KYUSHU UNIVERSITY 2011
100th Anniversary

What underlies between-frequency gap detection?

Shuji Mori

Kyushu University

2014 Symposium on Across-Channel Processing in Human Audition
Niagara-on-the-lake, Canada, 2014/08/06

KYUSHU UNIVERSITY

‘What’ and ‘Where’

What makes BF gap detection so difficult?

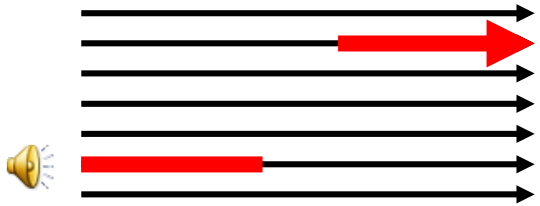
- Across-channel processing
  - Relative timing/attention shift
- Channel bandwidth
- Onset cue

Where in auditory pathway does it take place?

- Peripheral
- Central
  - Primary auditory cortex

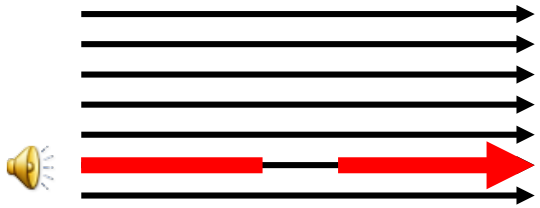
Relative timing

Monitoring offset of leading and onset of trailing marker (Phillips, 1999)



Reflects central processes

Discontinuity detection



Performed peripherally

Attention shift

Auditory attention

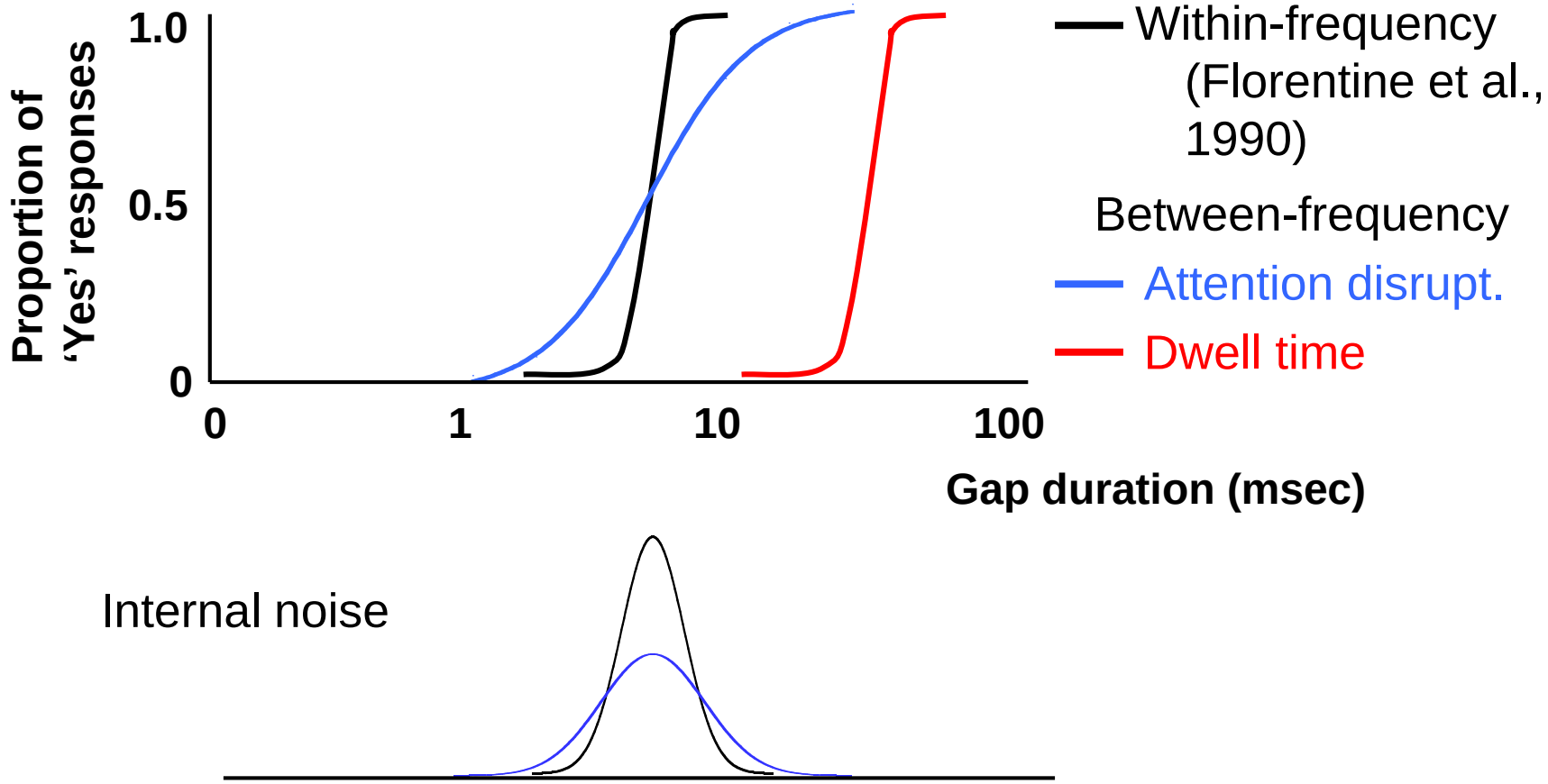
- Directed to frequency channel (attention band; Scharf et al., 1987)
- Enhances auditory processing

Two hypotheses

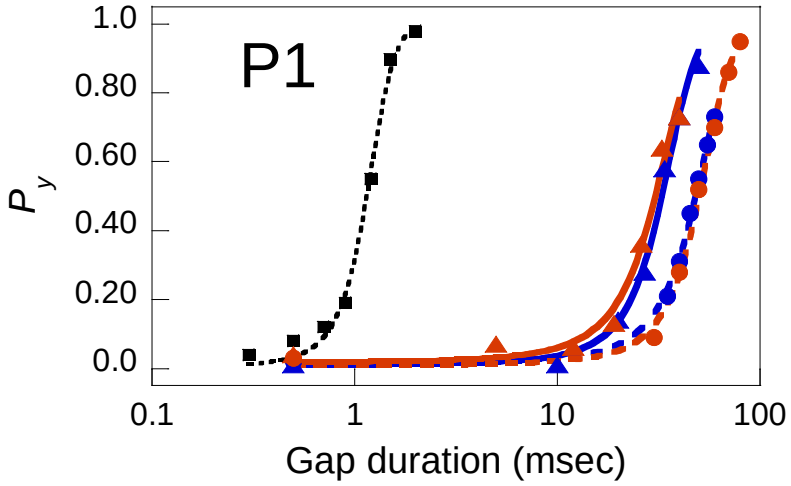
1. Attention dwell time (Fitzgibbons et al., 1974)
   - Minimum time spent at one channel before shifting to another channel
2. Attention disruption (Phillips et al., 1997)
   - Imprecise time-stamping when shifting to unattended channel

