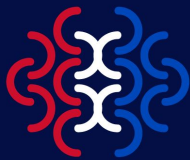




Hearing  
and  
Dementia

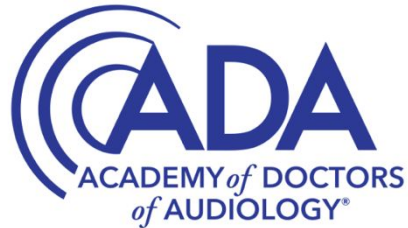


**BRAIN HEALTH  
ACADEMY™**  
UsAgainstAlzheimer's

July 19, 2023

# Acknowledgements

This course is presented in partnership with



Canadian Academy of Audiology  
Académie Canadienne d'audiologie

This course is provided free of charge, with support from:



# Presenter



Frank R. Lin, MD, PhD, Director of the Cochlear Center for Hearing and Public Health; Professor of Otolaryngology, Medicine, Mental Health, and Epidemiology at Johns Hopkins University



# Hearing and Dementia

## Course Description

There is growing evidence that suggests a link between hearing loss and dementia. Several studies have shown that individuals with hearing loss are at a higher risk of developing dementia and other cognitive impairments. This course provides strategies and resources to help health professionals to address hearing loss and build cognitive resilience.

## Learning Objectives



Participants will be able to list 6 or more modifiable risk factors for dementia.



Participants will be able to summarize the link between **hearing loss** and dementia.



Participants will be able to identify effective interventions and strategies to address **hearing loss** with a special focus on adults 45+.

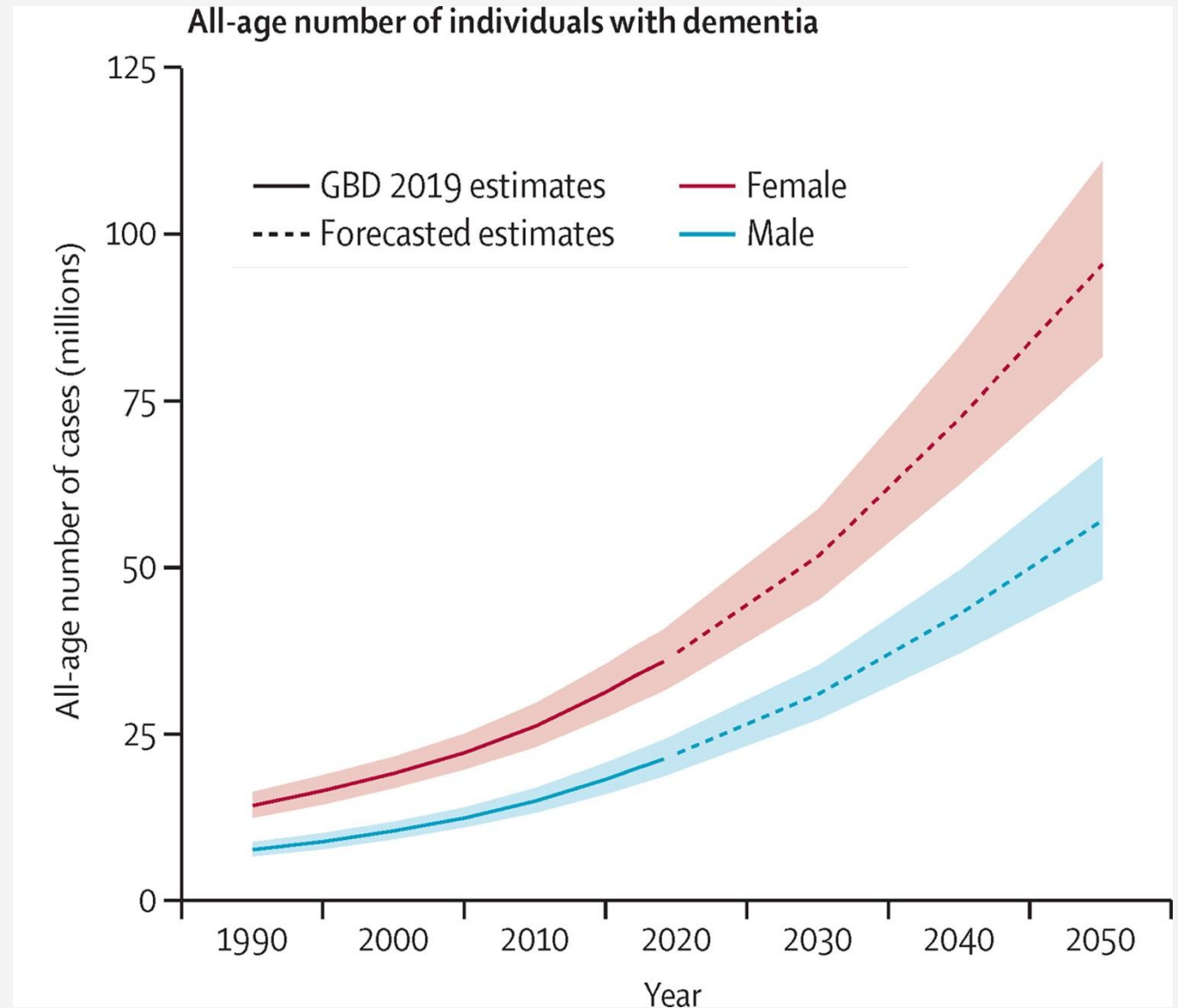


Participants will be able to identify special considerations for high-risk populations.



**Facts: Alzheimer's  
and related  
dementias (ADRD)**

**Global dementia prevalence is increasing rapidly because of the aging of the world's population**



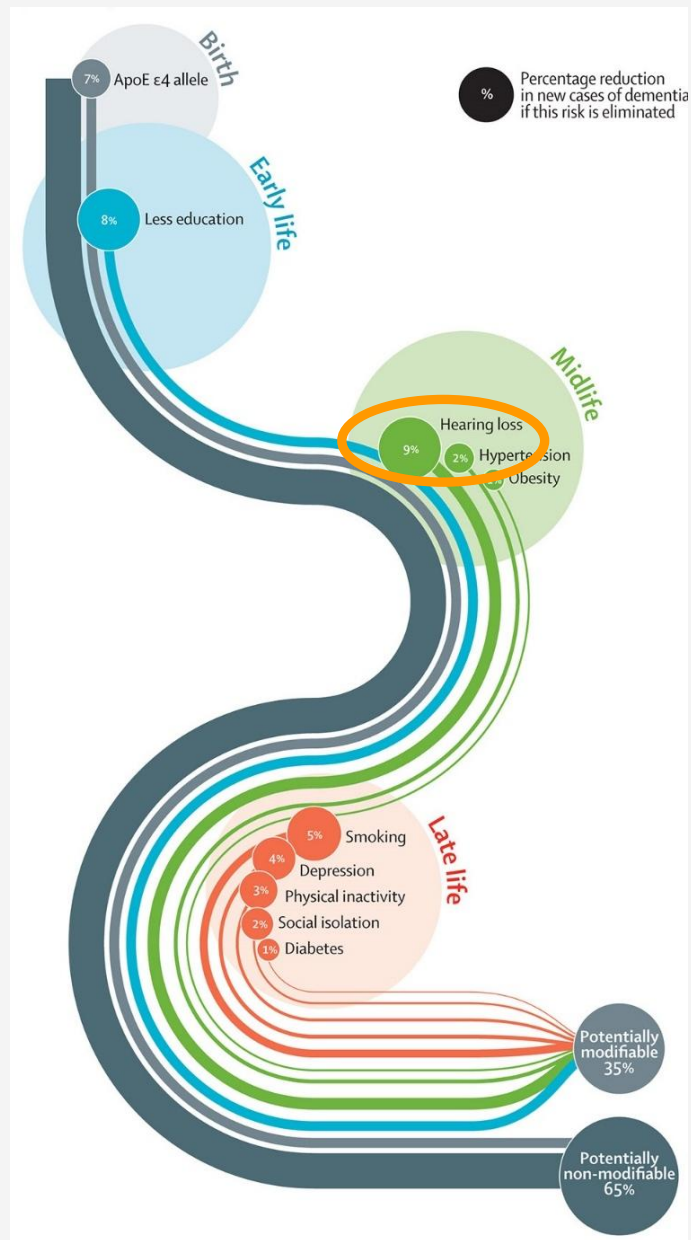


# Modifiable Risk Factors for Dementia

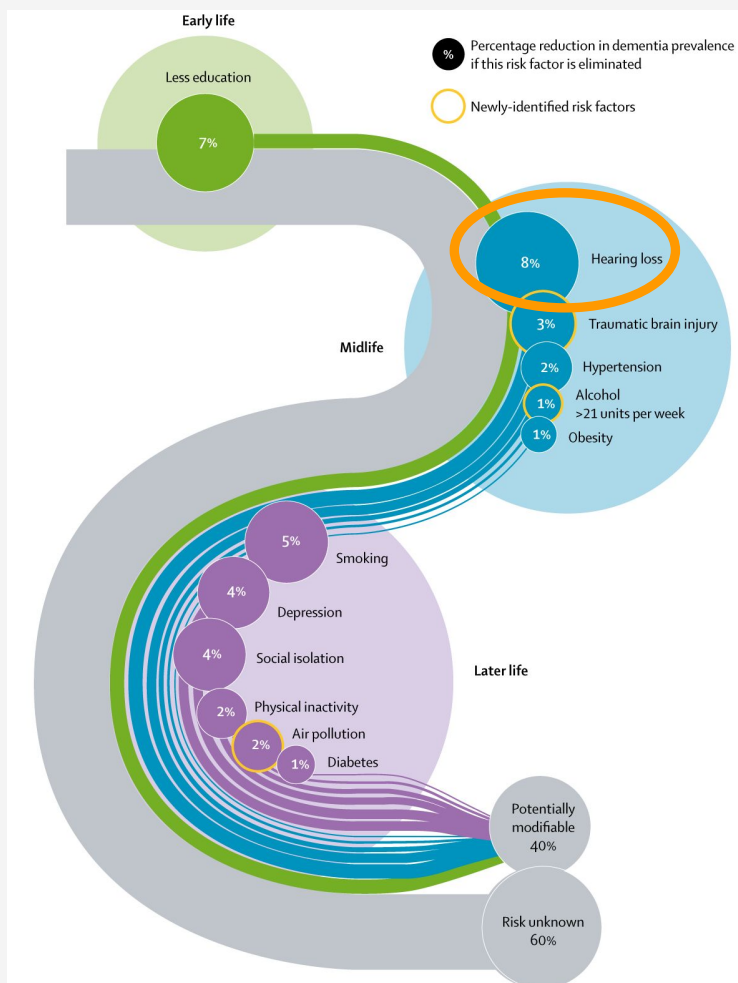
# Lancet Commission on Dementia Prevention, Intervention & Care

*Potentially Modifiable Risk Factors for Dementia*

## 2017

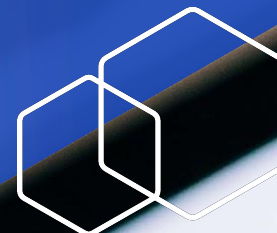


## 2020



**Hearing loss in mid & late life identified as the single largest potentially modifiable risk factor for dementia**





**The link between  
Hearing Loss &  
Alzheimer's and related  
dementias**

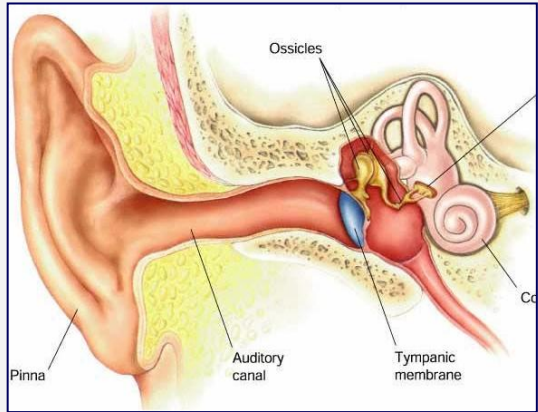
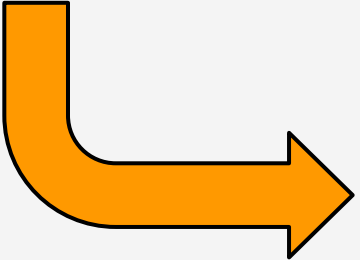
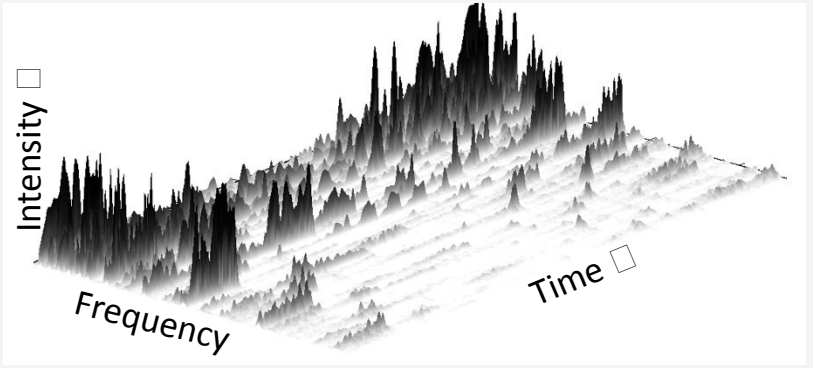


