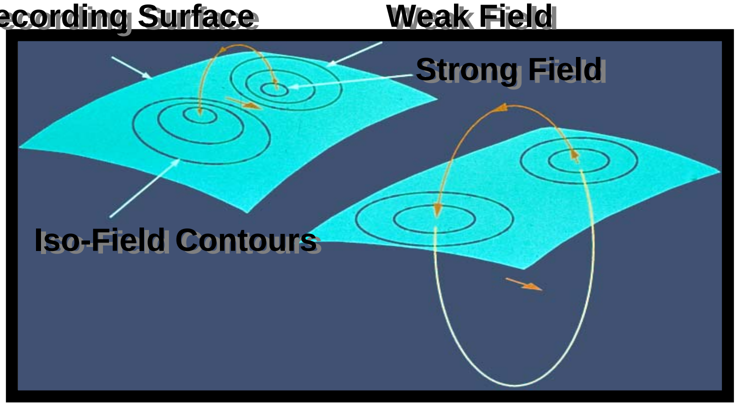


Magnetic Field

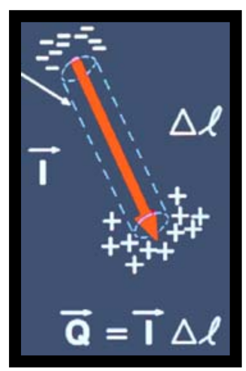
Magnetic Field Pattern

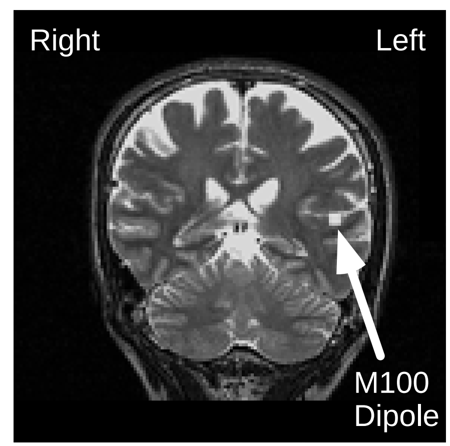
Recording Surface

Weak Field

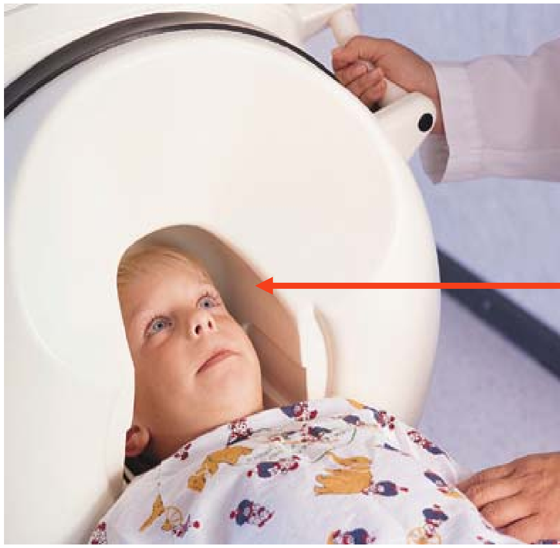


Model

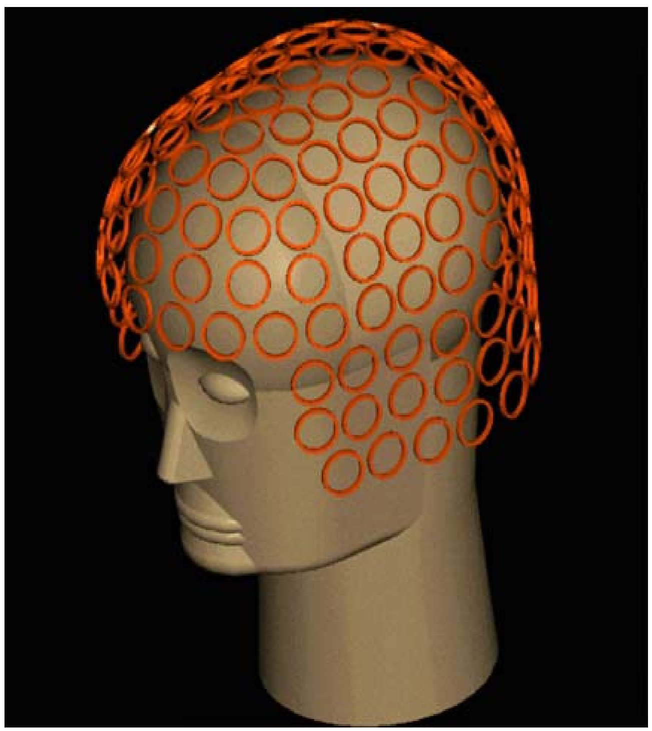




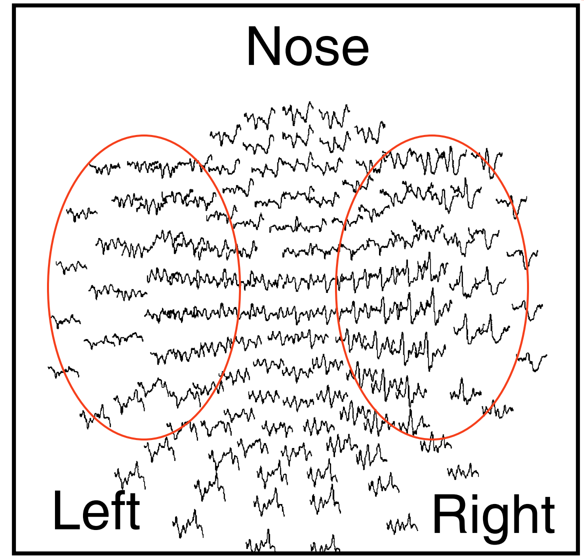
MEG recording of neuromagnetic evoked fields is entirely non-invasive … and silent



