Longitudinal Changes in Hearing and Speech Perception in Older Adults

Judy R. Dubno
Department of Otolaryngology-Head and Neck Surgery
Medical University of South Carolina
Charleston, SC

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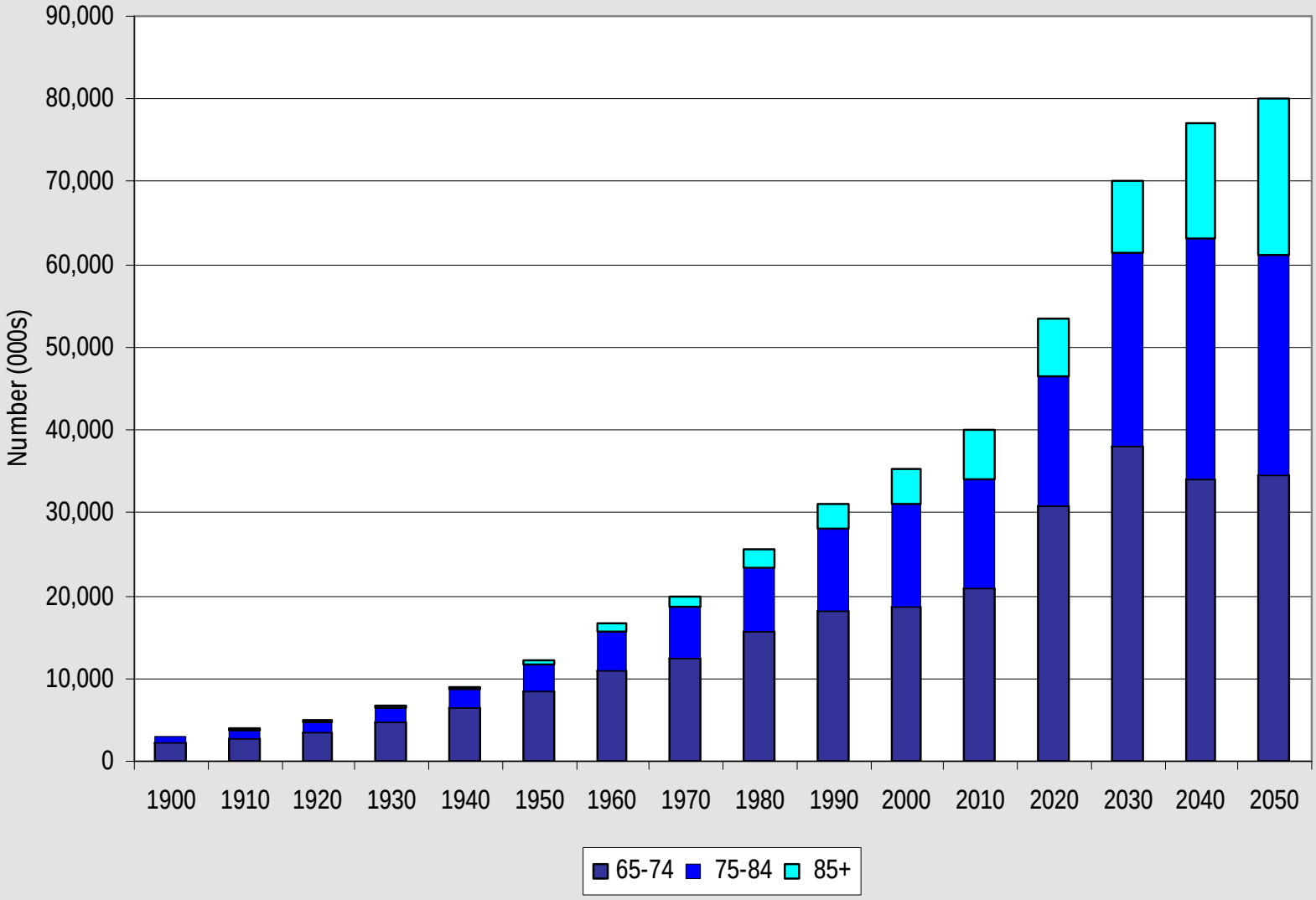
Older Population by Age: 1900-2050

Source: U.S. Bureau of the Census



Program on Age-Related Hearing Loss

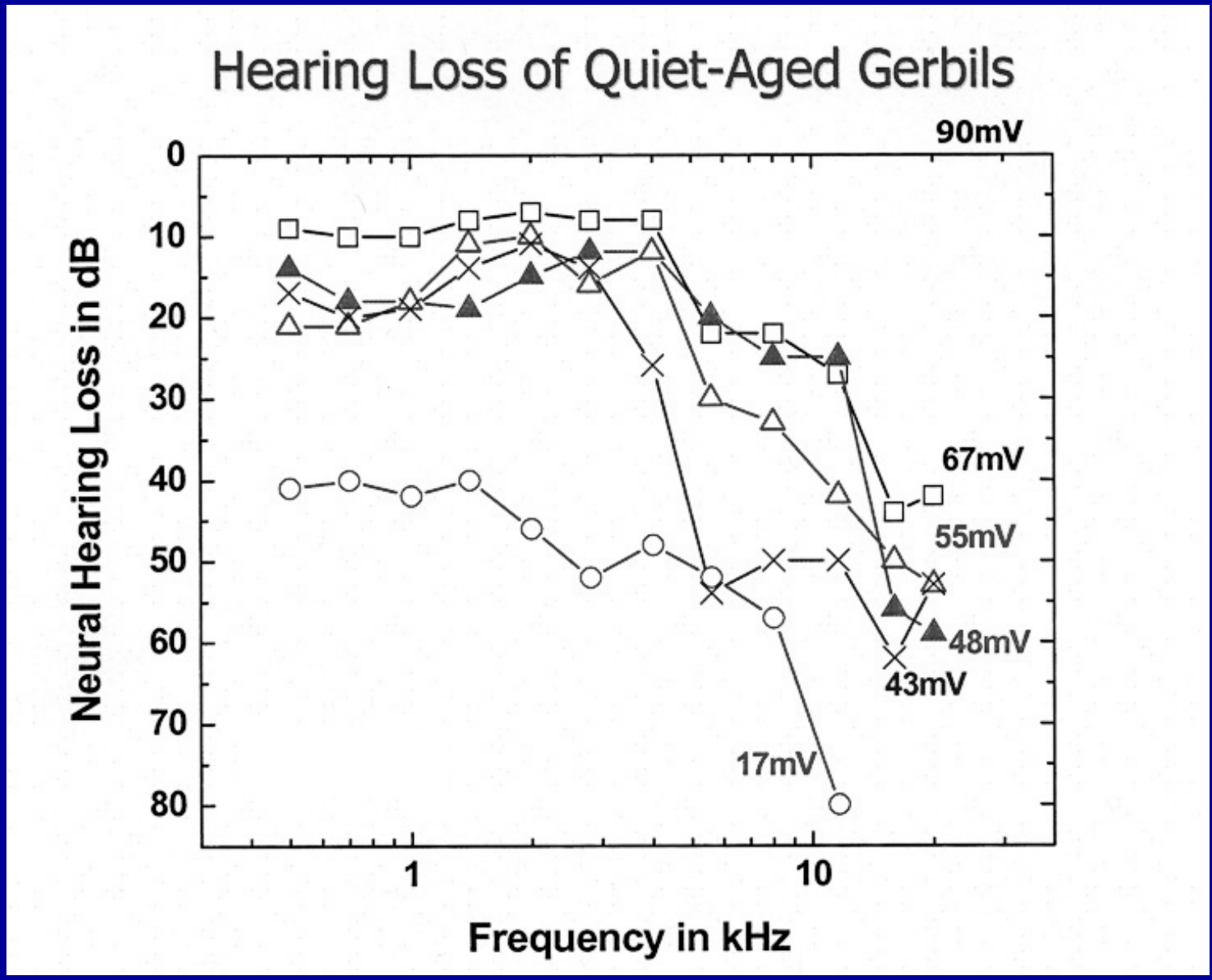
- Established as NIH Program Project Grant in 1987 to evaluate age-related changes in auditory function in humans and a gerbil animal model
- NIH/NIDCD Clinical Research Center now focused exclusively on hearing in older humans

