Hearing impairment and cognitive performance in extreme old age

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International Centenarian Consortium (ICC) Annual Meeting

Blue Mountains, NSW Australia, 5-6 September 2018

Maturitas 70 (2011) 164–168

Contents lists available at ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

Review

Diagnosing dementia in the oldest-old

Carrie Brumback-Peltz[a,*], Archana B. Balasubramanian[a], María M. Corrada[a,b], Claudia H. Kawas[a,b,c]

The very high prevalence of visual and hearing loss in the oldest-old make evaluations for cognitive impairment difficult and may lead to a misclassification bias where dementia is diagnosed more frequently in people with sensory losses. However, some studies have suggested that the sensory loss itself may be indicative of neurodegeneration and, thus, related to cognitive decline. For example, a case-control study of 100 AD patients and 100 matched controls found that hearing loss was associated with the severity of cognitive dysfunction in both the demented patients and normal controls after controlling for relevant variables (12). A prospective
vision and hearing impairme
of older women (13). Althou
neurodegenerative processes
the oldest-old, various meth
implemented.

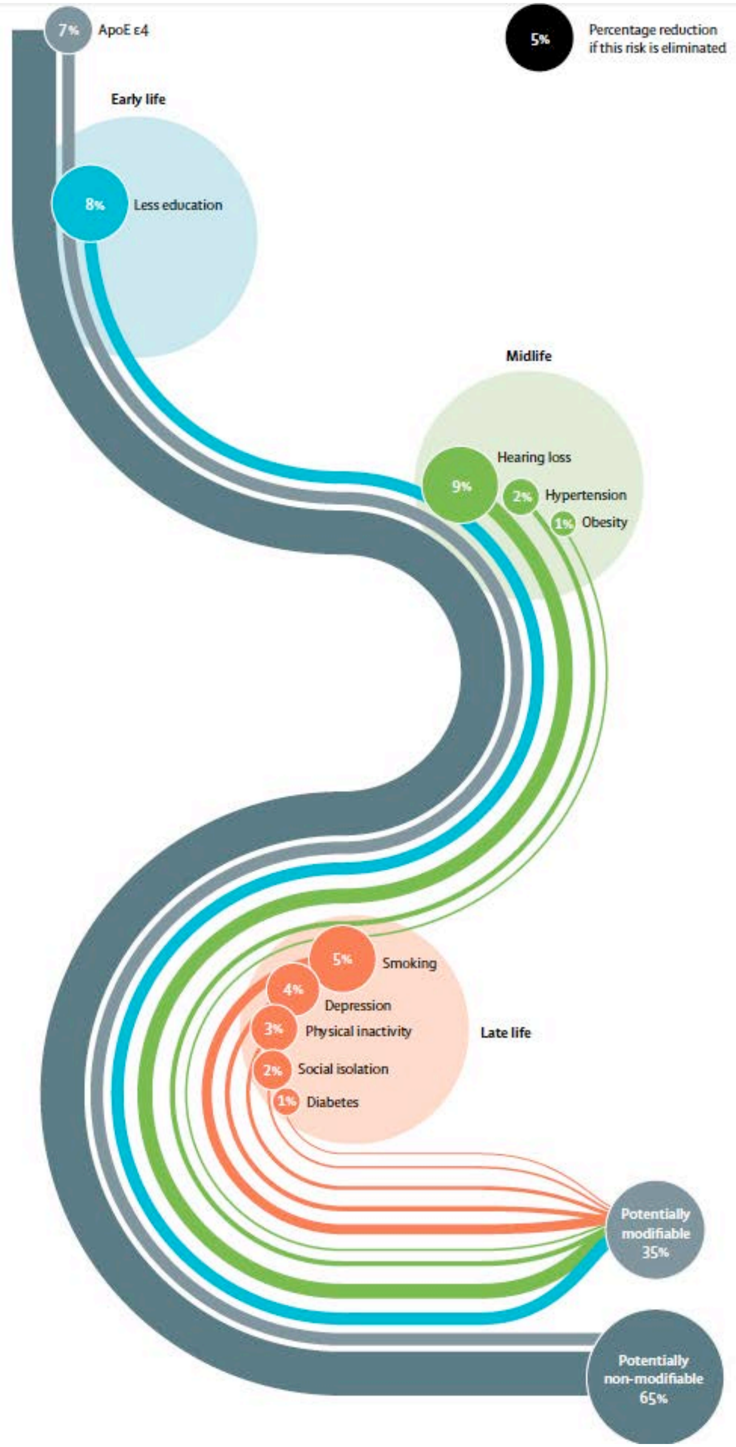
Journals of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
doi:10.1093/gerona/glt051

Review Article

Challenges of Diagnosing Dementia in the Oldest Old Population

Melissa J. Slavin,[1,2] Henry Brodaty,[1,2,3] and Perminder S. Sachdev[2,4]

Third, sensory or physical limitations, fatigue, and medical comorbidities may affect cognitive performance, which may be difficult to account for or to avoid in this group (for an in-depth discussion of these issues, see [8]).



Livingston et al. 2017

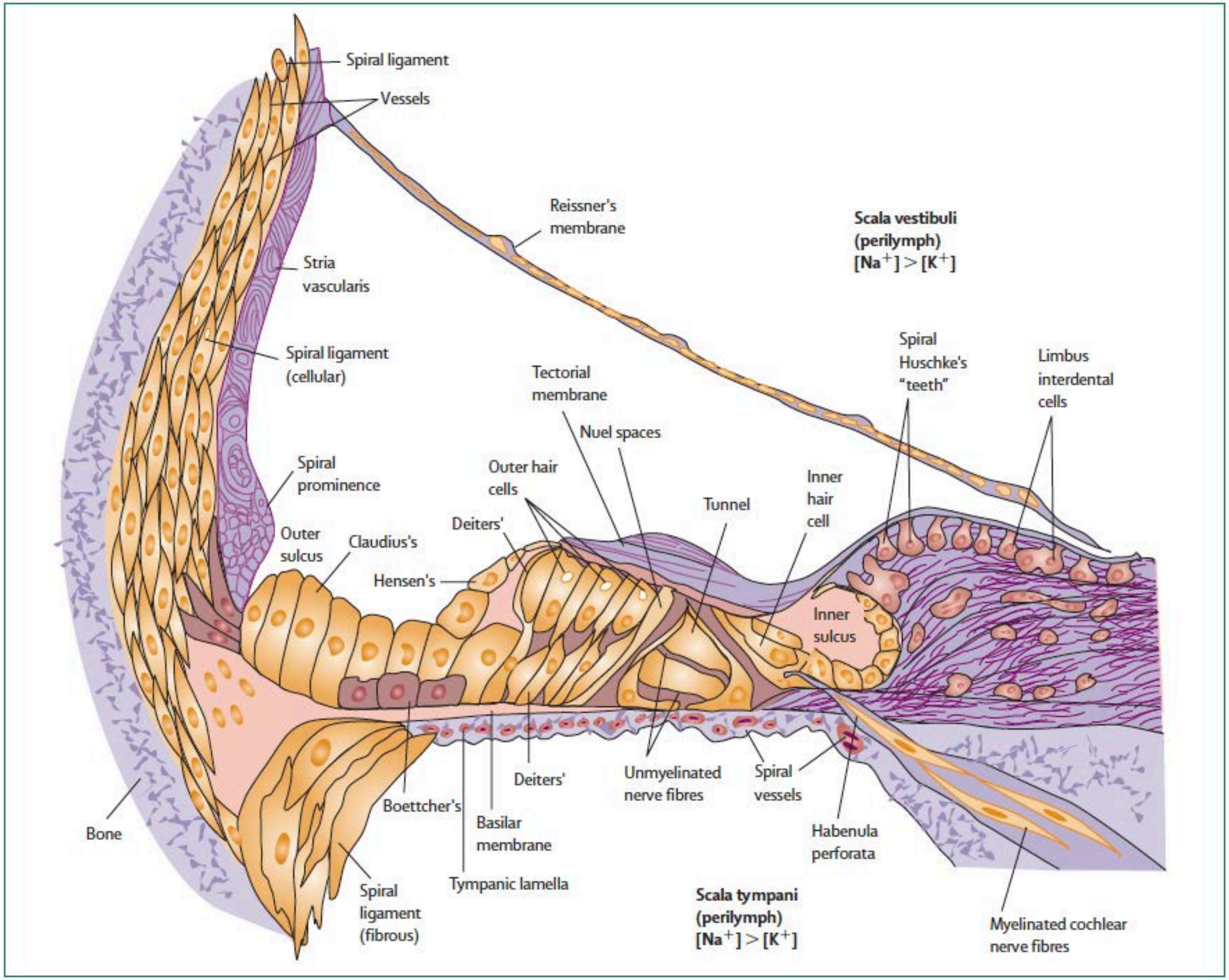


***Figure* 1: Cross-section of the cochlea**

Reproduced with permission of Lippincott Williams and Wilkins.[13]