# Hearing Loss & Dementia

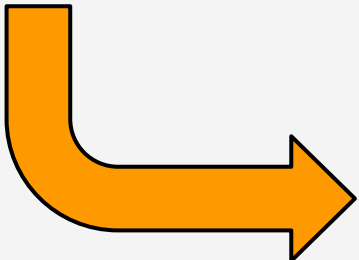
## Overview

- General definitions (hearing, cognition, dementia)
- Theoretical framework underlying the association of hearing loss and dementia
- Existing scientific evidence & ACHIEVE trial

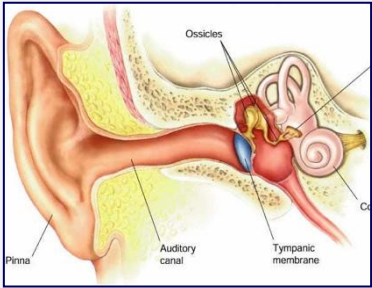
# Hearing depends on *peripheral auditory encoding and central auditory decoding*



**Peripheral auditory transduction (encoding by the cochlea)**

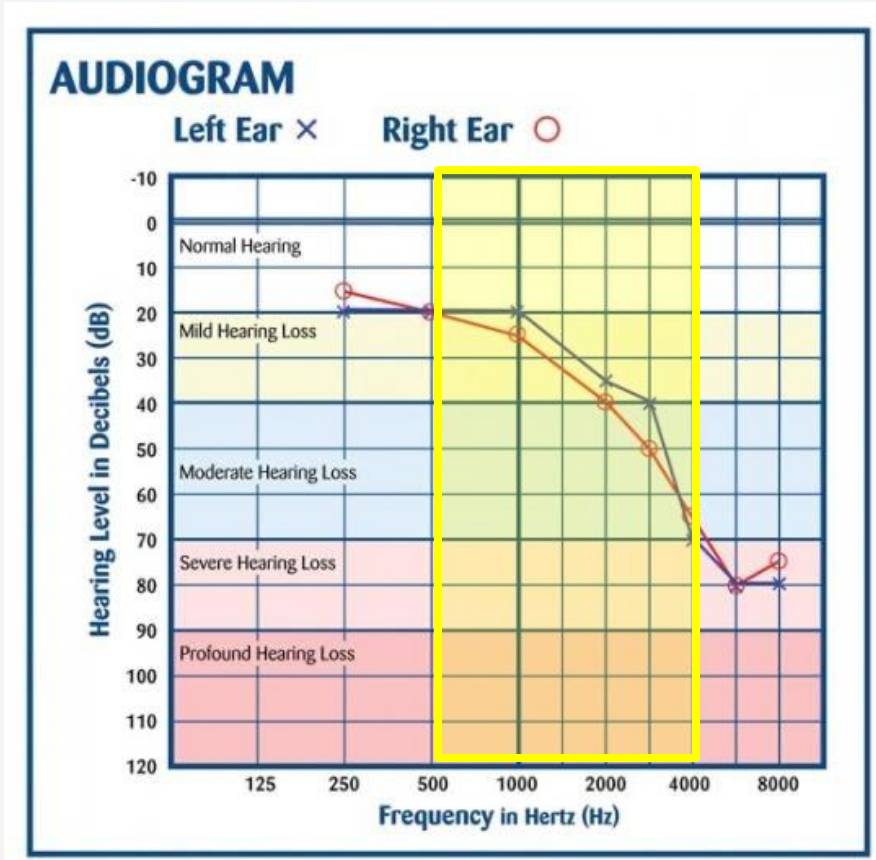


**Central auditory processing (decoding)**

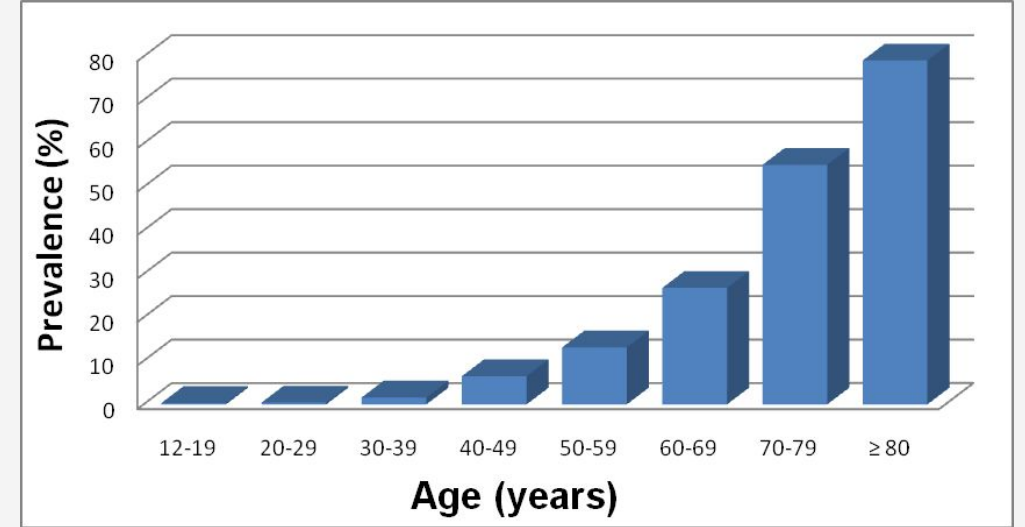


**“Hearing Loss”** – Result of progressive damage to the cellular structures of the cochlea from noise, aging, etc.

Pure tone average (PTA) of 0.5, 1, 2, & 4 kHz tones in the better-hearing ear



Prevalence of Hearing Loss in the U.S., 2001-2008



Better-ear PTA > 25 dB; Lin 2011, Arch Int Med

# Cognition in Older Adults

## *General Principles*



- Certain domains of cognitive function progressively decline with age (e.g., memory, executive function, processing speed) while others (e.g., numeracy) do not substantively change
- Testing is generally conducted by a trained psychometrist face-to-face in a quiet room free of distractions
  - Many/most cognitive tests also do not contain auditory stimuli
- Hearing loss, except for a more severe loss, would not directly interfere with speech understanding under these circumstances

# Dementia

## *General Principles*

- Dementia reflects the state of cognitive impairment when an individual can no longer independently perform their usual daily activities
- The most common etiologic causes include Alzheimer's disease & vascular disease. Most dementias in late life reflect a mix of these two.
- Exists on spectrum with a long prodromal state (cognitively normal, MCI [mild cognitive impairment], dementia) without 1:1 correlation of pathology to phenotype

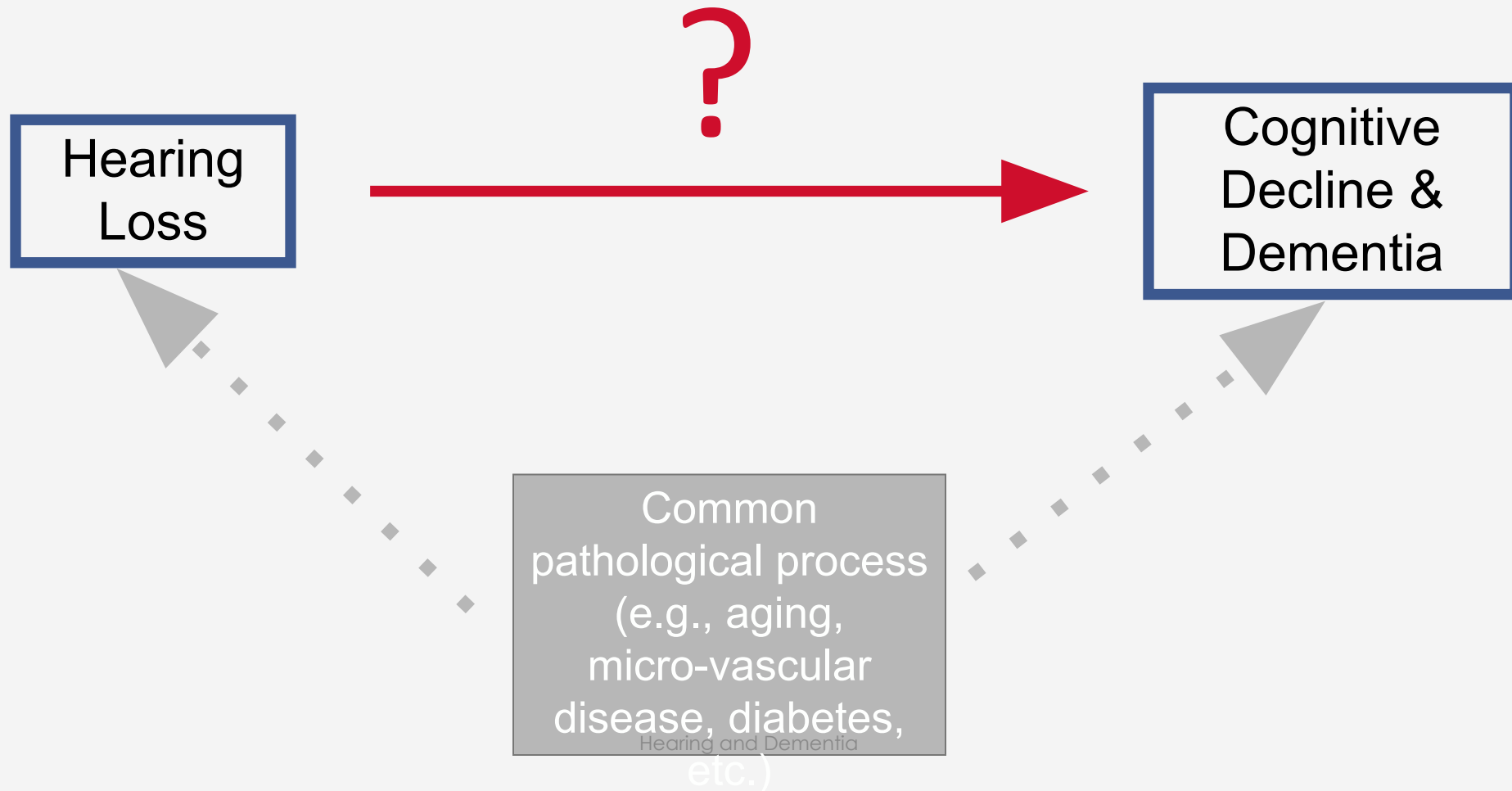
# Hearing Loss & Dementia

## Overview

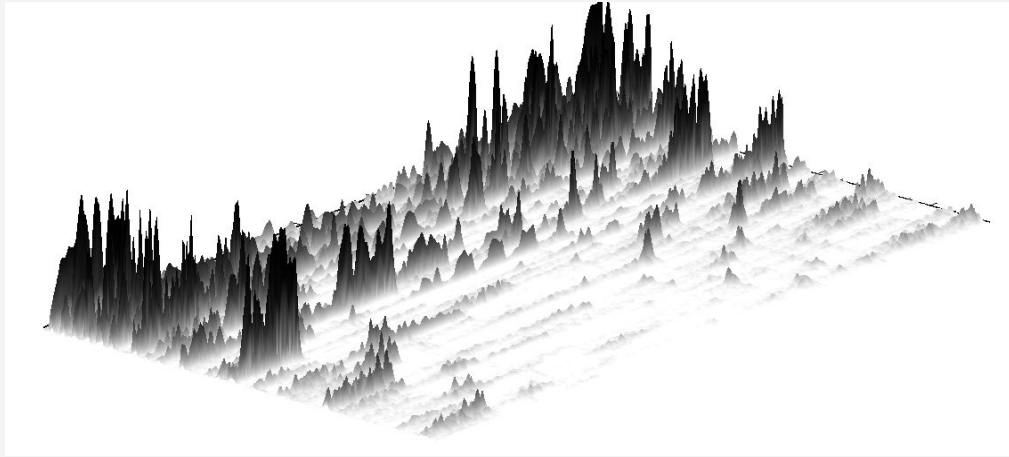
- General definitions (hearing, cognition/dementia)
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# Hearing Loss & Dementia

