Longitudinal Changes in Hearing and Speech Perception in Older Adults

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Work supported by the National Institutes of Health
Program on Age-Related Hearing Loss

- Established as NIH Program Project Grant in 1987 to evaluate age-related changes in auditory function in humans and a gerbil animal model
- NIH/NIDCD Clinical Research Center now focused exclusively on hearing in older humans
Outline

• Briefly review results from gerbil animal model of age-related hearing loss
• Human subject database (21+ years)
• Cross-sectional and longitudinal changes in hearing in older adults
• Longitudinal changes in speech recognition in older adults, independent of changes in hearing
Gerbil animal model of presbyacusis

- Only scattered hair cell loss (sensory presbyacusis)
- Primary degeneration of spiral ganglion neurons (neural presbyacusis)
- Systematic degeneration of cochlear lateral wall (stria vascularis, spiral ligament)
  - Metabolic presbyacusis
  - Lateral wall responsible for production and maintenance of endocochlear potential (EP)
CAP Thresholds

**RS192**
1mg/ml, 28D

- **RE w/ pump**
- **LE Control**

EP=28mV
30mV
18mV
64mV
84mV
96mV

Frequency in kHz
SPL in dB

Hearing Loss of Furosemide-Treated Gerbils


Gerbil animal model of presbyacusis

- Decline in endocochlear potential (EP)
  - Reduces voltage available to cochlear amplifier
  - Reduces cochlear amplifier gain
    - Low frequencies: as much as 20 dB
    - High frequencies: as much as 60 dB
  - EP declines result in the characteristic audiogram of older gerbils (metabolic presbyacusis)
- Is this the case for older humans?
**Human Subject Database**

- **Inclusion and Exclusion Criteria**
  - 60 years or older (now 18 or older)
  - Hearing ability to provide measurable results
  - In good general health
  - Screened with Mini-Mental State Exam (MMSE)
  - No evidence of conductive hearing loss
  - No evidence of active otologic disease
Human Subject Protocol

• Audiometric Measures
  • Hearing for pure tones, including extended high frequencies
  • Ability to understand speech in quiet and in noise
  • Otoacoustic emissions
  • Upward and downward spread of masking
  • Middle ear function
  • Auditory brainstem responses
Human Subject Protocol

- Cognitive Measures
  - Attention
  - Working memory
  - Processing speed
  - Perceived workload

- Brain imaging while listening to and understanding:
  - Low-pass filtered speech
  - Speech in background noise
Human Subject Protocol

- Questionnaires
  - Medical history
  - Prescription and over-the-counter drugs
  - Noise history
  - Hearing aid history
  - Hearing handicap (HHIE)
  - Tinnitus
  - Smoking
  - Handedness
  - Family pedigree for hearing loss

- Otologic examination
Human Subject Protocol

- **Blood measures**
  - Clinical chemistries
    - Lipid profile
    - Hematology panel
    - Hormones (Estradiol, Progesterone – Female subjects)
    - C-reactive protein
    - Electrolyte panel - Discontinued
    - Immunoglobulin panel - Discontinued
    - Thyroid function – Discontinued
  - DNA extracted
    - To identify and characterize genes that are under- or over-expressed with age
### Human Database Participants

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- Female: 85 (18-59), 483 (60-98), 10 (18-59), 235 (60-95), 14 (18-59), 201 (60-93)
- Male: 76 (18-59), 385 (60-98), 12 (18-59), 200 (60-95), 15 (18-59), 125 (60-93)

- Measures are made yearly or every 2-3 years
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Longitudinal Study Design

- Advantages
  - Participants act as their own controls
  - Minimizes effects of uncontrollable factors
    - noise history
    - occupation
    - nutrition
    - Pre-existing health conditions
  - Measures age-related changes for groups and individuals (cross-sectional designs – groups only)
Longitudinal Study Design

- Disadvantages
  - Data collection takes many years
  - Must retain participants for long periods of time
  - Recruitment more difficult
  - Selective attrition
    - For longitudinal studies of aging
    - Healthier or higher performing participants may remain in the study longer
  - High cost
Longitudinal Changes in Thresholds

- Serial audiograms obtained over ≥3 years
  - 3,690 audiograms from 376 ears
  - Mean number of audiograms per subject: 9.8 (Range 2-21)
  - Mean time span: 6.4 years (Range 3-12)
  - Mean age at entry: 68.1 years (Range 60-81)
  - Mean current age: 74.5 years (Range 64-89)
Longitudinal Changes in Speech Recognition

- SRT
- Word recognition in quiet (NU-6)
- Maximum word recognition (NU-6)
- Recognition of sentences in noise (Speech Perception in Noise Test, SPIN)
- Binaural word recognition (SSW)
Rationale

• To assess age-related declines in word recognition
  • Using AI (weighted average speech audibility), predict word recognition scores for each subject for each time point
  • Compare measured and predicted scores for each time point
AI = 0.14
Predicted score = 14%

AI = 0.46
Predicted score = 78%
Rationale

- To assess age-related declines in word recognition
  - If declines in word recognition over time are similar to predicted declines, poorer hearing (reduced audible speech) accounts for these changes, rather than increasing age
  - If declines are faster than predicted, poorer hearing does not entirely account for declines in word recognition – the remainder may be attributed to other factors, such as increasing age
Word Recognition in Quiet

• Serial measures obtained over ≥3 years
• Each subject had a minimum of 3 NU-6 scores
  • 3,704 scores from 512 ears
  • Mean number of scores per subject: 7.2 (Range 3-18)
  • Mean time span: 7.3 years (Range 3-15)
  • Mean age at entry: 67.6 years (Range 50-82)
  • Mean current age: 75.0 years (Range 60-91)
Word Recognition (%)

Mean Age (Years)

3704 scores from 512 ears

Observed
Word Recognition (%) vs Mean Age (Years)

- Predicted
- Observed

3704 scores from 512 ears
Effect of Initial Hearing Loss

- More severe injury to the auditory system resulted in faster declines in word recognition as subjects aged
- Not related simply to more-elevated thresholds
Effect of Serum Progesterone

- Consistent with the negative effect of hormone therapy that includes progestin reported by Guimaraes et al. (PNAS 2006)
- Consistent with a biochemical mechanism that relates progesterone to activation of inhibitory neurotransmitters, such as GABA, in the aging auditory system
Summary and Conclusions

- Pure-tone thresholds increase with age by an average of 1 dB/year (10 dB/decade)
- Rate of decline in high-frequency hearing increases for females but decreases for males
- Word recognition in quiet declines with age, even after accounting for reductions in audible speech due to poorer hearing
Summary and Conclusions

• Rate of decline is faster for individuals with more severe hearing loss
• Rate of decline is faster for females with higher levels of progesterone in their blood
Summary and Conclusions

- Audiogram shapes and longitudinal changes in hearing are consistent with the view of age-related hearing loss as a **metabolic**, **vascular**, **neural** disorder rather than a sensory disorder.
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Cognitive Test Battery

- Connections Test (Salthouse)
- Visual Search and Attention Task (VSAT)
- Stroop Neuropsychological Screening Test
- Abbreviated Wechsler Memory Scale (WMS-III)
- Wechsler Abbreviated Scale of Attention (WASI)
- Mini-Mental Status Exam (MMSE)
- Edinburgh Handedness Scale
- NASA Task Load Index (Workload)