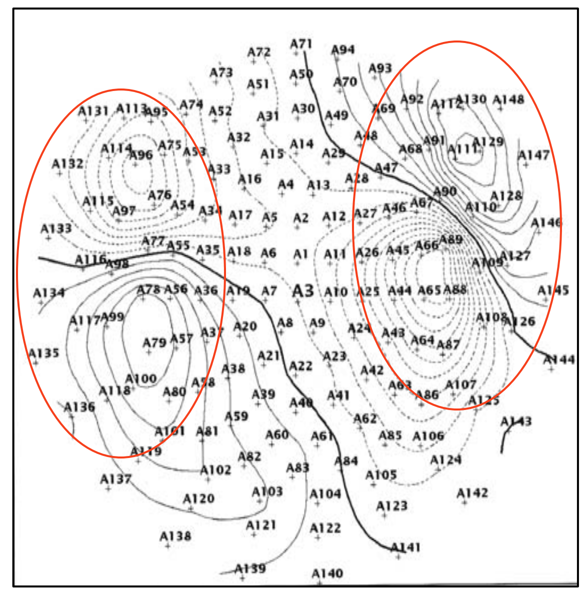
Sensor coils



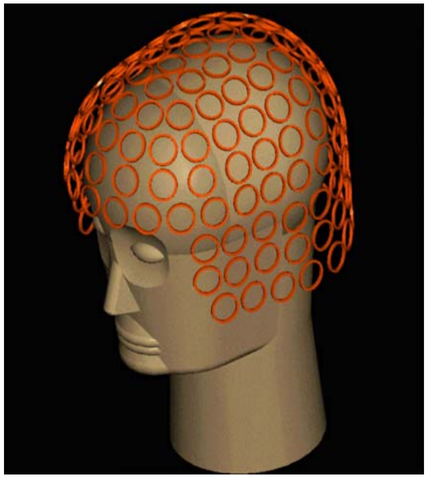
148 Channel Sensor Array

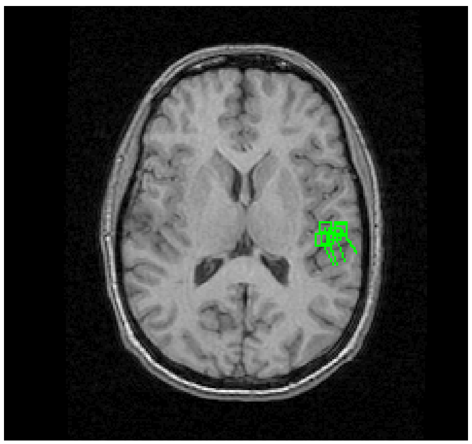


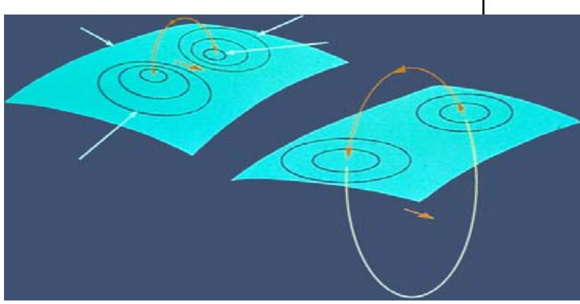
Magnetic Field Contour Map



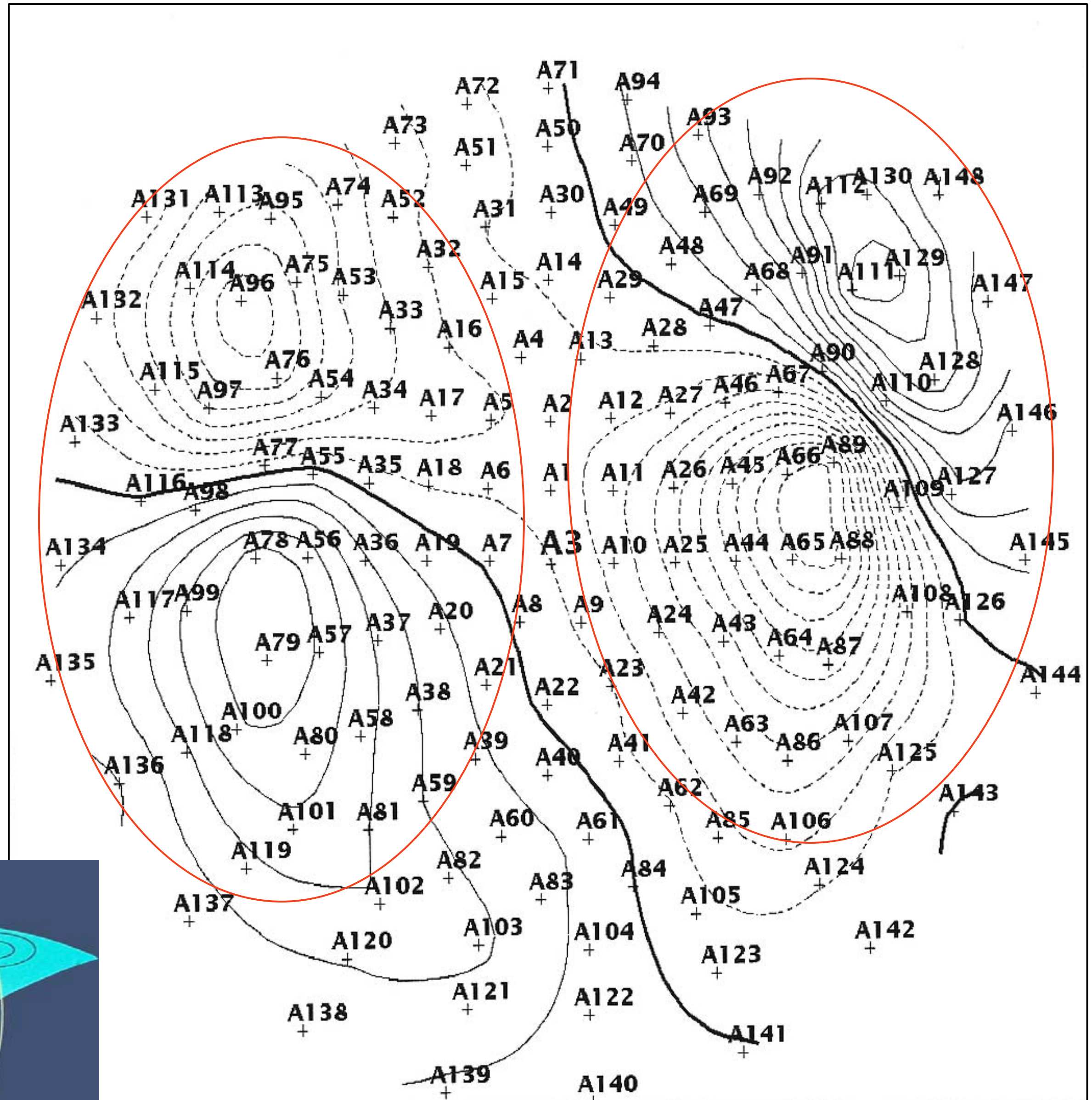
Left and Right Hemisphere Auditory Cortical Dipolar Activity





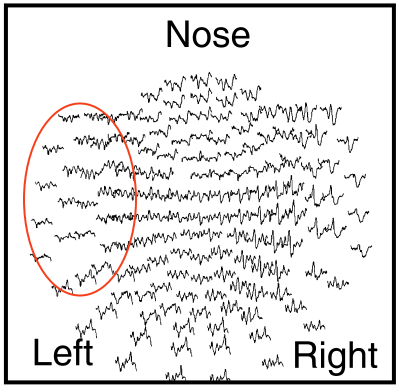


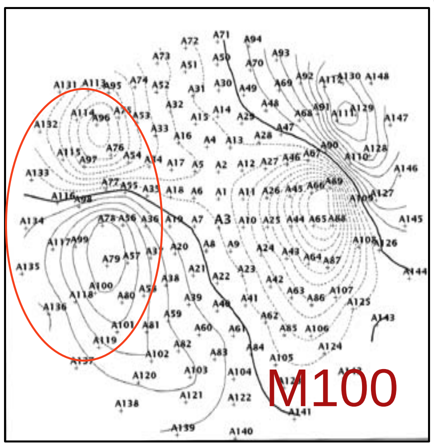
Magnetic Field Contour Map

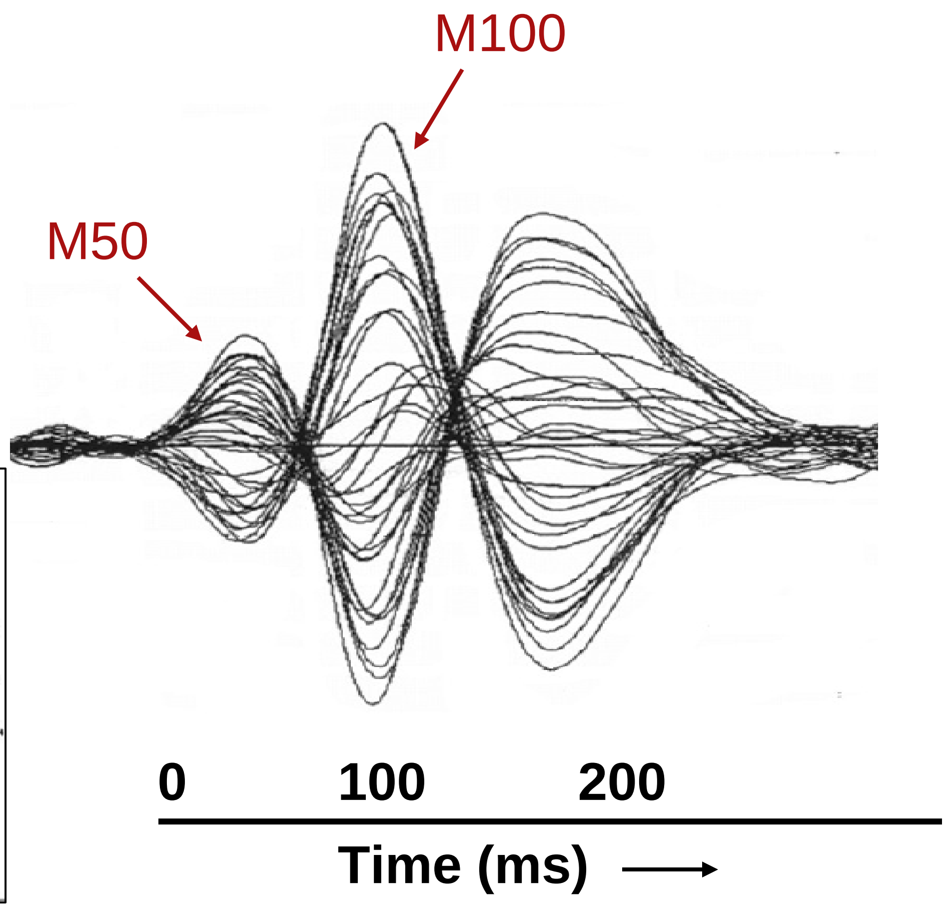


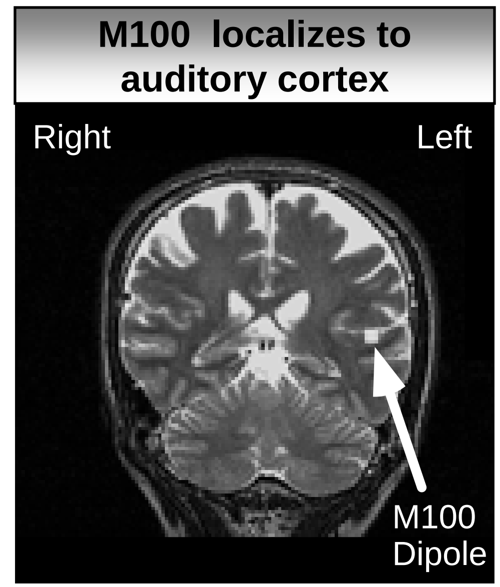
Left and Right Hemisphere Auditory Cortical Dipolar Activity

Neuromagnetic Auditory Evoked Field



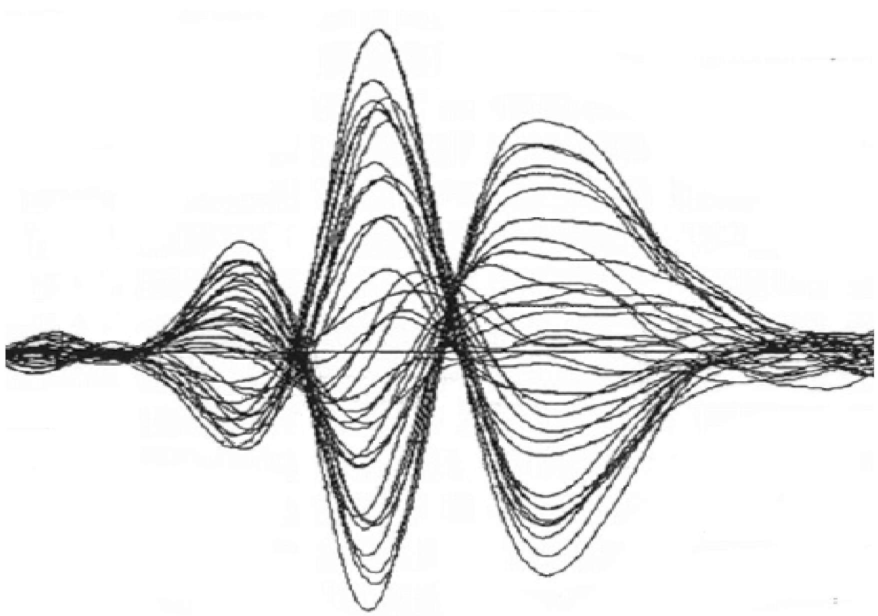






A prototype auditory evoked neuromagnetic field detected by MEG; 37 channels with y-scale representing evoked response magnitude in units of femtotesla (fT) are shown collapsed on the same horizontal time axis.