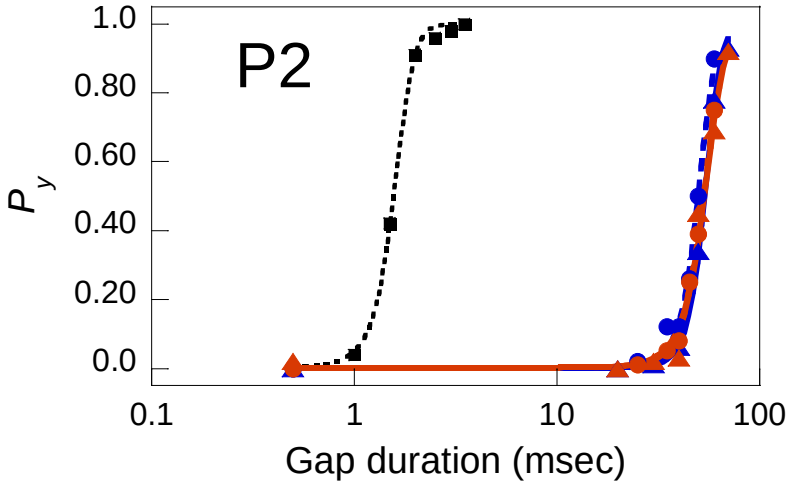
Can be differentiated in terms of **psychometric function** (Kikuchi et al., 2014)

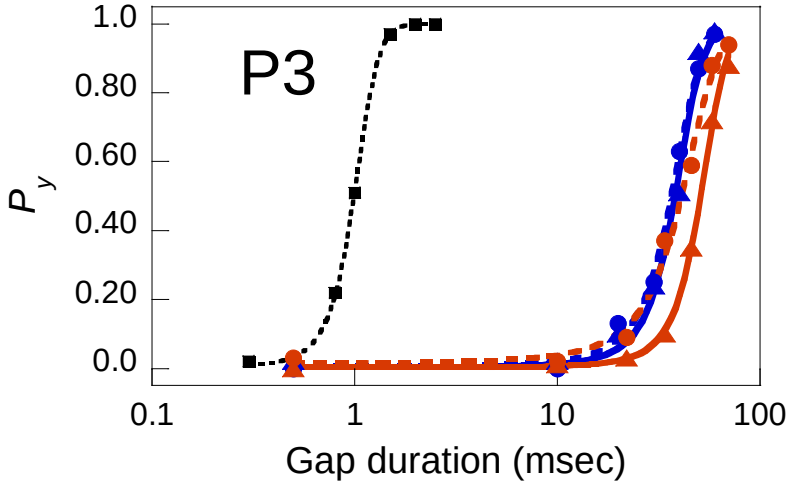
Psychometric function

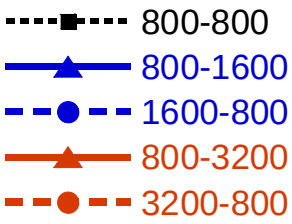


Kikuchi et al. (2014)









Problems on attention shift

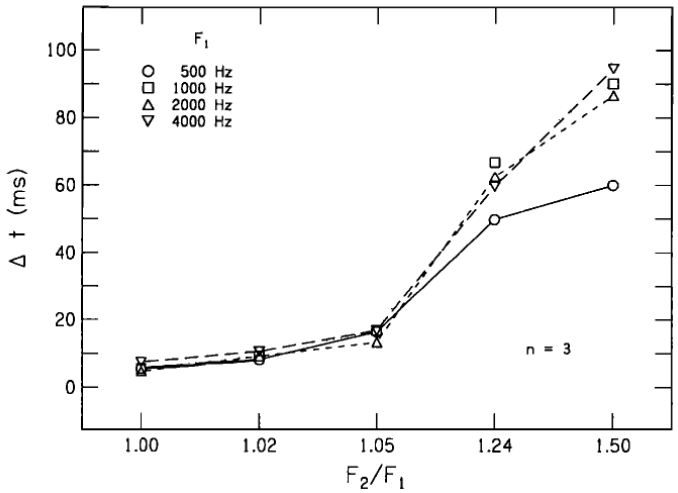
- Attention shifts instantaneously (Scharf et al., 2007)
- Attention can be directed to multiple frequencies (Schlauch & Hafter, 1991)

No study yet to manipulate attention in BF gap detection

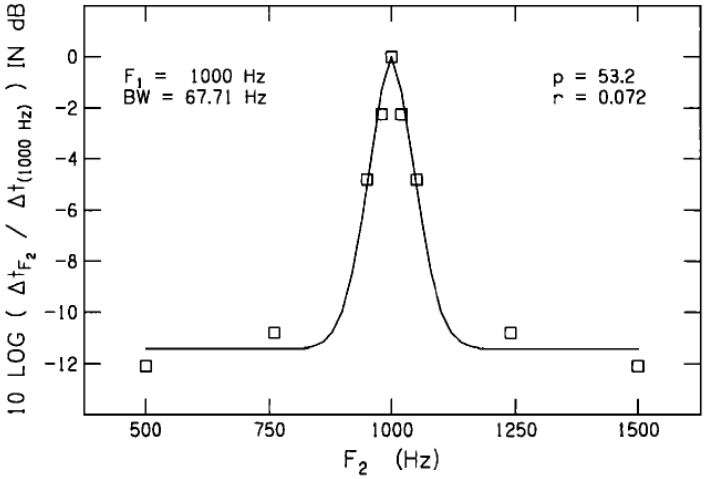
Channel bandwidth

Formby & Forrest (1991)

Estimate channel bandwidth from BF gap detection



(Formby & Forrest, 1991, p.834, Fig.3)

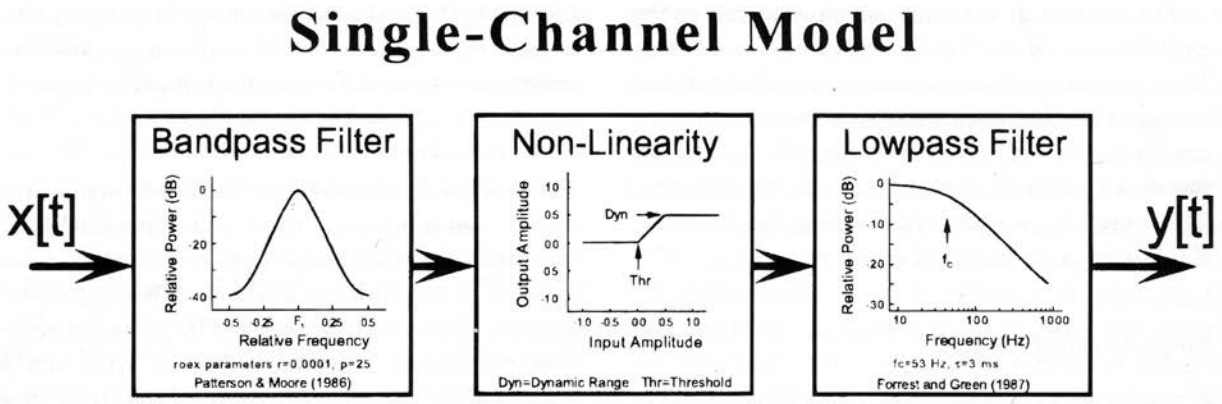


(Adapted from Formby & Forrest, 1991, p.836, Fig.4)

About half of bandwidth of typical auditory filters (e.g. Patterson & Moore, 1986)