Gates & Mills 2005

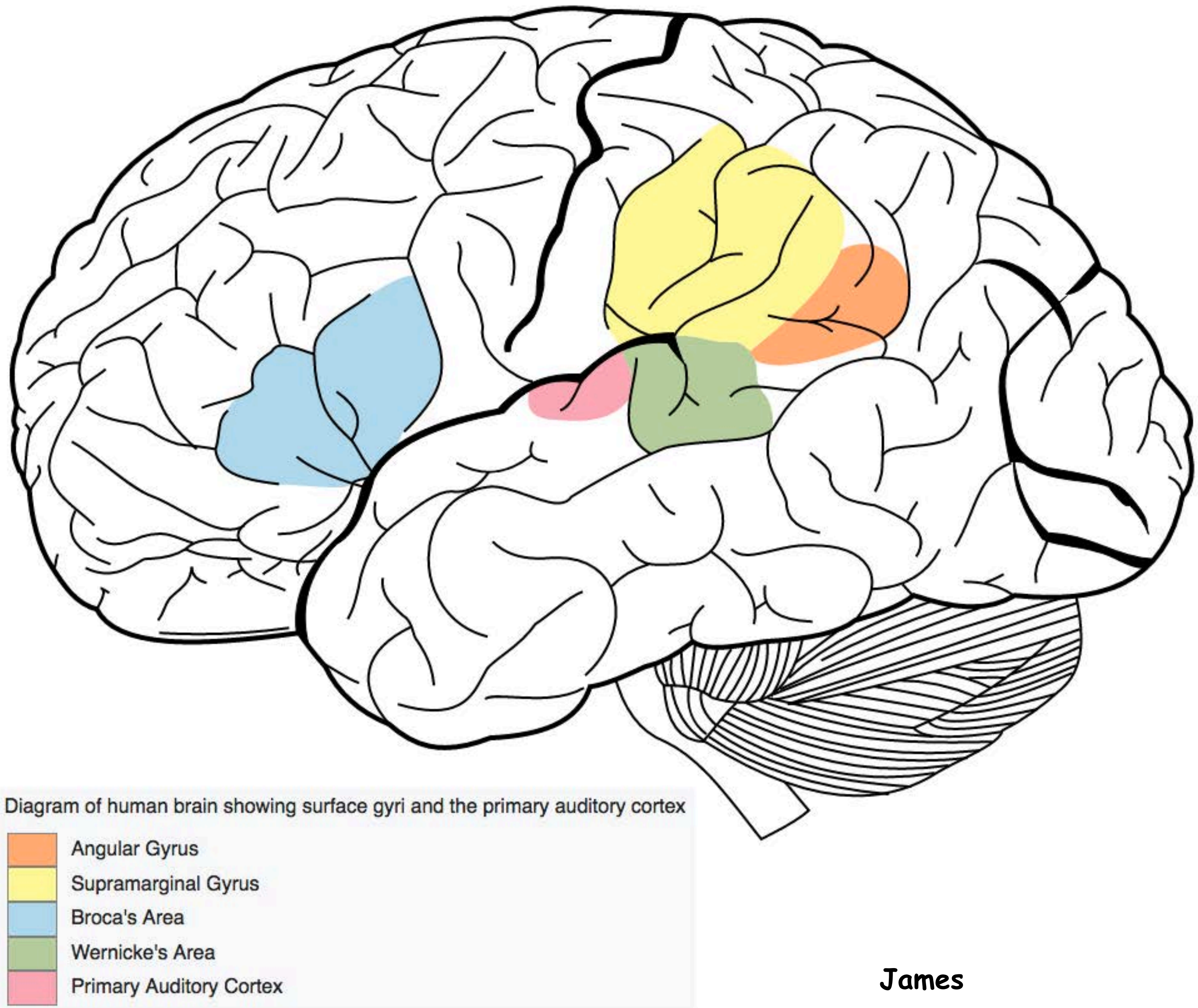
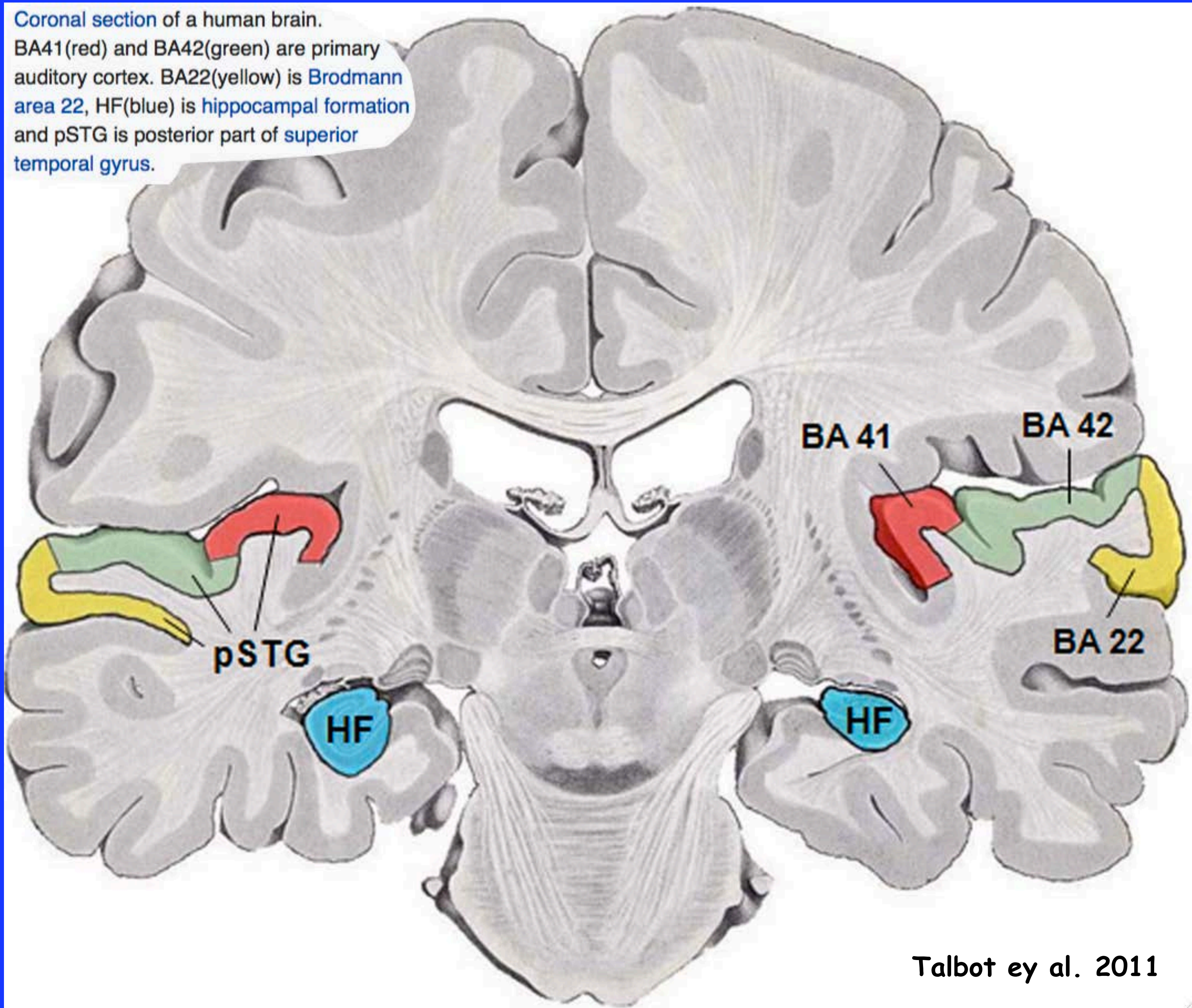


Diagram of human brain showing surface gyri and the primary auditory cortex
Angular Gyrus
Supramarginal Gyrus
Broca's Area
Wernicke's Area
Primary Auditory Cortex

James


Coronal section of a human brain.
BA41(red) and BA42(green) are primary auditory cortex. BA22(yellow) is Brodmann area 22, HF(blue) is hippocampal formation and pSTG is posterior part of superior temporal gyrus.
BA 41
BA 42
BA 22
pSTG
HF
HF
Talbot ey al. 2011

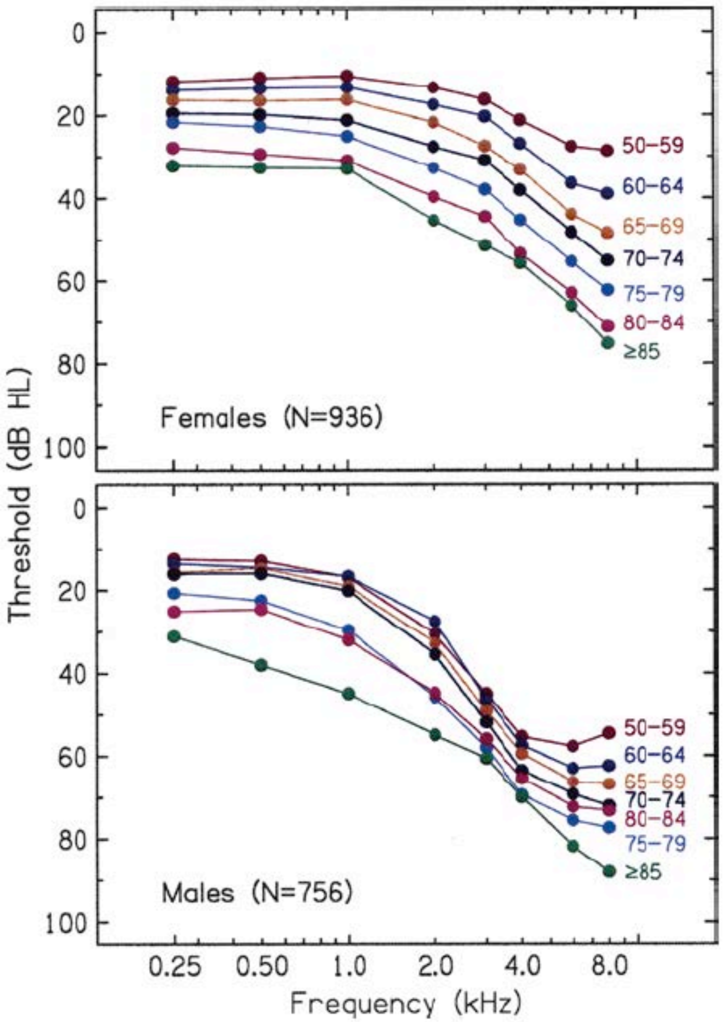


Fig. 2.4 Audiometric mean hearing losses (HL) in female (top) and male (bottom) participants in the ongoing study of age-related hearing loss at the Medical University of South Carolina (Lee et al. 2005; Dubno et al. 2008). The parameter is subject age at the time of enrollment. Note the characteristic profile of human age-related HL: a flat loss at low frequencies coupled with a sloping loss at frequencies above ~1 kHz. These subjects were not screened for noise history, and men typically show more threshold shifts at high frequencies than women, presumably from additional noise exposure (Jerger et al. 1993). Screening for noise history tends to minimize the gender difference. (Adapted with permission from Mills et al. 2006b.)

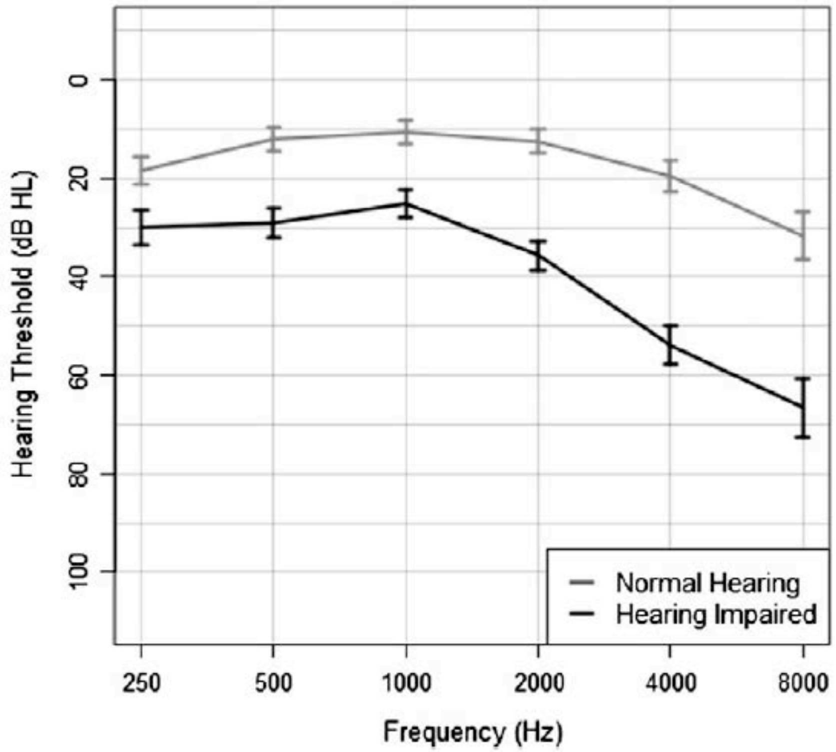


Fig. 1. Mean audiograms of individuals with normal hearing (n = 75) and hearing impairment (n = 51). Error bars denote 95% confidence intervals of the mean.