MEG Investigations of Spectrotemporal Resolution Properties of Auditory Cortex in Adults

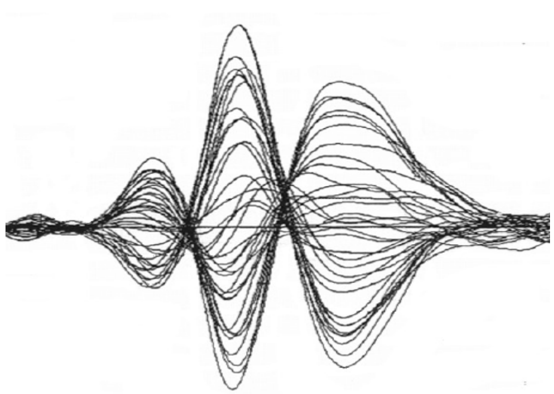


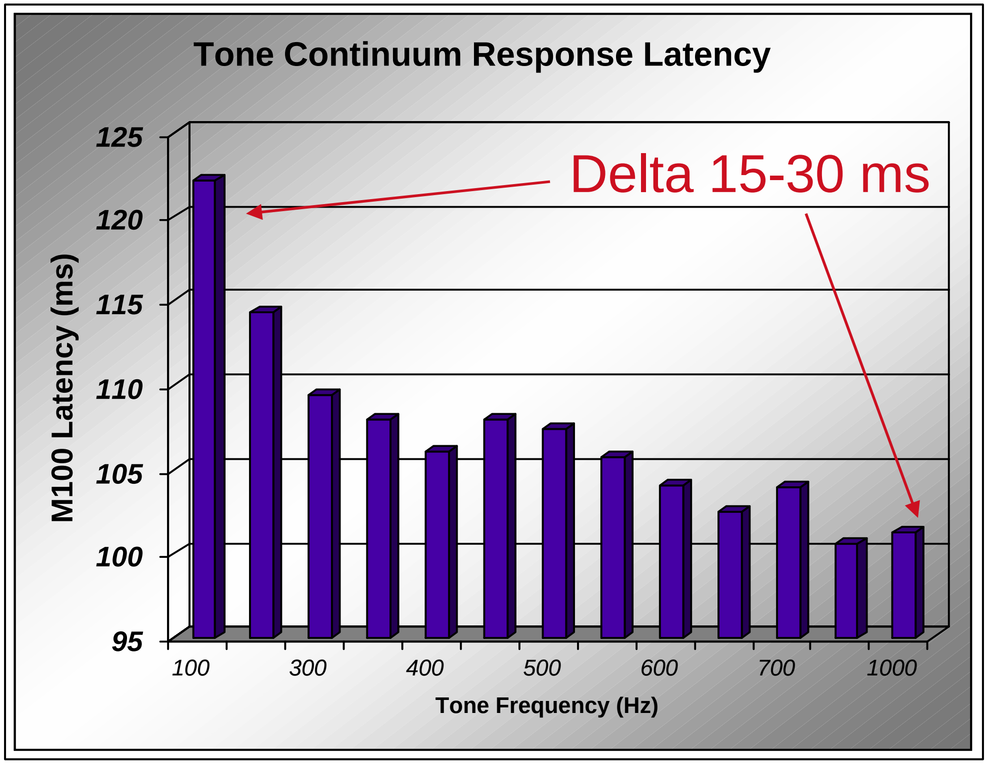
Frequency Dependence of the M100: In healthy adults, M100 latency is modulated by tone frequency, with longer latencies for low (100-200 Hz) as compared to high (1000-3000 Hz) frequency tones.

For sinusoidal tones, M100 latency is modulated as a function of tone frequency, with a ‘fixed cost of ~100 ms plus a period dependent time that is roughly equal to 3 periods of the sinusoid (~30 ms for a 100 Hz, ~3 ms for a 1kHz tone). The dynamic range of frequency modulation in adults is ~25 ms.

M100 Latency is modulated by tone frequency: sinusoidal

tones 100-1000 Hz





M100 Role in Speech Perception

Does the M100 reflect sensory (acoustic)
or perceptual (representational) processes?

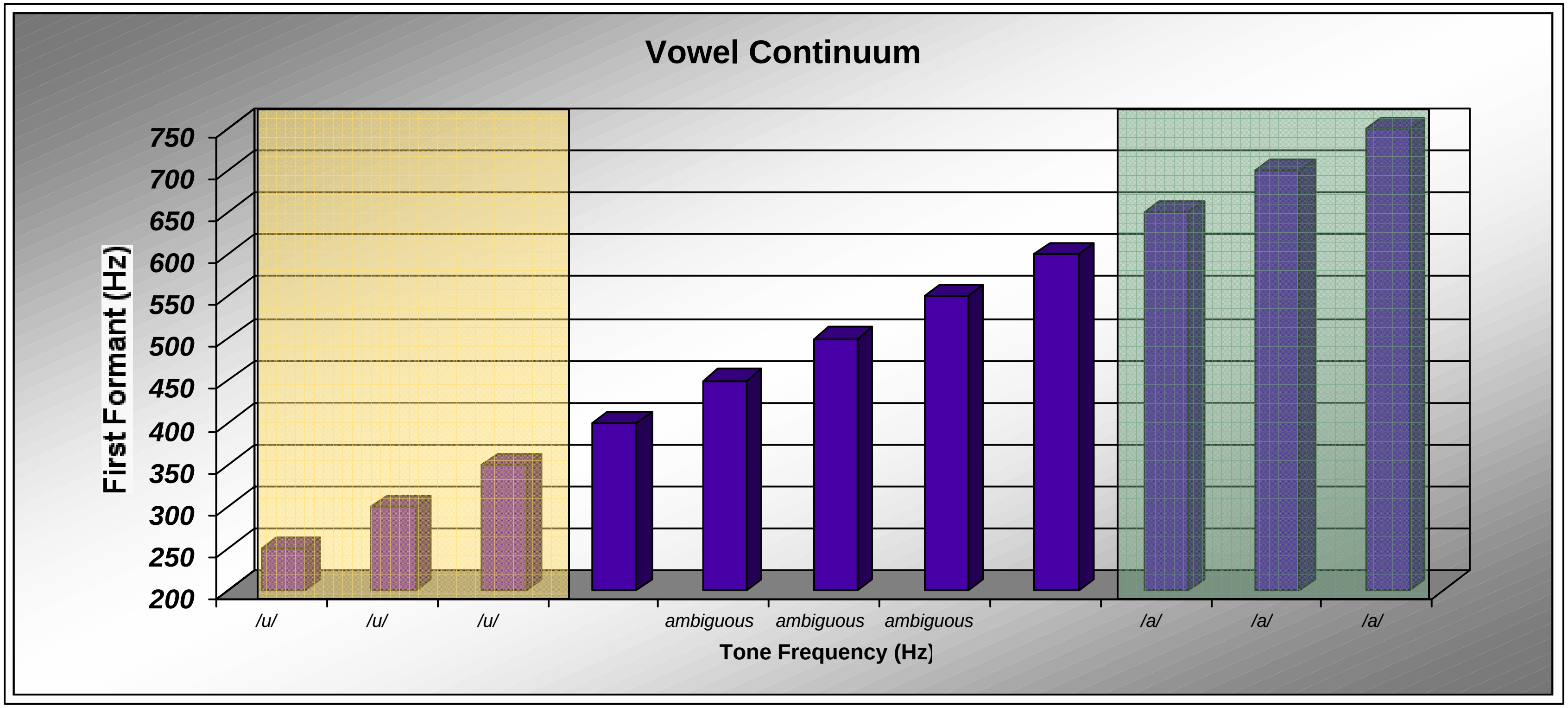
Frequency of F_1 is inversely related to vowel height, with lower F_1 associated with high vowels (/u/) and higher F_1 with low vowels (/a/).