Channel bandwidth

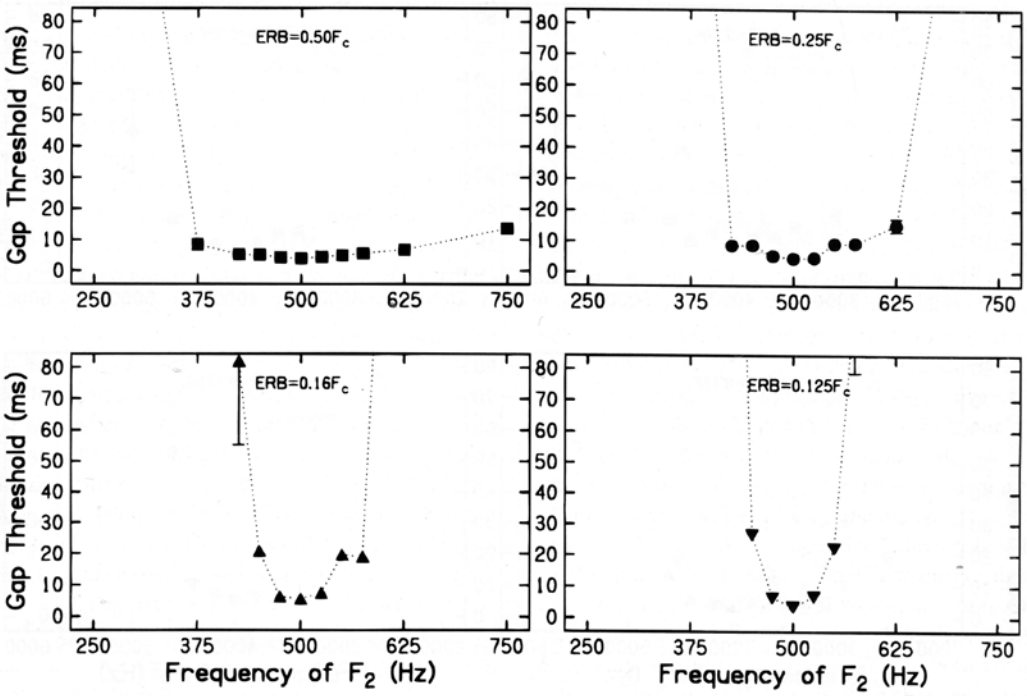
Single- and multiple-channel models (Forrest & Formby, 1996; Heinz et al., 1996)



(Forrest & Formby, 1996, p.24, FIGURE 1)

Channel bandwidth

Single- and multiple-channel models (Forrest & Formby, 1996; Heinz et al., 1996)



(Forrest & Formby, 1996, p.29, FIGURE 5)

Gap thresholds reflect *narrowed* channel bandwidth

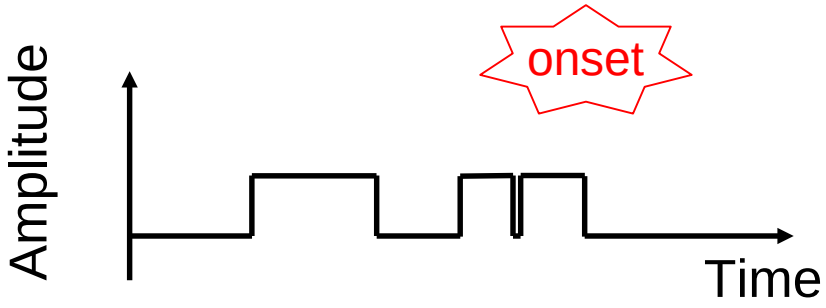
Problems on bandwidth account

No explanation of why channel is narrowed under BF gap detection

Empirical evidence lacking for effect of bandwidth on gap detection

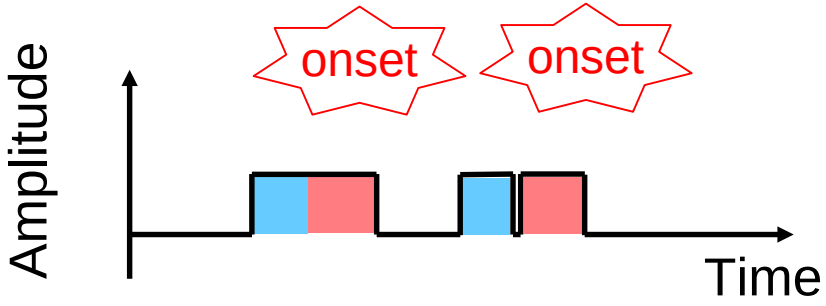
Trailing marker onset

WF



Can be accomplished by onset detection (≈discontinuity detection)

BF



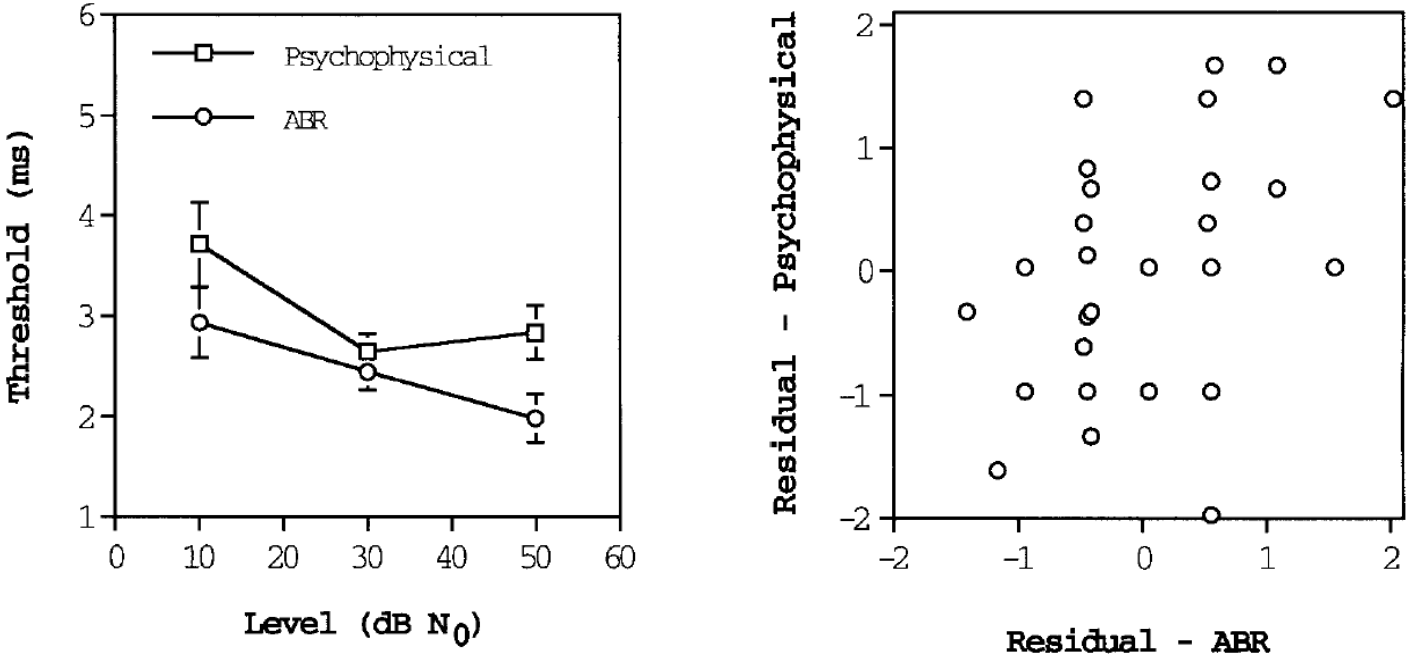
Onset cue unreliable

Onset account

Availability of TM onset cue distinguishes between WF and BF gap detection

- Neuronal onset responses match WF gap detection

  Werner et al. (2001)