Lin et al 2014

Scale of Hearing Impairment.
(Modified from Goodman. 1965).

Average Hearing Threshold Level in dB (re: 1969 ANSI)	Hearing Loss Label
-10-15	Normal Hearing
16-25	Slight Hearing Loss
26-40	Mild Hearing Loss
41-55	Moderate Hearing Loss
56-70	Moderately Severe Hearing Loss
71-90	Severe Hearing Loss
91+	Profound Hearing Loss

Clark 1981

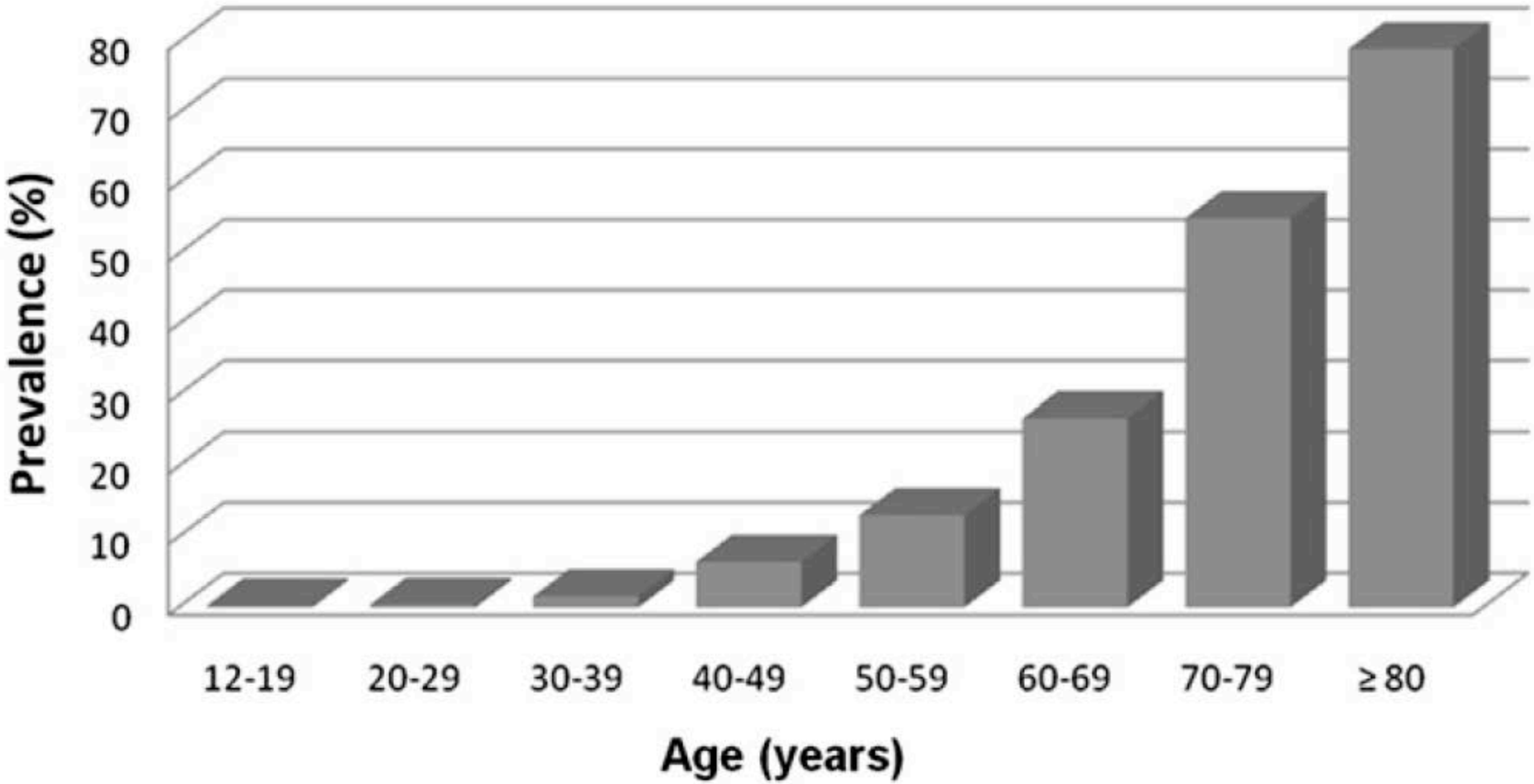
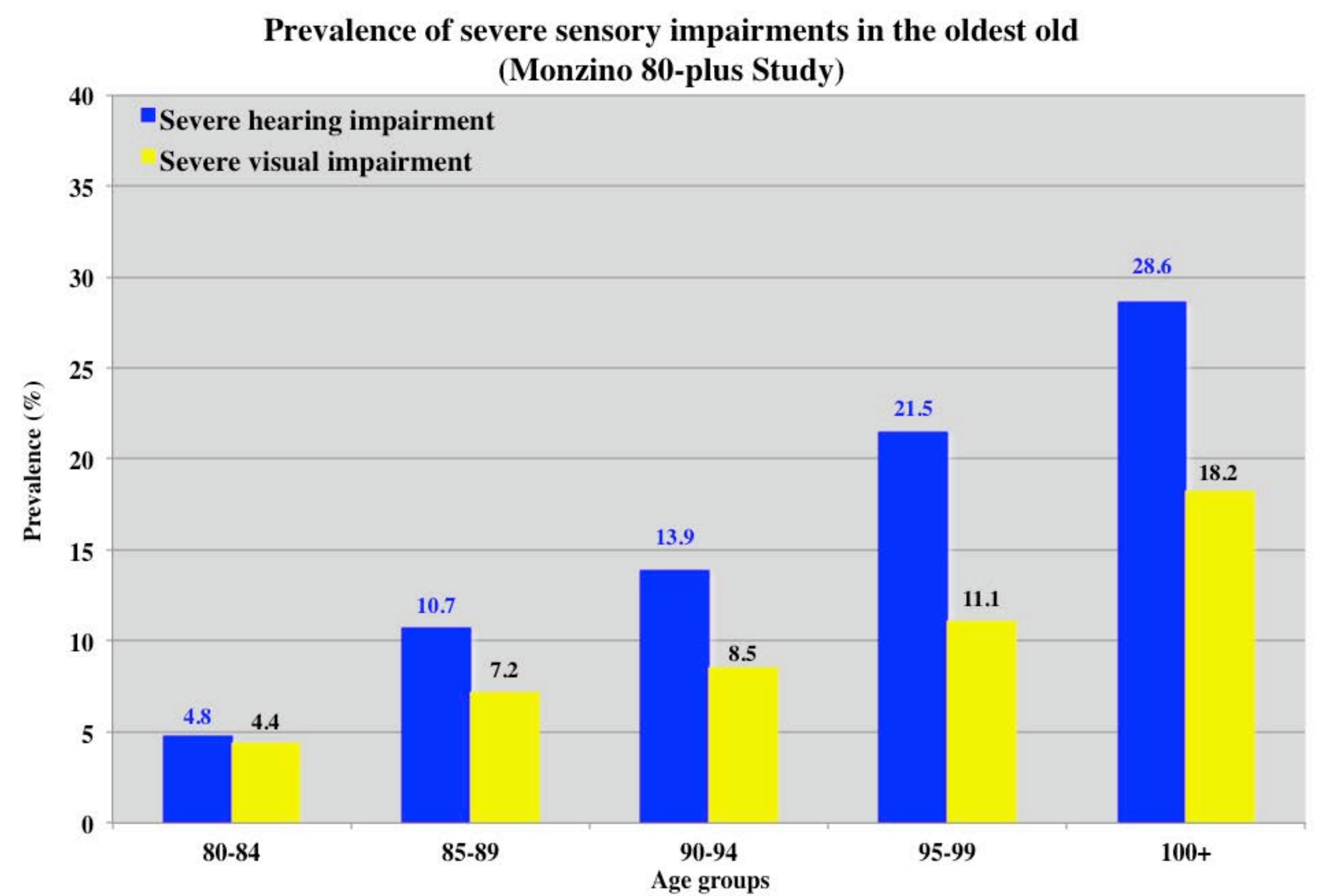


Fig. 1. Prevalence of hearing loss in the United States by age, 2001–2008. Hearing loss is defined by a PTA of 0.5–4 kHz thresholds in the better-hearing ear >25 dB.

Yamasoba et al. 2013



Lucca et al. 2017-2018

NeuroImage 90 (2014) 84–92

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adjusted for demographic and cardiovascular factors. We found that individuals with hearing impairment (n = 51) compared to those with normal hearing (n = 75) had accelerated volume declines in whole brain and regional volumes in the right temporal lobe (superior, middle, and inferior temporal gyri, parahippocampus, p < .05). These results were robust to adjustment for multiple confounders and were consistent with voxel-based

Association of hearing impairment with brain volume changes in older adults

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frontiers in Aging Neuroscience

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elderly cohort. From the population-based Rotterdam Study, 2,908 participants (mean age 65 years, 56% female) underwent a pure-tone audiogram to quantify hearing

statistically non-significant. Our findings demonstrate that hearing impairment in elderly is related to smaller total brain volume, independent of cognition and cardiovascular risk factors. This mainly seems to be driven by smaller WM volume, throughout the brain.