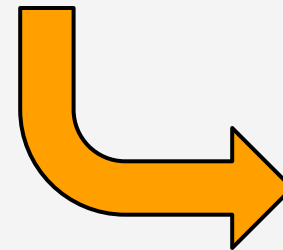
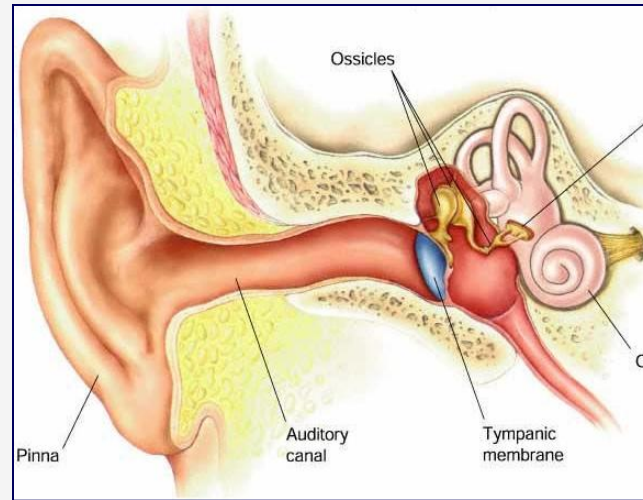
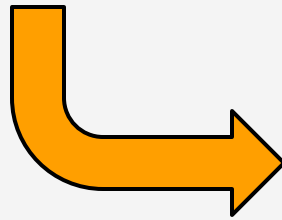
*Common Cause or Modifiable Risk Factor*







**“Sunday”**



**Hearing Loss &  
Cochlear impairment**



**Decreased sensitivity  
& distortion in sound  
encoding**

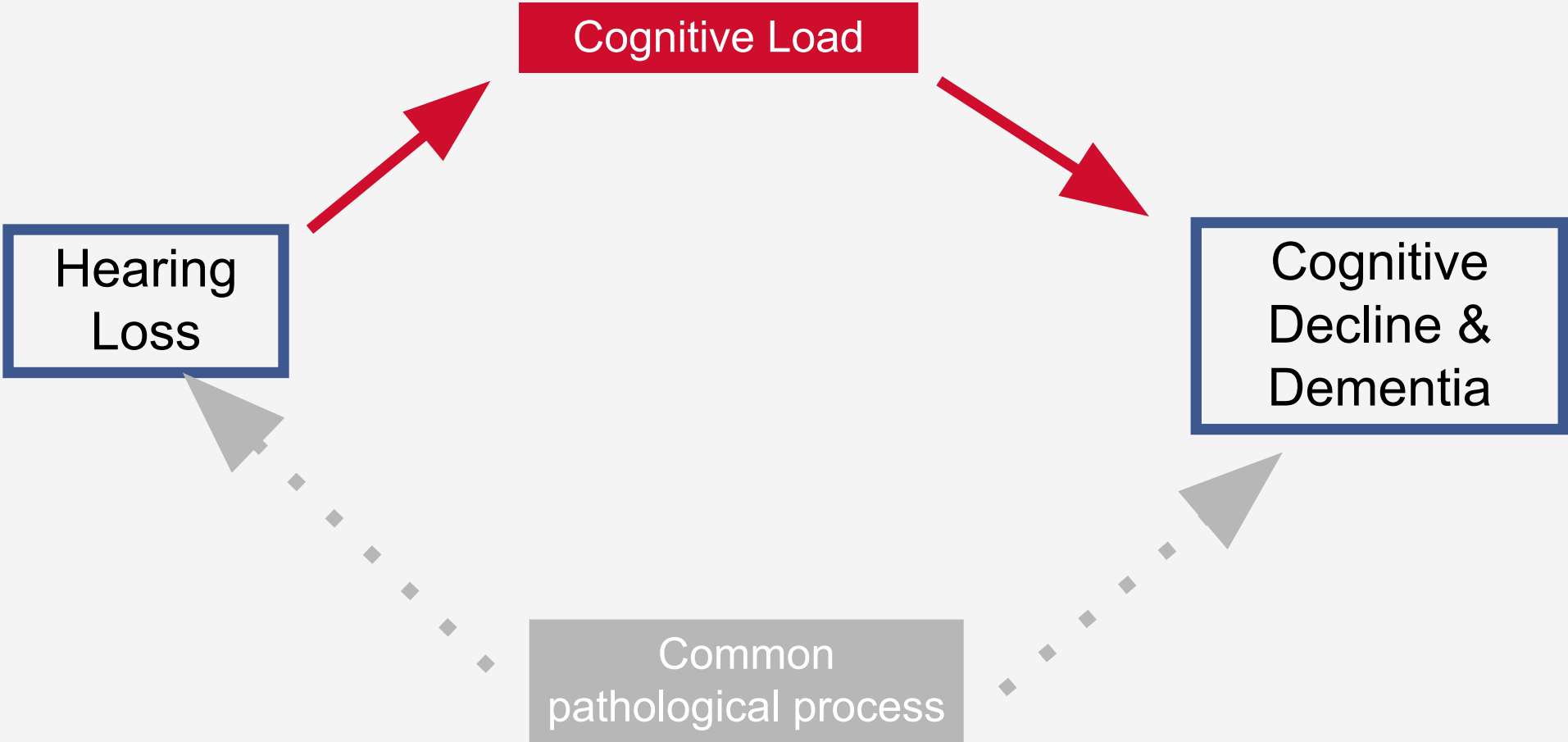


**“Effortful listening”**



# Hearing Loss & Dementia

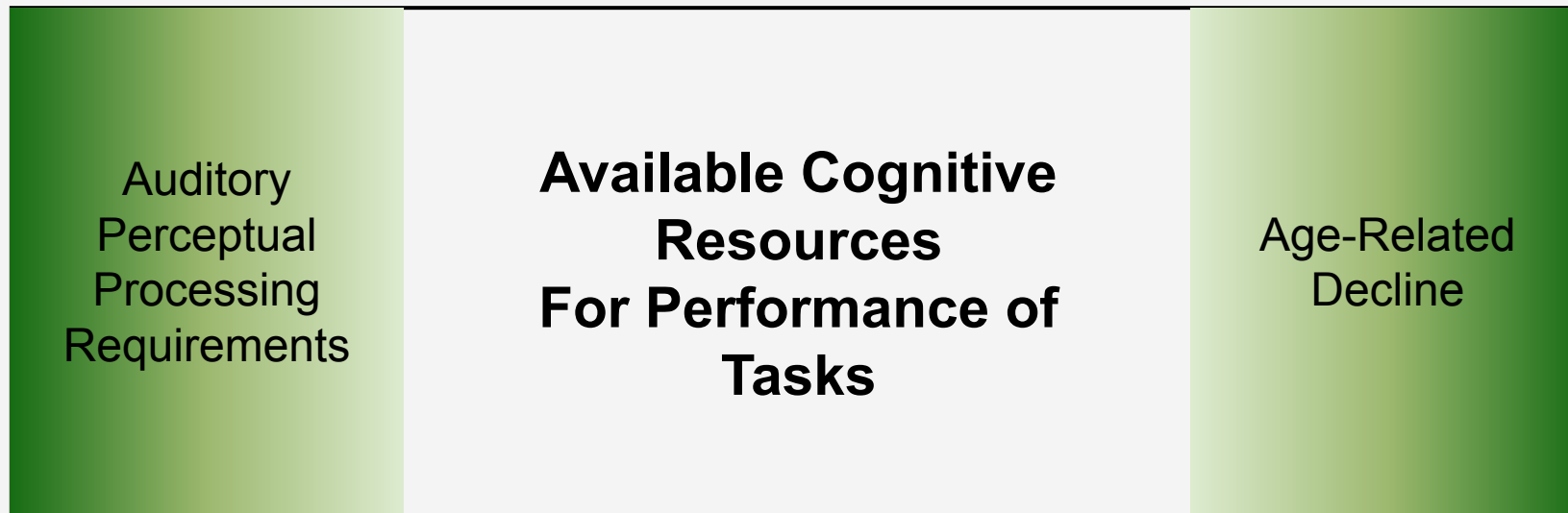
*Common Cause or Modifiable Risk Factor*



# Hearing Loss & Cognitive Load

Kahneman model of shared attention and resource capacity

## Cognitive Resource Capacity

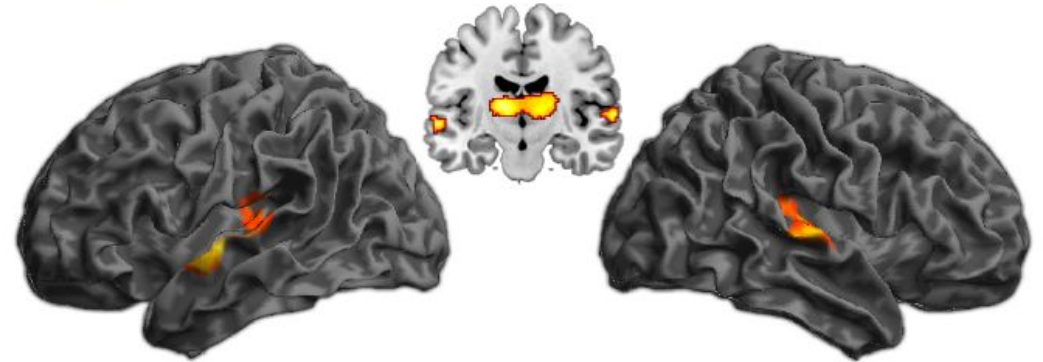


# Hearing Loss & Cognitive Load

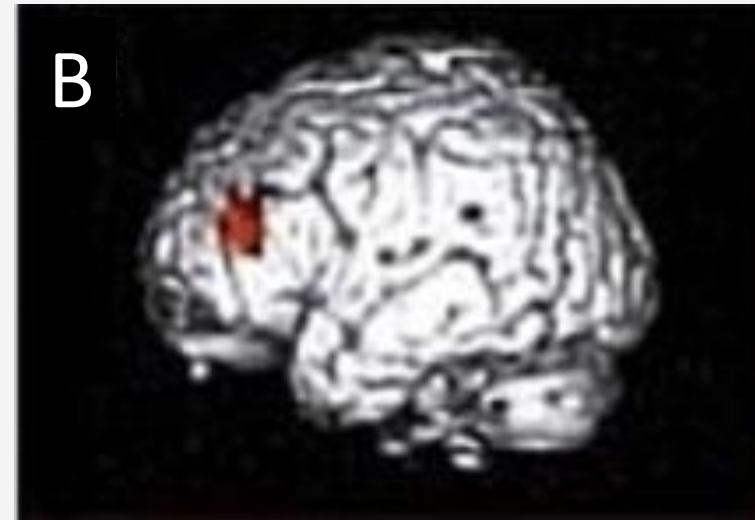
Poorer hearing is associated with:

- A. Reduced language-driven activity in primary auditory pathways
  
- A. Increased compensatory language-driven activity in pre-frontal cortical areas

