Hearing speech in noise Why is this interesting?

- Most speech is not heard in quiet.
- People vary a lot in how well they can understand speech in the presence of other sounds.
  - Auditory processing disorder (APD)?
- Hearing impairment makes perceiving speech in noise difficult.
- Effects of age
  - Ageing itself (≥60 y.o.) may lead to poorer speech perception in noise.
  - Younger children (≤12 y.o.) appear to be more affected by certain kinds of noise

Some determinants of performance: I

- The nature of the target speech material
  - context
    - e.g., the so-called SPIN test, Kalikow *et al*., 1977
    - Throw out all this useless …
    - We could have discussed the …
  - number of alternative utterances
    - listening for digits when given a telephone number vs. an individual's name
    - 'easy' (*mouth*) vs 'hard' (*mace*) words (see Bradlow & Pisoni, 1999)
      - tied to frequency of usage and size of lexical 'neighbourhoods'

Some determinants of performance: II

- The nature of the background noises
  - level (SNR)
  - spectral characteristics
  - genuine 'noise': periodic or aperiodic?
  - and/or other talkers
    - how many there are
    - speaking your own language or a language you don't know
  - How 'attention-grabbing' the background noises are

Some determinants of performance: III

- The configuration of the environment
  - Open air or in a room?
  - How 'dry' is a room?
    - effects of reverberation
  - spatial separation between target and noise
- or, the transmission system (e.g. mobile telephone)
  - distortion, reverberation, noise

Some determinants of performance: IV

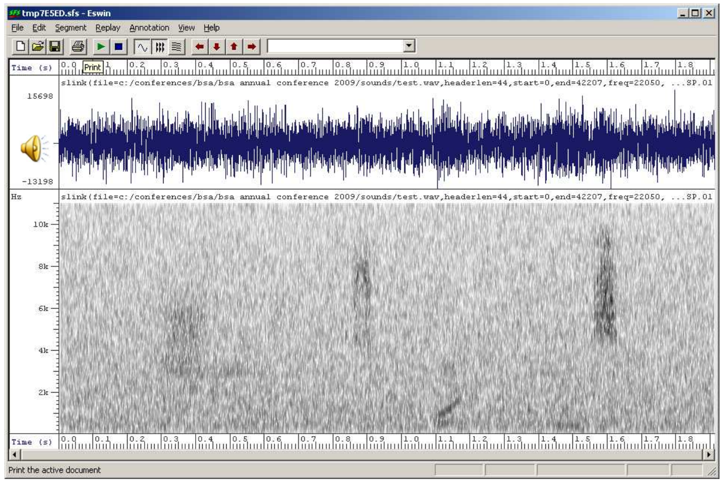
- Talker characteristics
  - Talkers vary considerably in intrinsic intelligibility
  - Talkers can vary their own speech depending upon demands of the situation (hyper/hypo distinction of Lindblom, 1990)
    - manipulations in vowel space, prosody, rate
  - Match between talker and listener accents
  - Individual familiarity

Some determinants of performance: V

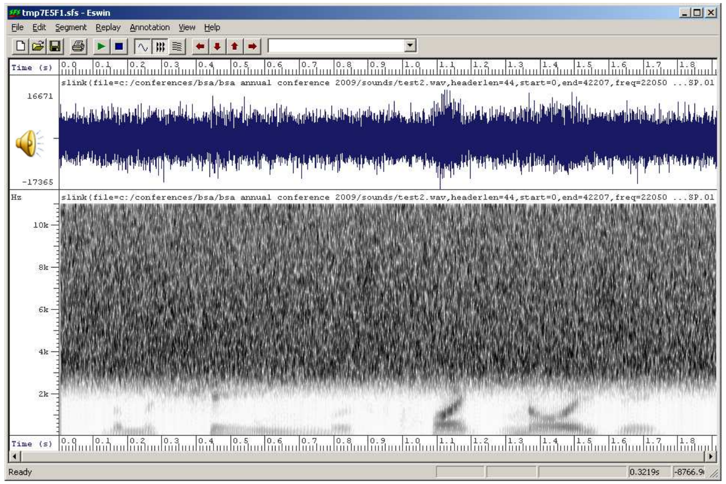
- Listener characteristics
  - Linguistic development
    - L1 vs L2
    - vocabulary knowledge
    - ability to use context
  - Hearing sensitivity and any hearing prosthesis used