Hearing Impairment Is Associated with Smaller Brain Volume in Aging

Stephanie C. Rigters[1], Daniel Bos[2,3], Mick Metselaar[1], Gennady V. Roshchupkin[2], Robert J. Baatenburg de Jong[1], M. Arfan Ikram[2,3,4], Meike W. Vernooij[2,3†] and André Goedegebure[1†]*

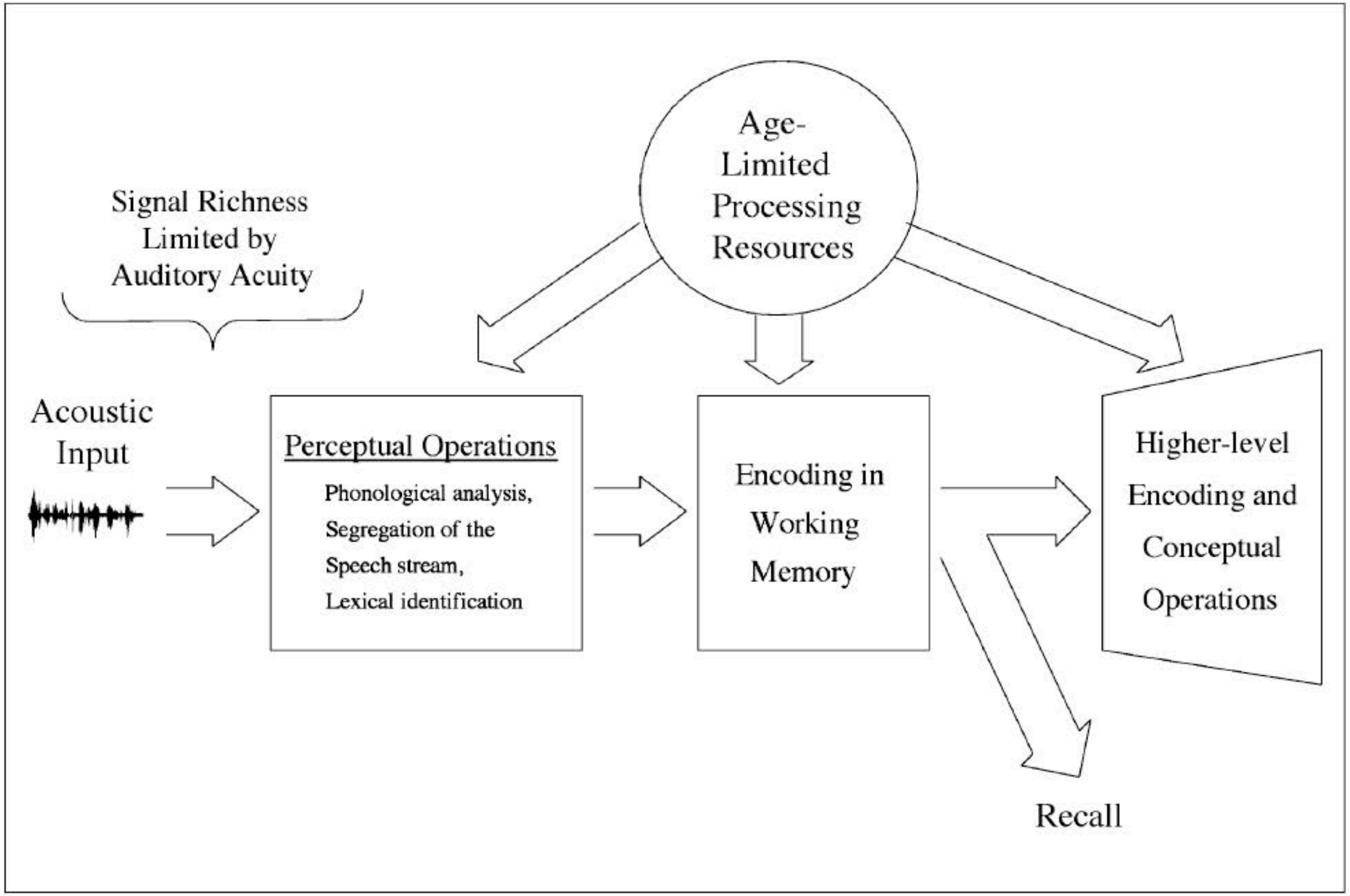

Fig. 1. Schematic diagram of the operations required for successful recognition of a speech message, beginning with the perceptual segregation of a continuous speech stream into its constituent words. The product of the perceptual analysis can be encoded in working memory for overt recall as well as serving as input to higher stages, such as understanding the input at the conceptual and discourse levels. Processing at each stage can be facilitated (or on occasion misled) by contextual support, such as the presence of a constraining linguistic context, when available. Age-related factors that may interfere with success include reduced signal richness consequent to peripheral hearing loss (such as a reduced ability to hear the high frequency sounds in speech) and central-auditory-processing deficits (such as reduced ability to discriminate the frequency components of complex auditory signals and to detect and maintain the ordering of rapid arriving sounds).

Wingfield et al. 2005

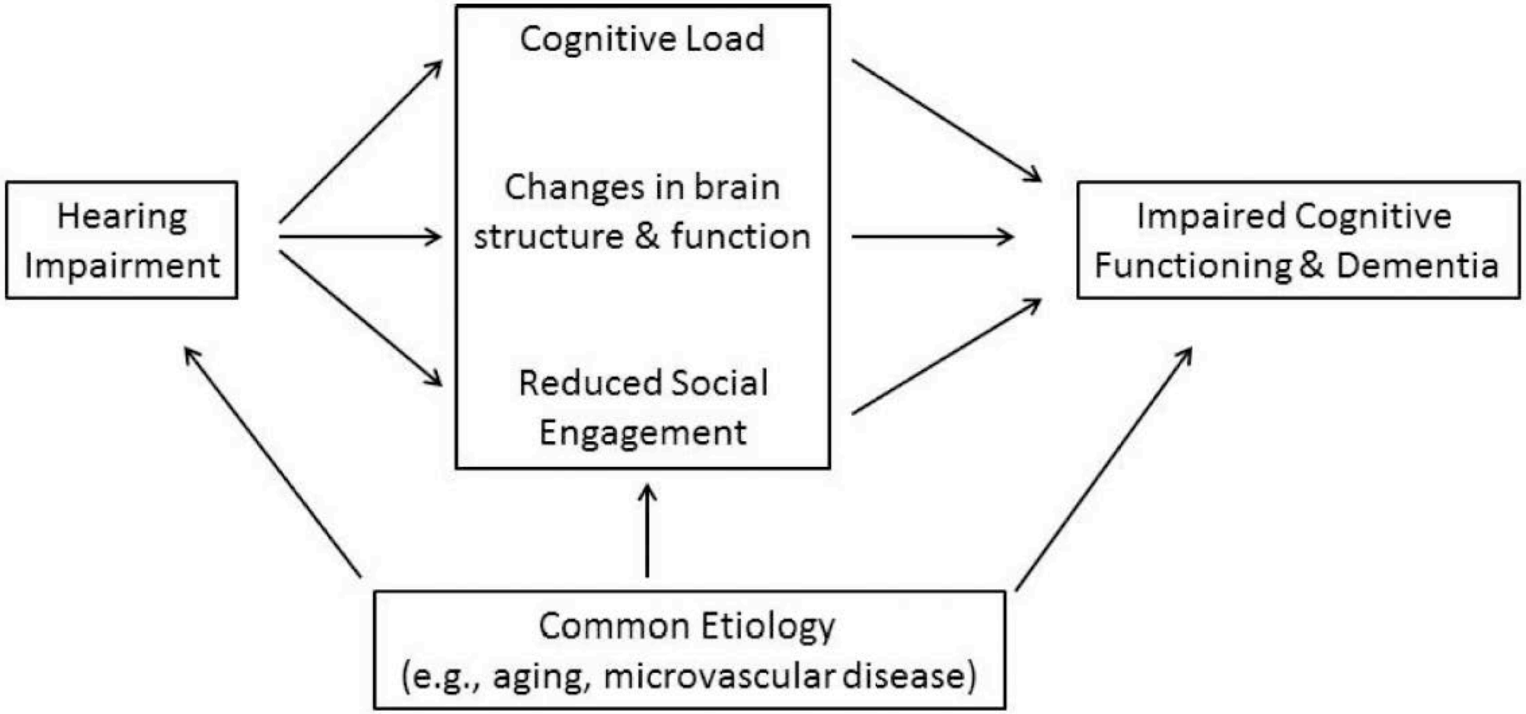

Figure 1.
Conceptual model of the association of hearing impairment with cognitive functioning and dementia.

The effect of poor peripheral encoding of sound by an impaired cochlea is demonstrated by studies in which under conditions where the auditory signal is degraded, greater cognitive resources are required for auditory perceptual processing to the detriment of other cognitive processes such as working memory (Rabbitt, 1968; Tun, McCoy, & Wingfield, 2009). Importantly, for an individual with hearing impairment, such a cognitive load would be a "dual task" that is always present (hearing and auditory processing are evolutionarily-evolved processes that remain constantly active (Horowitz, 2012)) and could, therefore, affect an individual's performance in usual activities and cognitive tasks (among the criteria for the diagnosis of dementia).