A Decreased language-driven speech activity in poorer hearers



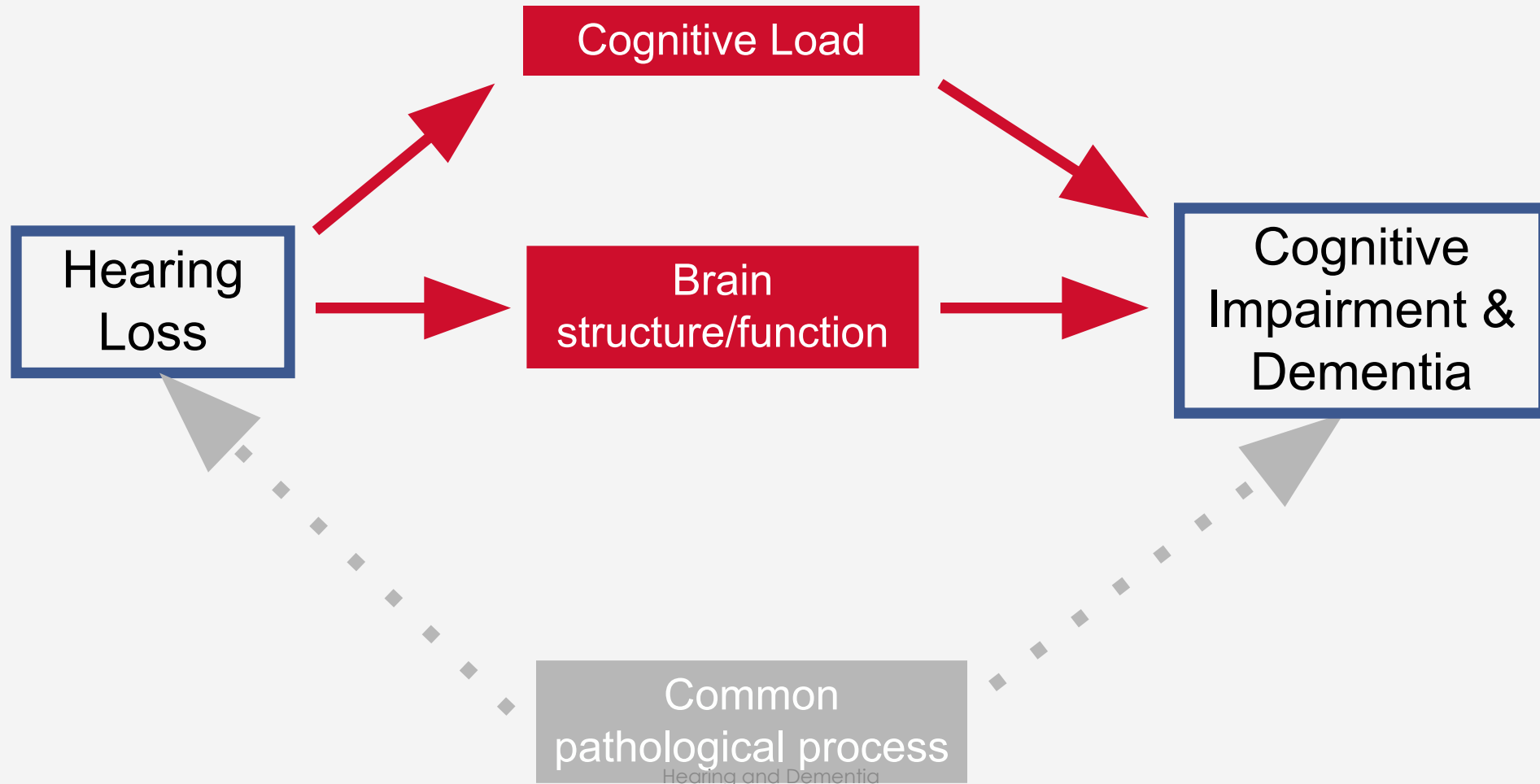
Peelle et al, J. Neurosci, 2011



Grossman et al, Brain Lang, 2002

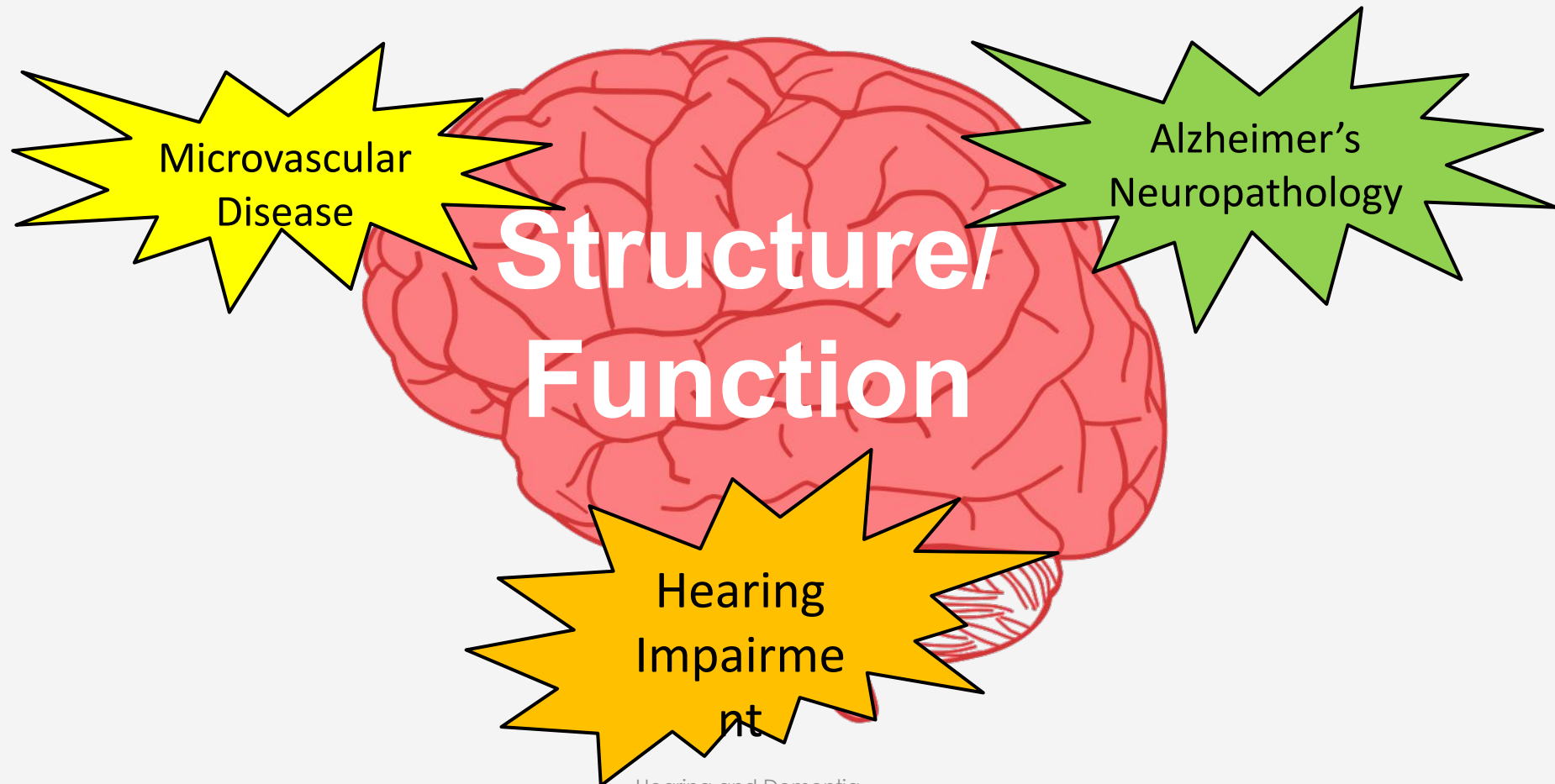
# Hearing Loss & Dementia

*Common Cause or Modifiable Risk Factor*



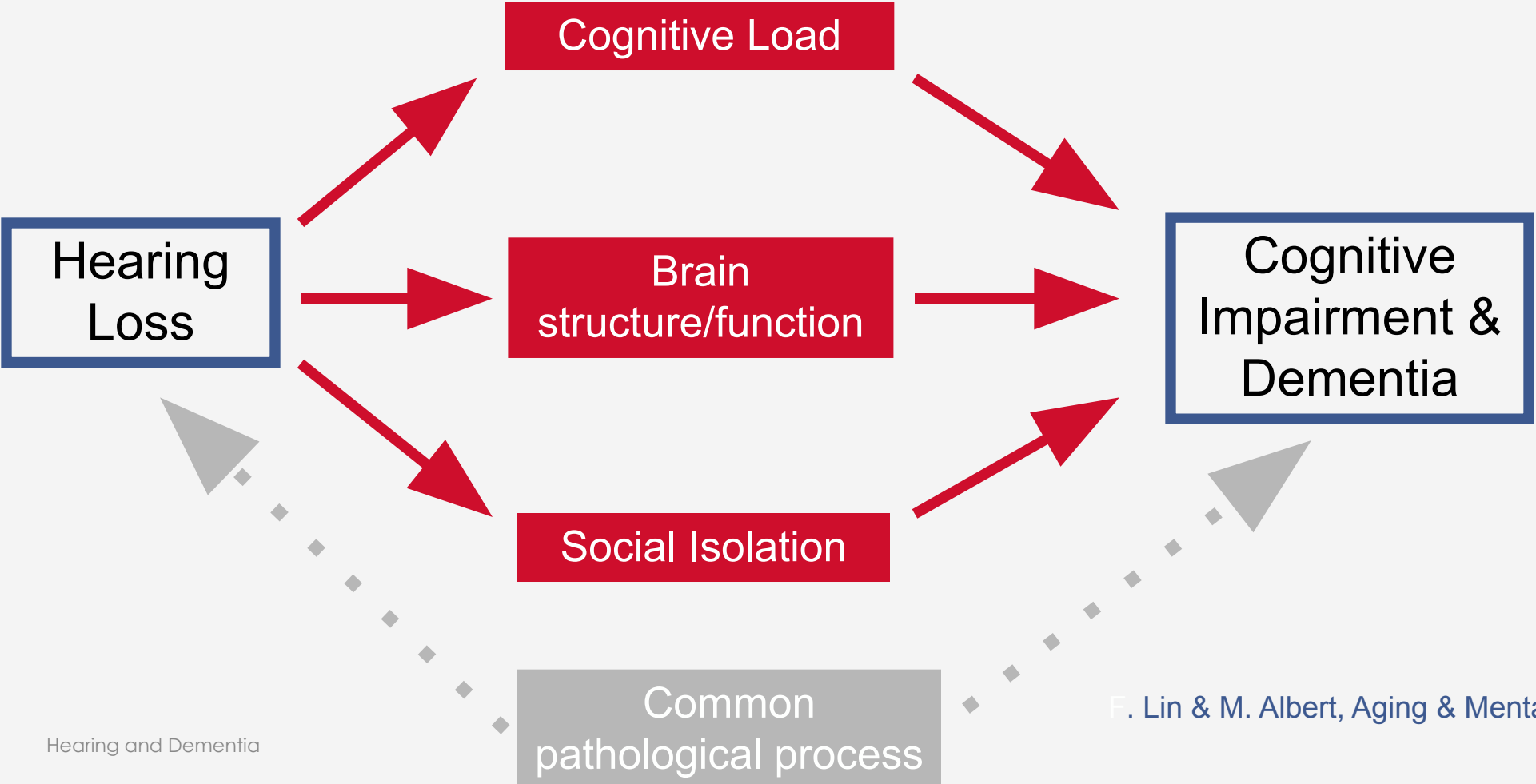
# Risk Factors for Dementia – Multi-Hit Theoretical Model

## *Hearing Loss & Brain Structure/Function*



# Hearing Loss & Dementia

*Common Cause or Modifiable Risk Factor*



# Hearing Loss & Dementia

## *Hypothesized Mechanistic Pathways*

- Cognitive load (“information degradation hypothesis”)
  - Hearing loss imposes a constant load on cortical resources that otherwise could have buffered against other pathological contributors to dementia (AD, vascular disease)
- Direct effects on brain structural integrity (“sensory deprivation hypothesis”)
  - Hearing loss contributes to accelerated brain atrophy & other pathologic brain changes (white matter tracts, amyloid/tau changes, altered functional connectivity)
- Social isolation/loneliness
  - Multiple factors could be involved—less physical activity & cognitively-stimulating activities, stress/inflammation, adherence to medical care, etc.



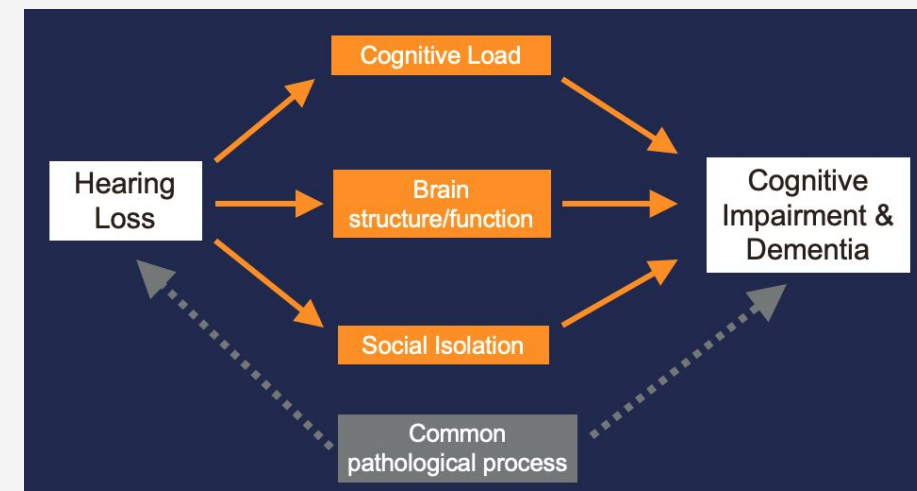
# Hearing Loss & Dementia

## *Overview*

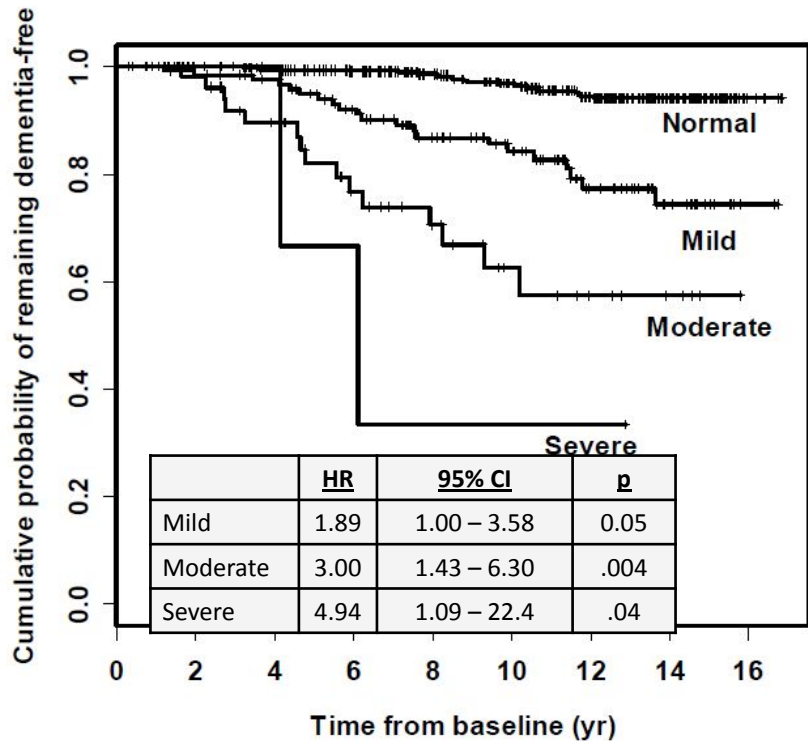
- General definitions (hearing, cognition/dementia)
- Theoretical framework underlying the association of hearing loss and dementia
- Existing scientific evidence & ACHIEVE trial

