Psychophysical Effects of Hearing Impairment

HST.723

Percentage of population with a hearing loss as a function of age and frequency region

See: A. Davis - National Study of Hearing in the UK.

Hearing impairment

Main types of hearing loss:

- Conductive
  - Reduced transmission efficiency through outer/middle ear (wax, fluid,damage to ossicles).
  - Results in linear attenuation of sound.
  - Diagnosed e.g., through normal bone-conduction thresholds, abnormal tympanic impedance. Can often be treated with drugs/surgery.

- Sensorineural
  - **Cochlear**
    - Damaged cochlear structures (inner/outer hair cells).
    - Often leads to loudness recruitment, reduced frequency selectivity, absent evoked otoacoustic emissions, difficulty understanding speech in noise.
  - Retrocochlear
    - Various causes at various stages of the auditory pathways – most common is tumor pressing against auditory nerve.
    - Various indicators, including poor speech reception relative to audiogram, reduced ABRs, rapid decay of auditory reflex.

Physiological Aspects: Basilar Membrane Responses

BM tuning curves (See Sellick et al., 1982)

Effects of furosemide on the input-output function of the BM. Numbers denote minutes after injection (See Ruggero and Rich, 1991).

Physiological Aspects: Effects of Inner and Outer Hair Cell Loss

Liberman et al. (1986): Combinations of noise exposure and ototoxic drugs to produce different patterns of damage.

- Loss of OHCs, IHCs intact
- Severe damage to both OHCs and IHCs
- OHCs intact, moderate damage to IHCs

Frequency Selectivity: Auditory Filter Shapes

- Auditory filters generally broader in impaired hearing, but correlation between hearing loss and filter bandwidth is not very strong.
- Sometimes difficult to test at comparable sound levels (same SPL, SL, or loudness level?).
- Much smaller effect of level in impaired hearing.

See Moore (1998)

Loudness

- Loudness recruitment very common in sensorineural hearing loss – probably linked to loss of BM nonlinearity.
- Differences across listeners recently ascribed to two types of cochlear hearing loss, HL_{OHC} and HL_{IHC} (Launer, 1995; Moore and Glasberg, 1997).
- Differences in loudness summation (how loudness changes with bandwidth) can also be understood in terms of loss of BM nonlinearity.

See Launer (1995)

A Behavioral Measure of BM Response

See Oxenham and Plack (1997)

Correlations between different psychoacoustic measures

- Hypothesis: *Broadened auditory filters, loudness recruitment, and more linear growth of masking all reflect the same underlying mechanisms.*

Measures:

- Filter bandwidth (ERB);
- Growth of masking slope (GOM);
- Loudness matches (unilateral listeners), resulting in model estimates of HL_{OHC} and HL_{IHC}.

(Moore, Vickers, Plack and Oxenham, 1999)

Correlations between measures

	HL_{OHC}	GOM		HL_{IHC}	HL_{TOT}
ERB	0.75	**0.92**		0.38(ns)	0.58
GOM	0.68			0.26(ns)	0.56

Using PTCs to Measure Suppression and Dead Regions

- Release from masking by suppression (e.g. Houtgast, 1972; Shannon, 1976) is reduced or absent in impaired hearing.
- Little or no difference in PTCs between simultaneous and nonsimultaneous masking (Wightman et al., 1977; Moore and Glasberg, 1986).

- Dead region: no transduction. Should result in PTCs with a shifted BF.
- May be important for hearing aid fitting: Amplifying sound in “dead” frequency regions would have no benefit and could have negative consequences (masking).

See Moore (1998)

Frequency Discrimination and Pitch Perception

Pure Tones

Place theory: Broader filters -> poorer discrimination

Temporal theory: No effect, unless phase-locking is affected.

- Generally some deterioration found in frequency difference limens (DLFs). However, correlation between hearing loss or ERB and DLF is not strong (Simon & Yund, 1993; Tyler et al., 1983).
- Low-frequency dead regions do not produce an upward shift in pitch, as predicted by simple place model (Florentine & Houtsma, 1983; Turner et al., 1983).

Complex Tones

Dominance of low harmonics does not always hold for HI listeners: higher harmonics can be more important, suggesting increased role of temporal cues.

Effect of widening auditory filter by a factor of 3 (See Moore, 1998).

Spatial Hearing

Lateralization and localization results very variable across listeners. Unilateral HI subjects generally show poor performance. Bilateral HI subjects can show normal performance for broadband stimuli, but are often impaired for narrowband sounds.

Possible causes for poorer ITDs:

- Stimuli at low SL
- Abnormalities in BM phase response
- Hearing aids introduce significant delays
- Abnormalities in phase locking

Possible causes for poorer ILDs:

- Stimuli at low SL
- Abnormal BM input-output level function

Smaller BMLDs often observed for same reasons.

Less benefit of head shadow listeners with HF hearing loss.

Everyday Consequences of Hearing Loss

Reduced frequency selectivity

- Poorer ability to separate sounds of different frequency; more susceptible to masking effects
- Formant peaks less well defined
- Loss of ability to use information in spectral valleys

Loudness recruitment

- Simple linear amplification not sufficient – some form of limiting or compression required

Reduced temporal resolution

- Unable to “listen in the valleys”; loss of advantage in fluctuating background noise

Reduced spatial acuity

- Loss of advantage due to spatial separation of sources

In general, HI listeners perform well in quiet but more poorly in the presence of competing sounds. No hearing aid can (yet) compensate fully for this.