Outline

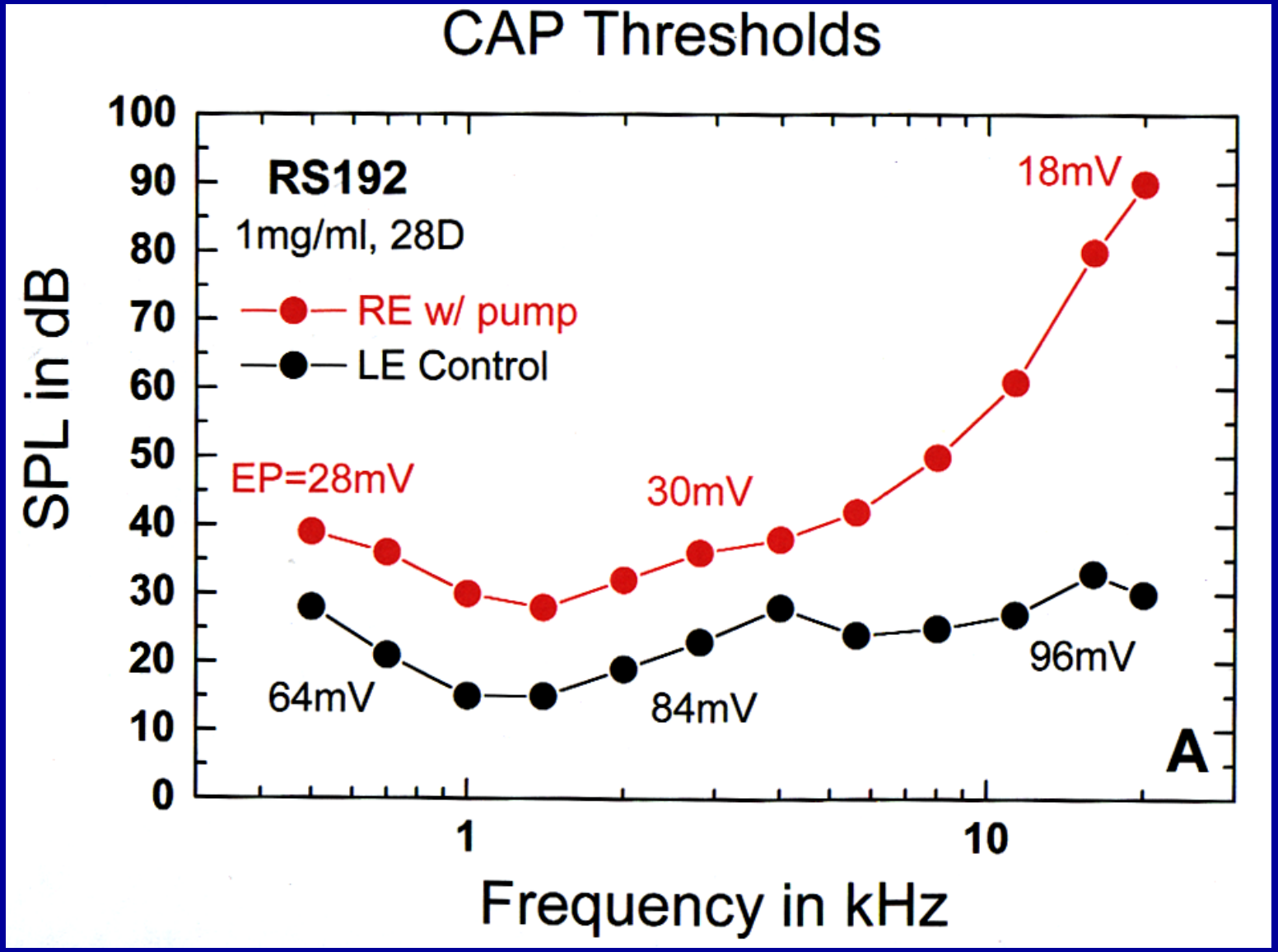
- Briefly review results from gerbil animal model of age-related hearing loss
- Human subject database (21+ years)
- Cross-sectional and longitudinal changes in hearing in older adults
- Longitudinal changes in speech recognition in older adults, independent of changes in hearing

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)



Schmiedt R, Lang H, Okamura H, Schulte B (2002). J Neurosci 22, 9643-9650.



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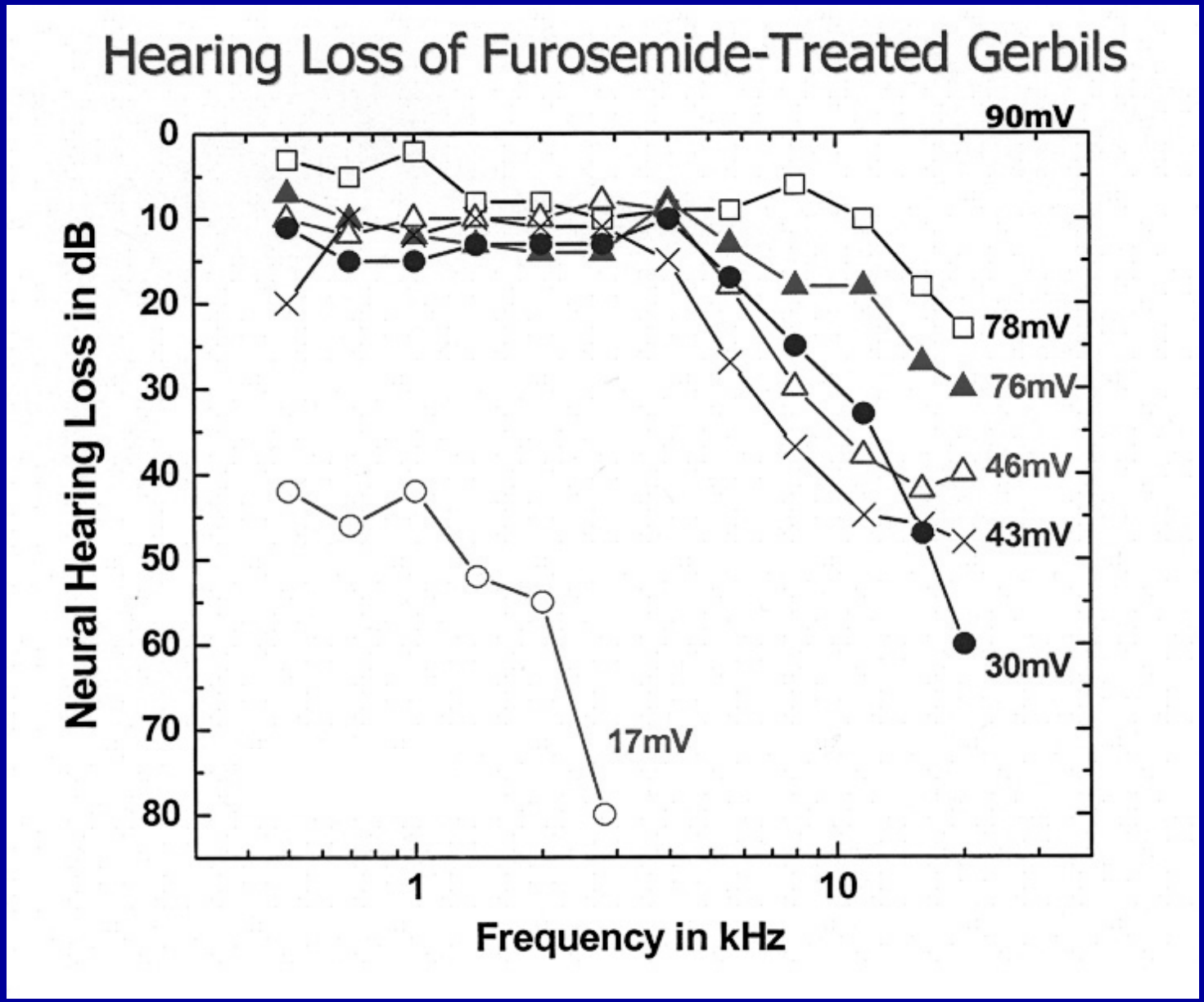

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Gerbil animal model of presbyacusis

- 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

	Total with any data		Total with longitudinal data		Currently Active	
Age Range	18-59	60-98	18-59	60-95	18-59	60-93
Female	85	483	10	235	14	201
Male	76	385	12	200	15	125
Total	161	868	22	435	29	326
Grand Total	1,029		457		355	