# Hearing Loss & Dementia

## *Epidemiological Studies*



- Importance of large epidemiological studies of older adults that allow for:
  - Precise measures of hearing, cognition, and other outcomes
  - Generalizable study cohorts
  - Sufficient sample sizes and analytic methods to adjust for confounding



Lin et al., Arch Neuro., 2011

## Dementia in 1057 Men Followed for 17 years in the Caerphilly Prospective Study (U.K.)

Cognitive impairment	Model 1: adjusted for age, OR <sup>a</sup> (95% CI), p value	Model 2: adjusted for age, social class, anxiety, OR <sup>a</sup> (95% CI), p value	Model 3: adjusted for age, social class, anxiety, premorbid intelligence, OR <sup>a</sup> (95% CI), p value
All dementia (n = 79)	4.07 (2.21-7.50), <0.001	3.26 (1.71-6.21), <0.001	2.67 (1.38-5.18), 0.004
Vascular dementia (n = 38)	3.83 (1.69-8.65), 0.001	2.93 (1.24-6.94), 0.015	2.40 (0.99-5.83), 0.05
Nonvascular dementia (n = 41)	4.20 (1.84-9.55), 0.001	3.58 (1.50-8.51), 0.004	2.96 (1.21-7.22), 0.017
CIND (n = 146)	2.32 (1.50-3.59), <0.001	1.72 (1.09-2.74), 0.021	1.24 (0.77-2.01), 0.38
All dementia (n = 46), omitting men with evidence of early cognitive decline	2.23 (1.04-4.77), 0.039	1.64 (0.72-3.73), 0.24	1.32 (0.57-3.12), 0.52

J. Gallacher et al., Neurology, 2012

## Dementia in 1,889 older adults followed for 9 years

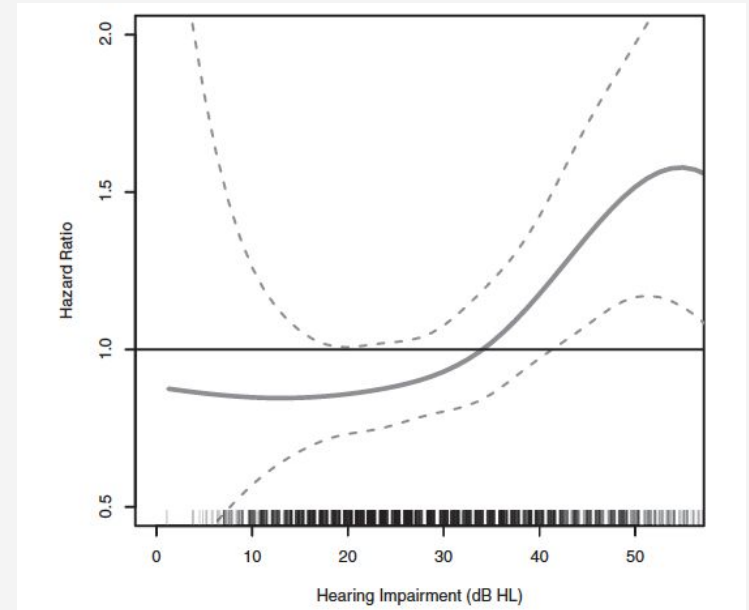
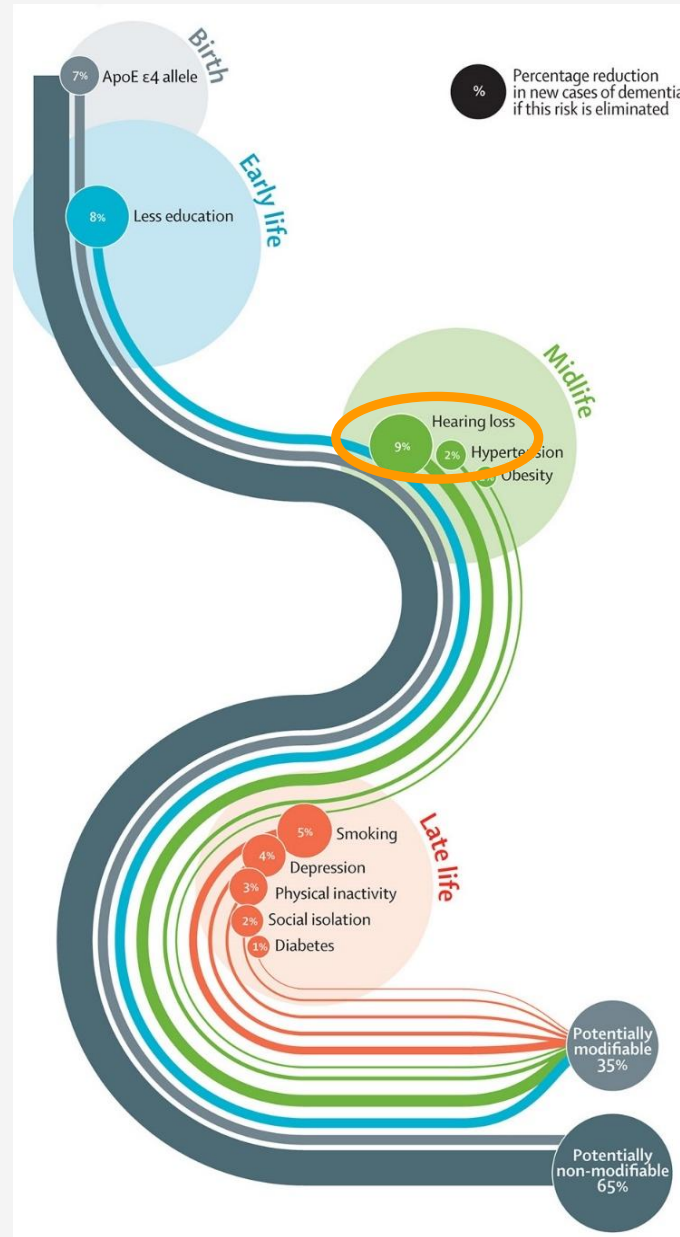


Figure 2. Multivariable-adjusted association between PTA and incident dementia, Health ABC Study, N = 1,889, 1999–2008. HR of incident dementia

# Lancet Commission on Dementia Prevention, Intervention & Care

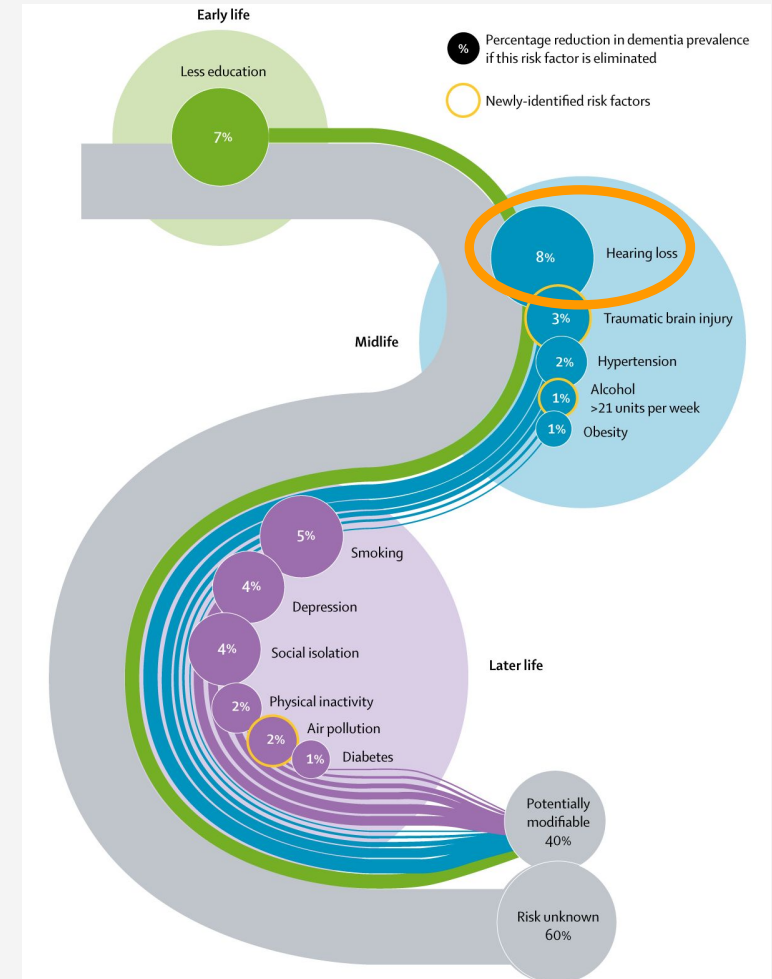
*Potentially Modifiable Risk Factors for Dementia*

## 2017



Hearing and Dementia

## 2020



**Hearing loss in mid & late life identified as the single largest potentially modifiable risk factor for dementia**

**The question of whether treating hearing loss could reduce cognitive decline or the risk of dementia remained unknown**

- Question could not be definitively answered through observational studies because of bias from residual confounding (income, health behaviors, etc.)
- There was never previously a randomized controlled trial of treating hearing loss to determine effects on cognitive decline/dementia & other key outcomes (e.g., brain atrophy, health care costs, etc.)

# Can treating hearing loss reduce cognitive decline over 3 years in older adults with hearing loss & without substantial cognitive impairment?

## Aging and Cognitive Health Evaluation in Elders (ACHIEVE) study

A landmark randomized controlled trial to determine how hearing intervention affects brain health in older adults.

### MAIN FOCUS



COGNITIVE  
DECLINE

### Other Areas



BRAIN  
STRUCTURE



MENTAL HEALTH  
& WELL-BEING



PHYSICAL  
FUNCTION



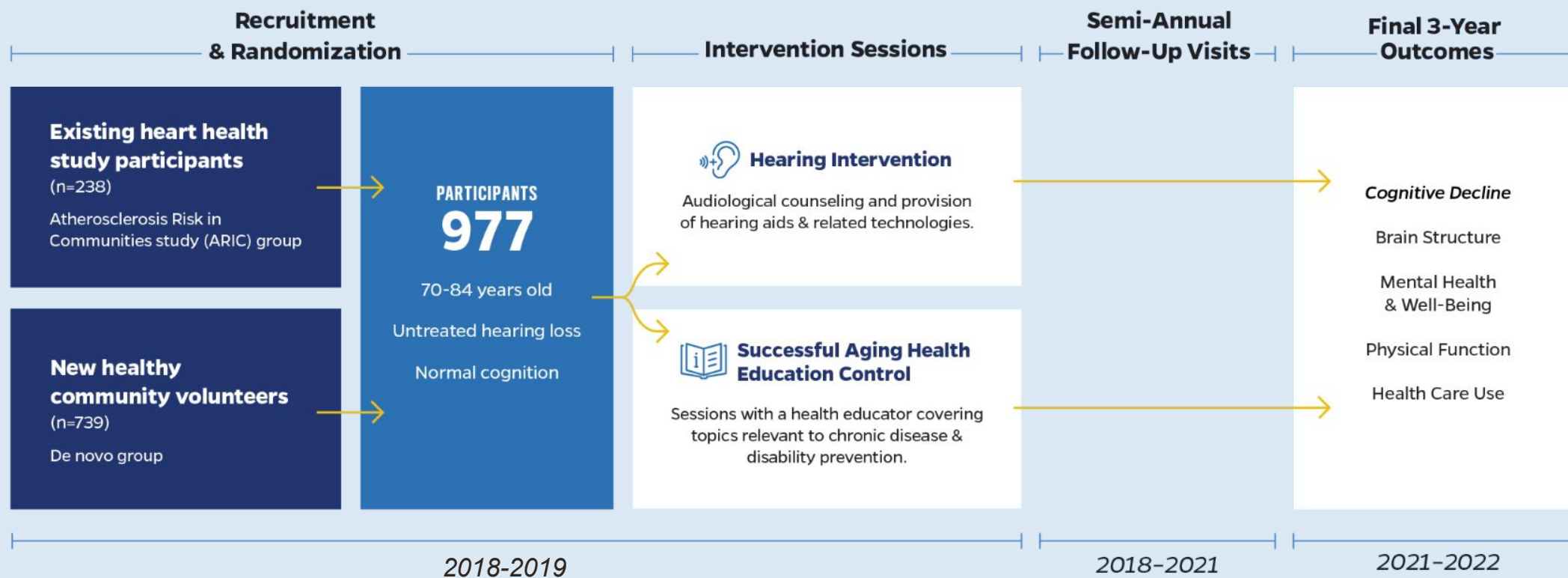
HEALTH  
CARE USE

**\*\*Main trial results presented July 18, 2023 at Alzheimer's Association International Conference & co-published in Lancet on the same day**