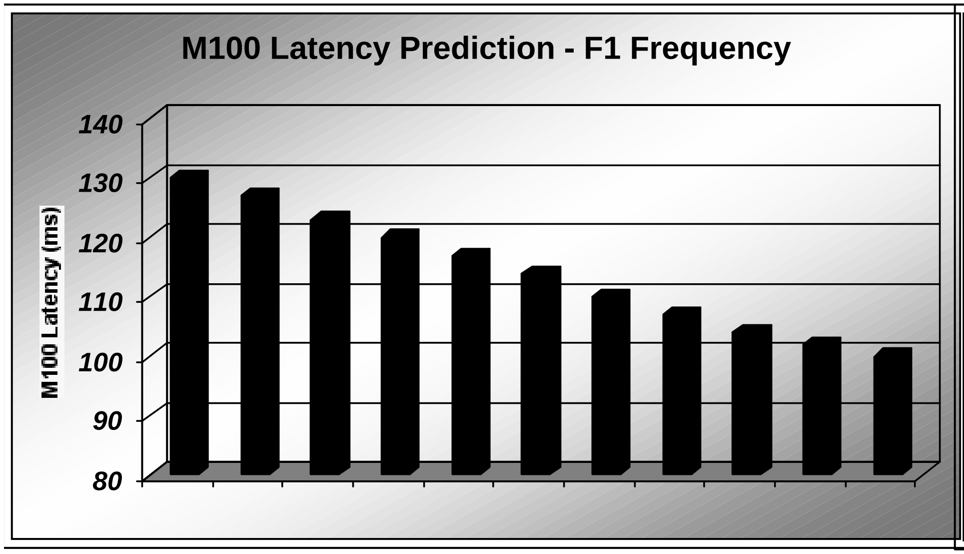
Vowel Continuum varying in values for F_1 but otherwise matched.

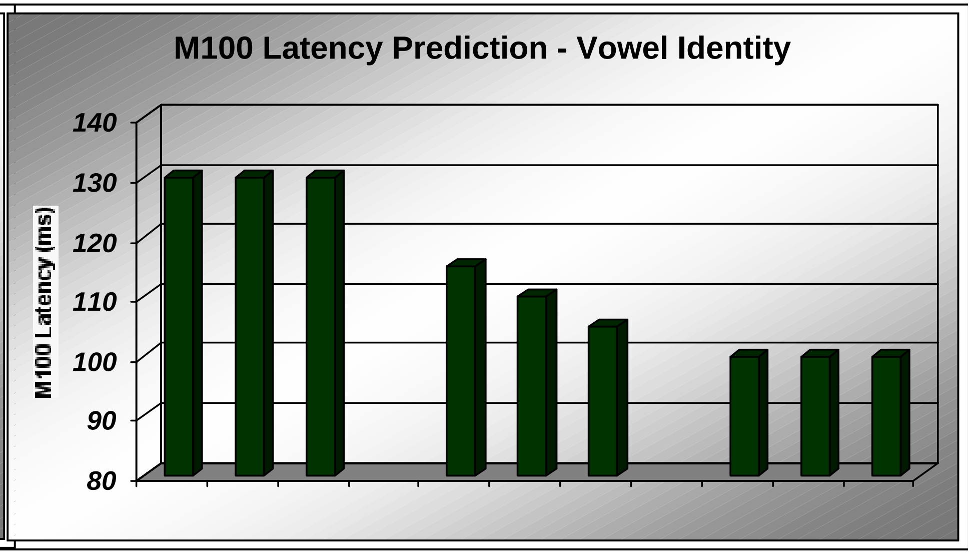
	/u/		/a/
F_0	100 Hz		100 Hz
F_1	250 Hz	50 Hz steps	750 Hz
F_2	1000 Hz		1000 Hz
F_3	2500 Hz		2500 Hz

Investigative Question:

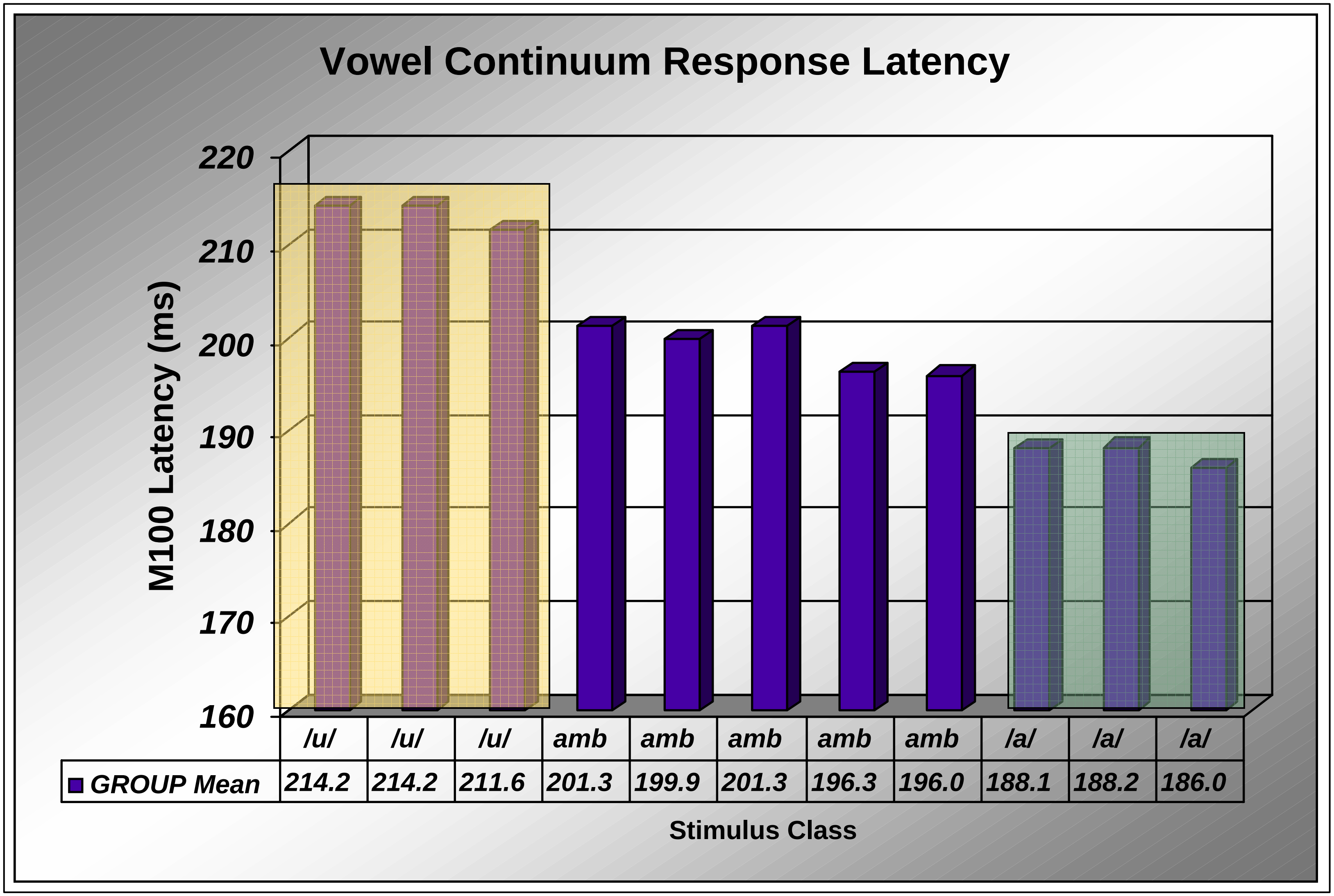
Will M100 latency reflect the spectral center of gravity of 3 formant vowels (curvilinear function) or vowel identity (stepped function)?


Vowel Continuum
First Formant (Hz)
750
700
650
600
550
500
450
400
350
300
250
200
/u/
/u/
/u/
ambiguous
ambiguous
ambiguous
/a/
/a/
/a/
Tone Frequency (Hz)