- Measures are made yearly or every 2-3 years

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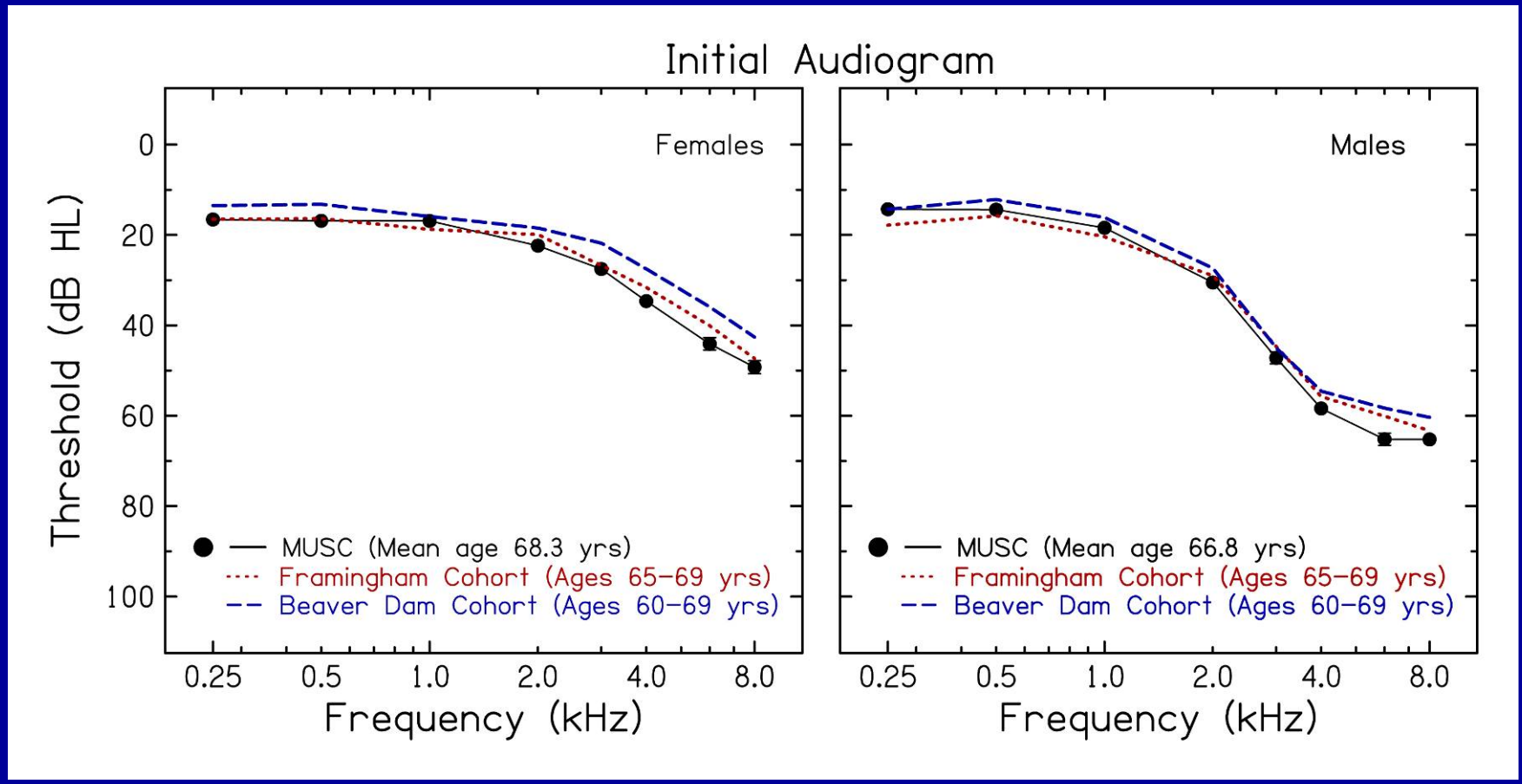
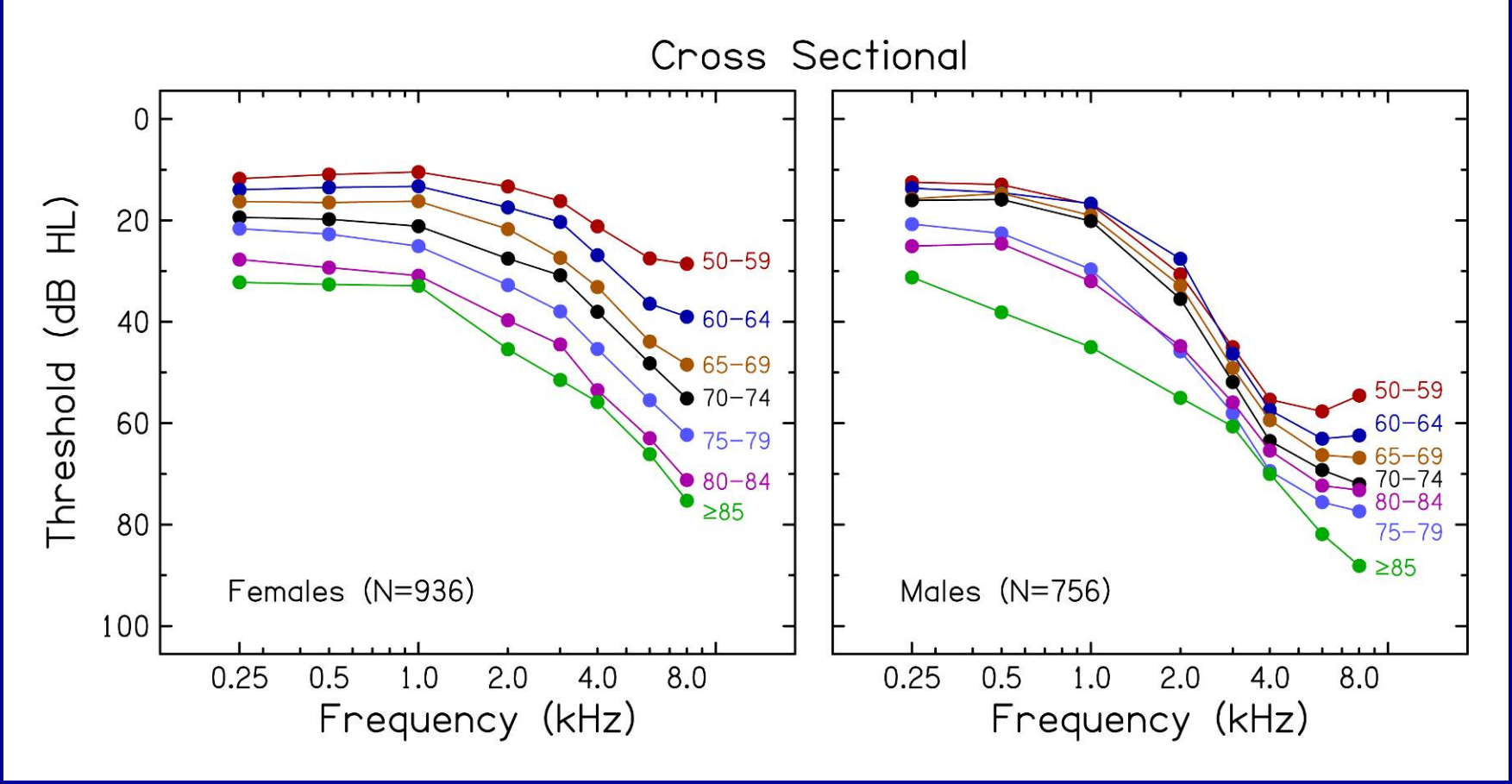
Longitudinal Study Design

