The GIN test and some clinical applications

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Lecture Outline

- Introduction
  - Auditory temporal processing
  - Temporal resolution/discrimination
  - Between and within channel gap detection
- Temporal basis of speech perception- some examples
- Development of the GIN© (Musiek et al, 2005)
- Case study
- GIN© results in some clinical populations
  - Patients with insular stroke
  - Patients with congenital abnormalities of interhemispheric pathway
  - Patients with stroke of the CANS: auditory processing deficits vs. disabilities
  - Patients with auditory neuropathy
- Conclusion

Introduction

- "Hearing… entails the successful online perceptual elaboration of the <u>short term</u> content of the acoustic signal"
- Phillips, J Am Acad Audiol 1999
- Different neural circuits may be responsible for encoding the different temporal features of the stimulus

Temporal processing

- Temporal ordering or sequencing
- Temporal resolution or discrimination
- Temporal integration or summation
- Temporal masking

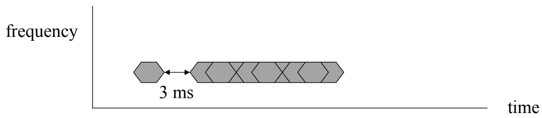
ASHA, 2005

Temporal resolution and discrimination

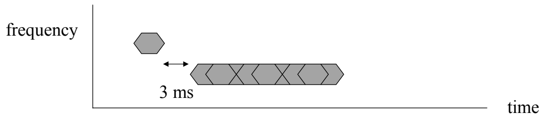
- The ability of the auditory system to respond to rapid changes in the envelope of a sound stimulus over time (Plack & Viemeister,1993) which underlies the ability of the listener to distinguish between two (brief) successive auditory signals
- **<u>Threshold</u>** for temporal discrimination: temporal acuity or minimal integration time (Green, 1971)
  - Temporal modulation transfer function, i.e. the listener's ability to detect modulation in a sound
  - **Gap detection threshold, ie the shortest gap within a sound that the listener can detect**

Gap detection

- Within channel design: the leading and trailing markers of the gap have common acoustic features (e.g., same spectral content, same laterality)



- Between channel design: the leading and trailing markers differ in ≥1 acoustic dimension, e.g. in frequency content:



Between vs. within channel gap detection

- May depend on different timing mechanisms:
  - Between (but not within) channel gap detection thresholds increase for leading marker <30s
  - Between channel gap detection thresholds show larger intersubject variability than within channel gap detection thresholds
  - Performance in one gap detection task poor predictor of performance in the other in the same listeners
- Philips, 1999; Philips et al., 1997; Philips and Smith, 1999

Within channel gap detection

- Long gap –silent period in carrier vs. short gap – discontinuity ("glitch") in homogeneous sound

Philips 1999

- Better performance for high vs. low centre frequency narrowband signals
- Gap thresholds decrease for increasing signal bandwidth for all centre frequencies
- Best performance significantly above amplitude threshold with little, if any, improvement above a certain level

Shailer and Moore, 1983

Within channel gap detection

- Leading and trailing markers stimulate same set of auditory nerve fibres
- Representation of gap stimulus in time course of spike discharges of single cochlear fibres
- Dip or discontinuity in ongoing discharge rate of cochlear nerve fibres corresponds to behavioural gap thresholds

Zhang et al.. 1990

Some clinical notes

- Some elderly listeners may exhibit loss in temporal resolution which is unrelated to hearing loss (Schneider et al., 1993)
  - Sensory processing, peripheral or central
  - Cognitive factors
- Longer gap detection thresholds correlate with poorer speech discrimination in noise, even when the SNHL has been controlled for (Tyler et al., 1982)
- Longer gap detection thresholds correlate with poorer reverbant speech discrimination (Gordon-Salant and Fitzgibbons, 1993)

Temporal basis of speech perception – some examples

- Pitch contour at termination of a phrase is rapid change in fundamental frequency
- Duration cues important for identification of fricatives
- Cue for intervocalic stop is brief silent interval of few ms
- Vowels shorter when followed by voiceless consonant
- Second formant transitions (of < 40 ms) most important cue for place of articulation
- Voice Onset Time (VOT) (gaps in the speech stream)
  - (only) cue for distinguishing stop consonants with same place of articulation
  - VOT → categorical perception