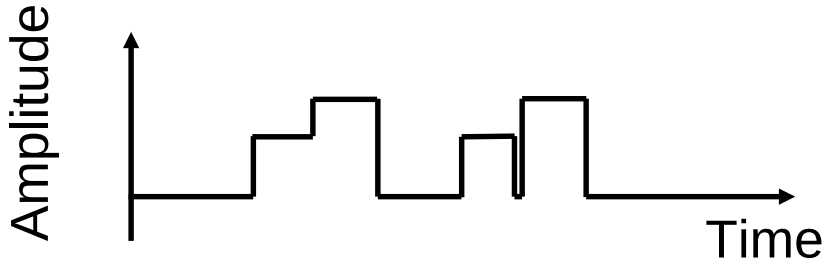
(Werner et al., 2001, p.741, Figures 2 and 3)

Onset account

- Reducing onset-cue availability impairs gap detection

  Oxenham (2000)

  Inducing amplitude difference to two WF markers



Worsens gap detection to *BF level*

Grose et al. (2007)

Presenting secondary tone with TM worsens BF gap detection

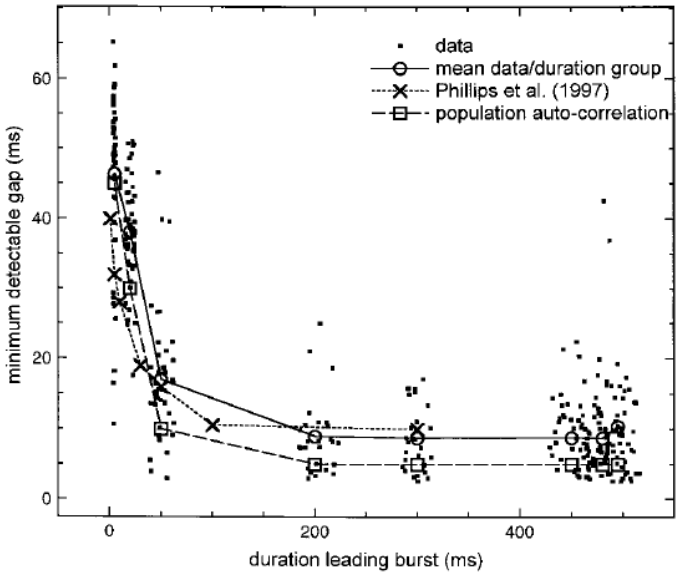
TM onset obscured by the tone

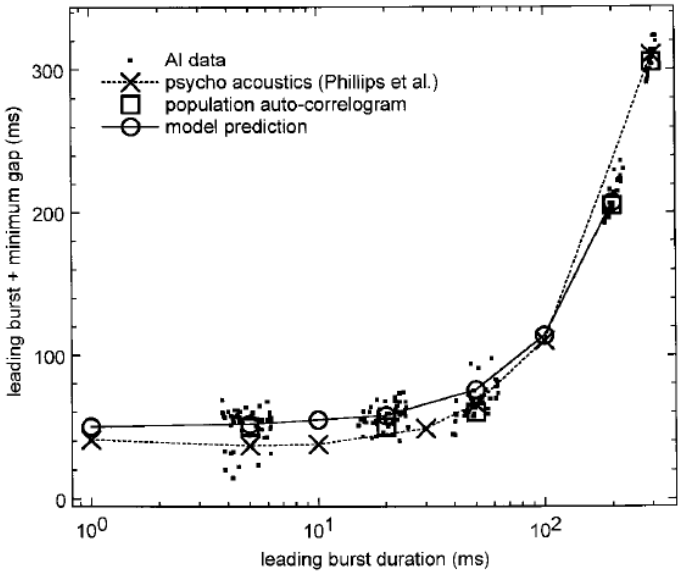
Onset account

Eggermont (2000)

Single-cell recording at cat auditory cortex

Manipulating LM duration





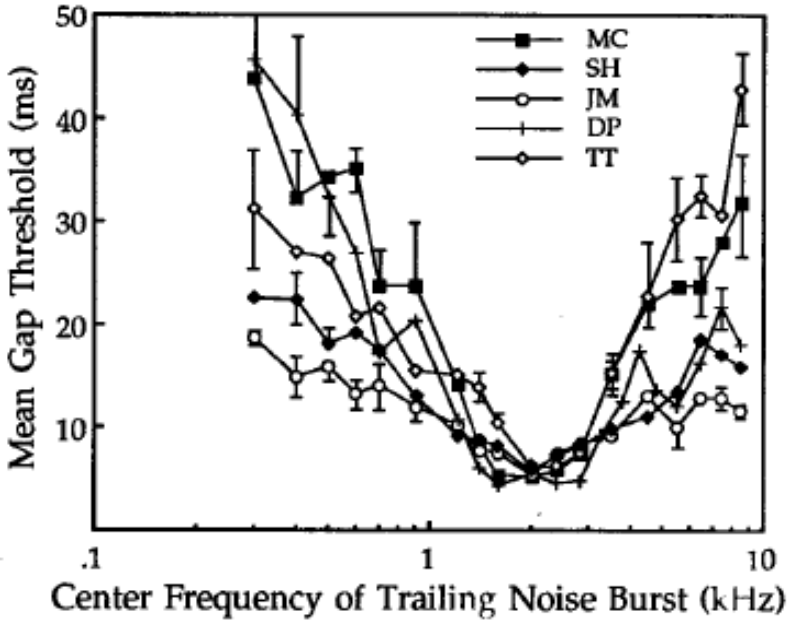
(Eggermont, 2010, pp.1458, Fig.6; pp.1459, Fig.7)

TM onset responses appear **40-55 ms after** LM onset

Corresponds to behavioral data (Phillips et al., 1997)

Problems on onset account

- Only explains qualitative categorical difference between WF and BF
  - Unable to deal with **frequency separation effects** on BF gap detection



(Phillips et al., 1997, JASA, pp.3697, Fig.2)

‘Where’ in auditory pathway

Peripheral

Auditory filter (Formby & Forrest, 1991; Forrest & Formby, 1996)

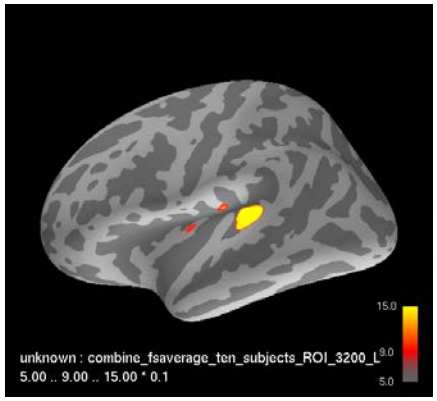
Central

Channel monitoring (Phillips et al., 1997)
Attentional operation (Fitzgibbons et al., 1974)