- 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

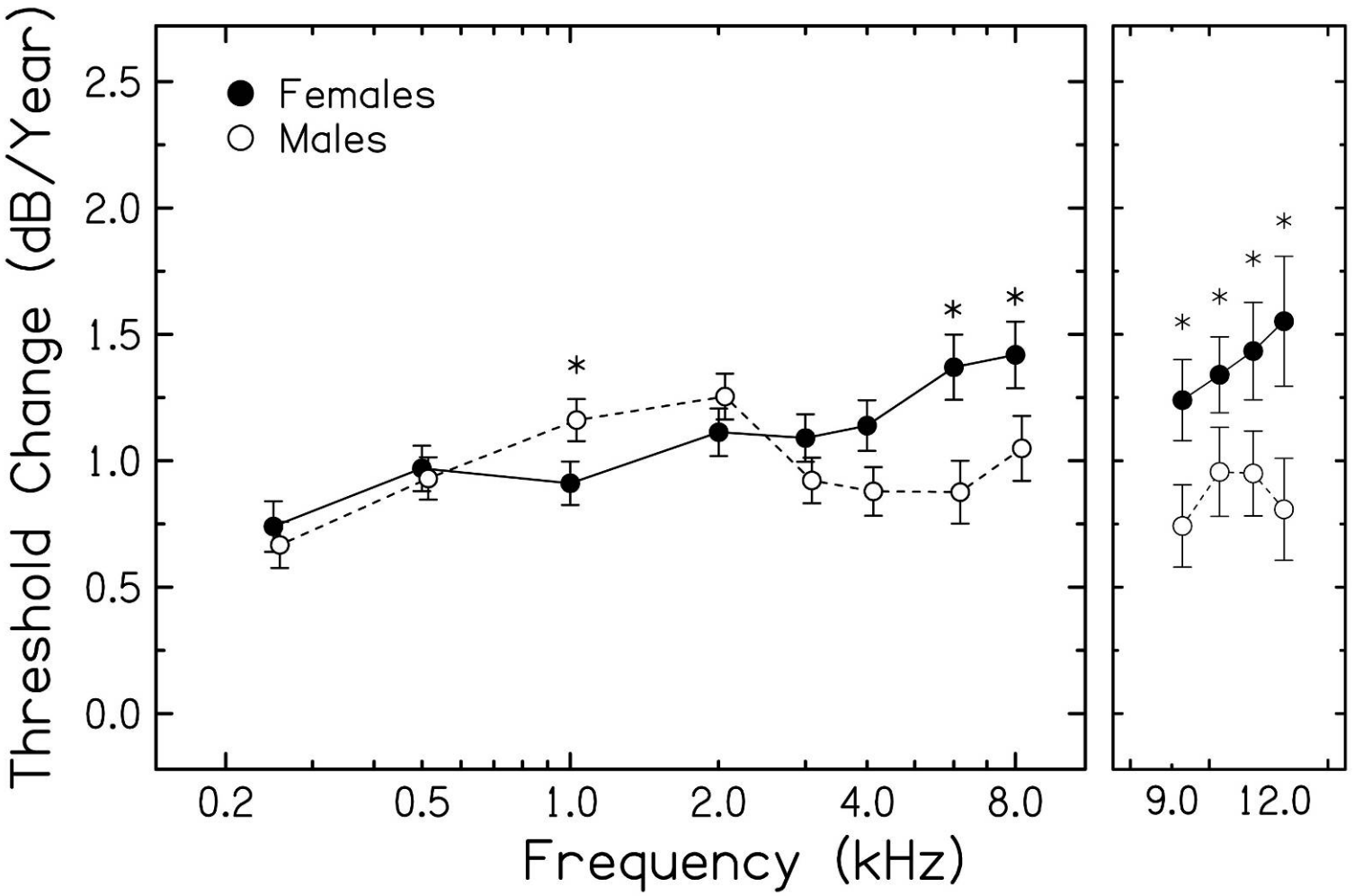
- Disadvantages
  - Data collection takes many years
  - Must retain participants for long periods of time
  - Recruitment more difficult
  - Selective attrition
    - For longitudinal studies of aging
    - Healthier or higher performing participants may remain in the study longer
  - High cost


Initial Audiogram
Females
Males
Threshold (dB HL)
0
20
40
60
80
100
0.25
0.5
1.0
2.0
4.0
8.0
Frequency (kHz)
MUSC (Mean age 68.3 yrs)
Framingham Cohort (Ages 65–69 yrs)
Beaver Dam Cohort (Ages 60–69 yrs)
MUSC (Mean age 66.8 yrs)
Framingham Cohort (Ages 65–69 yrs)
Beaver Dam Cohort (Ages 60–69 yrs)

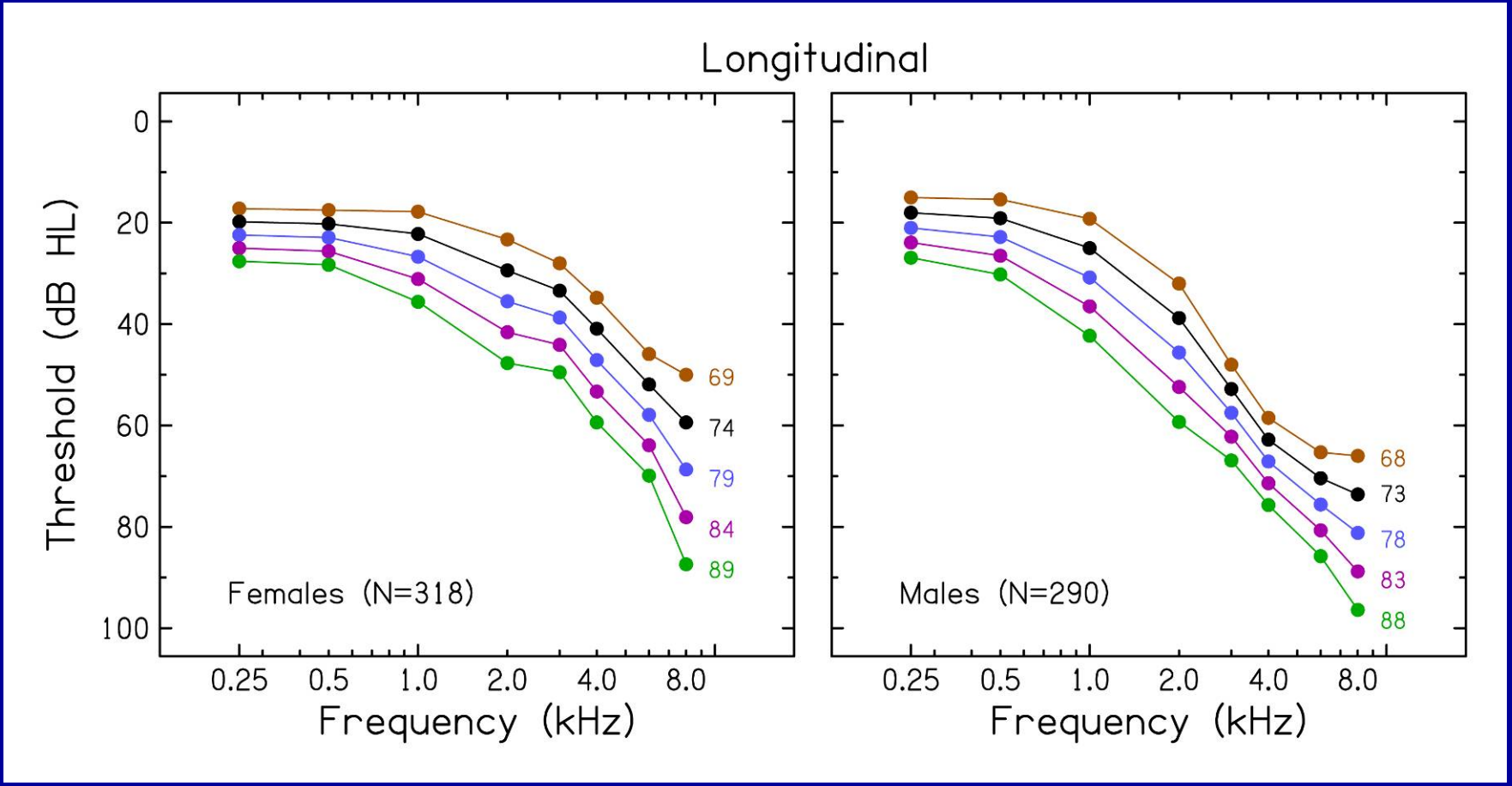

Cross Sectional
Threshold (dB HL)
0
20
40
60
80
100
Females (N=936)
Males (N=756)
50–59
60–64
65–69
70–74
75–79
80–84
≥85
0.25
0.5
1.0
2.0
4.0
8.0
Frequency (kHz)