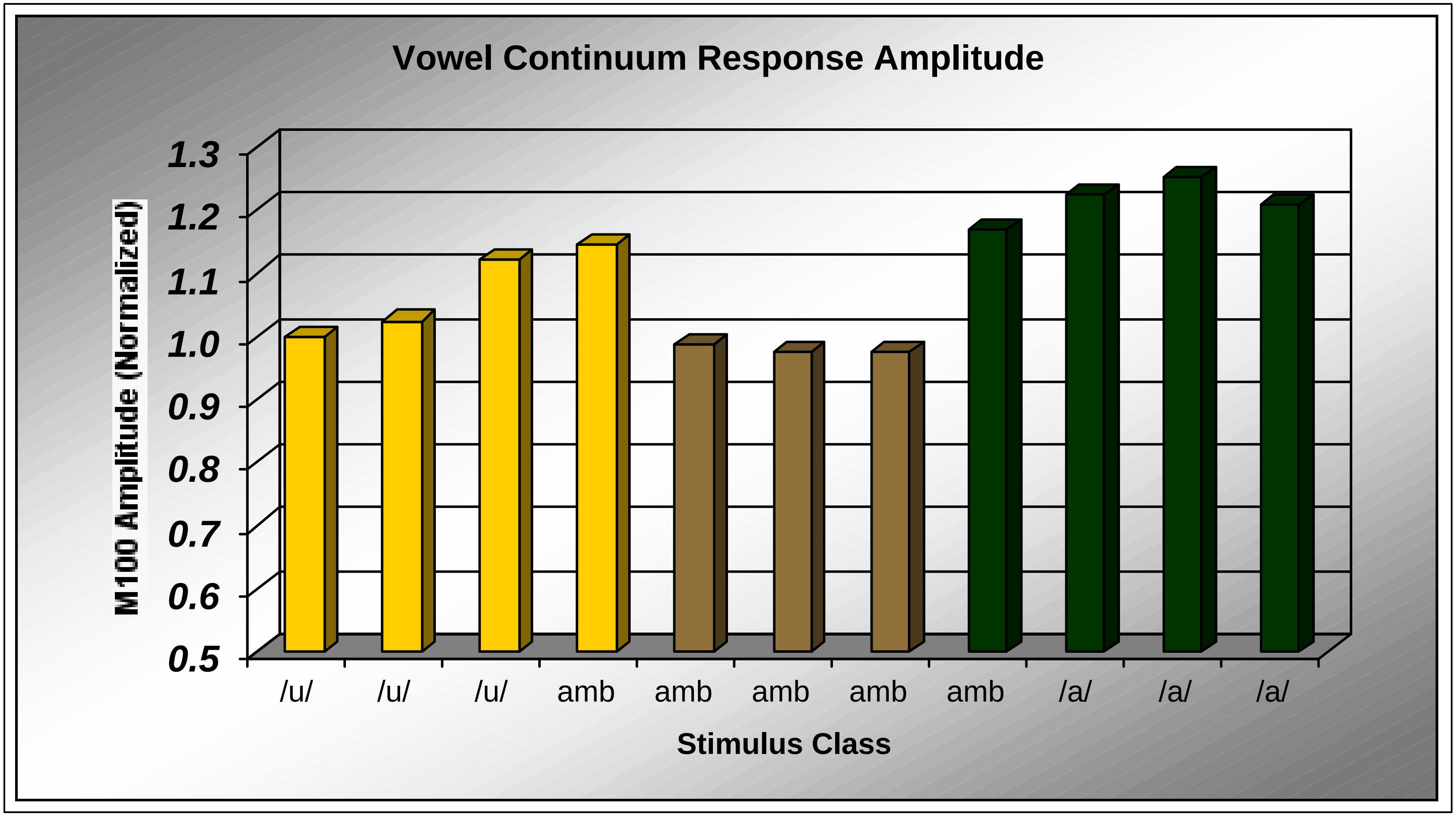

M100 Latency Prediction - F1 Frequency
M100 Latency (ms)
140
130
120
110
100
90
80


M100 Latency Prediction - Vowel Identity
M100 Latency (ms)
140
130
120
110
100
90
80

M100 latency reflects vowel identity as well as secondary spectral features in speech sounds

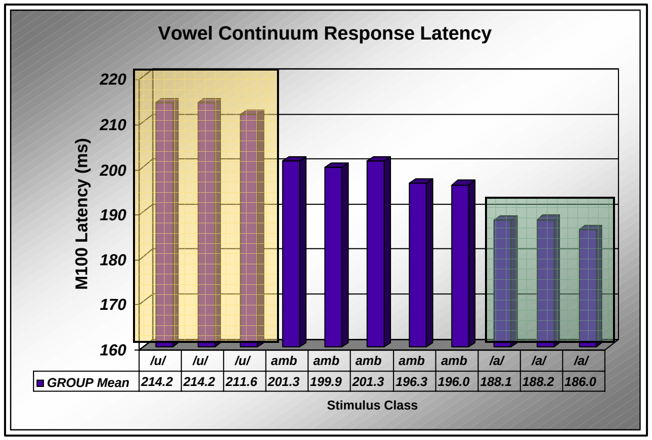


M100 amplitude reflects experience with speech sounds, with lower response amplitudes to novel tokens.

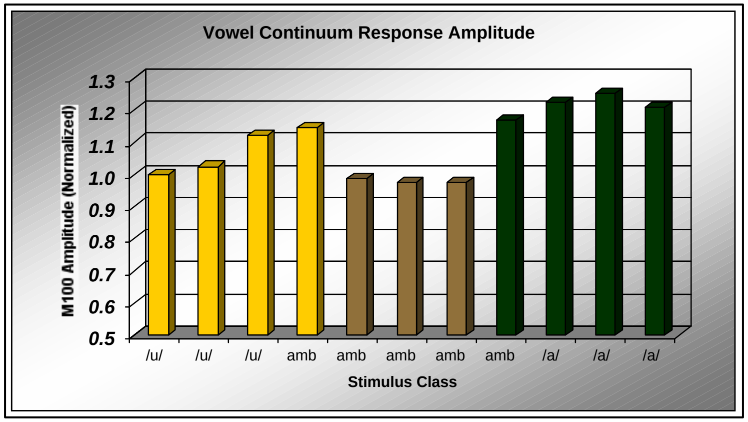


Neural mechanisms underlying the M100 component reflect phonetically-relevant features in speech

M100 latency reflects vowel identity as well as secondary spectral features in speech sounds

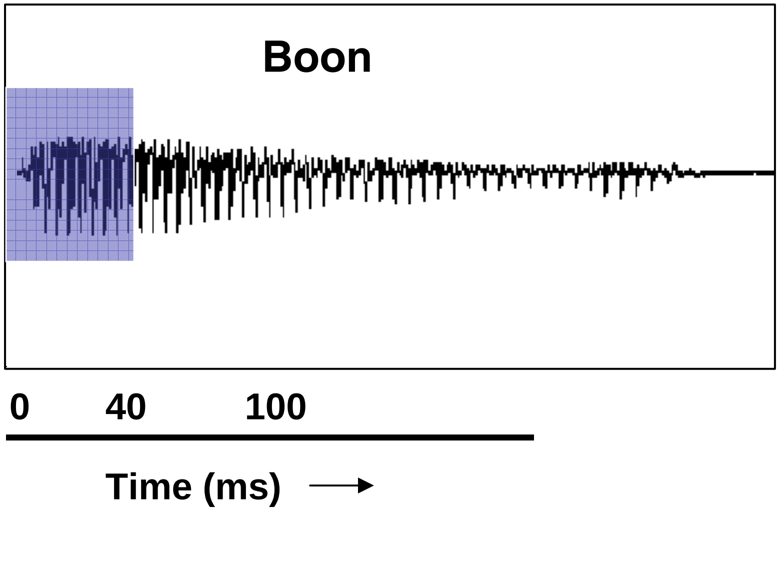


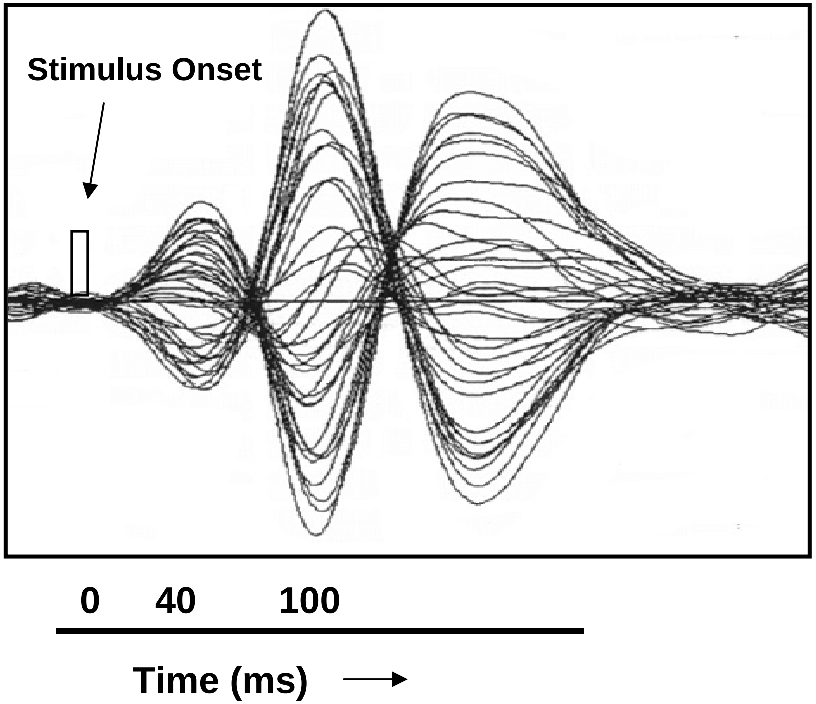
M100 amplitude reflects experience with speech sounds, with lower response amplitudes to novel speech-like tokens.



Roberts, Flagg, & Gage, 2004

A Temporal Window of Integration for the M100





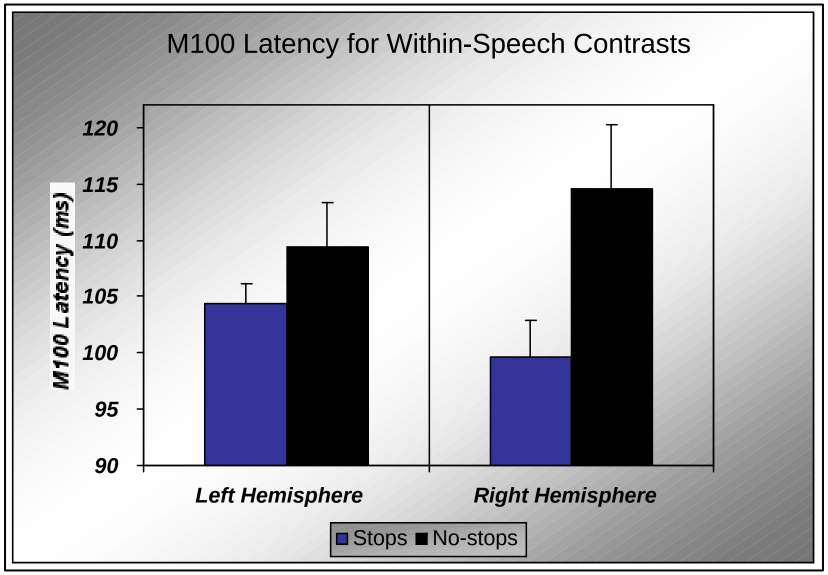
The M100 component has a brief (~35 ms) and finite integrative window during which stimulus attributes are accumulated in the processes leading to the formation of the M100 peak.