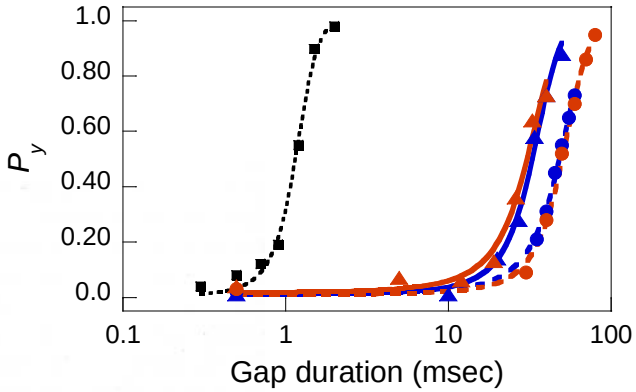
Primary auditory cortex

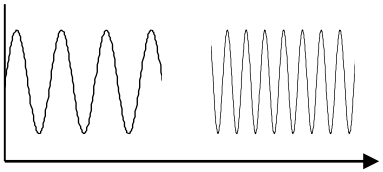
- Broadly-tuned onset-sensitive neurons (Eggermont, 2000)
- Comparable MMN for WF and BF generated near PAC (Heinrich et al., 2004)
- Frequency-separate regions of onset responses (Mitsudo, Hironaga)

Our approach



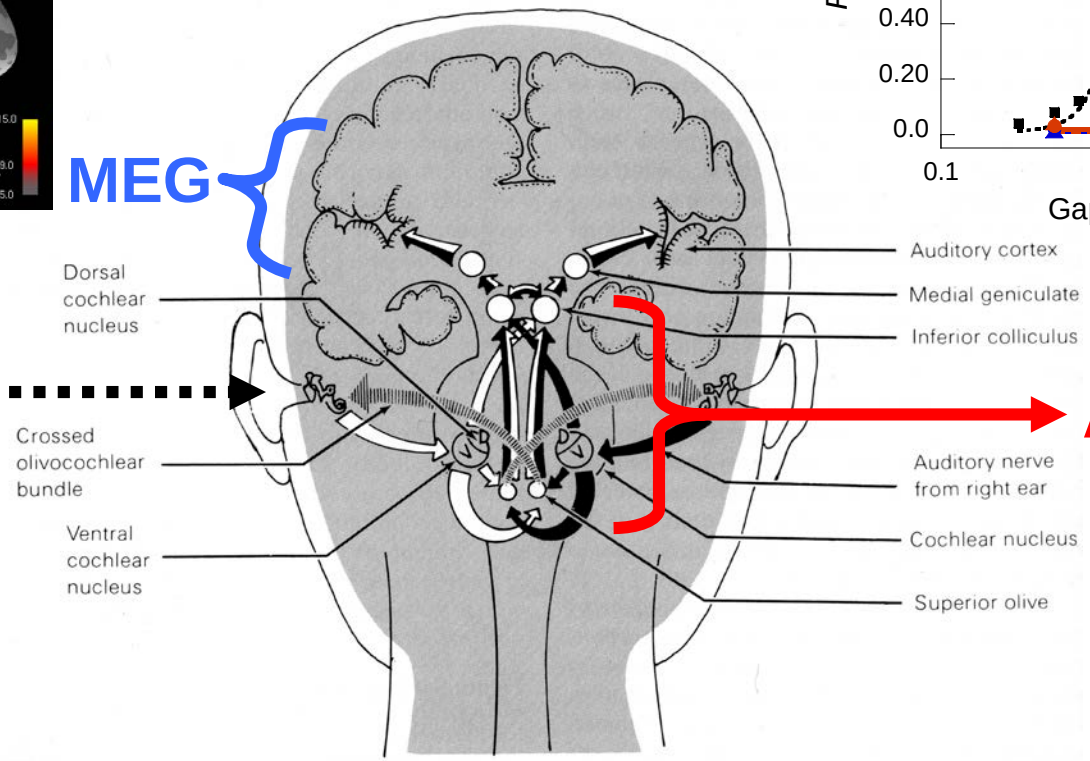
Psychophysics





MEG

ABR



(Coren et al., 1994, Sensation & perception, pp.204, Fig.6-17)

Auditory brainstem response

Reflects onset responses of auditory nerves and brainstem neurons

Mostly measured to WF TM onset

Werner et al., 2001; Poth et al., 2001

Grose et al. (2007)

Measured ABR to BF TM onset consisting of two-tone complex

Method

Participants

10 healthy male students (mean 22.9 yrs)

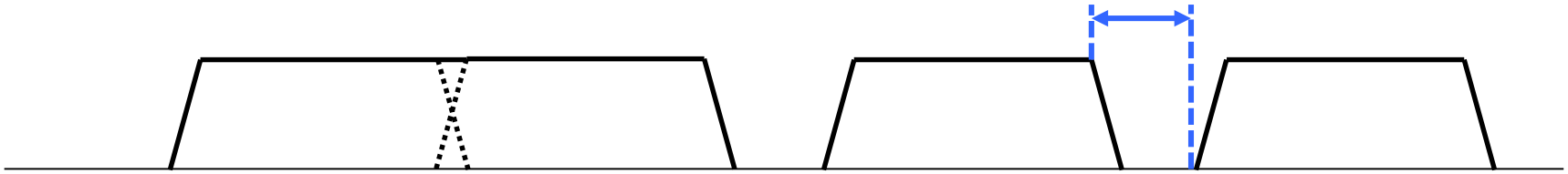
Stimuli

LM & TM – 0.5-oct. bandnoise of 50 ms (rise/fall 3 ms) 45 dB SPL
monaurally presented to left ear