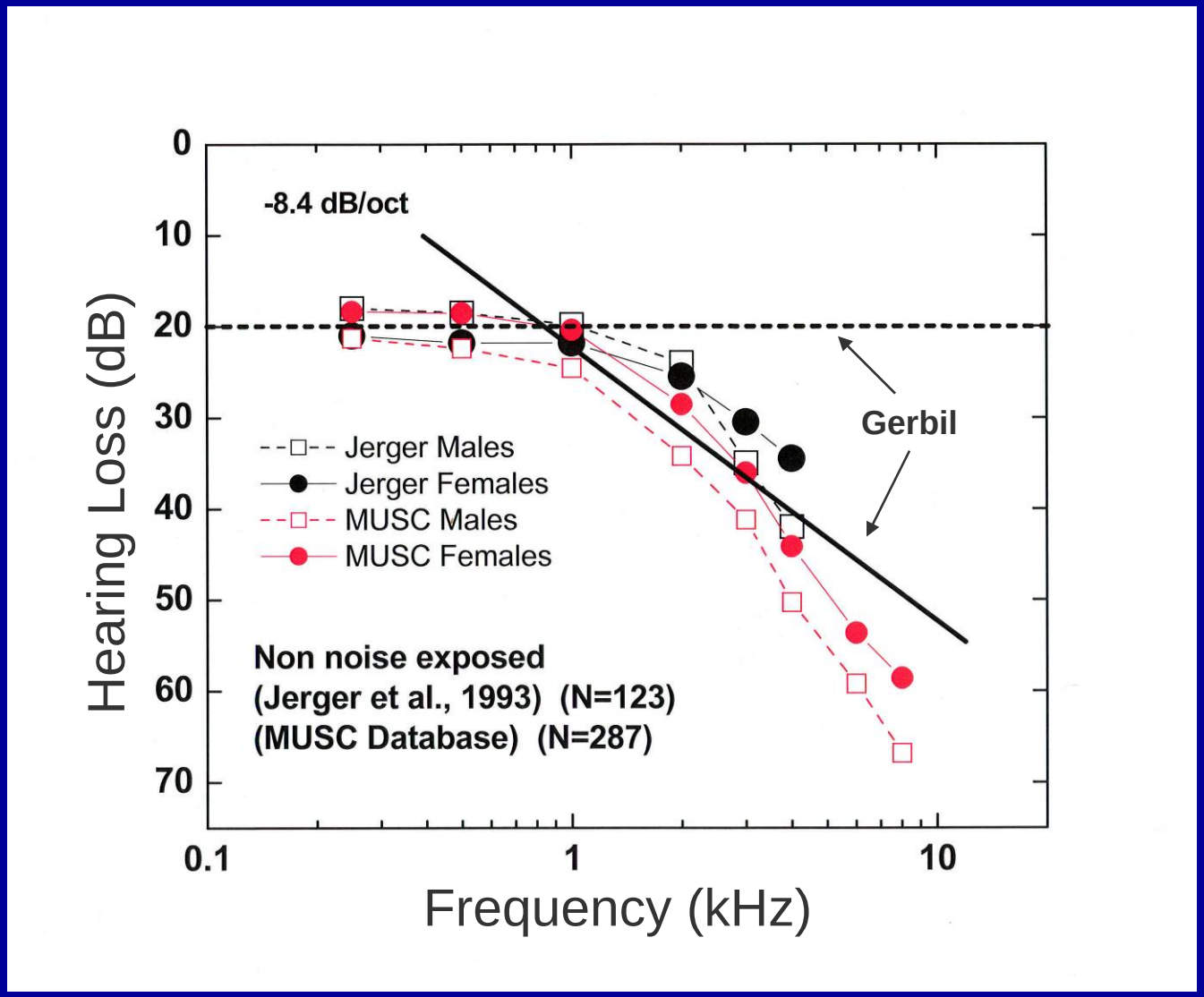
Longitudinal Changes in Thresholds

- 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)



Lee F, Matthews L, Dubno J, Mills J (2005). Ear Hear 26, 1-11.

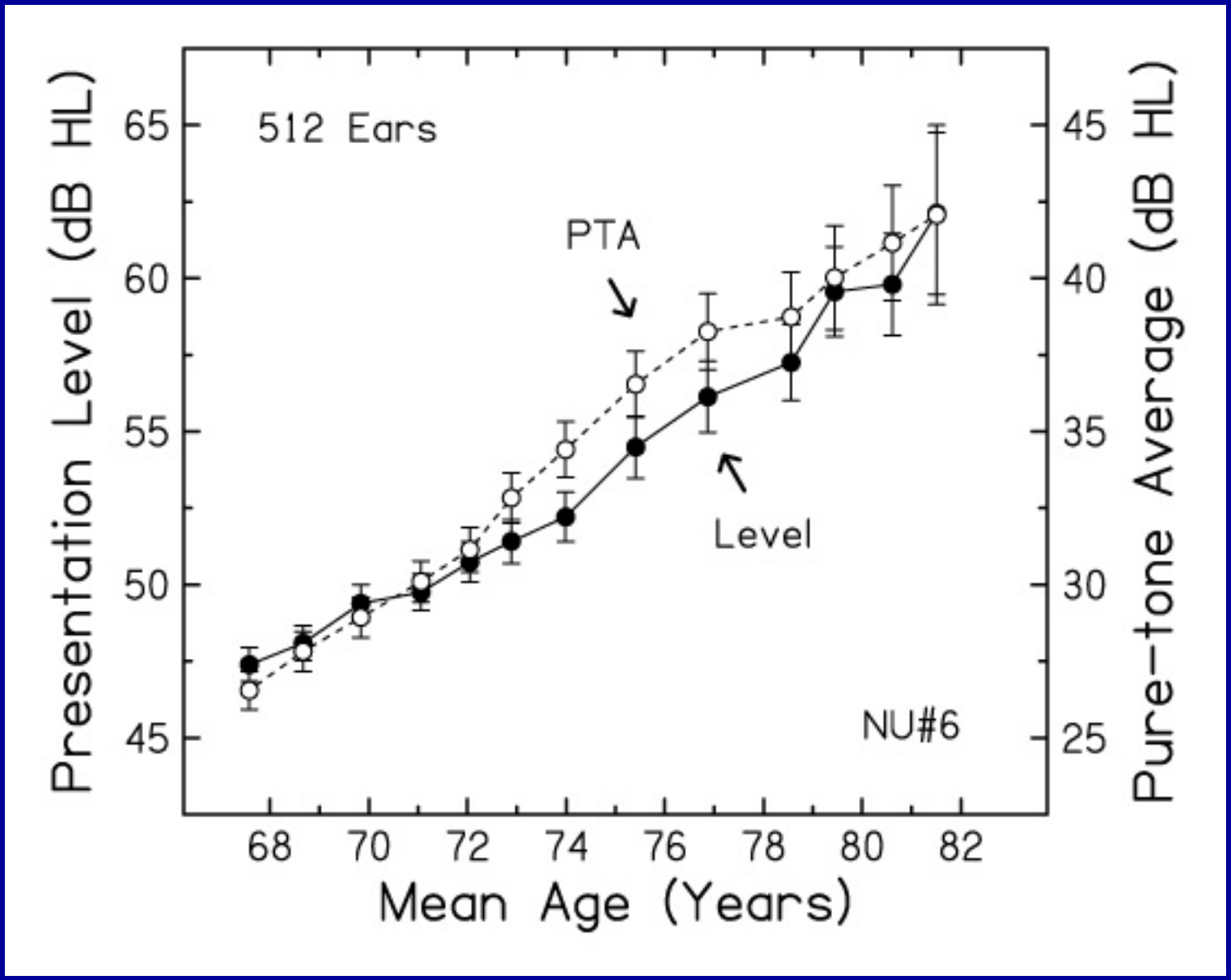

Longitudinal
Threshold (dB HL)
0
20
40
60
80
100
0.25
0.5
1.0
2.0
4.0
8.0
Frequency (kHz)
Females (N=318)
69
74
79
84
89
Males (N=290)
68
73
78
83
88



Schmiedt R, Lang H, Okamura H, Schulte B (2002). J Neurosci 22, 9643-9650.