Minimal APD Test Battery

- Behavioural
  - PTA
  - Performance – intensity functions for word recognition
  - Dichotic tests
  - Duration pattern sequence test
  - **Temporal gap detection**
- Electrophysiological
  - Immitance audiometry
  - OAEs
  - ABR and MLR

Consensus Conference on APD in Children, 2000

The Gaps-In-Noise (GIN) test

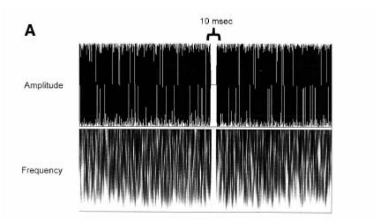
- "Developed to provide a clinically feasible means for evaluating gap detection abilities in a variety of clinical populations, with a special focus on patients with central auditory disorders."
- Musiek et al., Ear & Hearing 2005

Subjects

- Group I (control) 50 normal subjects (14 m, 36 f) aged 13 to 46 yrs, (mean age = 24.6 yrs) with
  - pure-tone thresholds ≤ 20 dB HL across 250 - 8,000 Hz
- Group II (subjects) 18 subjects (14 m, 4 w) aged 20 to 65 yrs of age (mean age, 46.4 yrs) with
  - pure-tone thresholds ≤ 20 dB HL across 250 - 8,000 Hz
  - lesions involving (but not limited to) the central auditory nervous system (Galaburda & Sanides (1980; Musiek & Baran, 1986) on brain MRI
    - 9 brainstem (3 right, 4 left , 2 bilateral)
    - 9 cortex/subcortex (2 right, 6 left , 1 bilateral)

Stimuli and Procedures

- Computer-generated white noise uniformly distributed between - 32,000 and 32,000 with an RMS value of 32,000/sqrt(2). Sampling rate was 44,100 Hz.
- The noise was turned on and off instantaneously



Spectral and time displays of a noise segment with representative gap. From Musiek et al., 2005 *Ear & Hearing*

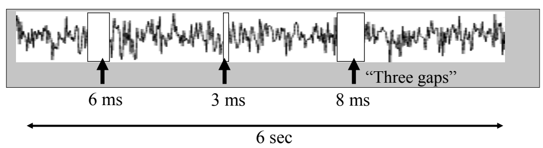
Stimuli and Procedures

- Gap durations of 2, 3, 4, 5, 6, 8, 10, 12, 15, 20 msec.
- Gap duration and location within the noise segments pseudorandomized.
- Number of gaps per noise segment is varied.
- Shortest interval between two consecutive gaps > 500 msec.

Stimuli and Procedures

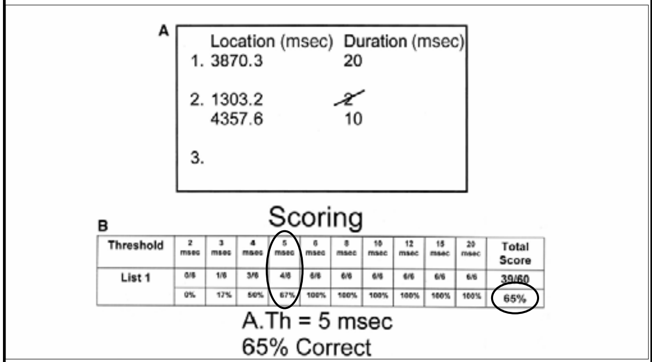
- Ten practice items
- Stimuli monaurally presented at 50 dB SL re: PTA
- CD with GIN stimuli, played on a Sony XE 270 CD player, routed through a GSI61 diagnostic audiometer to TDH-50 matched earphones.
- Test in a sound treated booth

Gaps In Noise test



- Listener has to identify gaps in each noise burst (press a button) + count gaps.
- six tokens for each gap duration in each list, 4 lists available for testing.
- Two measures, threshold and % correct score

GIN sample score sheet
From Musiek et al., Ear & Hearing 2005



A

	Location (msec)	Duration (msec)
1.	3870.3	20
2.	1303.2	~~2~~
	4357.6	10
3.		