# STUDY DESIGN

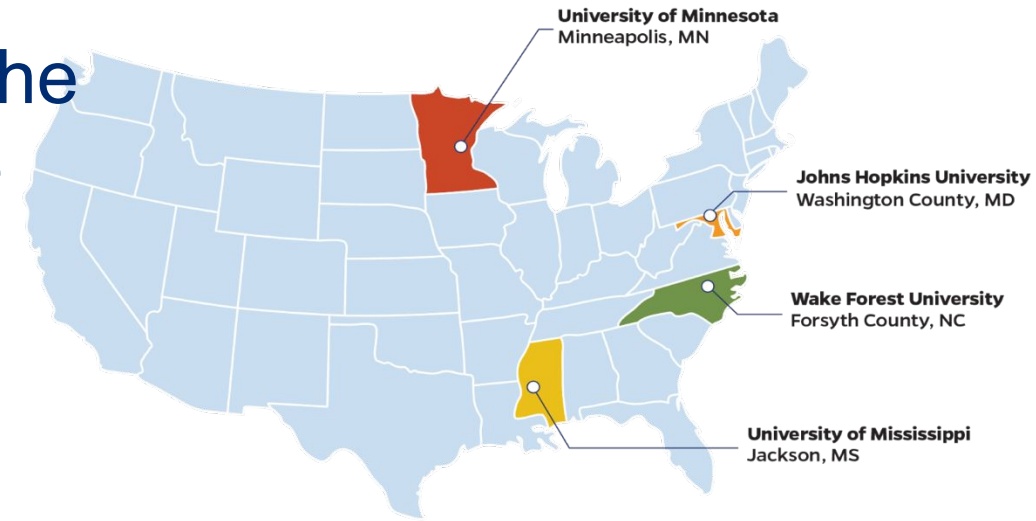
Study design, methods, & ACHIEVE cohort characteristics

# ACHIEVE STUDY DESIGN





# The ACHIEVE study was based within the scientific & physical infrastructure of the Atherosclerosis Risk in Communities (ARIC) study



- ARIC study – ongoing longitudinal observational study of 15,792 adults recruited in 1987-89 from the surrounding communities at the 4 field sites (ages 45-64 yrs at recruitment)
- Main goal of ARIC was to understand risk factors for heart disease & stroke
- ACHIEVE study was carried out at the same 4 field sites with participants recruited at each site from both ARIC and de novo (healthy community volunteers)

# The ACHIEVE study cohort (n = 977) was recruited from two distinct study populations at each site

- **ARIC Cohort** (n = 238)
  - ARIC participants came from a random sample of the population at each field site in 1987-89 and have been followed to the present day with 6 visits prior to ACHIEVE
- **De novo cohort** (n = 739)
  - New volunteers responding to advertisements about a clinical trial focused on interventions for healthy aging
- All participants informed they would be randomized to one intervention & offered the other intervention after Year 3

## Main Inclusion Criteria:

- 70-84 years-old
- MMSE  $\geq 23$  for high school degree or less;  $\geq 25$  for some college or more
- Untreated hearing loss with 0.5-4 kHz pure tone average  $\geq 30$  and  $< 70$  dB in the better-hearing ear
- Word recognition in quiet  $\geq 60\%$  correct in the better-hearing ear
- Community-dwelling

## Main Exclusion Criteria:

- Self-reported disability in 2+ ADL
- Presenting near visual acuity worse than 20/63 (14-point font)
- Permanent conductive hearing loss

# Design: Randomization & Interventions

- Eligible participants randomized 1:1 to hearing intervention versus health education control, stratified by severity of hearing loss, recruitment source (ARIC vs de novo), and field site

## Hearing Intervention

- Best-practices hearing intervention provision with a certified study audiologist
- 4 sessions to receive hearing loss education and hearing aids & related technologies (streamers, remote mic, etc.)
- Semiannual visits thereafter for 3 years to receive booster sessions

## Health Education Control

- Established program (10 Keys) to promote understanding of key health topics (nutrition, etc.) important for healthy aging
- 4 sessions with a certified health educator to cover healthy aging topics
- Semiannual visits thereafter for 3 years to receive booster sessions

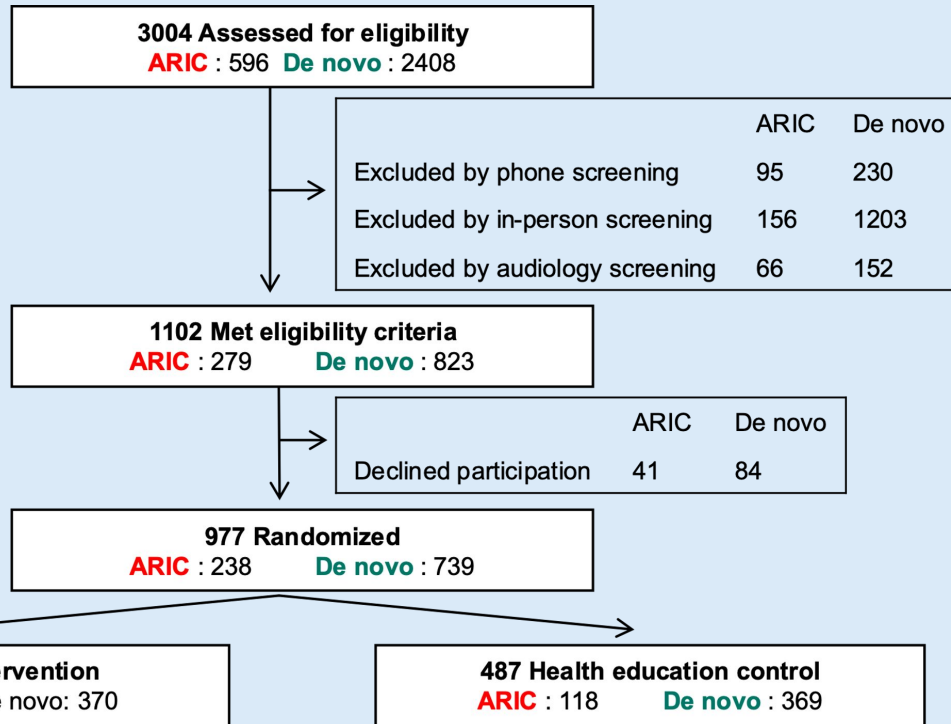
# Design: Study Outcomes

- Baseline & semiannual in-person visits for intervention delivery & outcome assessments for 3 years
- **Primary endpoint:** Change from baseline to Year 3 in a global cognition standardized factor score derived from a comprehensive neurocognitive battery administered annually
- Secondary cognitive outcomes:
  - Domain-specific cognitive function (memory, executive function, & language)
  - Incident cognitive impairment
- Other pre-specified outcomes
  - Hearing Handicap Inventory for the Elderly\* (HHI; measure of self-reported communication impairment); Cohen Social Network Index\*, UCLA Loneliness Scale\*; Brain MRI; depression; physical functioning/activity & accelerometry; falls; hospitalizations; health care costs

# ACHIEVE

## Study Cohort Recruitment

### *Recruitment*



ACHIEVE Planned, Actual, and Adjusted Enrollment

Based on Data Retrieved October 30, 2019 (UC7497A1)

Type of Participant All Participants

Site All Sites



# Follow-Up Visits

Complete Year 3 follow-up data available on 89.8% (877/977) of participants.

<b>490 Hearing intervention</b>		
<b>ARIC:</b> 120		<b>De novo:</b> 370

<b>ARIC</b>	<b>Year 1</b>	<b>De novo</b>
114	Assessed in-person	320
0	Assessed by phone	39
5	Incomplete assessment	5
0	Lost to follow-up	4
0	Withdrew	1
1	Deceased	1

<b>ARIC</b>	<b>Year 2</b>	<b>De novo</b>
79	Assessed in-person	95
28	Assessed by phone	255
4	Incomplete assessment	7
2	Lost to follow-up	3
2	Withdrew	0
4	Deceased	4

<b>ARIC</b>	<b>Year 3</b>	<b>De novo</b>
97	Assessed in-person	336
4	Assessed by phone	3
5	Incomplete assessment	3
0	Lost to follow-up	9
2	Withdrew	1
3	Deceased	5

<b>487 Health education control</b>		
<b>ARIC:</b> 118		<b>De novo:</b> 369

<b>ARIC</b>	<b>Year 1</b>	<b>De novo</b>
115	Assessed in-person	296
1	Assessed by phone	48
1	Incomplete assessment	4
0	Lost to follow-up	3
0	Withdrew	17
1	Deceased	1

<b>ARIC</b>	<b>Year 2</b>	<b>De novo</b>
80	Assessed in-person	101
33	Assessed by phone	235
3	Incomplete assessment	4
0	Lost to follow-up	1
0	Withdrew	1
1	Deceased	6

<b>ARIC</b>	<b>Year 3</b>	<b>De novo</b>
106	Assessed in-person	323
1	Assessed by phone	7
3	Incomplete assessment	5
2	Lost to follow-up	0
1	Withdrew	1
3	Deceased	4

# Baseline Characteristics by Recruitment Source

**ARIC** cohort at increased risk for cognitive decline compared to **De novo**

Baseline characteristics	All Participants (N=977)	ARIC Cohort (N=238)	De novo Cohort (N=739)
*Age, mean (SD), y	76.8 (4.0)	78.9 (2.9)	76.1 (4.0)
*Female sex, No. (%)	523 (53.5)	147 (61.8)	376 (50.9)
*Black race, No. (%)	112 (11.5)	68 (28.6)	44 (6.0)
*Education, No. (%)			
Less than high school	37 (3.8)	22 (9.3)	15 (2.0)
High school, GED, or vocational school	418 (42.8)	96 (40.5)	322 (43.6)
College, graduate, or professional school	521 (53.4)	119 (50.2)	402 (54.4)
*Income, No. (%)			
Under \$25,000	147 (15.5)	60 (26.7)	87 (12.0)
\$25,000-\$49,999	283 (29.8)	77 (34.2)	206 (28.4)
\$50,000-\$74,999	210 (22.1)	47 (20.9)	163 (22.5)
\$75,000-\$100,000	140 (14.7)	21 (9.3)	119 (16.4)
Over \$100,000	170 (17.9)	20 (8.9)	150 (20.7)

*\*indicates statistically significant difference between groups*

# Baseline Characteristics by Recruitment Source (cont'd)

ARIC cohort at increased risk for cognitive decline compared to De novo

Baseline characteristics	All Participants (N=977)	ARIC Cohort (N=238)	De novo Cohort (N=739)
One or more apolipoprotein E ε4 alleles, No. (%)	224 (24.7)	59 (25.7)	165 (24.3)
*Diabetes, No. (%)	195 (20.0)	68 (28.6)	127 (17.2)
Hypertension, No. (%)	651 (66.8)	169 (71.9)	482 (65.2)
*Living alone, No. (%)	290 (30.0)	83 (35.9)	207 (28.1)
Pure tone average, mean (SD), dB	39.4 (6.9)	39.1 (6.7)	39.5 (7.0)
*Hearing handicap inventory, mean (SD)	15.3 (9.8)	12.0 (9.5)	16.3 (9.6)
*Mini-mental state exam, mean (SD)	28.2 (1.6)	28.0 (1.8)	28.3 (1.6)
*Global cognition, mean (SD)	0.000 (0.926)	-0.379 (1.042)	0.123 (0.851)
*Executive function, mean (SD)	-0.001 (0.888)	-0.318 (0.999)	0.102 (0.824)
*Language, mean (SD)	0.000 (0.837)	-0.395 (0.924)	0.127 (0.765)
*ACHIEVE study Memory, mean (SD)	0.000 (0.909)	-0.191 (0.937)	0.061 (0.892)