LM/TM center frequency (Hz):
800/800, 800/1600, 1600/800, 800/3200, 3200/800

No gap

Gap duration

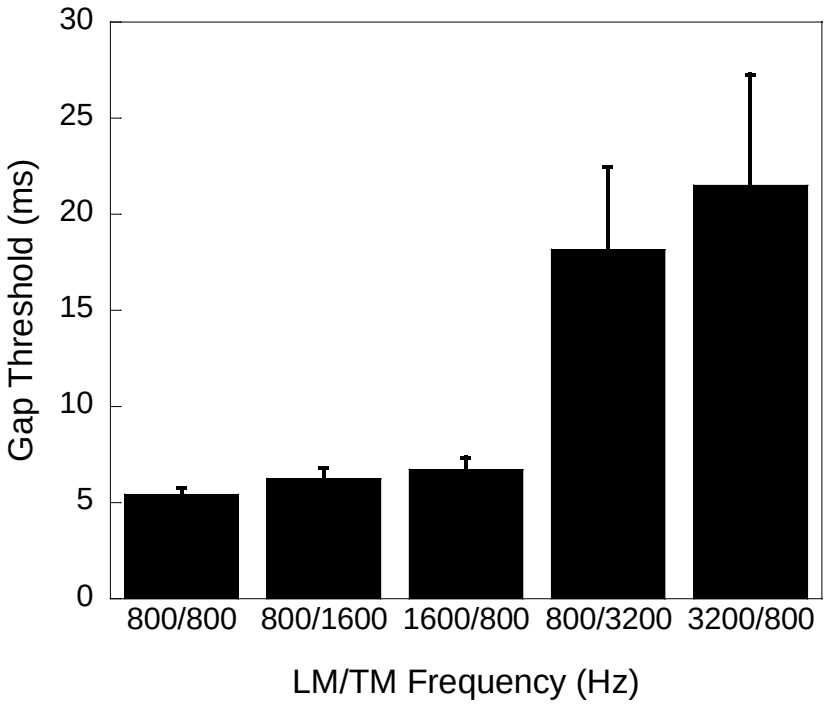


Method

Procedure

threshold measurement

2IFC 1-up 6-down procedure to obtain 89.1% accuracy gap thresholds



Method

ABR measurement

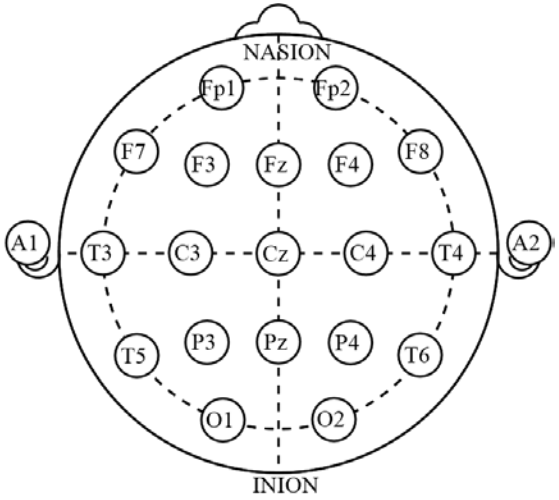
Gap durations set to 0 (no gap), and 0.5, 1.0, and 1.5 times of individual gap thresholds for each LM/TM frequency

2000 presentations for each gap/frequency at 3-Hz rate

Recorded at Cz with a reference at A2 and a ground at Fpz

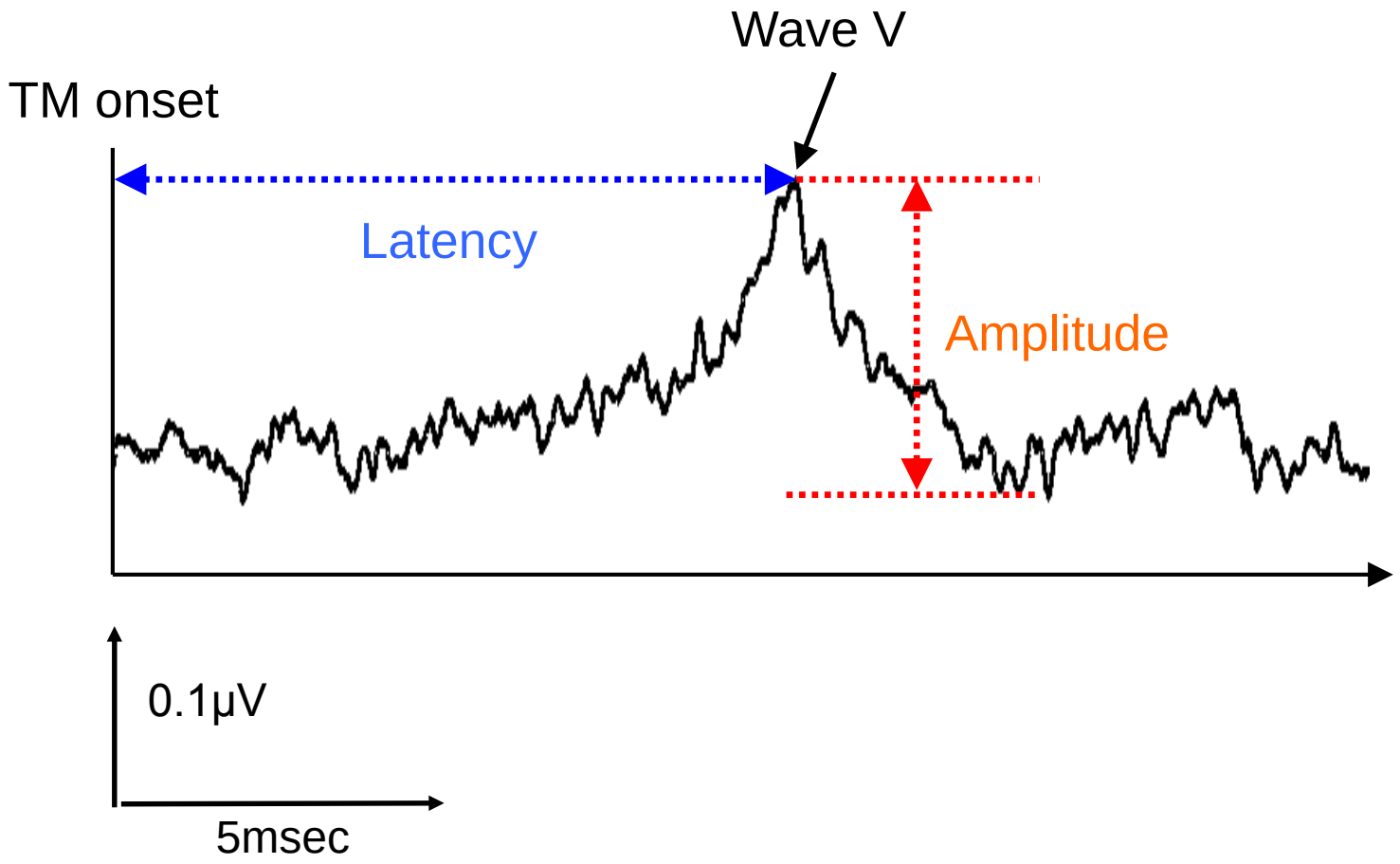
Band-pass filtering between 100 and 3000 Hz