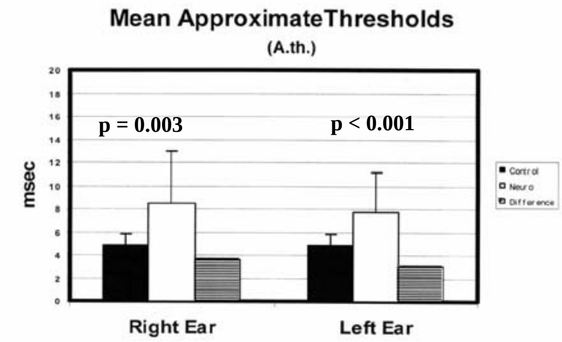
B

Scoring

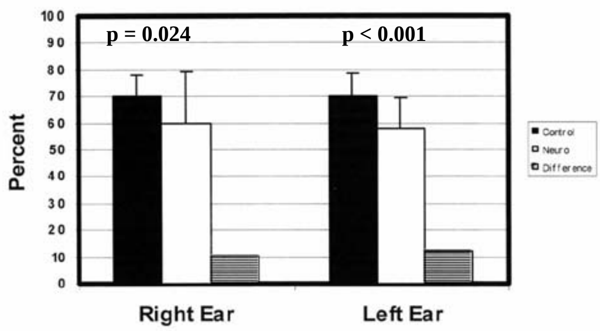
Threshold	2 msec	3 msec	4 msec	5 msec	6 msec	8 msec	10 msec	12 msec	15 msec	20 msec	Total Score
List 1	0/6	1/6	3/6	4/6	6/6	6/6	6/6	6/6	6/6	6/6	39/60
	0%	17%	50%	67%	100%	100%	100%	100%	100%	100%	65%

A.Th = 5 msec
65% Correct

Results
From Musiek et al., Ear & Hearing 2005



Results
From Musiek et al., Ear & Hearing 2005



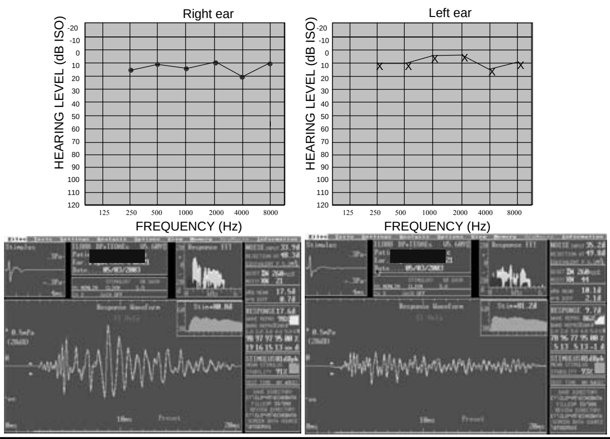
Clinical applicability

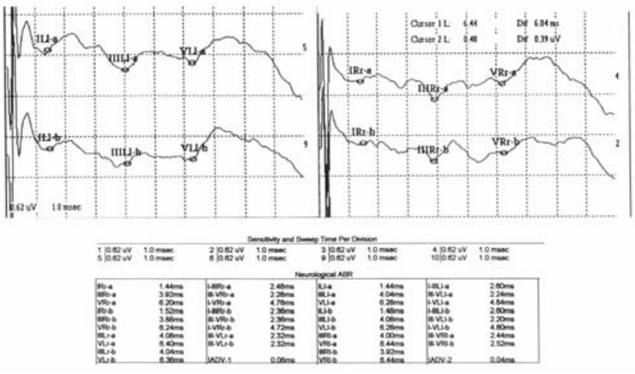
- Norms: 5-msec threshold (73% sensitivity and 84% specificity) and/or 62% cutoff for percent correct index (56% sensitivity and 87% specificity)
- No significant differences across lists for either ear (*p* 0.792).
- Test-retest reliability (*r* 0.95 and 0.88, *p* 0.01, Pearson product-moment correlations for right ear and left ears on 10 normal listeners).
- 17 min test time