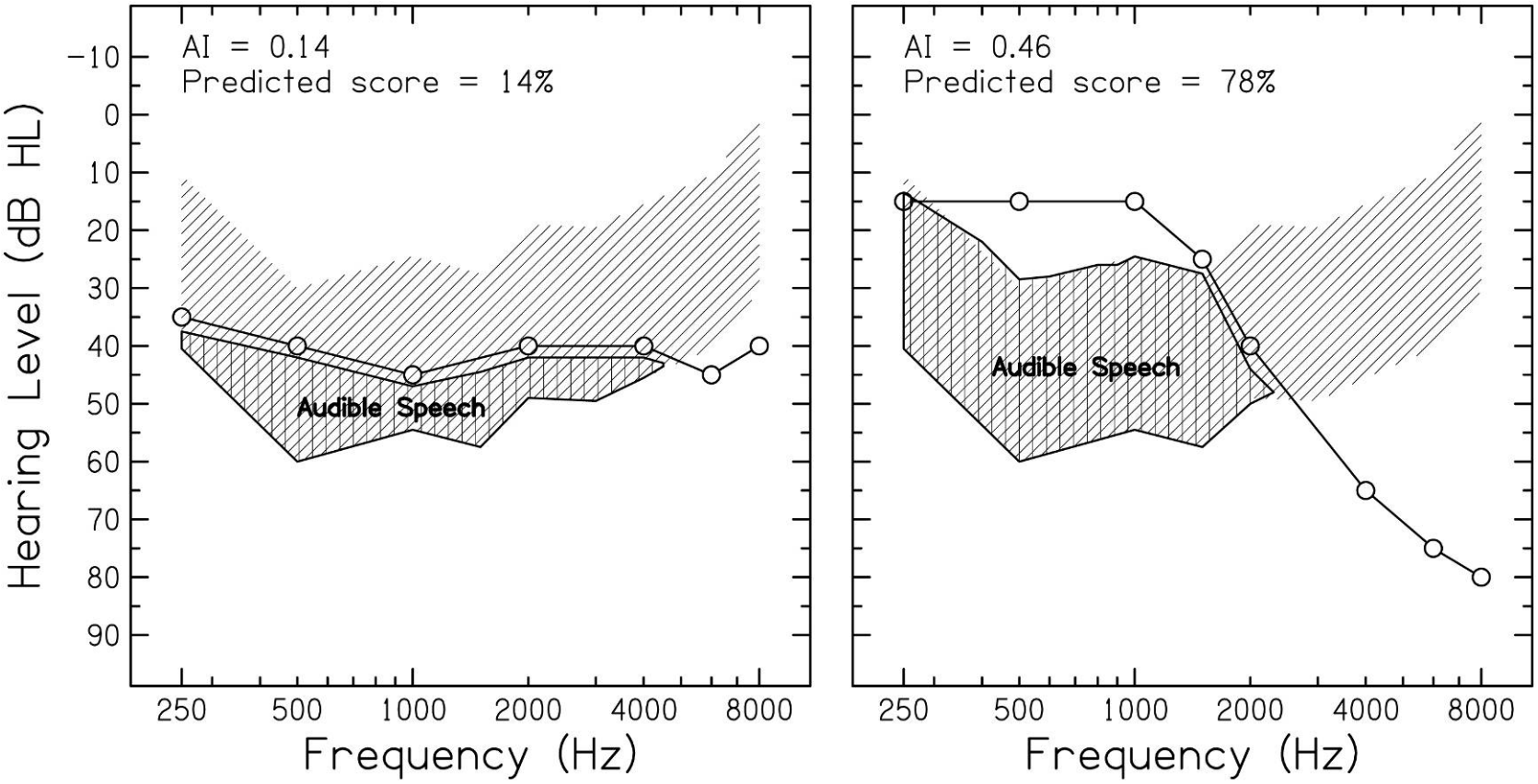
Longitudinal Changes in Speech Recognition

- 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)


512 Ears
PTA
Level
NU#6
Presentation Level (dB HL)
Pure-tone Average (dB HL)
Mean Age (Years)
65
60
55
50
45
45
40
35
30
25
68
70
72
74
76
78
80
82

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

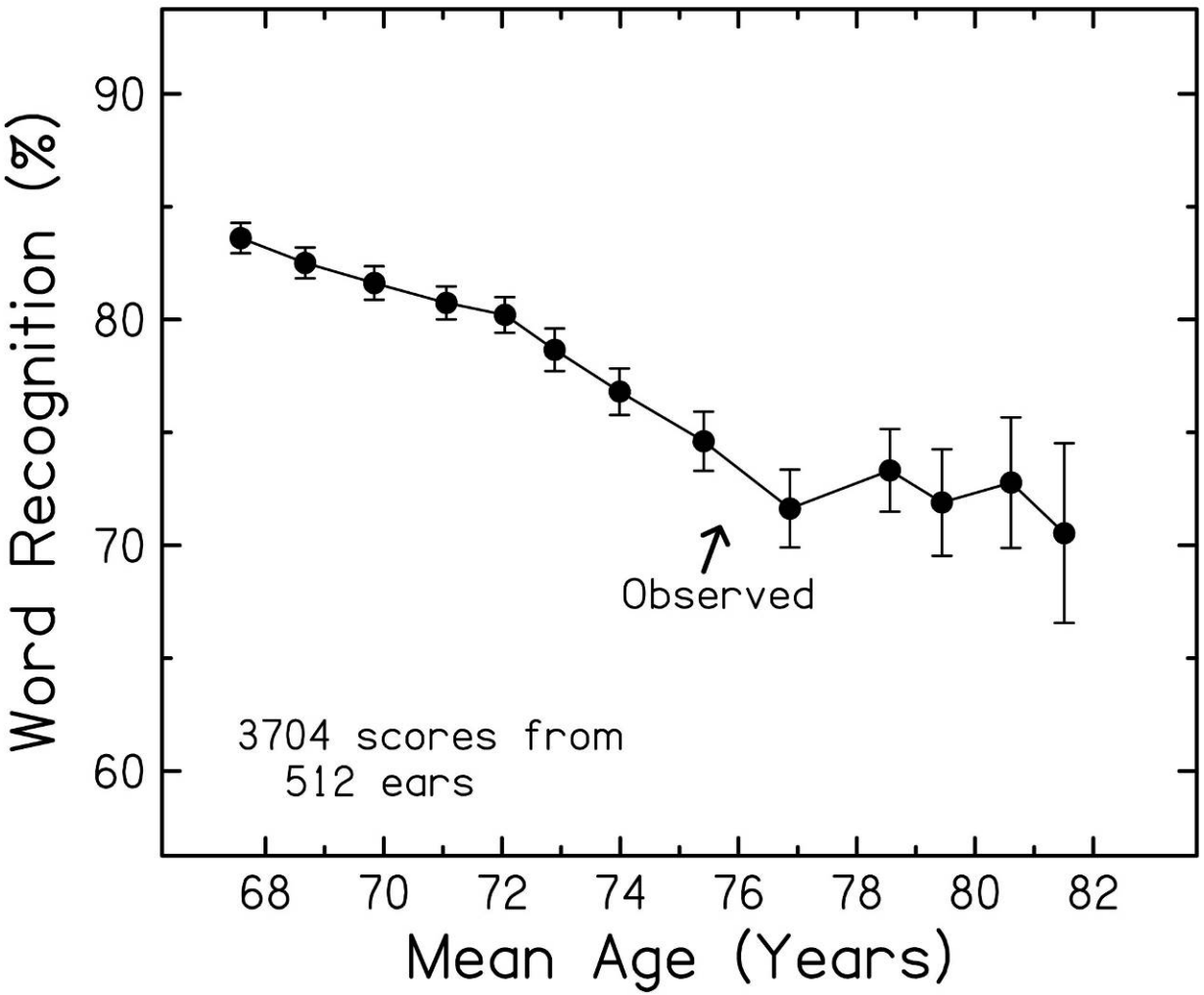

AI = 0.14
Predicted score = 14%
Audible Speech
Hearing Level (dB HL)
−10
0
10
20
30
40
50
60
70
80
90
250
500
1000
2000
4000
8000
Frequency (Hz)
AI = 0.46
Predicted score = 78%
Audible Speech
250
500
1000
2000
4000
8000
Frequency (Hz)