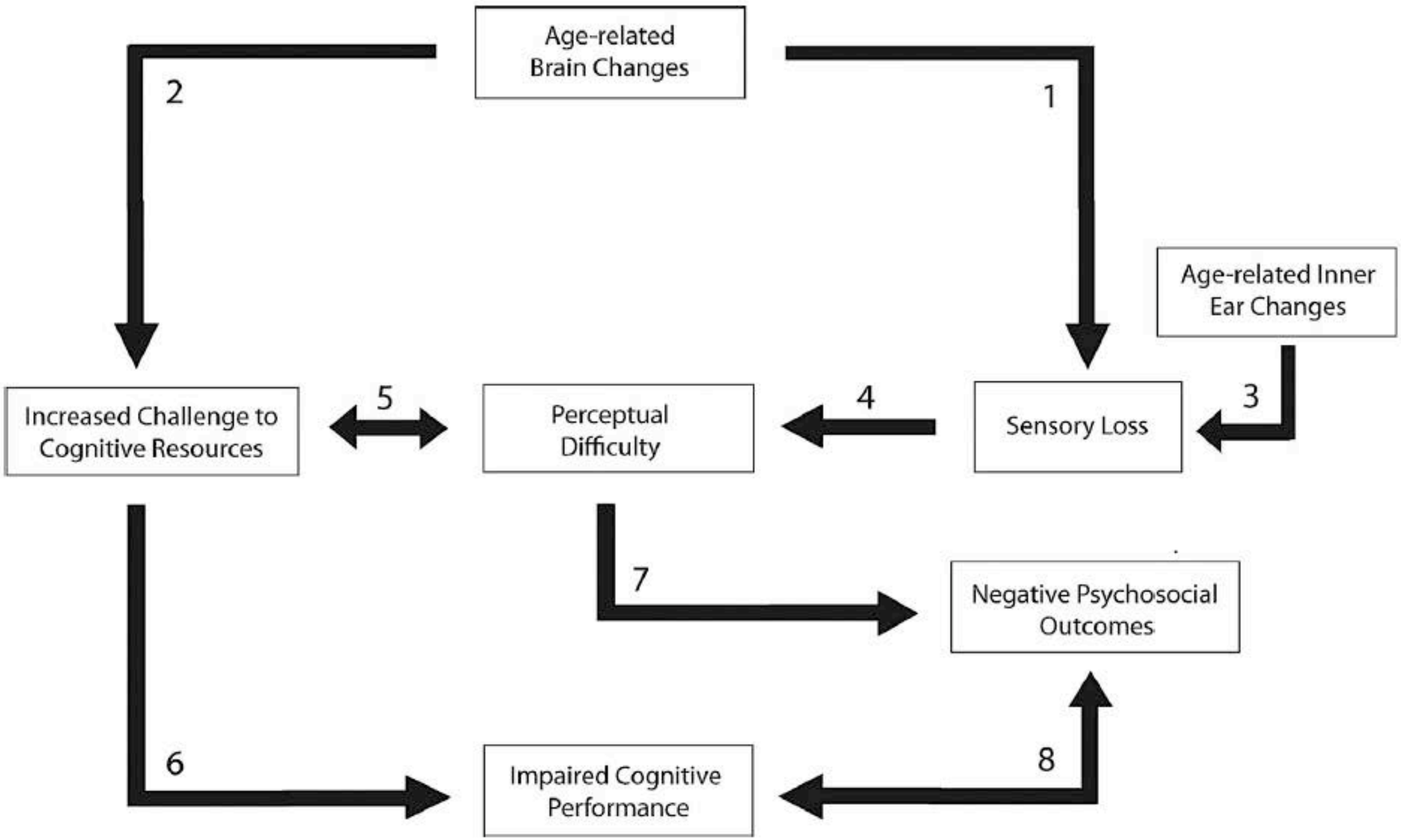

Fig. 2. An alternative framework for conceptualizing the relationship between hearing loss and cognitive decline.

Relationship of Hearing Impairment to Dementia and Cognitive Dysfunction in Older Adults

Richard F. Uhlmann, MD, MPH; Eric B. Larson, MD, MPH; Thomas S. Rees, PhD;
Thomas D. Koepsell, MD, MPH; Larry G. Duckert, MD, PhD

We conducted a case-control study in 100 cases who had Alzheimer's-type dementia and 100 age-, sex-, and education-matched, nondemented controls to evaluate the hypothesis that hearing impairment contributes to cognitive dysfunction in older adults. The prevalence of a hearing loss of 30 dB or greater was significantly higher in cases than in controls (odds ratio, 2.0; 95% confidence interval, 1.2 to 3.4), even when adjusted for potentially confounding variables. In addition, we observed a dose-response relationship in which greater hearing loss was associated with a higher adjusted relative odds of having dementia. Hearing loss was also significantly and independently correlated with the severity of cognitive dysfunction, as measured by the Mini-Mental State Examination, in nondemented as well as demented patients. These results demonstrate an association between hearing impairment and dementia and lend support to the hypothesis that hearing impairment contributes to cognitive dysfunction in older adults.

(*JAMA*. 1989;261:1916-1919)

METHODS

Subjects

The study was conducted from 1985 to 1987. Subjects included 100 cases with dementia and 100 age-, sex-, and education-matched nondemented controls who were outpatients at the Adult Medicine Clinics at Harborview Medical Center and the University Hospital in Seattle, Wash. In addition to primary care, these clinics provide specialized dementia evaluations for which patients are referred from throughout the Pacific Northwest.[12] The sample size was chosen to afford a statistical power of 80% for detecting a twofold increase in the

Table 5.—Risk of Dementia at Various Levels of Hearing Loss

Hearing Loss, dB	Adjusted Odds Ratio*	95% Confidence Interval
Mild (20-29)	1.5	0.4-5.4
Moderate (30-39)	2.2	0.6-7.8
Moderate/severe (≥40)	4.1	1.1-15.8

*Odds ratio was adjusted for family history of dementia, depression diagnosis, number of prescription medications, and source of primary care. Reference odds ratio for normal hearing (<20-dB loss) is 1.0. Trend of increasing risk of dementia for increasing level of hearing loss is statistically significant ($P<.05$).

Study	RR (95% CI)	Weight % (random)	Risk ratio
Lin et al (2011)[66]	2·32 (1·32–4·07)	27·3%	
Gallacher et al (2012)[67]	2·67 (1·38–5·17)	21·3%	
Deal et al (2016)[65]	1·55 (1·10–2·19)	51·4%	
Random effects model	**1·94 (1·38–2·73)**	**100%**	

Heterogeneity: I^2=29%, tau^2=0·0278, p=0·2445

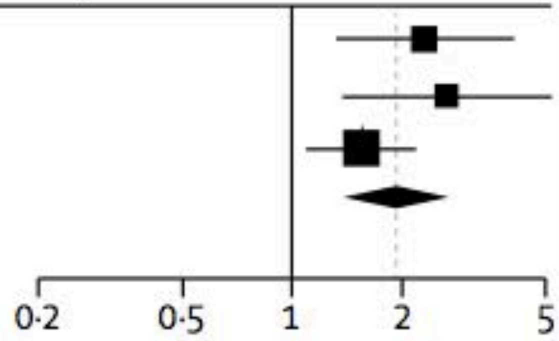

***Figure* 3: Forest plot of the effect of hearing loss on incidence of dementia 9–17 years later in cognitively healthy people**
Hearing loss was measured by pure-tone audiometry. RR=risk ratio.

Livingston et al. 2017

Visual Impairment, Hearing Loss and Cognitive Function in an Older Population: Longitudinal Findings from the Blue Mountains Eye Study

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Citation: Hong T, Mitchell P, Burlutsky G, Liew G, Wang JJ (2016) Visual Impairment, Hearing Loss and Cognitive Function in an Older Population: Longitudinal Findings from the Blue Mountains Eye Study. PLoS ONE 11(1): e0147646. doi:10.1371/journal.pone.0147646

Editor: Chen-Wei Pan, Medical College of Soochow University, CHINA

Received: October 11, 2015

Accepted: January 6, 2016

Published: January 25, 2016

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: PM was supported by National Health and Medical Research Council, Australia (grant nos.

Abstract

The presence of visual impairment (VI) and hearing loss (HL) with may be a marker for subsequent cognitive decline over time in older people. A prospective, longitudinal population-based study of the 3654 participants of the Blue Mountains Eye Study were assessed for the associations between VI and HL and a decline in mini-mental state examination (MMSE) scores over a duration of 10 years from the 5-year (baseline of this report) to the 15-year follow-up visits. MMSE was assessed at the 5-, 10- and 15-year follow-up visits. A decline ≥3 scores from 5-year to 10- or 15-year visits indicated possible cognitive decline. VI was defined as best-corrected visual acuity <6/12 in the worse-eye, HL was defined as pure-tone average >40 decibels in the worse-ear and dual sensory impairment (DSI) was defined by the co-presence of VI and HL, detected at 5-year follow-up (baseline of this report). Participants with no VI and HL over the same 5- or 10-year corresponding period were controls. Associations of VI, HL and DSI with possible cognitive decline were assessed using logistic regression models adjusting for age and sex after excluding subjects with a stroke history. The presence of VI, HL or DSI was not associated with possible cognitive decline over 5 years (odds ratio (OR) 0.84, 95% confidence-intervals (CI) 0.40–1.79, OR 1.02, 95% CI 0.61–1.70 and 1.41, 95% CI 0.54–3.72, respectively) or 10 years (OR 1.09, 95% CI 0.52–2.30, OR 1.09, 95% CI 0.65–1.82 and 1.15, 95% CI 0.28–4.73, respectively). There were no changes to these findings after adjustment for other potential confounders. Age was significantly associated with possible cognitive decline (OR 1.07, 95% CI 1.04–1.10 for both periods). Neither visual impairment, hearing loss nor dual sensory impairment was independently associated with subsequent decline in cognition.

Hearing loss and cognition

Case-control studies have found higher auditory threshold to be associated with greater risk of dementia and cognitive impairment.[4-7]

Cross-sectional evidence is mixed. Although several studies show strong associations,[2,8,9] others find only weak or null associations.[3,10-12]

Longitudinal data are less convincing. Of 4 studies that showed an association of hearing with cognitive change, only 1 used pure-tone audiometry to assess hearing impairment[13]; the remainder used self-reported hearing difficulty[14,15] or the finger friction test.[16] In contrast, 4 studies with follow-up periods of up to 12 years, using pure-tone audiometry, did not detect an association with cognitive change,[17-20] although 1 recent study with 12 years of follow-up has shown an association between pure-tone audiometric threshold and dementia.[21] (Gallacher et al. 2012)

plus 5 recent studies:

Gallacher et al. (2012): association of auditory threshold with dementia and cognitive decline in men (mean: ~ 56 years).

Lin et al. (2013): hearing loss associated with accellerated cognitive decline and incident cognitive impairment (in older adults: mean = 77.4 years).

Gurgel et al. (2014): association between hearing loss and increased rate of developing dementia and more rapid cognitive decline in older adults (65+ y).

Amieva et al. (2015): hearing-loss is associated with accellerated cognitive decline in older adults (65+ years); hearing aid attenuates such decline.

Deal et al. (2017): moderate/severe audiometric hearing impairment (vs normal) was associated with increased risk of incident dementia over over 9 years (older adults aged 70-79 years): No association was observed between hearing impairment and rates of domain-specific cognitive change over 7 years.