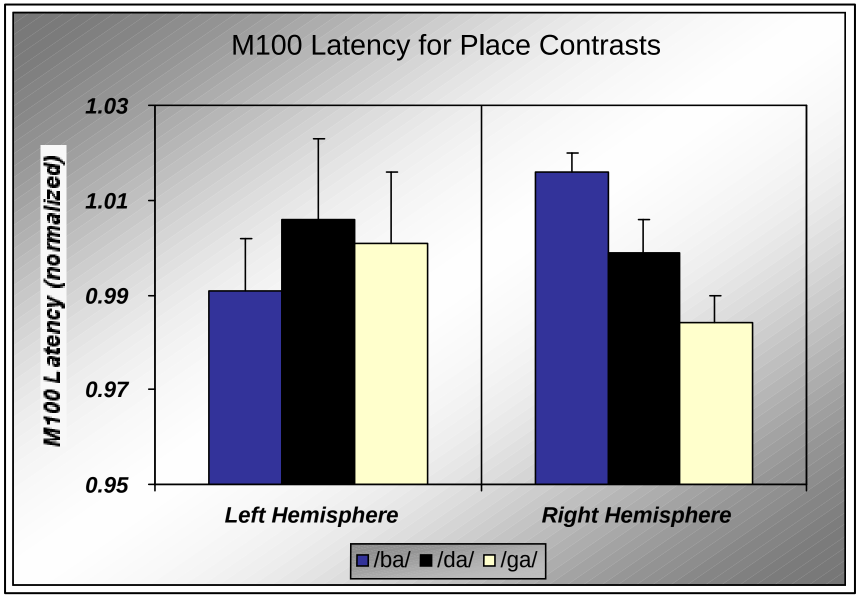
Within this integrative window, it is stimulus presence -- and not peak or integrated energy -- that dominates the processes underlying the M100.

Gage & Roberts, 2000

M100 is highly sensitive (within a brief integrative window) to transient features in consonants that cue distinctive feature contrasts in speech, such as manner and place of articulation, voicing.

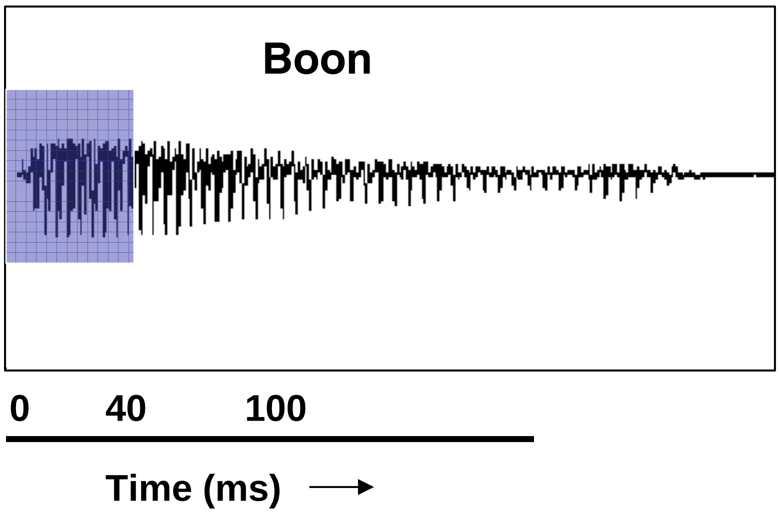
The selective activation of the M100 for some stimulus features (periodicity, formant transitions) and not others (absolute sound level) has led to its description as an intermediate processing stage between sensory (acoustic) and perceptual (representational) processing.

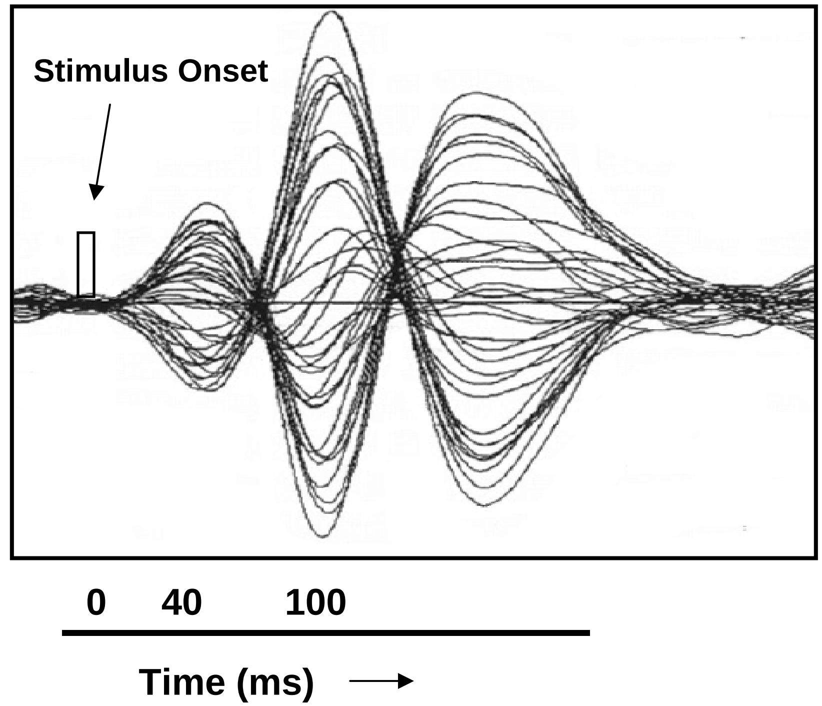




Gage et al., 1998, Gage et al., 2002

What is the Temporal Resolution for Resolving Brief Discontinuities in Sounds within the M100 Integrative Window?





Temporal Resolution of the Auditory M100: Gap Detection Experiments

Psychophysical investigations of auditory perceptual acuity frequently employ gap detection paradigms, where a silent gap is inserted in a tone or noise burst and the minimum detectable gap is measured

Gap detection thresholds correspond to speech perception acuity, indicating that similar or overlapping neural processes are employed both in detecting brief silent gaps and in resolving the fine structure of the speech signal.

The investigation: we know that the M100 is sensitive to the presence of a stimulus within a brief and finite integrative window.

What are the lower limits of the resolution for brief discontinuities – or the absence of a stimulus – within the M100 window of integration?