Focus on factors more centrally related to audiology

The simplest case: A steady-state background noise



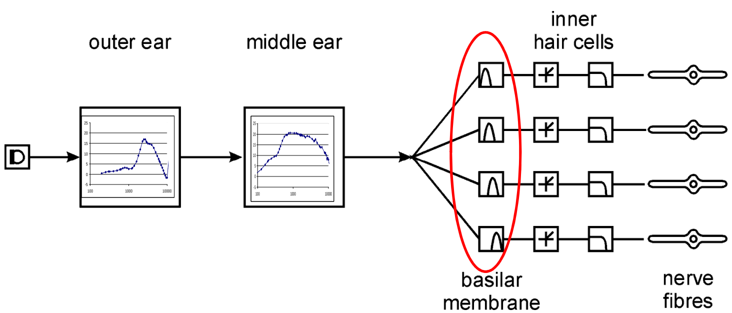
Much is understood about what makes one steady noise more or less interfering than another



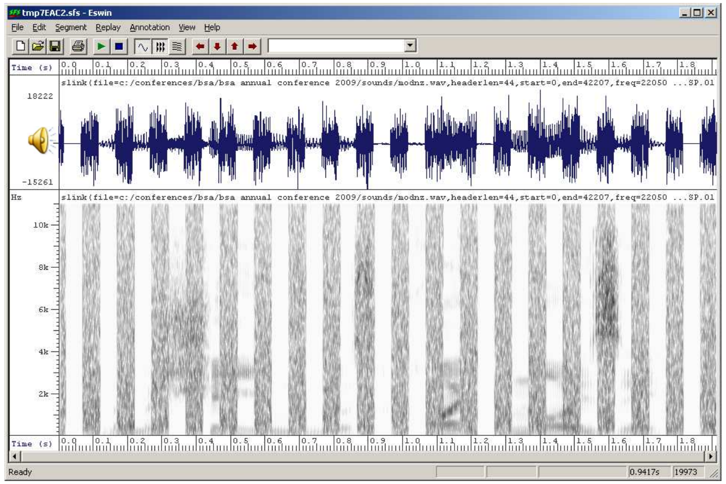
‘Energetic’ masking

- Noises interfere with speech to the extent that have energy in the same frequency regions
- Can be quantified in the ‘articulation index’
- Reflects direct interaction of masker and speech in the cochlea, which acts as a frequency analyser
- Hearing impaired listeners are more affected by steady noises …
  - because they typically have impaired frequency selectivity (wider auditory filters).

Better frequency selectivity keeps noise in its place



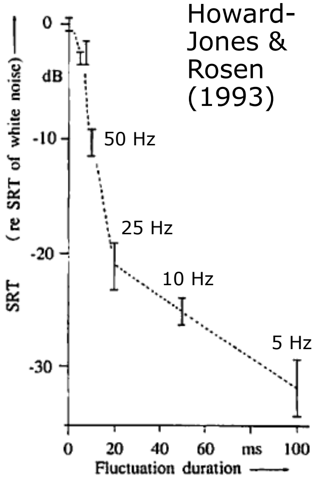
But noises are typically not steady …



‘dip listening’ or ‘glimpsing’

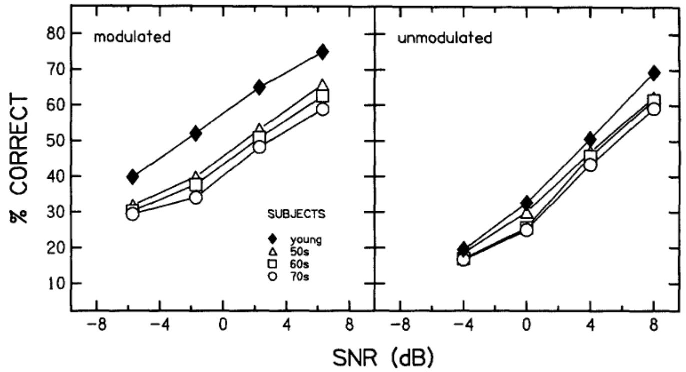
People with normal hearing can listen in the ‘dips’ of an amplitude modulated masker

The speech reception threshold for consonants in simple on/off fluctuations as a function of the duration of the fluctuation.