100 kHz sampling rate



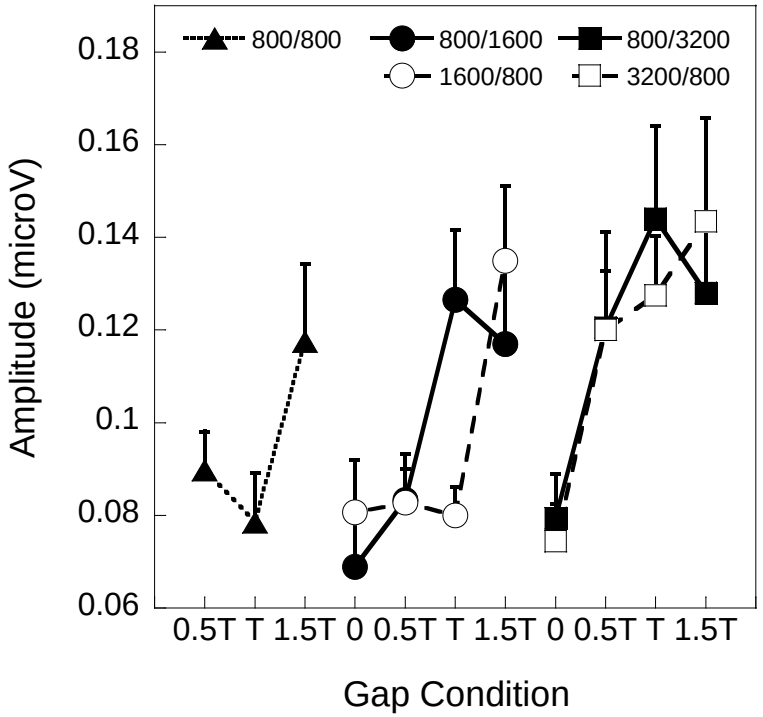
Method

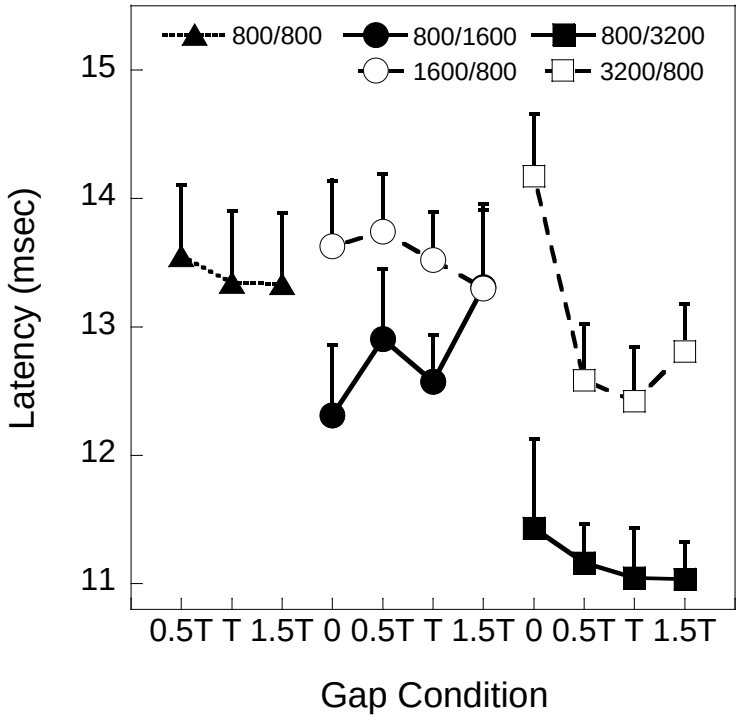
Amplitudes and latencies extracted from individual ground averages



Results

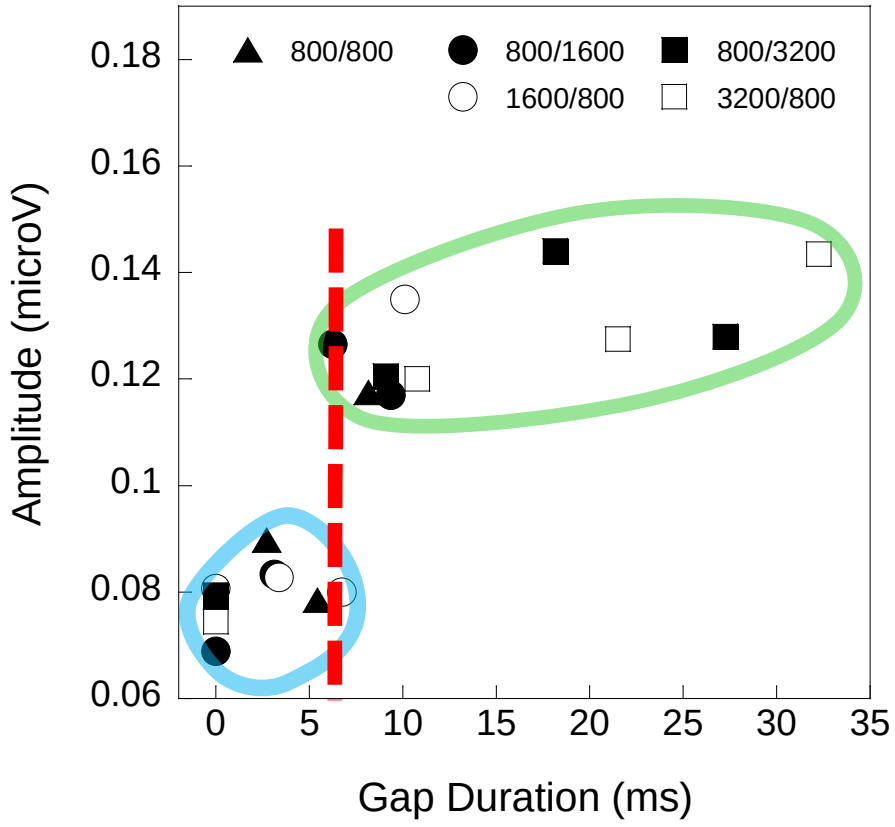
Mean amplitudes and latencies of 10 ps





Results

Mean amplitudes as a function of gap duration in ***ms***

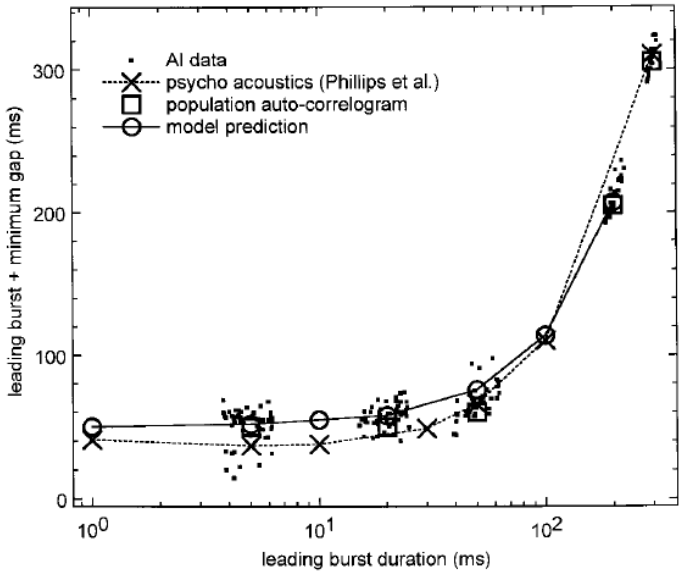


6~7 ms
+ 50-ms LM duration
≈ **55-ms** from LM onset

Discussion

Increased ABR amplitude (TM onset response?) at ~**55 ms** after LM onset

- TM onset responses appear **40-55 ms after** LM onset (Eggermont)



(Eggermont, 2010, pp.1459, Fig.7)

Discussion

- ABR to TM onset reflects physical duration rather than psychophysical threshold
  - ✓ TM onset response is not a sole determinant of gap threshold
  - ✓ Very high accuracy (89.1%) of gap detection criterion may contribute to the discrepancy
  - ✓ LM duration needs to be manipulated
- ABR reflects broadly tuned mechanism
  - ✓ Low (suppressed?) ABR observed for BF below 55 ms

Conclusion

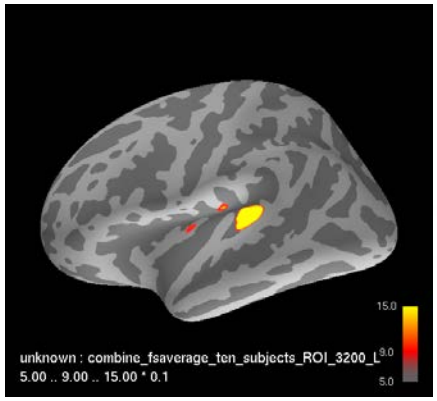
What makes BF gap detection so difficult?