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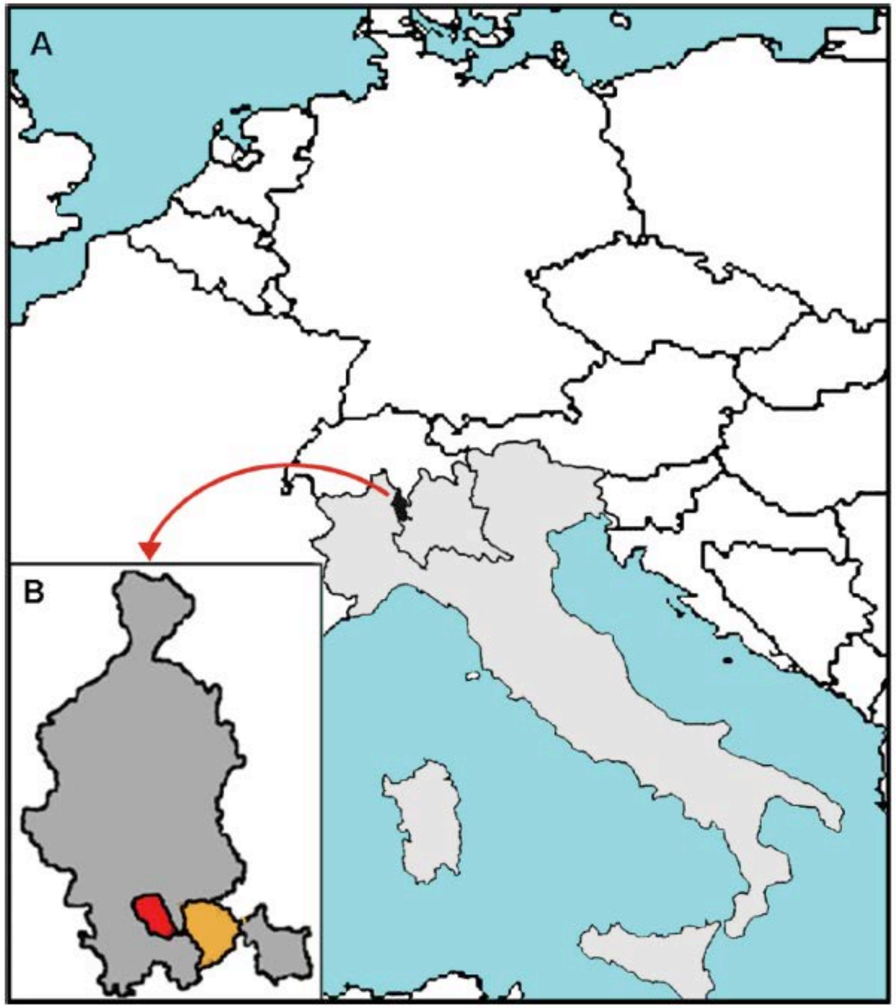

Figure 1 Map of the study area of the Monzino 80-plus Study: A. Europe, Italy (in grey) and, within the borders of the Lombardy region, the province of Varese (in black). B. The study area: the province of Varese (in grey) and the area of the eight municipalities initially investigated: in red Gallarate and in orange the seven municipalities of the lower Olona valley (Fagnano Olona, Gorla Maggiore, Solbiate Olona, Gorla Minore, Olgiate Olona, Marnate, and Castellanza)

Lucca et al. 2011

To grade sensory impairments we did not use audiometry, but self- and informant-reported data together with psychologists' observations during the interview and cognitive testing.
Psychologists were trained, among other procedures, to appropriately modulate voice volume, to speak more slowly and to articulate more clearly. Unreliable responses or refusals because of sensory problems (but also disabilities) were discarded from the total score and the points on the remaining items were summed up and re-scaled to the total (for example, for the MMSE a maximum of five missing responses was re-scaled to a 30-point scale).

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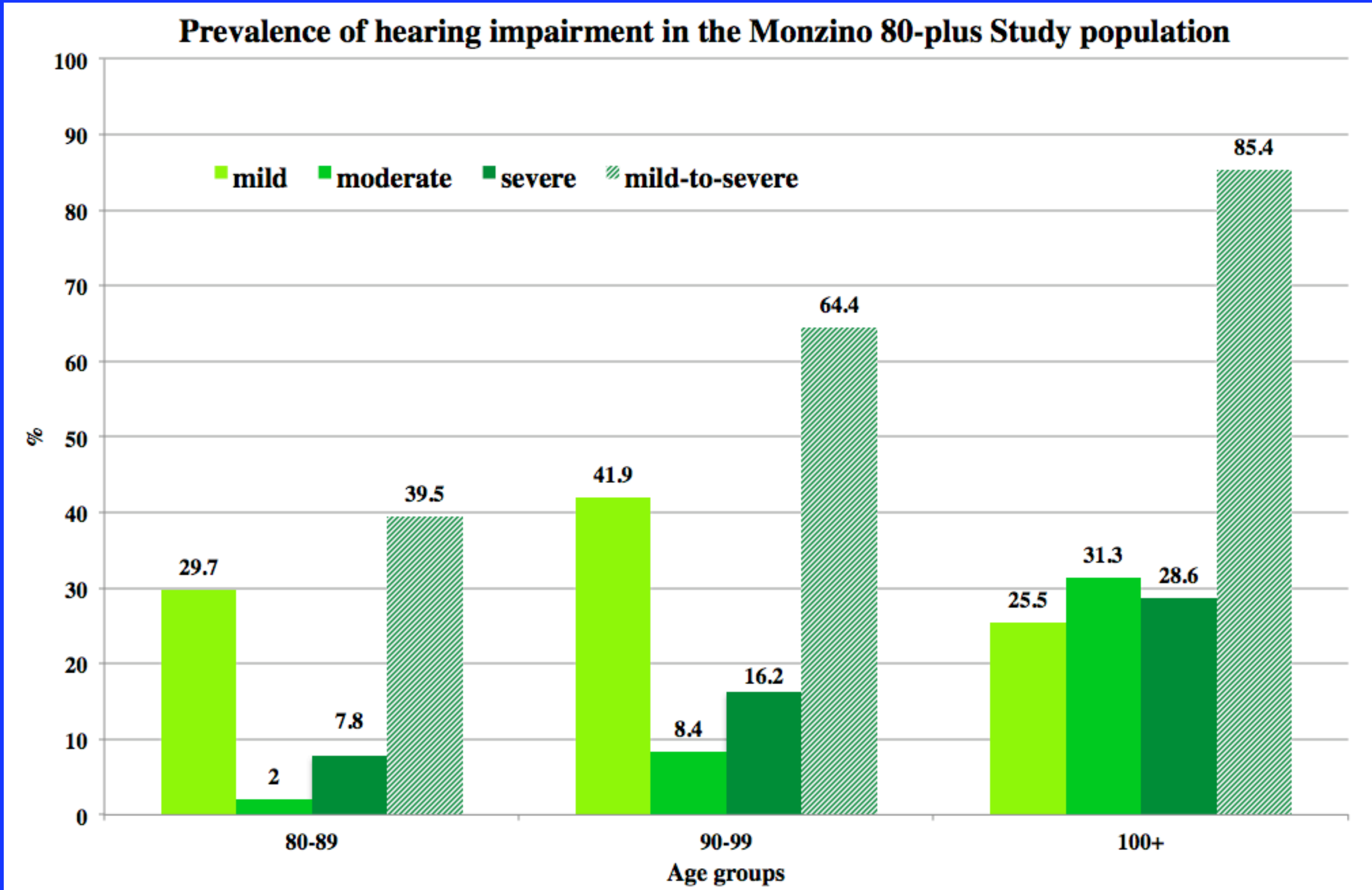
Table 4 Self-reported prevalence of age-related hearing loss in elderly 60+ years: study overview

Reference	Study	Prevalence: impairments of any kind[a]
Chou [34]	UK; English Longitudinal Study of Ageing (ELSA), wave I (2002–2003) and II (2005)	>18.9% (≥65 years)
Davis et al. [10]	UK; National Study of Hearing (NSH)	>40.3% (≥75 years)
Davis [30]	See Table 3	>14.6% (> 60 years)
Hietanen et al. [32]	Denmark, Sweden, Finland; NORA (Nordic Research on Aging); 1989–1991	>27.7% (75 years)
Hietanen et al. [28]	Finland; 1990–2000	>44.7% (80 years)
Martini et al. [36]	Italy; 1989	>8.1% (> 60 years)
Rosenhall et al. [35]	Sweden; Part of the Swedish Survey of Living Conditions (ULF); conducted by Statistics Sweden (SCB); 1986–1993	>16% (>64 years)
Liljas et al. JAGS 2017	English Longitudinal Study of Ageing (ELSA) 2004	32.6% (80>)
	Monzino 80-plus	**43.1% (≥80)**



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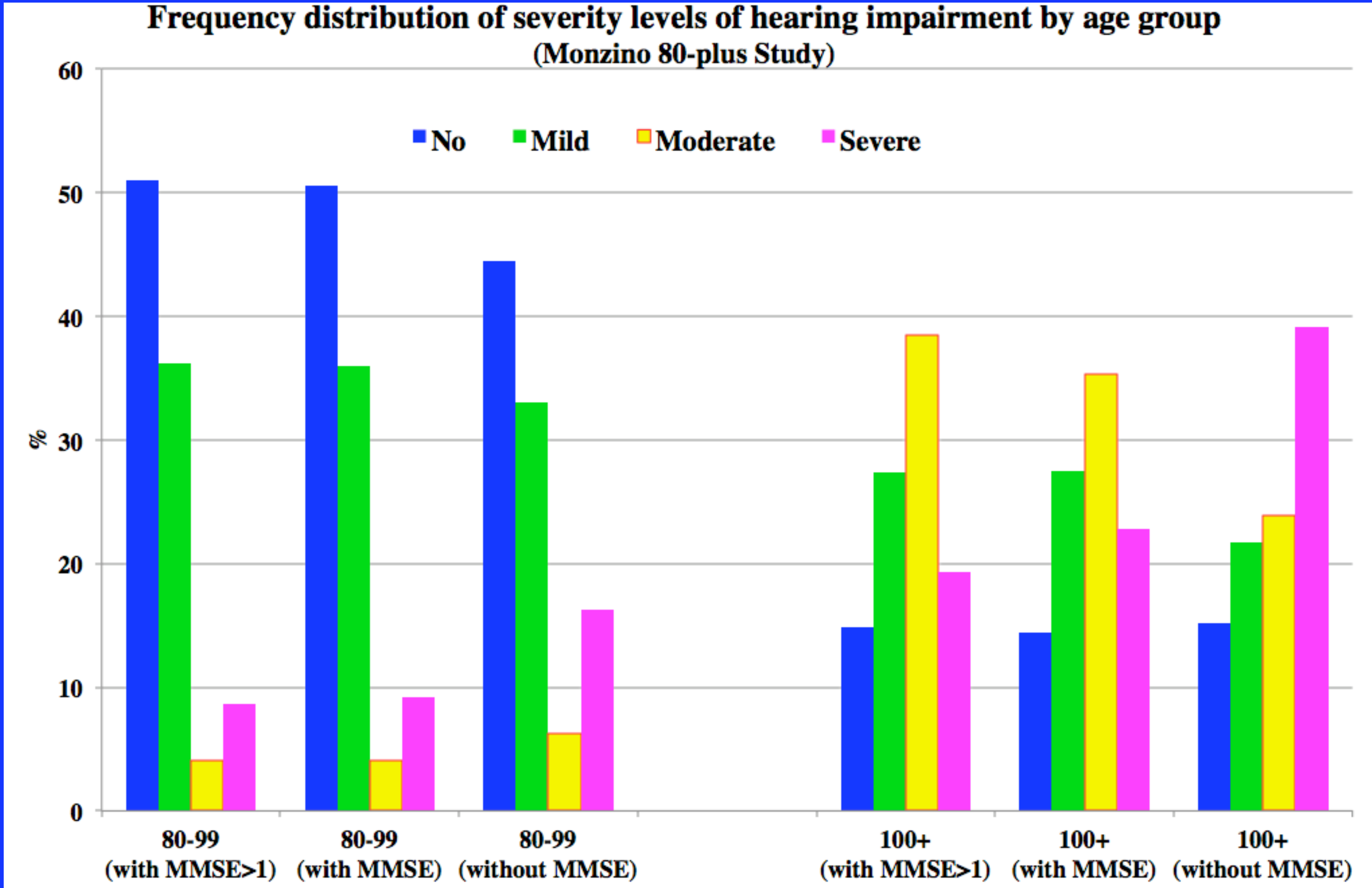