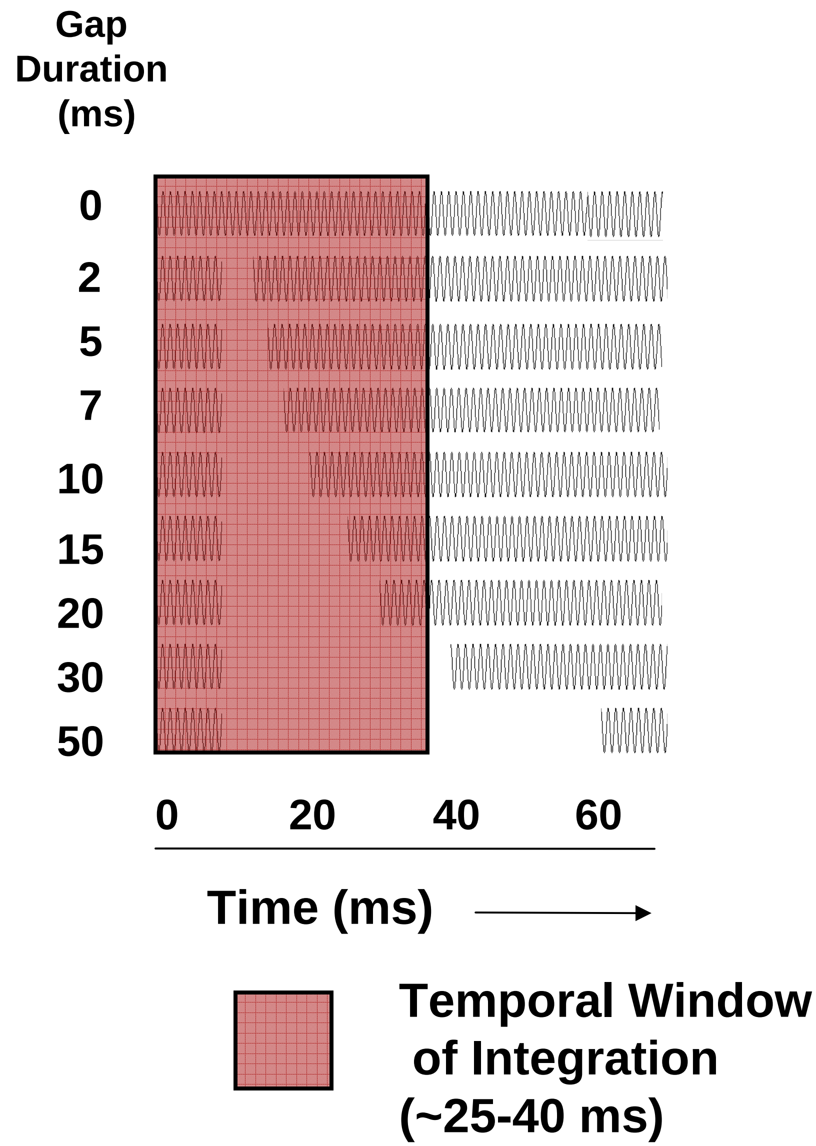
Gage, Roberts, & Hickok, In Press 2005

Temporal Resolution of the Auditory M100: Gap Detection Experiments

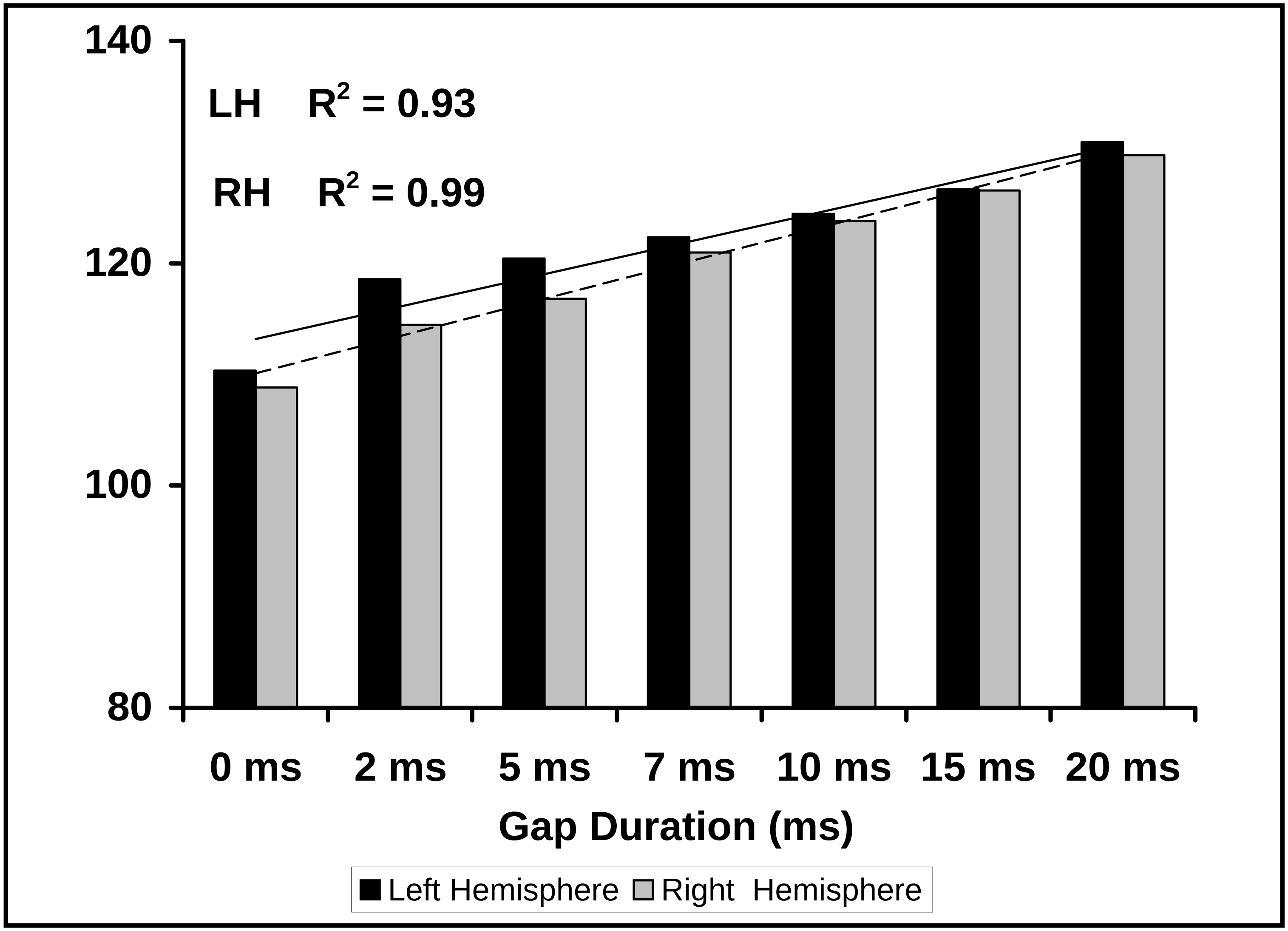
How sensitive is the M100 to fine-grained temporal discontinuities in sounds?

We address this question by inserting brief gaps of silence at +10 ms post stimulus onset and measuring M100 modulation as a function of gap duration.

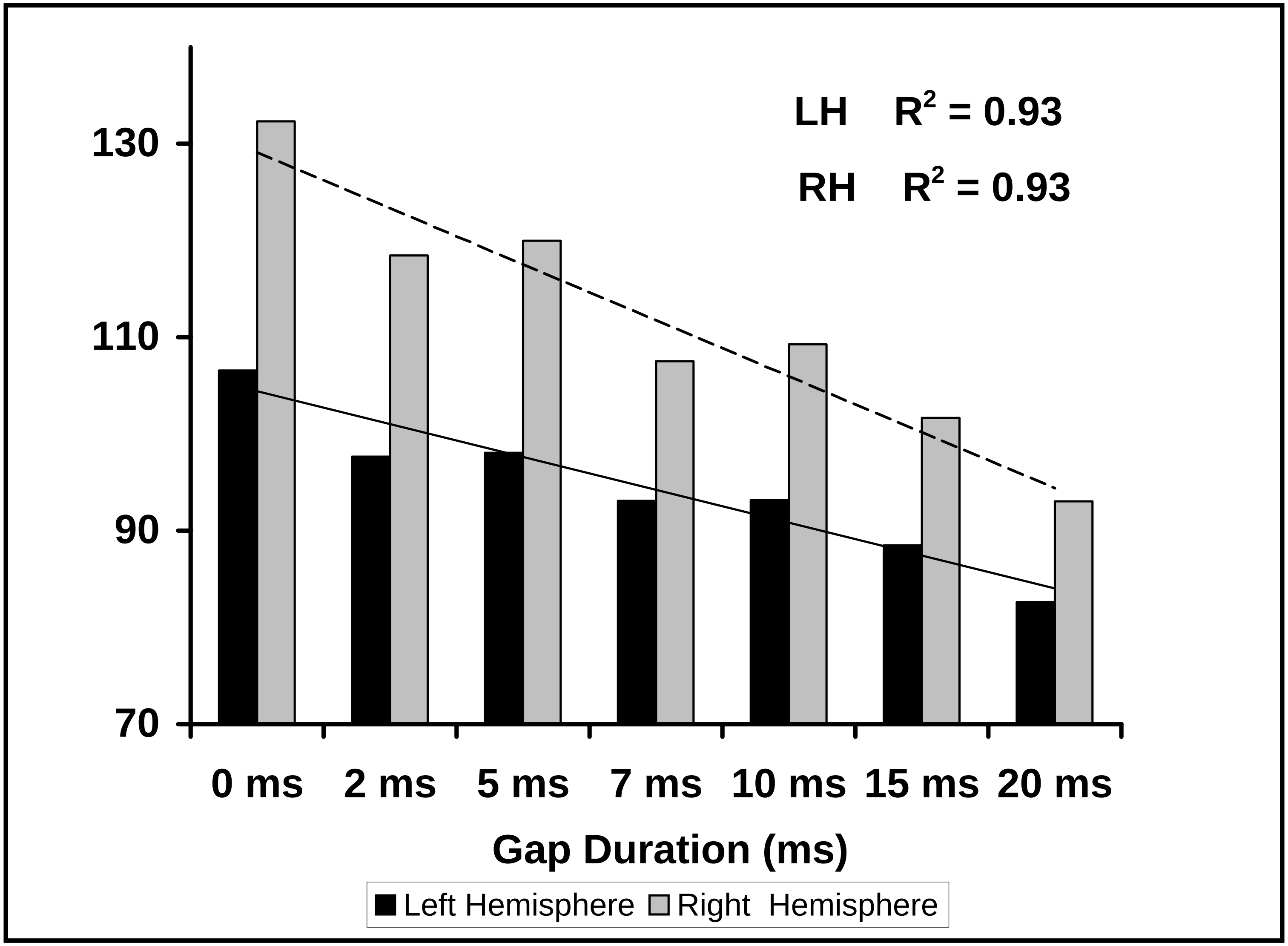
In a second condition, we inserted gaps at +40 ms post onset. Here we predicted that M100 would not be modulated by gaps of silence because the gaps were inserted outside the integrative window.