- Unavailability of TM onset cue
- Other processes to be identified for frequency separation effect

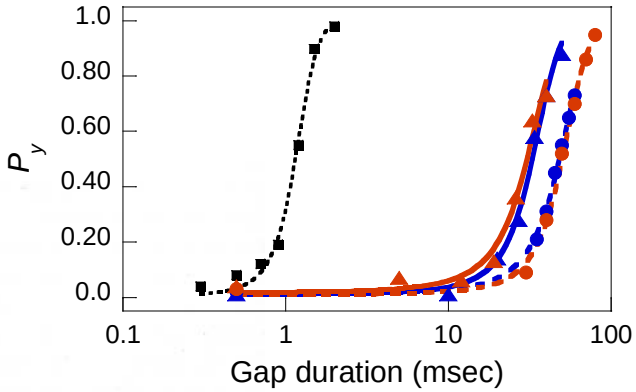
Where in auditory pathway does it take place?

- As early as brainstem for onset cue
- Primary auditory cortex
- Peripheral?

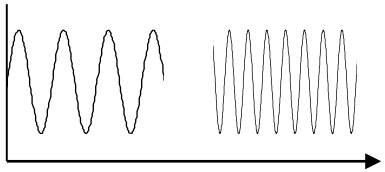
Comprehensive approach

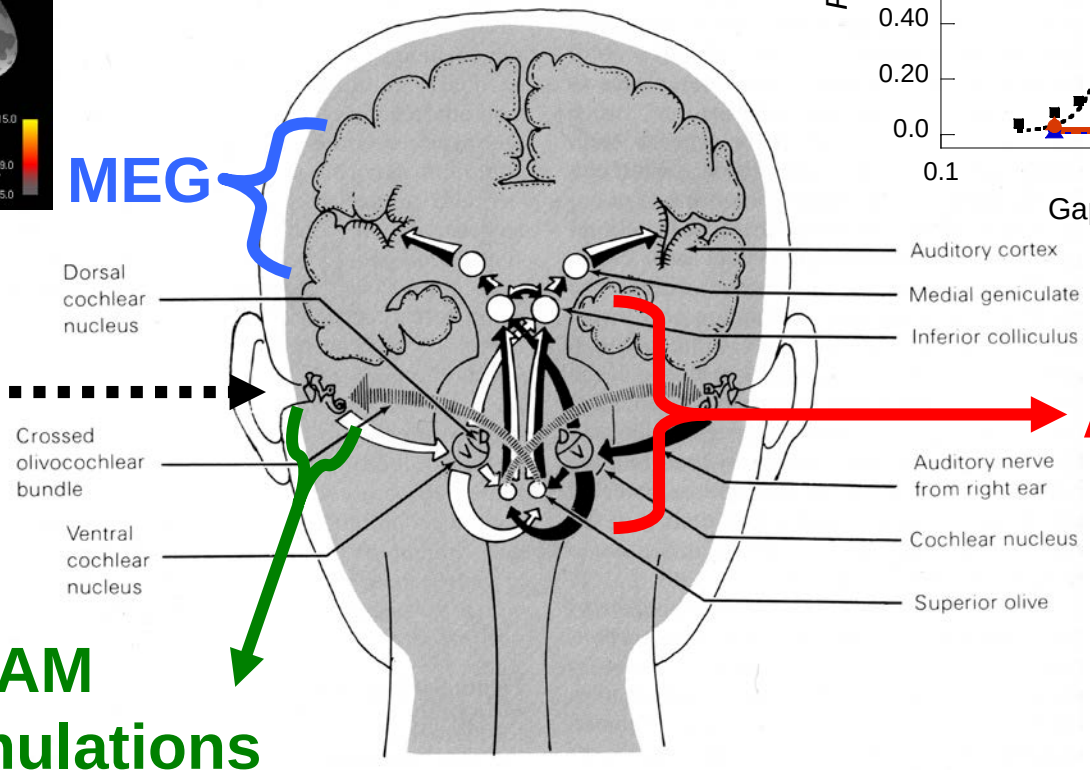


Psychophysics



MEG





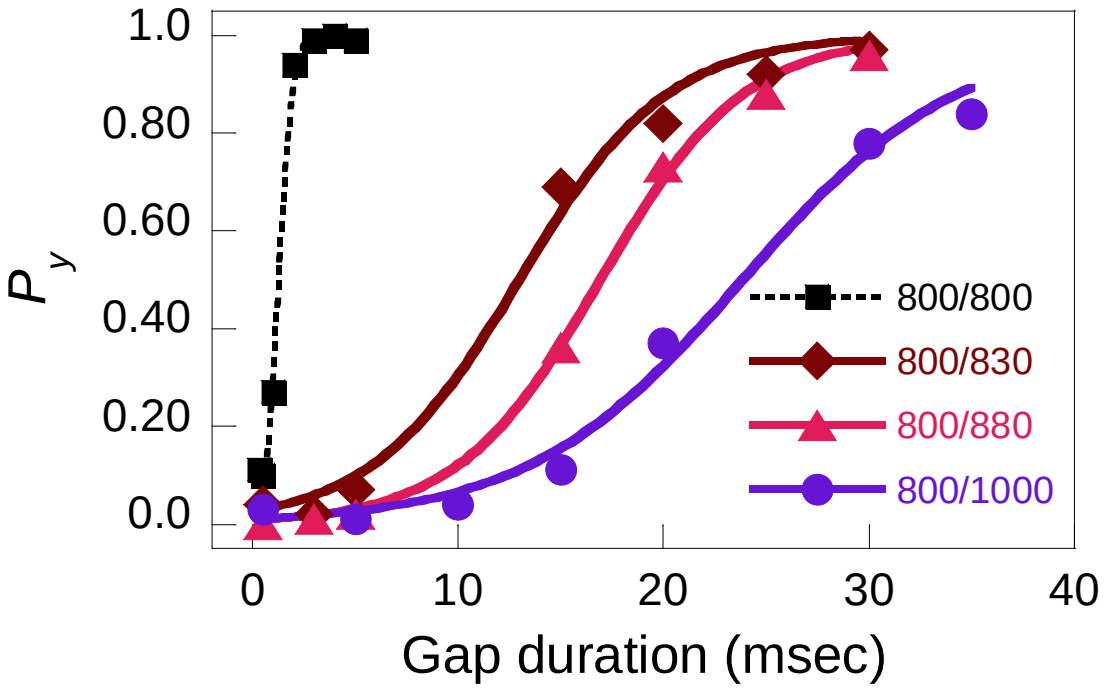
ABR

DSAM simulations

(Coren et al., 1994, Sensation & perception, pp.204, Fig.6-17)

Currently ongoing…

BF gap detection with close frequency separation



Followed by MEG, ABR, and DSAM

Acknowledgement

Kyushu University
Psychophysics lab, ISEE:

Nobuyuki Hiirose
Takako Mitsudo
Yousuke Kikuchi
0ther students
and staffs

Faculty of Medicine

Shozo Tobimatsu
Naruhito Hironaga

University of Toronto

Willy Wong

JSPS 独立行政法人 日本学術振興会 Japan Society for the Promotion of Science

一般財団法人 カワイサウンド技術・音楽振興財団 KAWAI FOUNDATION FOR SOUND TECHNOLOGY & MUSIC

Thank you for your attention