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Characteristics at first vist
Age group: 80-99 years (Monzino 80-plus Study)

	MMSE ≥ 1 (n ≤ 1291)	MMSE (n ≤ 1353)	c-MMSE (n ≤ 585)
Age, years	88.2	88.4	89.5
Sex, % women	68.9%	69.3%	72.3%
Education, years	5.4	5.3	4.8
Number of drugs	3.4	3.4	3.0
In institution, %	10.1%	11.8%	16.8%
Severe visual impairment, %	6.9%	7.2%	7.3%
Severe hearing impairment, %	8.7%	9.2%	16.3%
MMSE (30-0)	23.4	22.3	—
c-MMSE (28.1-1.89)	23.5	22.6	19.0
SBI-SI (0-34)	5.5	6.7	11.6
IQCODE (1-5)	3.62	3.69	4.09
SBI-bADL (0-30)	4.7	5.8	11.9
IADL (0-100%)	39.7	42.5	66.0
SBI-BP (0-27)	0.8	0.9	1.6

Lucca et al. 2017

Characteristics at first vist
Age group: 100+ years (Monzino 80-plus Study)

	MMSE ≥ 1 (n ≤ 135)	MMSE (n ≤ 167)	c-MMSE (n ≤ 92)
Age, years	100.9	101.0	101.3
Sex, % women	92.6%	92.8%	91.3%
Education, years	4.5	4.6	4.3
Number of drugs	3.6	3.5	2.8
In institution, %	31.9%	37.7%	40.2%
Severe visual impairment, %	16.3%	18.0%	18.5%
Severe hearing impairment, %	19.3%	22.8%	39.1%
MMSE (30-0)	18.9	15.3	—
c-MMSE (28.1-1.89)	18.0	15.0	11.9
SBI-SI (0-34)	11.2	15.4	20.6
IQCODE (1-5)	4.18	4.28	4.66
SBI-bADL (0-30)	13.4	16.4	20.1
IADL (0-100%)	78.4	82.6	92.7
SBI-BP (0-27)	0.8	0.9	1.6

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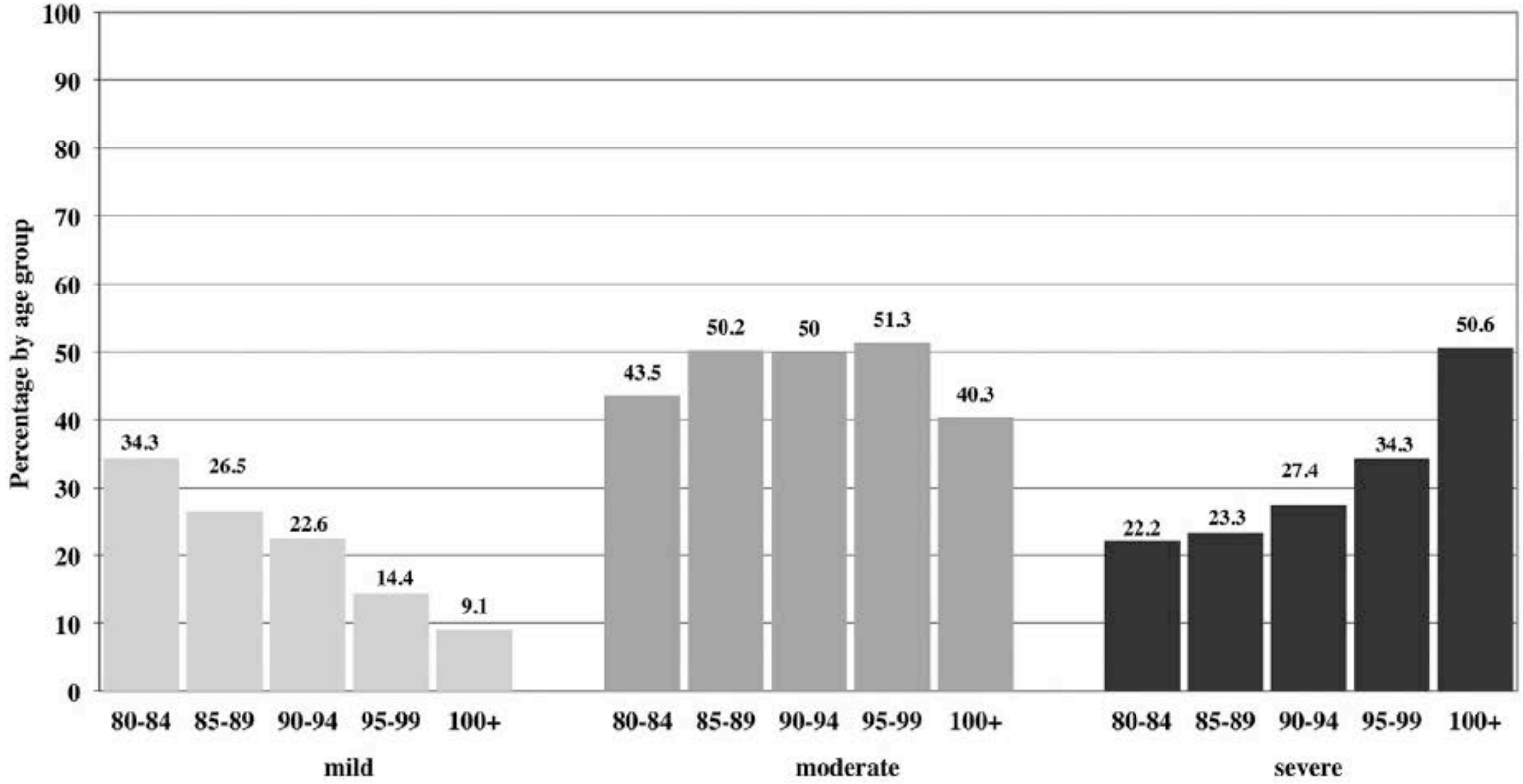
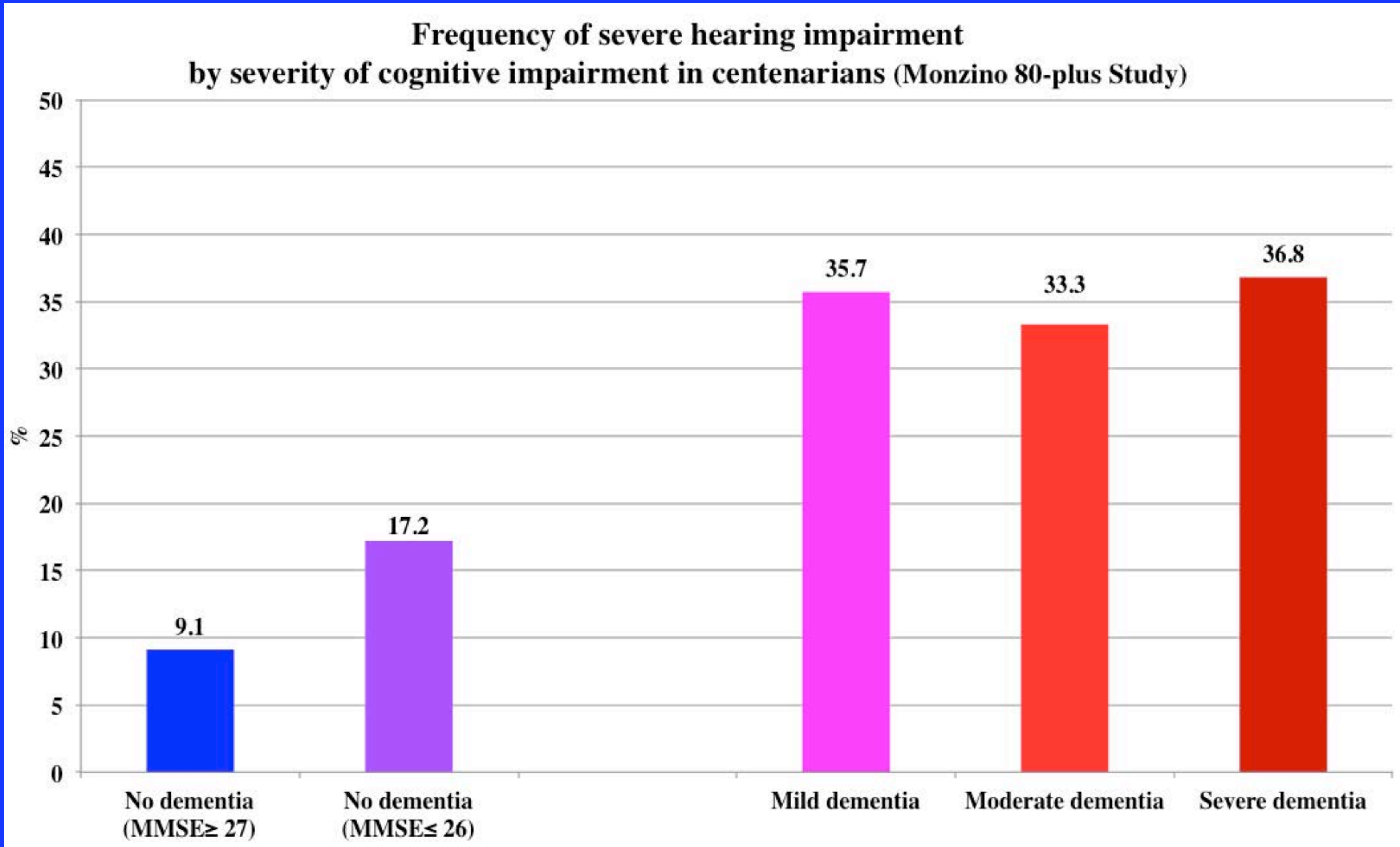


Supplementary Fig. 2. Percentage of mild, moderate, and severe dementia in each age group in the Monzino 80-plus Study.