Howard-Jones & Rosen (1993)

Hearing impaired listeners have limited ‘glimpsing’ capabilities



Performance in the SPIN task as a function of SNR for modulated and unmodulated noises (not an effect of ageing) Takahashi & Bacon (1992)

Takahashi & Bacon (1992)

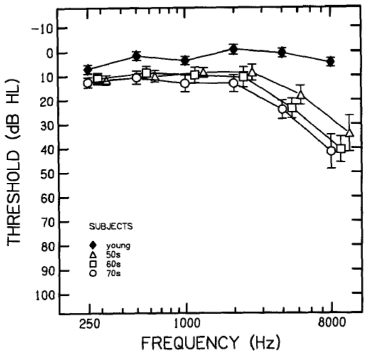


FIGURE 1. Mean pure-tone audiometric thresholds (in dB HL) for each subject group. The three older groups are represented by open symbols and the young group by closed symbols. Error bars indicate ±1 standard error. Data for the older groups have been shifted horizontally.

- SPIN low probability sentences
- SAM noise at 8 Hz, 100% modulation

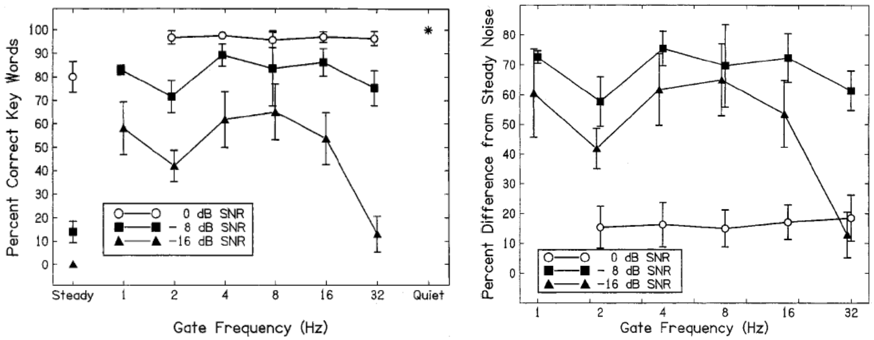
Why is ‘dip’ listening limited in hearing-impaired listeners?

- Audibility can be an influence
- Some of the lack of masking release may be due to SNRs being higher for HI listeners.
- Speculations that HI listeners are relatively insensitive to ‘temporal fine structure’ (TFS).
  - Processing the regularities in periodic sounds

little glimpsing for CI users Nelson *et al.* (2003)

speech-spectrum-shaped masking noise square-wave modulated added to IEEE sentences

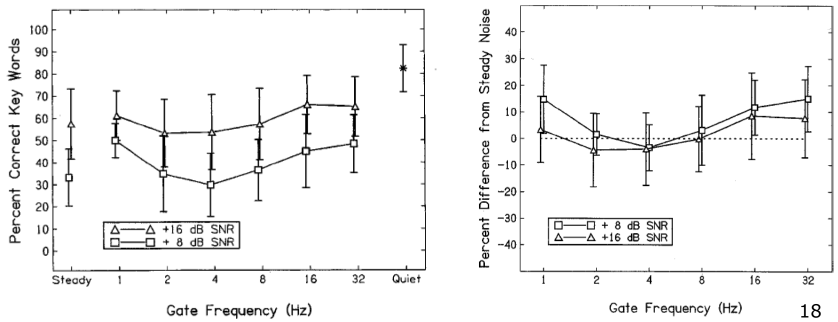
normal listeners



CI users

not only poor frequency selectivity, but lack of sensation of voice pitch (poor perception of TFS) makes auditory scene analysis difficult:

How do you tell the noise from the speech?

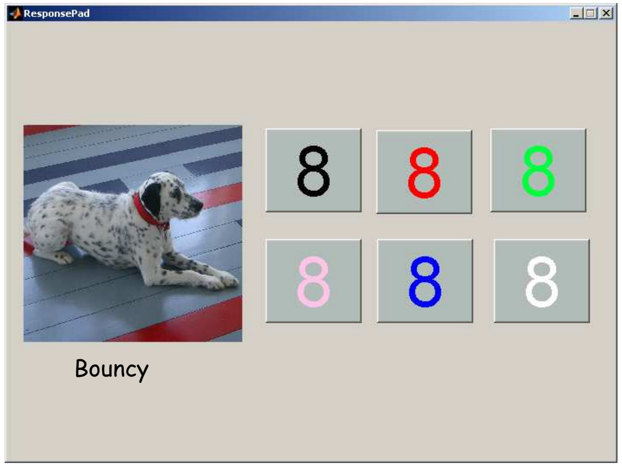


But maskers can be periodic too, most importantly, when speech is in the background.