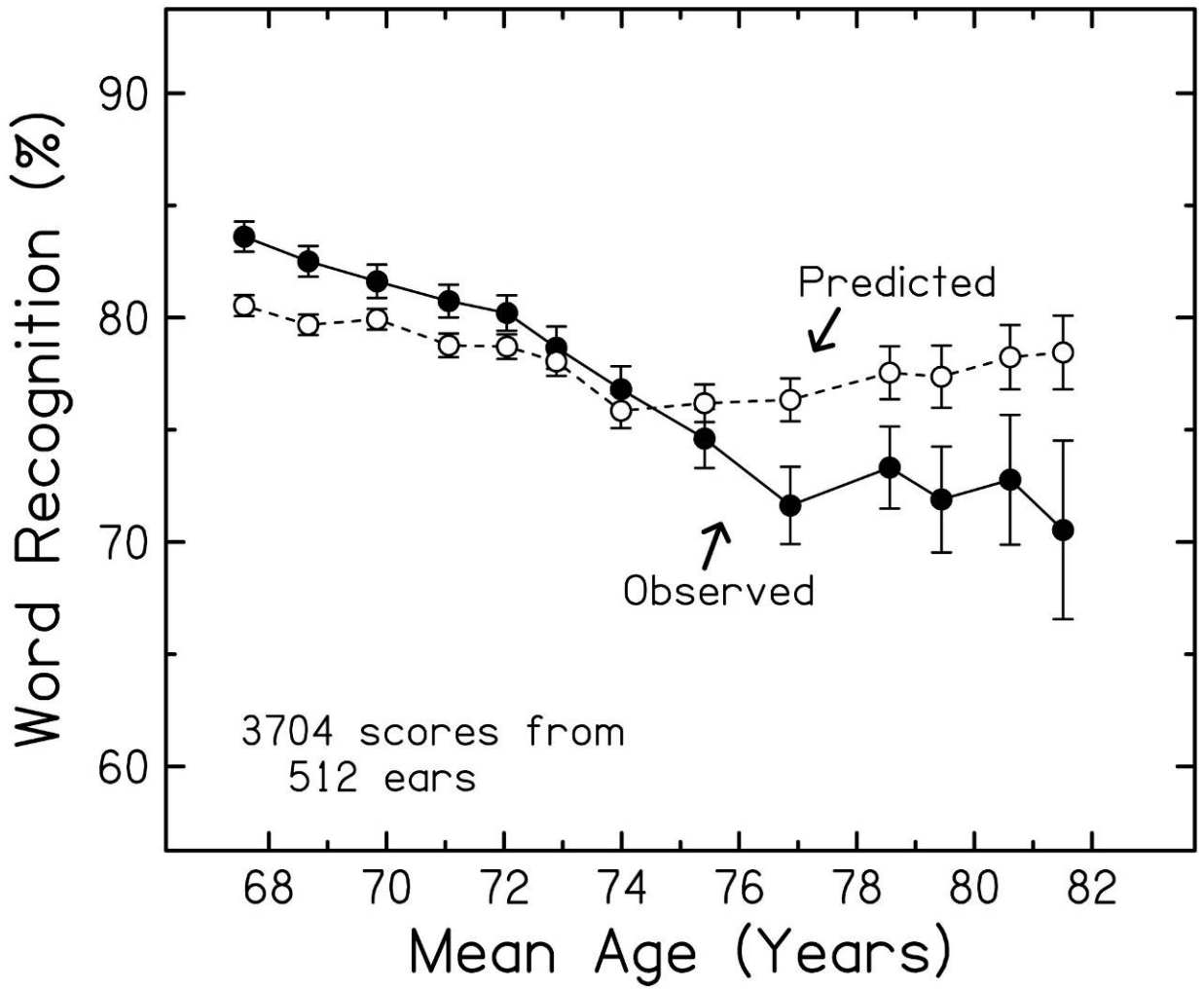
Rationale

- 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 (%)
90
80
70
60
Observed
3704 scores from
512 ears
68
70
72
74
76
78
80
82
Mean Age (Years)


Word Recognition (%)
90
80
70
60
Predicted
Observed
3704 scores from
512 ears
68
70
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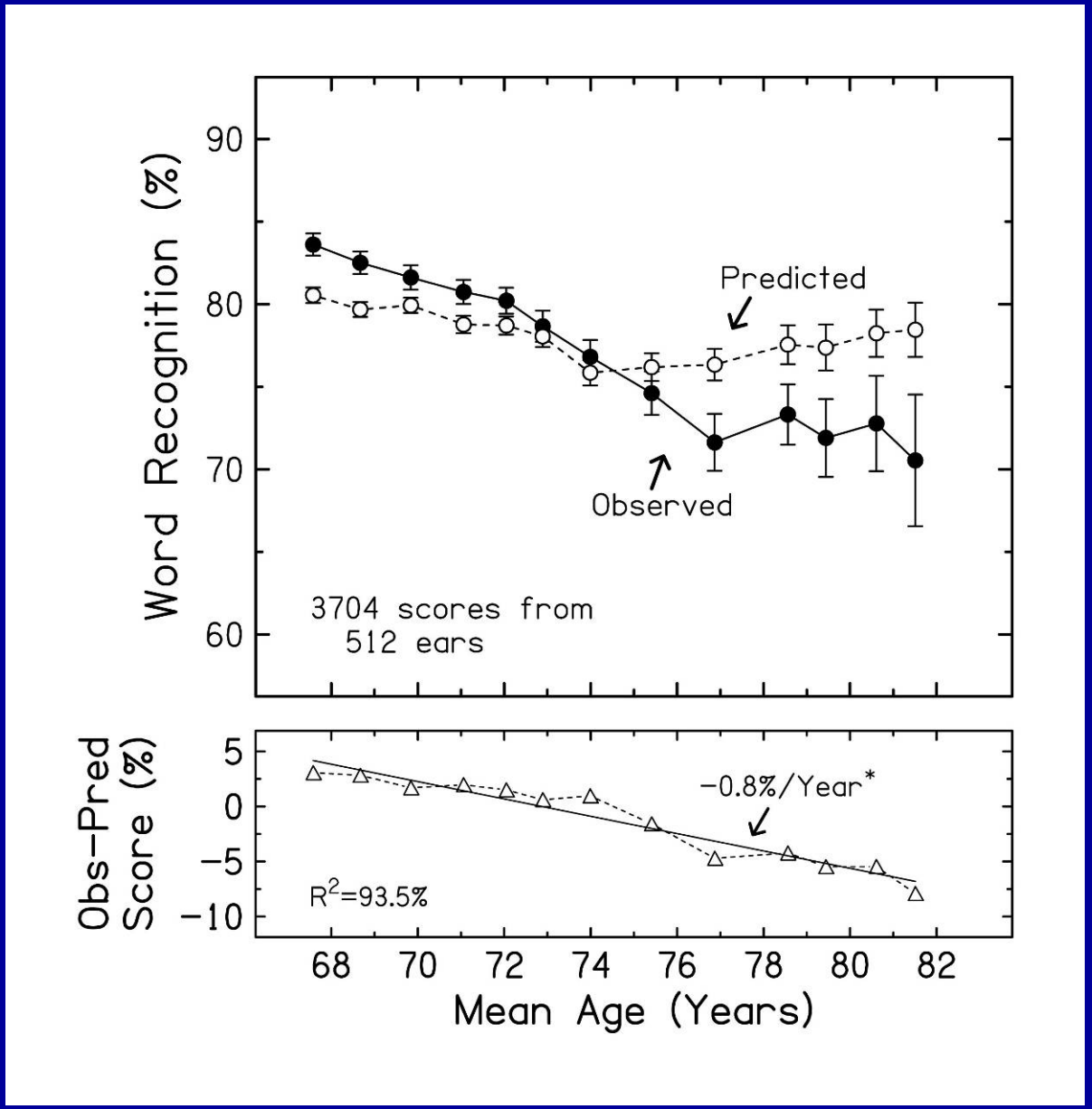
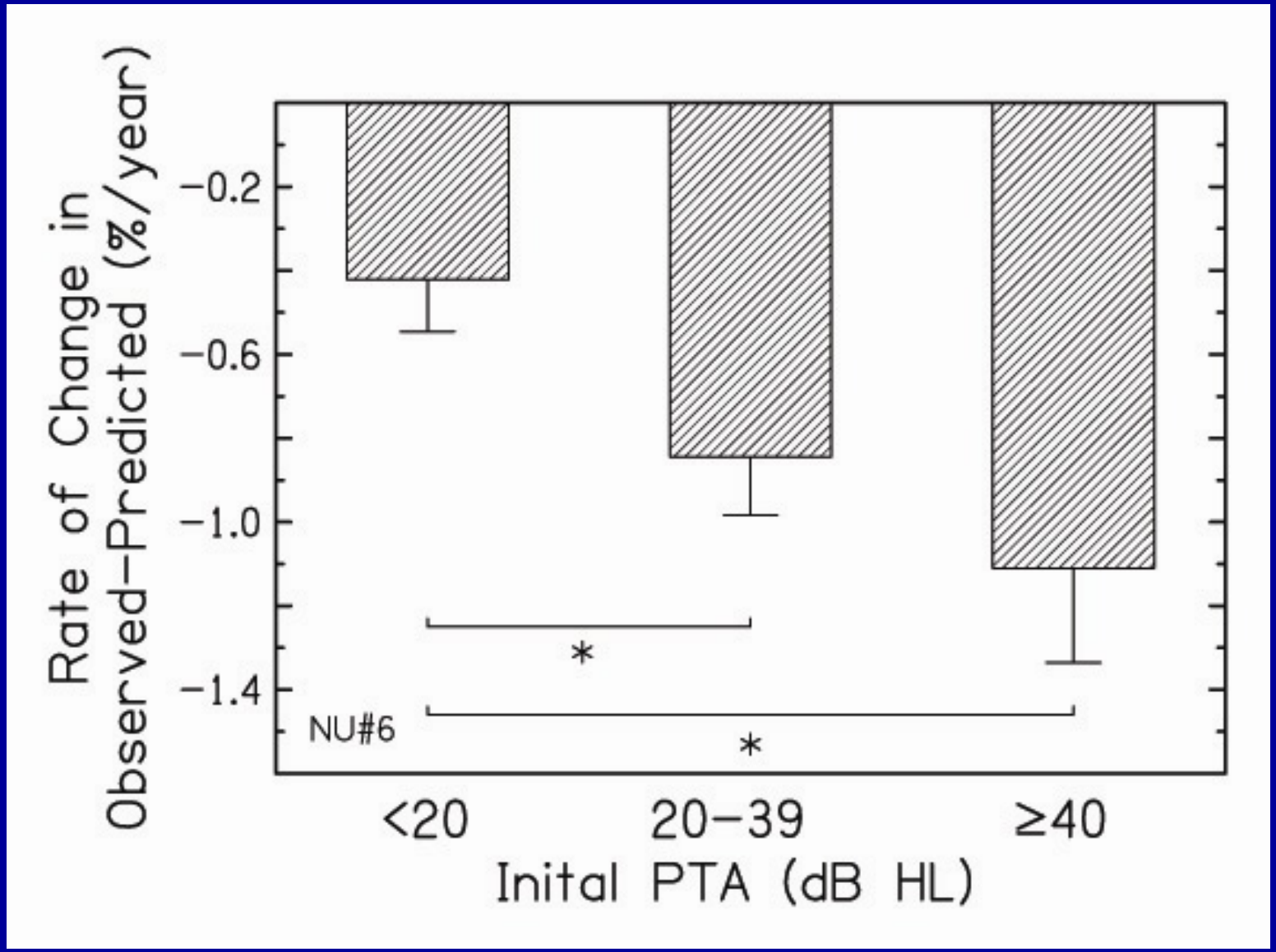
74
76
78
80
82
Mean Age (Years)