*\*indicates statistically significant difference between groups*

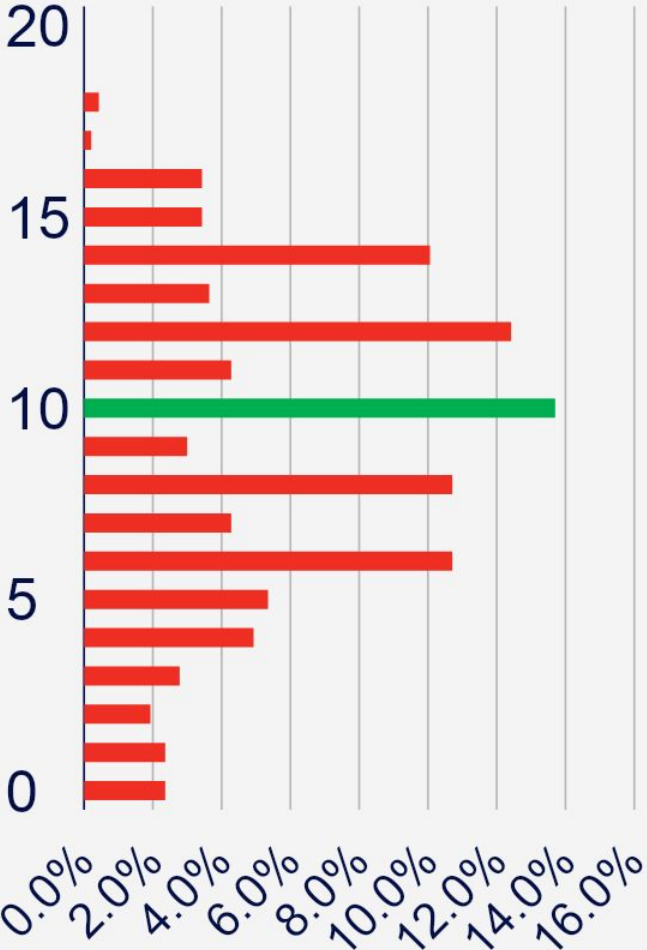


# HEARING INTERVENTION TARGET ENGAGEMENT

Hours of hearing aid use & self-reported communication impairment

# Hearing Intervention Participant Self-Reported Hours of Hearing Aid Use Over 3 Years

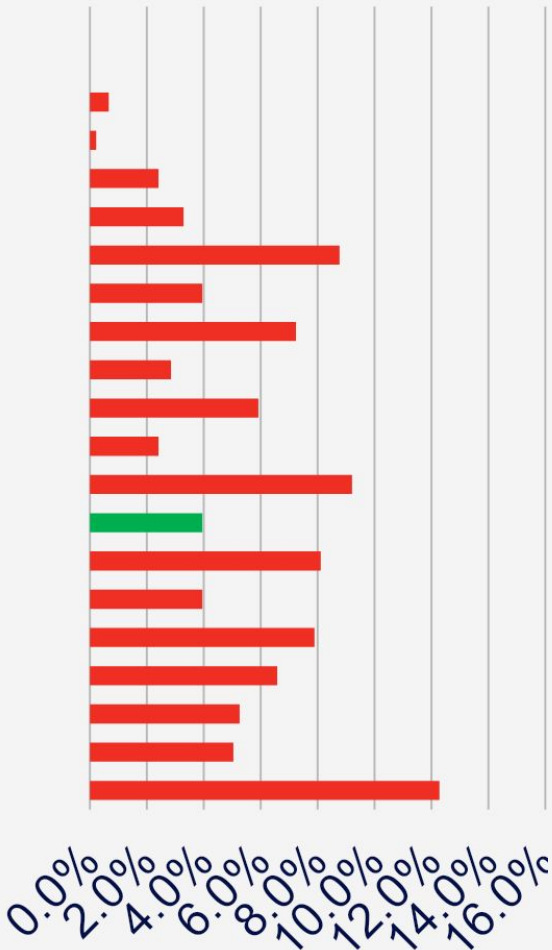
**6 Months**  
Median = 10 Hours



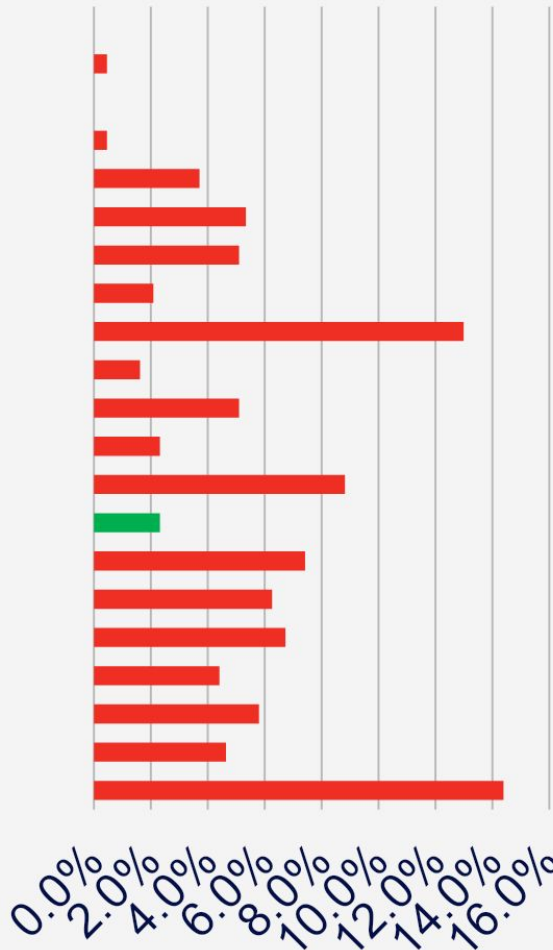
**1 Year**  
Median = 8 Hours



**2 Years**  
Median = 7 Hours



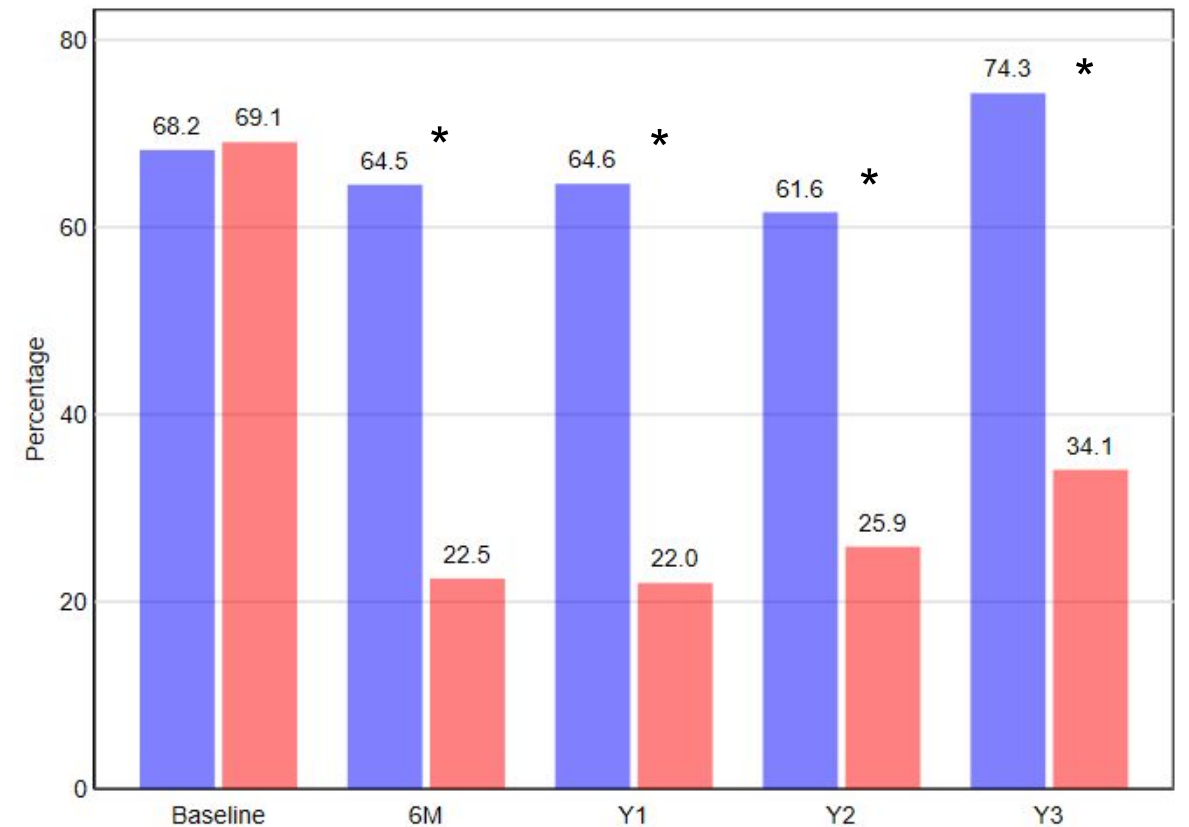
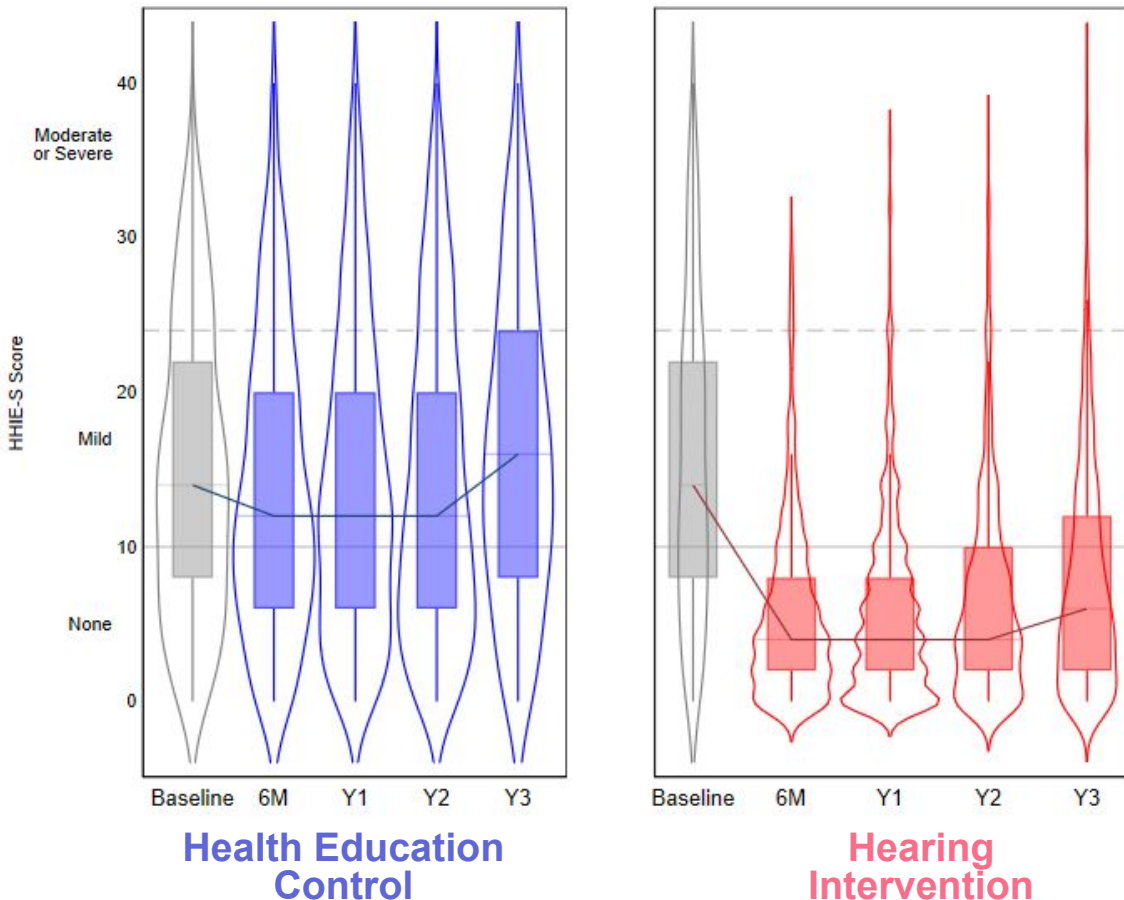
**3 Years**  
Median = 7 Hours



# Self-perceived communicative function<sup>†</sup> significantly decreases with hearing intervention

Total (ARIC & De novo)  
Continuous Score

Total (ARIC & De novo)  
% with Impairment (HHIE-S  $\geq 10$ )