Miller (1947) 'The masking of speech'

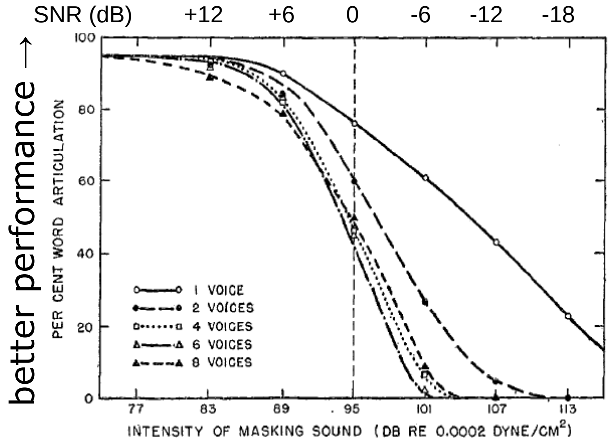
It has been said that the best place to hide a leaf is in the forest, and presumably the best place to hide a voice is among other voices.

Listening to speech in 'noise'



in quiet | in steady noise | in modulated noise | against another talker

Miller (1947)
Increasing the number of talkers in the masker



'It is relatively easy for a listener to distinguish between two voices, but as the number of rival voices is increased the desired speech is lost in the general jabber.'

- target words from multiple males
- babble: equal numbers of m/f
  (1 VOICE is male)

Why is it easy to ignore one other talker and not more?

- More opportunities to glimpse with one talker
- Differences in pitch contour for two talkers makes it easier to ignore one and attend to the other

A useful distinction

- Energetic masking
  - maskers interfere with speech to the extent that have energy in the same time/frequency regions
  - primarily reflecting direct interaction of masker and speech in the cochlea
  - relevance of glimpsing/dip listening
    - Temporal and/or spectral 'dips' in the masker allow 'glimpses' of target speech
- Informational masking
  - everything else!

Informational masking

- Something to do with target/masker similarity?
  - signal and masker 'are both audible but the listener is unable to disentangle the elements of the target speech from a similar-sounding distracter' (Brungart, 2005)

Informational masking: a finer distinction (Shin-Cunningham, 2008)

- Problems in 'object formation'
  - Related to auditory scene analysis
  - similarities in auditory properties make segregation difficult
    - voice pitch, timbre, rate

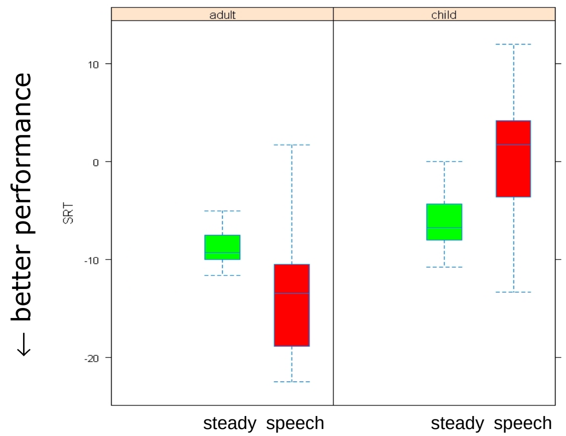
1 woman, 1 man 2 men

- Problems in 'object selection'
  - Related to attention and distraction
  - the masker may distract attention from the target
    - e.g., more interference from a known as opposed to a foreign language

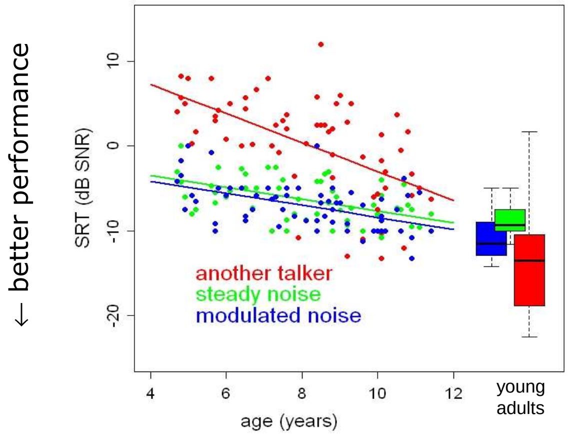
EM & IM appear to operate at different parts in the auditory pathway