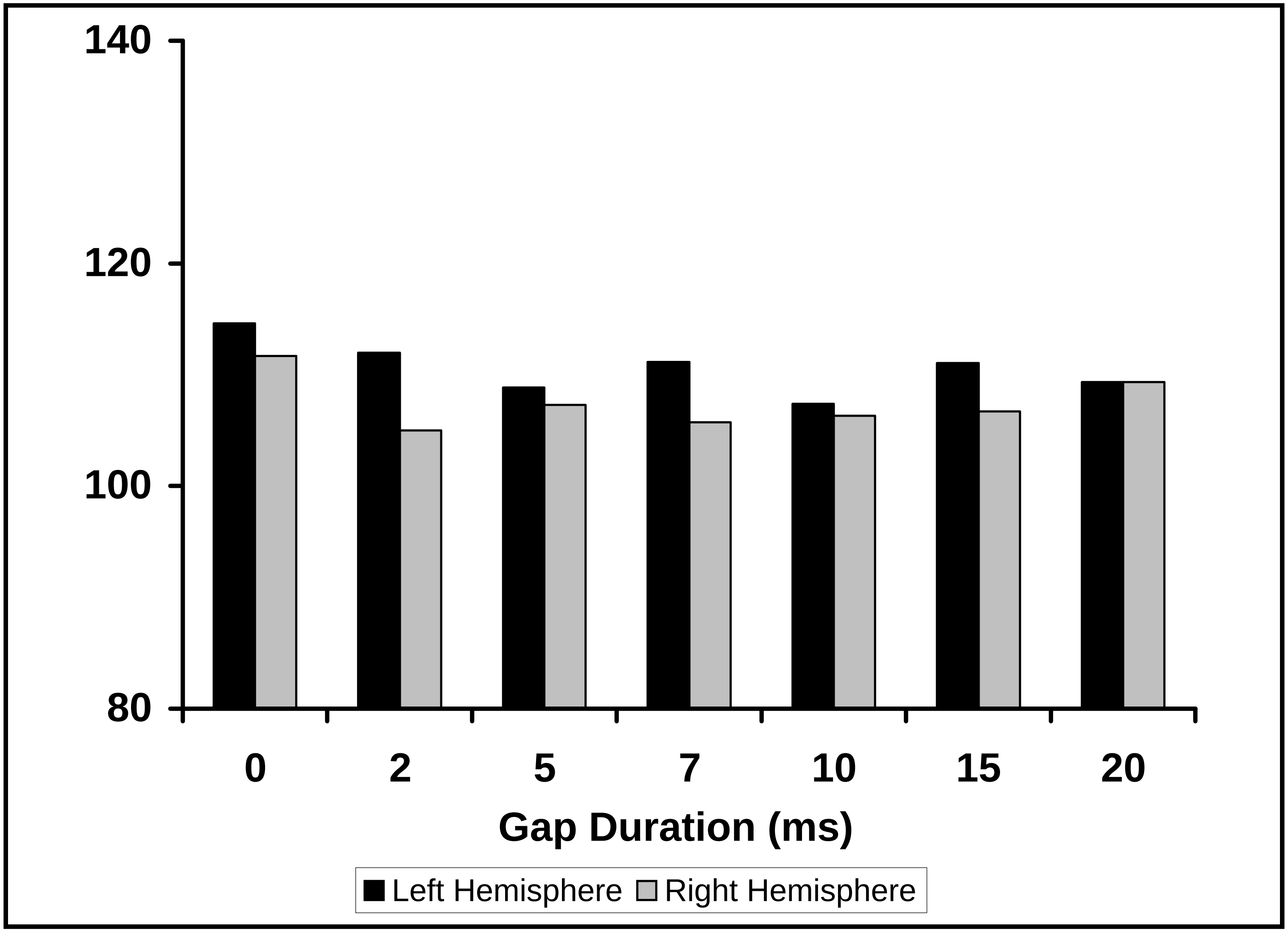
Results: M100 Latency is modulated by Gap Duration

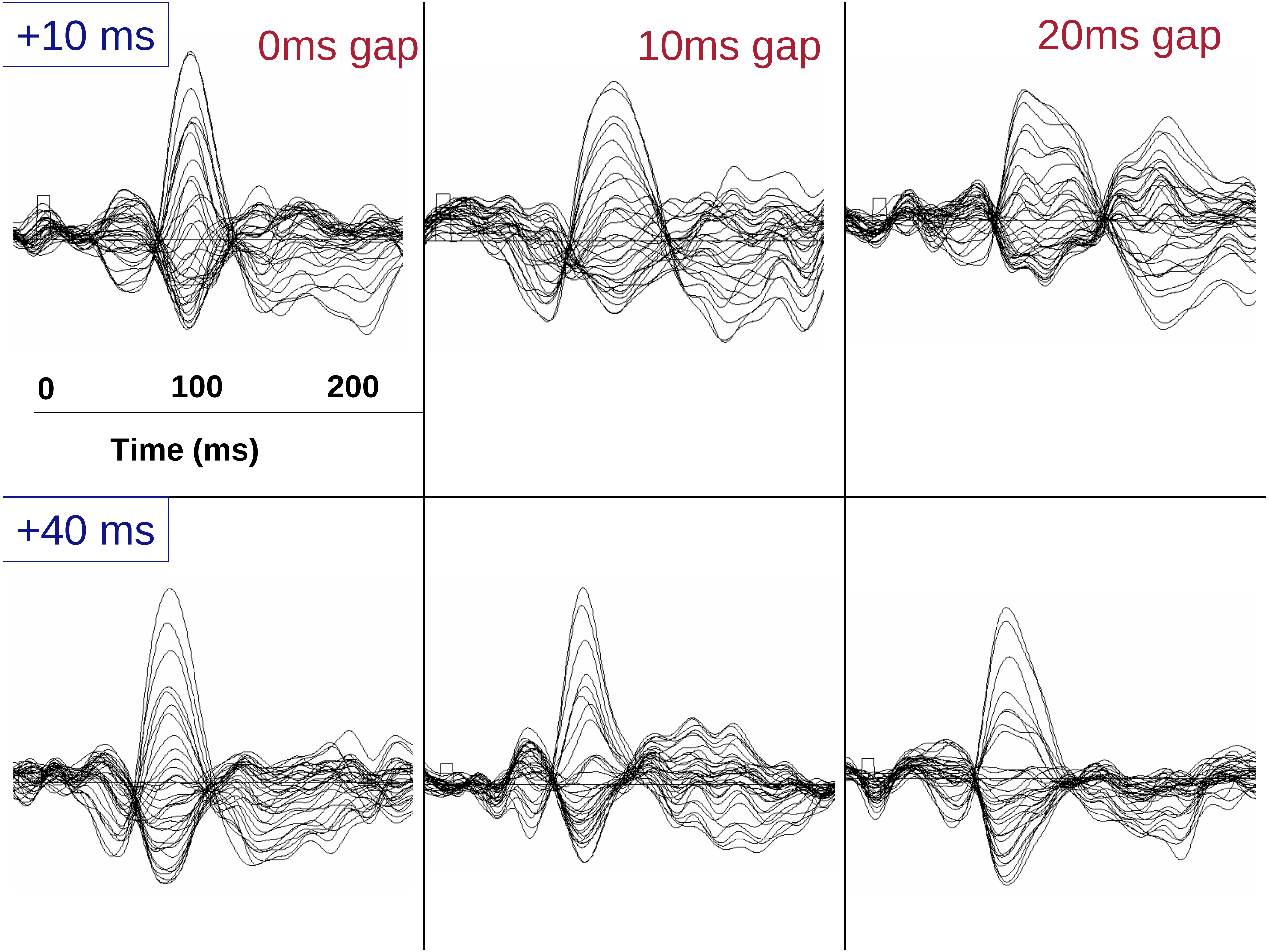


Results: M100 Amplitude is modulated by Gap Duration



Results: M100 is not affected when gaps are inserted at +40 ms post onset





+10 ms
0ms gap
10ms gap
20ms gap
0
100
200
Time (ms)
+40 ms

Conclusions

A Finite Temporal Window of Integration for the M100

These data provide further evidence for a short (~35 ms) and finite window of integration in the accumulation processes leading to the M100 peak.

Fine-grained Temporal Resolution of the M100

The integrative processes underlying M100 formation are highly sensitive to fine-grained discontinuities in sounds.

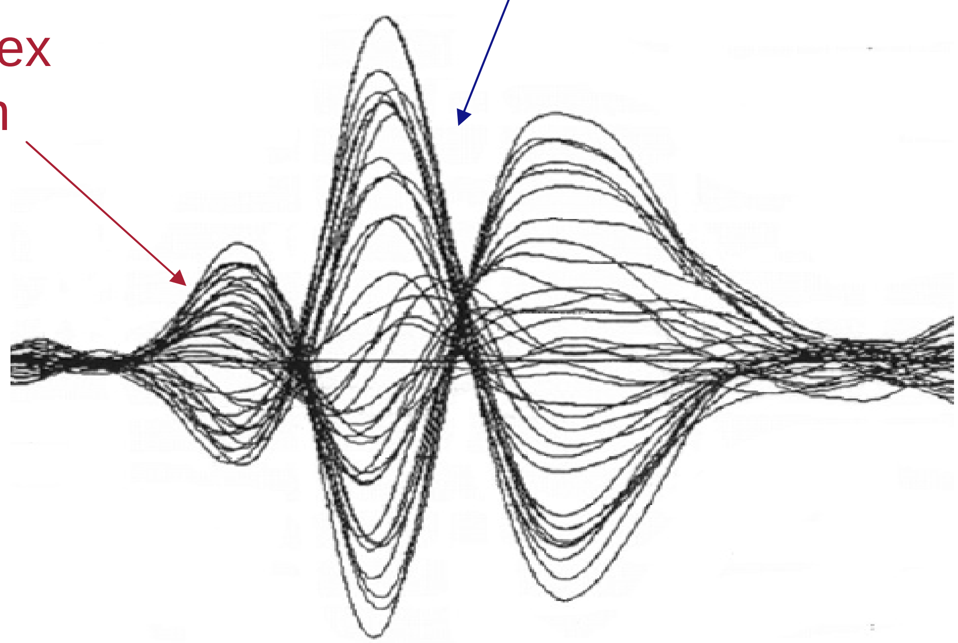
M100 sensitivity to the shortest gap (2 ms) corresponds to clinical and behavioral measures of auditory acuity, where detection thresholds have been reported for gaps of <5 ms.

The Time Course of Auditory Cortical Processing

Integrative Windows for the M50 and M100 Components Reflect Underlying Sensory and Perceptual Mechanisms

M100 - ~35 ms TWI
Secondary Auditory Cortex
Feature Discrimination Processes

M50 - ~10 ms TWI
Primary Auditory Cortex
Detection, Habituation
Mechanisms



Gage, Hickok, & Roberts, 2005

The CNL Team …