Case study

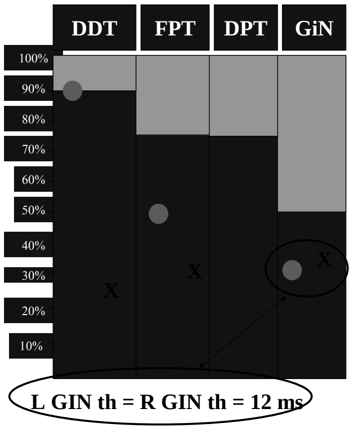
- C has complained of hearing difficulties since school (8 yrs old). Repeated PTAs have always been normal.
- His early speech and language normal.
- C finished school without educational support and obtained 3 O and 1 A levels.
- Aged 26 yrs, he saw a neurologist due to his brother being diagnosed with x-linked adrenoleukodystrophy (Demyelination - ↓ beta-oxidation of VLCFA in peroxisomes) and was diagnosed with X-ALD
- Bamiou et al., JAAA 2004

32 year old male with X-ALD





ARTs: absent both ipsilaterally and contralaterally at 2 and 4 kHz



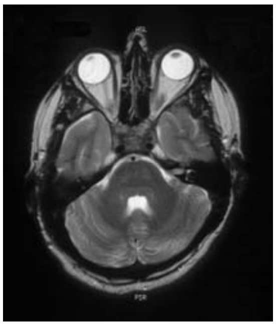
Reported difficulties:

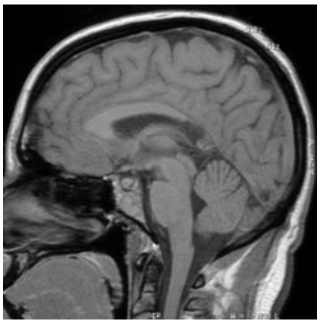
With speech in background noise

With degraded speech

No appreciation of music.

Bamiou et al., JAAA 2004



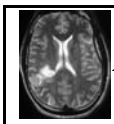
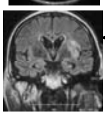


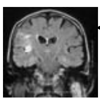
Bamiou et al., JAAA 2004

The GIN in clinical populations

I. Patients with insular stroke.

- Eight patients with stroke affecting the insula and adjacent areas and eight neurologically normal controls (matched to the patients for age, sex, handedness, and hearing thresholds).
- The lesion spared the adjacent auditory areas in three patients and included other auditory structures in five cases.
- Results of the gaps in noise test were abnormal in all the cases, contralaterally to the lesion in three and bilaterally in five cases.
- Insular lesions may affect central auditory function and, in particular, temporal resolution
- Bamiou et al., Neurology 2006



	Lesion	R th	L th
1	R STG, STG,post Ins	**8**	**8**
2	L STG, STG, post Ins	**10**	**8**
3	L total Ins –corona radiata	**8**	6
5	R putamen –Ins limen	**8**	**10**
6	L total Ins - frontotemp	**15**	4
7	R middle Ins (short gyri)	**12**	**12**
8	R total Ins +frontotemp	6	**8**
9	R total Ins + IFG	**10**	**8**



The GIN in clinical populations

II. Patients with congenital abnormalities of the interhemispheric pathway

- "*PAX6* mutations are associated with abnormalities of the human auditory interhemispheric pathway.
- We conducted central auditory tests (dichotic speech, pattern, and gaps in noise tests) on 8 *PAX6* subjects and 8 age- and sex-matched controls.
- Brain MRI showed absent/hypoplastic anterior commissure in 6 and a hypoplastic corpus callosum in 3 *PAX6* subjects.
- The control group gave normal central auditory tests results.
- All the *PAX6* subjects gave abnormal results in at least two tests that require interhemispheric transfer, **and all but one gave normal results in the GIN test"**

Bamiou et al., Ann Neurol 2006

The GIN in clinical populations III. Patients with stroke of the CANS: auditory processing deficits vs. disabilities

- Bamiou et al., submitted

The GIN in clinical populations IV. Patients with auditory neuropathy

- Bamiou et al., in preparation

Conclusion

- GIN is
  - Easy to administer
  - sensitive
  - Clinically useful in many different populations

Acknowledgements

- Linda M Luxon
- Frank E Musiek

- Martin Brown

- Rachael Taylor
- Tracey Draper