- Energetic masking at the periphery, in the cochlea
  - Early developing abilities
  - Increased EM from hearing impairment
- Informational masking at higher centres
  - Late developing abilities?
  - Increased IM in younger and older listeners?
  - But aspects of IM can be made difficult by peripheral factors
    - *e.g.*, CI users difficulties with auditory scene analysis

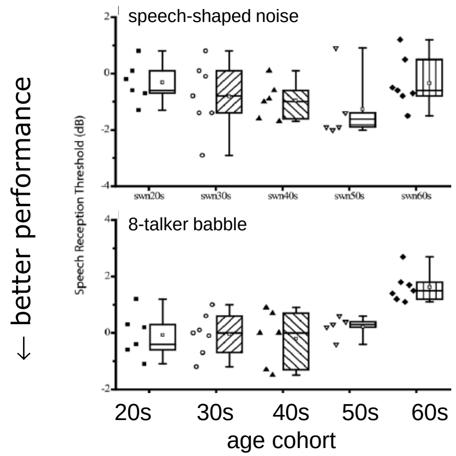
Children find it hard to ignore another talker



Slow development of abilities that minimise IM



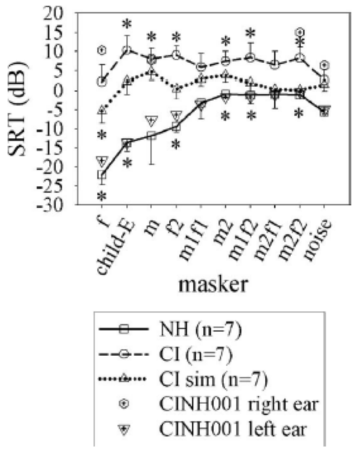
Increased IM in older listeners



Rajan & Cainer (2008)

Cullington & Zeng (2008)

- HINT (BKB) sentences
- SRT for 50% correct sentences
- little variation in SRT for different maskers



Spatial Release from Masking: when target and masker come from different directions

- Head-shadow effects often result in one ear having a better SNR than the other (the "better-ear" advantage).
  - not a result of genuine binaural interaction
- Additionally, binaural mechanisms can produce improvements in speech comprehension as well as detection of tones (BMLD).
  - 'squelch'
- These operate optimally in different frequency regions
  - Why?
- Spatial separation reduces both EM and IM

Bronkhorst & Plomp (1988)

- Measured HRTFs on an acoustic manikin to simulate spatial cues over headphones
- Allowed the separation of ITD from ILD cues so each could be presented in isolation
- Simple sentences in an adaptive procedure to measure SRT
- target speech always straight ahead; speech spectrum noise varied in position

Bronkhorst & Plomp (1988)

- ILD more important than ITD
  - why?
- But both really matter
- Implications for HI?
  - monaural fittings
  - mismatched hearing aids (*e.g.*, knee point of compression)

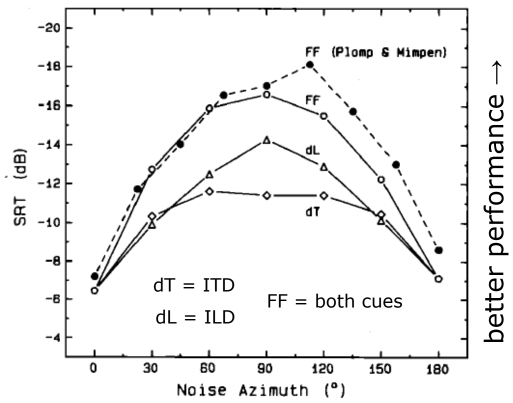


FIG. 5. Mean speech reception thresholds obtained in experiment I for three different noise types: FF (free field), dL (headshadow only), and dT (ITD only). The closed data points represent results of Plomp and Mimpen (1981) obtained in a free field.

What you need to know

- Energetic vs. informational masking
- Object formation vs. object selection
- glimpsing/dip listening
  - What it is
  - That HI listeners find it harder
  - That CI listeners find it harder still, and why

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