Speech Recognition Across the Lifespan: Middle Aged to Older Adults

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NIH/NIDCD
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<tr>
<th>All Ages</th>
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<td>Cataracts</td>
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**Source:** National Academy on an Aging Society analysis of National Health Interview Survey data.

- ~17% of American adults report some degree of hearing loss (36 million)
- 75% are over 55 years of age
- One of the most common chronic conditions of aging (first for older males)
- Prevalence and severity will increase as the population ages
- Hearing impairment is also a common chronic condition in middle age
The Aging Auditory System

- Damaging effects to the periphery from a lifetime of environmental exposures and disease processes
- Naturally occurring age-related changes to the auditory periphery
  - Anatomic, physiologic, neurochemical deficits
  - Reduced detection for low-level signals (hearing loss)
  - Impaired function for higher level signals
    - Complex signal processing
    - Speech understanding
The Aging Auditory System

- Auditory periphery delivers degraded signal representations for processing by aging central auditory pathways and cortex

- Cognitive declines
  - Working memory, executive function
  - Attention, processing speed
  - Reduced ability to suppress irrelevant information
  - Inadequate compensation strategies

- Imposes increased demands on an aging brain with already limited resources and loss of inhibition
The Aging Auditory System

• Multiple risk factors (aging, noise, drugs, disease, comorbid conditions...)

• In older humans, how to disentangle the effects to:
  • allocate to each risk factor
  • determine contribution of aging alone
  • identify promising targets for intervention
  • develop strategies to prevent or delay onset of age-related declines

• Longitudinal studies across the lifespan can identify risk factors and estimate age-relate changes and interactions
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 subjects for long periods of time
  - Recruitment more difficult
  - Selective attrition
    - For longitudinal studies of aging
    - Healthier or higher performing subjects may remain in the study longer
  - High cost
Longitudinal Studies of Speech Recognition

• Very few studies
• Limitations
  • Small sample sizes
  • Not population-based samples
  • Narrow age ranges (not including middle age)
  • Short follow-up periods
  • Did not include measures of speech in noise
  • Did not control for effects of age-related declines in detection thresholds
Longitudinal Studies of Speech Recognition

- Dubno et al. (2008)
  - Initial analysis of same cohort
  - Different statistical procedure
  - Declines greater than predicted from thresholds

- Pronk et al. (2013)
  - Longitudinal Aging Study of Amsterdam cohort
  - Speech reception threshold in noise ($SRT_n$)
  - Health, environmental, cognitive variables
  - Declines in SRT related only to processing speed
  - No control for threshold changes over time
MUSC Longitudinal Study

- Peripheral and central auditory function
  - Detection of pure tones (0.25 - 8.0 kHz)
  - Detection of high frequencies (10 - 18 kHz)
- Middle ear function
- Cochlear function (OAEs, masking)
- Auditory brainstem responses
- Understanding simple and complex speech
  - In quiet and noise
  - Single words and sentences
  - Using one and two ears (not included here)
Human Subject Database (1988- )

- N = 1,495 (participants with any data)
- N = 444 (active participants)
- 69% age 60 and older
- 60% female
- 29% racial/ethnic minority

Current analysis (40 - 96 years)
- N = 1,220 (54.5% female)
Analysis Plan

• Estimate longitudinal changes in pure-tone thresholds, as measured during participants’ time in the study

• Estimate longitudinal changes in speech recognition in quiet and babble
  • Control for effects of changes in thresholds over the same time period
  • Control for effects of other covariates
Analysis Plan

- To assess changes in pure-tone thresholds over time
  - Multivariable Generalized Linear Repeated Mixed Model
  - Accounts for correlations over time within participants
  - Allows for different numbers of repeated measures, so all thresholds contribute (no missing cases)
  - Gender and ear were added to the model as covariates

- Current analysis: 16,027 audiograms from 2,433 ears
Pure-tone Thresholds

- Consistent with proposed audiometric phenotypes (Dubno et al., 2013)

- Metabolic Phenotype (Females)
  - ↓ EP (power supply)
  - ↓ cochlear amplifier gain
  - ↓ nonlinearities, but maintains

- Sensory Phenotype (Males)
  - Higher thresholds
  - Loss of sensory cells
  - Loss of cochlear amplifier
  - Loss of nonlinearities
• Rates of threshold increase averaged 0.4 - 0.8 dB/yr (4-8 dB/decade)
• Faster rates of increase for males than females at 2.0 - 8.0 kHz
Longitudinal Changes in Speech Recognition

- Speech-recognition threshold (spondees)
- Word recognition in quiet (NU-6)
- Maximum word recognition (NU-6)
- Key word recognition in sentences in babble (Speech Perception in Noise Test, SPIN)
- Binaural word recognition (SSW)
Word Recognition in Quiet