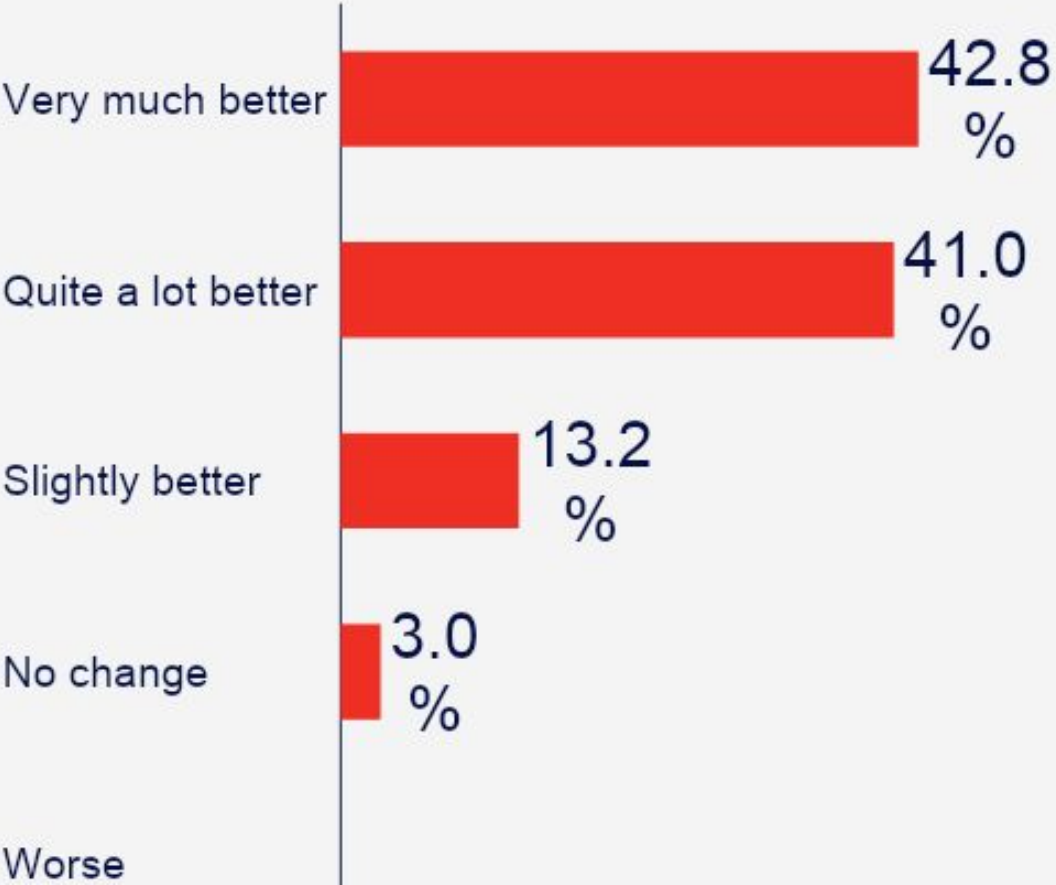


<sup>†</sup> Hearing Handicap Inventory for the Elderly-Screening

\* p < 0.001

# Hearing Intervention Participant Evaluations After 3 Years

## How has a hearing aid changed your enjoyment of life?



## Do you think a hearing aid is worth the trouble?

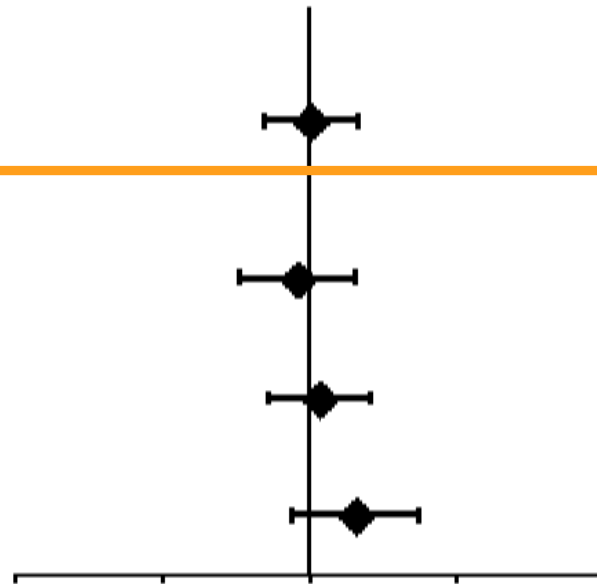


# 3-YEAR COGNITIVE OUTCOMES



# 3-Year Change in Global & Domain-Specific Cognition

## Main Analysis of the Total Cohort (ARIC and De novo)



In the total combined cohort, hearing intervention had no effect on reducing cognitive decline within 3 years

# 3-Year Change in Global & Domain-Specific Cognition

## Pre-Specified Sensitivity Analysis Stratified by Study Population

Bedford Center for  
Economic and Public Health

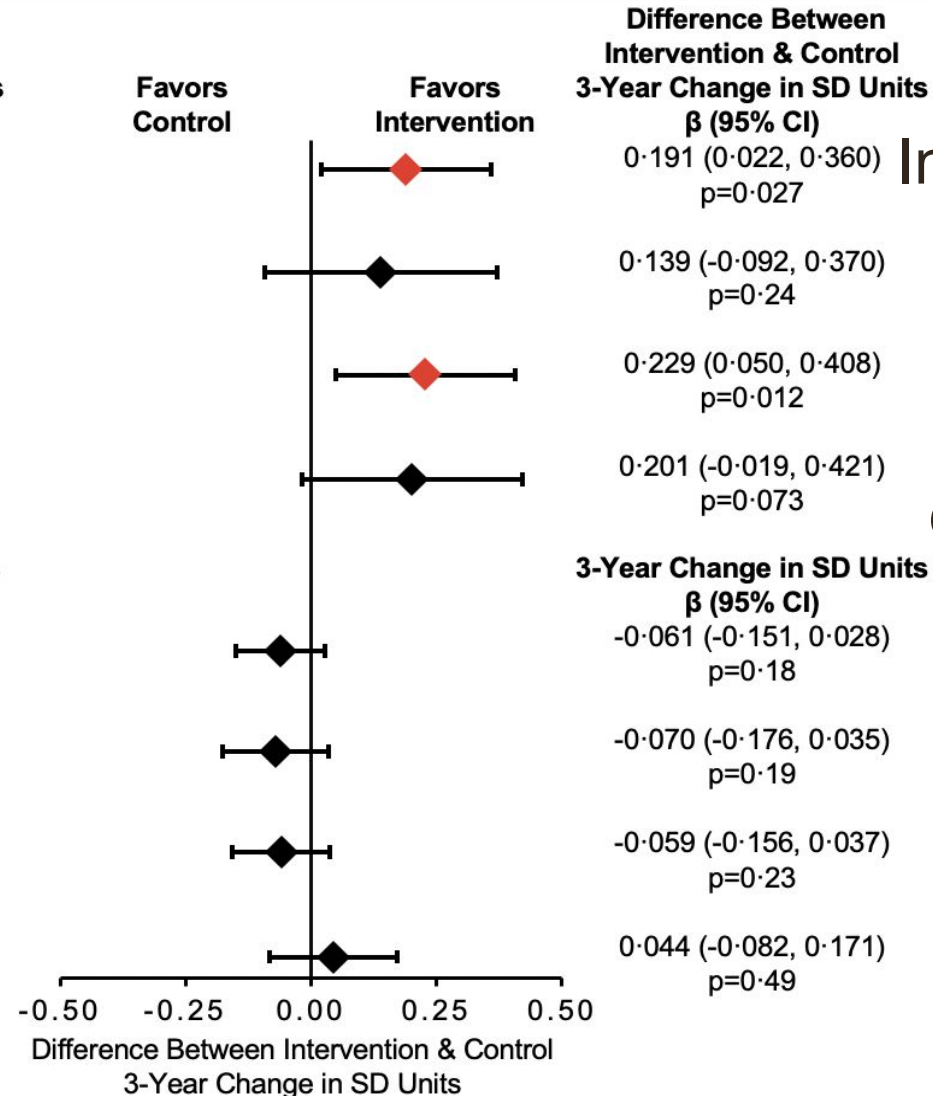
ARIC  
Cohort

**ARIC (N=238^)**  
3-Year Change in SD Units

Global Cognition*	$\beta$ (95% CI)
Control	-0.402 (-0.536, -0.267)
Intervention	-0.211 (-0.349, -0.073)
<b>Executive Function</b>	
Control	-0.387 (-0.578, -0.197)
Intervention	-0.248 (-0.434, -0.062)
<b>Language*</b>	
Control	-0.344 (-0.488, -0.201)
Intervention	-0.116 (-0.264, 0.032)
<b>Memory</b>	
Control	-0.154 (-0.335, 0.027)
Intervention	0.047 (-0.132, 0.227)

**De Novo (N=739^)**  
3-Year Change in SD Units

Global Cognition*	$\beta$ (95% CI)
Control	-0.151 (-0.215, -0.087)
Intervention	-0.213 (-0.277, -0.148)
<b>Executive Function</b>	
Control	-0.202 (-0.273, -0.131)
Intervention	-0.272 (-0.351, -0.194)
<b>Language*</b>	
Control	-0.111 (-0.178, -0.044)
Intervention	-0.170 (-0.241, -0.100)
<b>Memory</b>	
Control	-0.032 (-0.118, 0.055)
Intervention	0.013 (-0.081, 0.106)



In the **ARIC** cohort,

hearing  
Rates of  
intervention  
cognitive  
change ~3x  
reduced 3-year  
faster in ARIC  
cognitive by 48%  
than De novo  
controls

3-way interaction  
GC: p = 0.010  
EF: p=0.077  
L: p=0.005  
M: p=0.29

# Hearing Intervention & 3-Year Cognitive Outcomes

## *Summary*

- Strong effects in ARIC (48% reduction) suggests that hearing intervention may reduce cognitive decline within 3 years in populations at increased risk for cognitive decline
- Slow rate of cog. change in De novo may limit ability to observe any positive effect of hearing intervention within just 3 years
  - De novo control -0.05 SD unit/yr vs ARIC control -0.13 SD unit/year, respectively, consistent with moderate vs. slow rate of cognitive decline\*
  - Slow decline in de novo may reflect “healthy volunteer” effect of newly recruited participants responding to study advertisements versus ARIC participants recruited >30 years ago from a random sample

\* K. Hayden et al., *Age Ageing* 2011



# Hearing Intervention & 3-Year Cognitive Outcomes

## *Limitations*

- Effects of hearing intervention on populations at decreased risk of cognitive decline & on rates of cognitive impairment (dementia) will require follow-up beyond 3 years
- Control participants could perform more poorly on tests comprising only auditory stimuli (2/10 tests). However, strongest effects in ARIC observed in language domain which did not consist of any auditory-only tests
- Participants & study staff could not be feasibly masked to intervention assignment

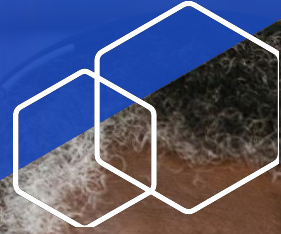
# SUMMARY & CONCLUSION

# ACHIEVE Study – Key Findings

- Positive effects of hearing intervention (versus control) observed in all participants on self-perceived communication impairment, loneliness, & social network size & diversity over 3 years
  - Clinical significance of the magnitude of effect on loneliness & social network size/diversity unknown
- Strong effects (48% reduction) on 3-year global cognitive decline in ARIC but not in de novo
  - Slow rate of cognitive change in healthy de novo volunteers may limit any apparent cognitive benefits of hearing intervention within just 3 years
- Key inference: Hearing intervention may reduce cognitive change within 3 years for populations of older adults at increased risk for cognitive decline.

# ACHIEVE Study – Implications

- Findings consistent with 2020 Lancet Commission on Dementia & 2021 U.S. National Plan to Address Alzheimer’s Disease recommendations to address hearing loss in older adults as part of national dementia risk reduction strategies
  - Hearing loss in adults – highly prevalent condition with established interventions that are underused, without risk, & now demonstrated to confer reduction in cognitive change for those at increased risk for cog decline
- Policy re-evaluation needed for insurance coverage of hearing intervention in older adults with hearing loss
  - Coverage for audiological support services needs to be distinguished from coverage for hearing aids given recent developments with the availability of regulated OTC hearing aids in the U.S. market



# Clinical Implications

# ACHIEVE Study – Clinical Implications

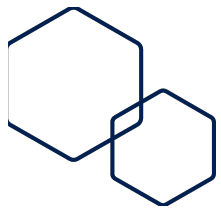
- Older adults should regularly get their hearing checked
  - Audiologist or other hearing professional
  - Smartphone – [www.HearingNumber.org](http://www.HearingNumber.org)
- If there is evidence of hearing loss (range of hearing for the ACHIEVE study was a PTA4/Hearing Number between 30-70 dB) or concerns about hearing, consider getting the hearing loss addressed (communication/social benefits, possible benefits in helping support cognition)
  - Web resources listed at end
  - Book resource: AARP Hearing Loss for Dummies book
    - \*\*\*Disclaimer – I wrote this book with a colleague & earn ~70 cents off each book but I am donating the proceeds
- OTC hearing aids are now available in the U.S. as of October 2022 but the OTC market will still take 1-2 years to stabilize and until prices decrease
  - Many individuals will still need to see an audiologist for guidance and advice



**Tools and  
resources for health  
professionals**

# Provider-Patient Resources

- ACHIEVE Study: <https://www.achievestudy.org/>
- Know Your Hearing Number campaign: [www.HearingNumber.org](http://www.HearingNumber.org)
- Rack Card: [Healthy Brain Infographic](#)
- Rack Card: [Infografía de Cerebro Sano](#)
- [American Academy of Audiologists – Find an Audiologist](#)
- [American Doctors of Audiology – Find and Audiologist](#)
- More brain health resources available from AARP at [GlobalCouncilonBrainHealth.org](http://GlobalCouncilonBrainHealth.org)





# ACHIEVE Acknowledgments

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Thank you

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 @DrFrankRLin

 @JHSPH\_Hearing

# Thank you!



This presentation and related resources are available at:  
<https://www.usagainstalzheimer.org/hearing-and-dementia>

Please register for additional courses at:  
<https://www.usagainstalzheimer.org/brain-health-academy>

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