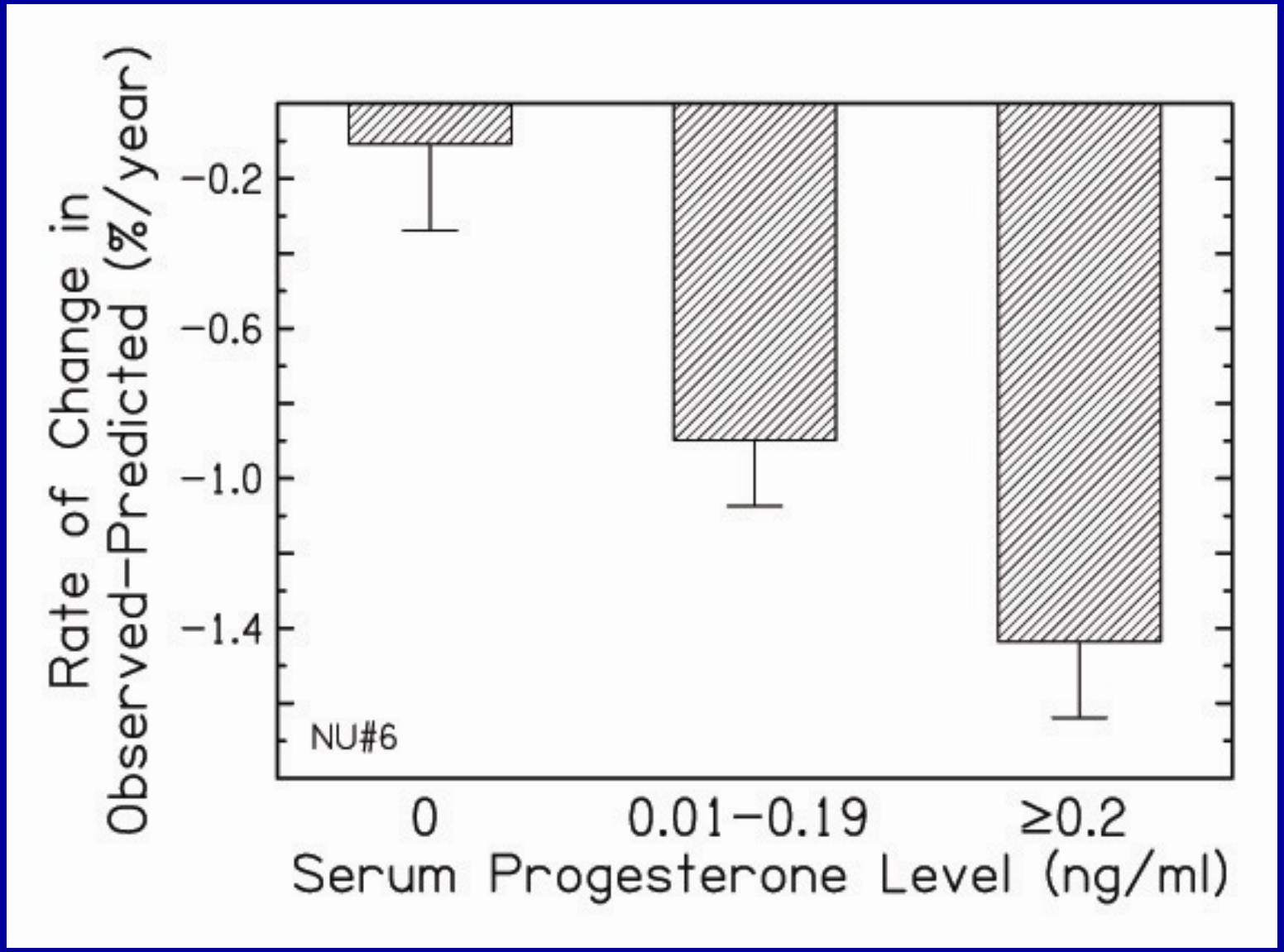


Dubno, Lee, Matthews, Ahlstrom, Horwitz, Mills (2008). J Acoust Soc Am 123, 462-475.


Rate of Change in Observed–Predicted (%/year)
−0.2
−0.6
−1.0
−1.4
NU#6
*
*
<20
20–39
≥40
Inital PTA (dB HL)

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


Rate of Change in Observed–Predicted (%/year)
−0.2
−0.6
−1.0
−1.4
NU#6
0
0.01–0.19
≥0.2
Serum Progesterone Level (ng/ml)

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

Acknowledgements

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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)