- NU#6 word lists
- Monosyllabic CVC words
  - Examples: back, good, home, sell, take

- Monaural, ear each tested, with audiogram
- 30-40 dB SL re: SRT

- Measured at each visit, yearly or more often
- Different lists used for each ear at each visit
Word Recognition in Quiet

- 16,027 scores from 2,435 ears
- 1-28 visits per participant (audiogram and scores)

Baseline age:
- Mean 67.1 yrs (±9.4 yrs)
- Range 40-96 yrs

Time in study:
- Mean 4.4 yrs (±5.4 yrs)
- Range 0-25 yrs
Key Words in Sentences in Babble

- Speech Perception in Noise Test (SPIN) (Kalikow et al., 1977)
- High context: “The watchdog gave a warning growl”
- Low context: “I had not thought about the growl”

- Monaural, each ear tested, with audiogram
- Sentences at 50 dB re: babble threshold (Bilger, 1984)
- Signal-to-babble ratio +8 dB

- Measured every 2-3 years
- Different lists used for each ear at each visit
Key Words in Sentences in Babble

- 3,587 scores from 1,790 ears
- 1-8 visits per participant (audiogram and scores)

Baseline age:
- Mean 67.6 yrs (±8.1 yrs)
- Range 40-89 yrs

Time in study:
- Mean 3.6 yrs (±4.7 yrs)
- Range 0-23 yrs
Data Analysis

- To assess changes in speech recognition over time
  - Multivariable Generalized Linear Repeated Mixed Model
  - Accounts for correlations over time within participants
  - Allows for different numbers of repeated measures, so all scores contribute (no missing cases)

- Gender and ear added to the model as covariates
- Covariates added to account for effects of changes over time in:
  - Pure-tone thresholds (0.25-4.0 kHz; 6-8 kHz ns)
  - Speech levels
  - Participant Age
Word Recognition in Quiet

- For every 1 year of aging, scores declined by 1.32 rau \((p<0.0001)\)

- While controlling for threshold increases over same period, scores declined by 0.24 rau for each year of aging \((p<0.0001)\)
Word Recognition in Quiet

- Rates of decline did not differ for Males and Females ($p>0.05$)
- Declines accelerate near age 65-70
- Scores for Males were poorer after controlling for gender differences in thresholds ($p=0.0125$)
- Related to their different phenotypes?
- More neural loss for males?
Key Words in Low-Context Sentences

- For every 1 year of aging, scores declined by 0.72 rau ($p<0.0001$)
- While controlling for threshold increases over same period, scores declined by 0.11 rau for each year of aging ($p<0.0027$), with no gender difference
Key Words in High-Context Sentences

- For every 1 year of aging, scores declined by 0.44 rau ($p<0.0001$)
- While controlling for threshold increases, scores remained constant (0.04 rau/yr, ns)
- Declines faster for Males than females (Males: 0.13 rau, $p=0.016$)
Key Words in Sentences in Babble

- In contrast to scores in quiet, no gender difference after threshold differences controlled ($p > 0.05$)

- Declines accelerate near age 75-80

- Differences related to task (word/sentence or quiet/babble) or performance levels?
Contribution of Thresholds

- Each dB increase in threshold over time contributes 0.10-0.45 rau to the decline in score over time
- Threshold increases at 2.0 kHz are the largest contributor
- Some differences for three tasks
Next Steps

- Include as covariates measures of:
  - Auditory function, audiometric phenotype, self-assessments
  - Cognitive function
  - Environmental factors (noise, drug exposures)
  - Demographic factors
  - Health conditions

- Include data from SSW (binaural speech)

- Confirm with biomarkers
  - Neuroimaging
  - Genetics
  - Otopathology from human temporal bones
Conclusions - Pure-tone Thresholds

- Pure-tone thresholds increased with increasing age by an average of 0.4-0.8 dB/year (4-8 dB/decade)
- Slower overall rates of threshold increase for this sample (<1.0 dB/year) may reflect inclusion of middle-aged adults
Conclusions - Word Recognition in Quiet

• Word recognition in quiet declines with age, even after accounting for reductions in audible speech due to poorer hearing
• Rates of decline were similar for males and females, but scores were poorer for males
• May relate to differences in etiology (metabolic vs. sensory phenotypes for females vs. males)
Conclusions - Key Word Recognition in Babble

• Key word recognition in babble declined slightly with age or remained constant (with context)
• No gender differences
• Key word recognition in sentences preserved to older ages than for monosyllabic word recognition in quiet
• Threshold increases are large contributors to speech recognition declines, especially in mid frequencies, and are larger than age alone
Conclusions

- Gender differences: social or biological construct
  - Relate to differences in environmental exposures, which lead to differences in age-related pathologies?
  - Due to underlying gender-related neurobiological mechanisms?
- Although answers are unclear, gender remains a useful clinical marker for age-related hearing loss
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