Lucca et al. 2015



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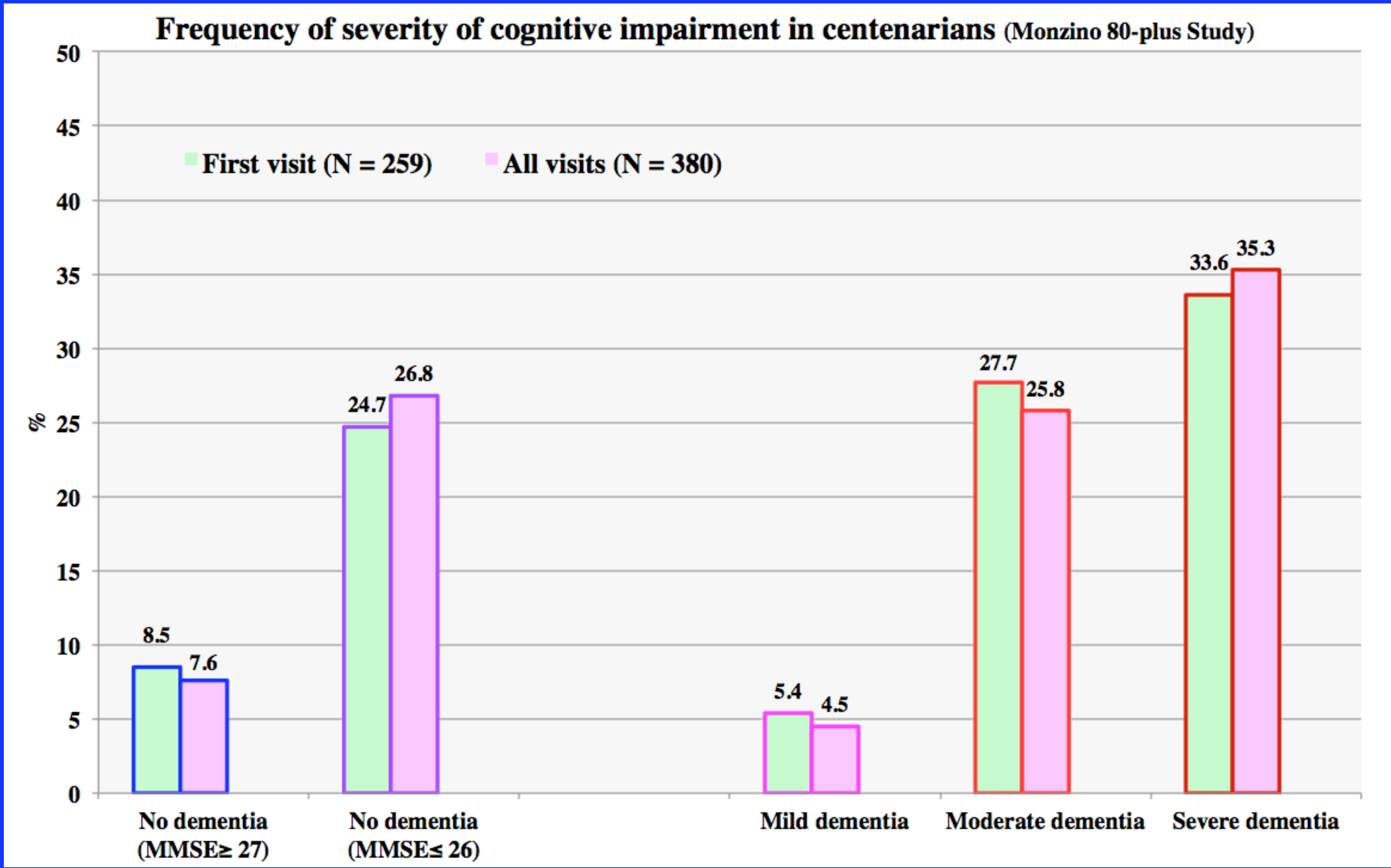

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Mean (SD) cognitive, functional, and problem behaviour scores/rates by cognitive status of participants aged 100+ at first visit (N = 259)

	No dementia		Dementia		
			mild	moderate	severe +
MMSE or cMMSE scores	**27-30** [a]	**≤ 26** [a]	**≥ 18** [a]	**9-17** [a]	**0-8** [a]
Test or scale (score range: best-worst)	19-22	51-64	13-14	36-72	48-87
MMSE or converted-MMSE (30-0)	28.3 (1.0)	**23.3 (2.2)**	**19.8 (1.5)**	13.4 (2.4)	3.3 (3.0)
MMSE (30-0)	28.4 (1.0)	**23.4 (2.3)**	**19.8 (1.5)**	13.6 (2.6)	1.5 (2.5)
IQCODE (1-5)	3.4 (0.4)	**3.8 (0.5)**	**4.6 (0.2)**	4.7 (0.3)	4.9 (0.4)
Spontaneous Behaviour Interview-Social Interaction (0-34)	1.0 (1.1)	**5.9 (2.7)**	**13.1 (3.5)**	17.9 (4.1)	29.8 (4.5)
Spontaneous Behaviour Interview-basic ADL (0-30)	4.7 (6.3)	**10.0 (5.8)**	**16.4 (4.8)**	17.8 (6.0)	26.5 (3.7)
IADL, % disability (0-100%)	38.6 (24.5)	**70.9 (24.1)**	**93.4 (14.4)**	96.0 (9.4)	99.9 (0.5)
Spontaneous Behaviour Interview-Behavioural Problems (0-27)	0.0 (0.0)	**0.3 (0.9)**	**1.0 (2.1)**	1.7 (2.4)	1.7 (2.6)
GDS-10 (0-10)	0.9 (2.2)	**1.9 (2.2)**	**2.0 (1.9)**	4.1 (3.2)	7.8 (3.6)
Cornell Scale for Depression in Dementia (0-38)	1.1 (2.2)	**1.9 (3.7)**	**4.3 (4.2)**	5.3 (5.6)	6.1 (4.6)

Age, sex, and education adjusted p-values for all comparisons both among all groups and between the no dementia group with MMSE or cMMSE ≤ 26 and the mild dementia group (MMSE or cMMSE ≥ 18) < 0.0001.

Lucca et al. 2017

Mean (SD) cognitive, functional, and problem behaviour scores/rates by cognitive status of all participants aged 100+ (N=380)

	No dementia		Dementia		
			mild	moderate	severe +
MMSE or cMMSE scores	**27-30**	**≤ 26**[a]	**≥ 18**	**9-17**	**0-8**
Test or scale (score range: best-worst)	26-29	69-102	14-17	38-98	54-134
MMSE or converted-MMSE (30-0)	28.0 (1.0)	**23.2 (2.2)**	**19.5 (1.5)**	13.4 (2.5)	3.4 (2.9)
MMSE (30-0)	28.1 (1.0)	**23.4 (2.2)**	**19.7 (1.6)**	13.4 (2.6)	1.5 (2.5)
IQCODE (1-5)	3.4 (0.4)	**3.7 (0.4)**	**4.5 (0.3)**	4.8 (0.3)	4.9 (0.5)
Spontaneous Behaviour Interview-Social Interaction (0-34)	1.5 (1.9)	**6.0 (2.5)**	**13.1 (3.2)**	18.1 (4.0)	30.1 (4.4)
Spontaneous Behaviour Interview-basic ADL (0-30)	4.6 (5.8)	**9.1 (6.0)**	**15.1 (5.3)**	17.7 (6.1)	26.3 (3.9)
IADL, % disability (0-100%)	36.6 (23.4)	**63.0 (26.2)**	**93.3 (13.5)**	95.3 (10.4)	99.9 (0.6)
Spontaneous Behaviour Interview-Behavioural Problems (0-27)	0.0 (0.0)	**0.2 (0.7)**	**0.8 (1.9)**	1.5 (2.2)	1.3 (2.4)
GDS-10 (0-10)	1.0 (2.0)	**1.6 (2.1)**	**2.1 (1.8)**	4.2 (3.2)	7.6 (3.6)
Cornell Scale for Depression in Dementia (0-38)	0.9 (2.0)	**1.5 (3.1)**	**3.6 (4.1)**	5.3 (5.3)	6.0 (4.6)

Age, sex, and education adjusted p-values for all comparisons both among all groups and between the no dementia group with MMSE or cMMSE ≤ 26 and the mild dementia group (MMSE or cMMSE ≥ 18) < 0.0001.

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Mean (SD) cognitive, functional, and problem behaviour scores by cognitive status of participants aged 100+ with severe hearing impairment at first visit (N = 74)

	No dementia		Dementia			Age, sex and
			mild	moderate	severe +	education
Test or scale (score range: best-worst)	**27-30 ***	**≤ 26 ***	**≥ 18 ***	**9-17 ***	**0-8 ***	**adjusted p #**
N	≤ 2	**≤ 11**	**≤ 5**	≤24	≤ 32	
MMSE or c-MMSE (30-0)	27.6 (0.5)	**22.2 (2.4)**	**20.1 (1.8)**	13.7 (2.5)	3.3 (2.9)	**< 0.0001**
MMSE (30-0)	28.0 (-)	**22.2 (2.6)**	**20.3 (2.1)**	14.0 (2.5)	1.1 (2.6)	**< 0.0001**
IQCODE (1-5)	3.0 (0.04)	**3.9 (0.3)**	**4.6 (0.2)**	4.7 (0.4)	4.7 (0.5)	**< 0.0001**
SBI-Social Interaction (0-34)	2.0 (1.4)	**7.3 (2.1)**	**12.2 (3.3)**	17.1 (4.5)	29.5 (5.0)	**< 0.0001**
SBI-basic ADL (0-30)	7.0 (9.9)	**8.6 (4.7)**	**17.6 (7.8)**	15.7 (6.6)	26.3 (4.0)	**0.0004**
IADL (% disability: 0-100%)	37.5 (39.8)	**66.2 (30.5)**	**89.3 (23.9)**	93.5 (11.0)	99.8 (0.9)	**0.0001**
SBI-Behavioural Problems (0-27)	0.0 (0.0)	**0.5 (1.2)**	**2.8 (2.8)**	2.2 (2.6)	1.5 (2.9)	**NS**

* MMSE or converted-MMSE scores. **SBI**: Spontaneous Behavior Interview

For comparisons between the no dementia group with MMSE or c-MMSE ≤ 26 and the mild dementia group.

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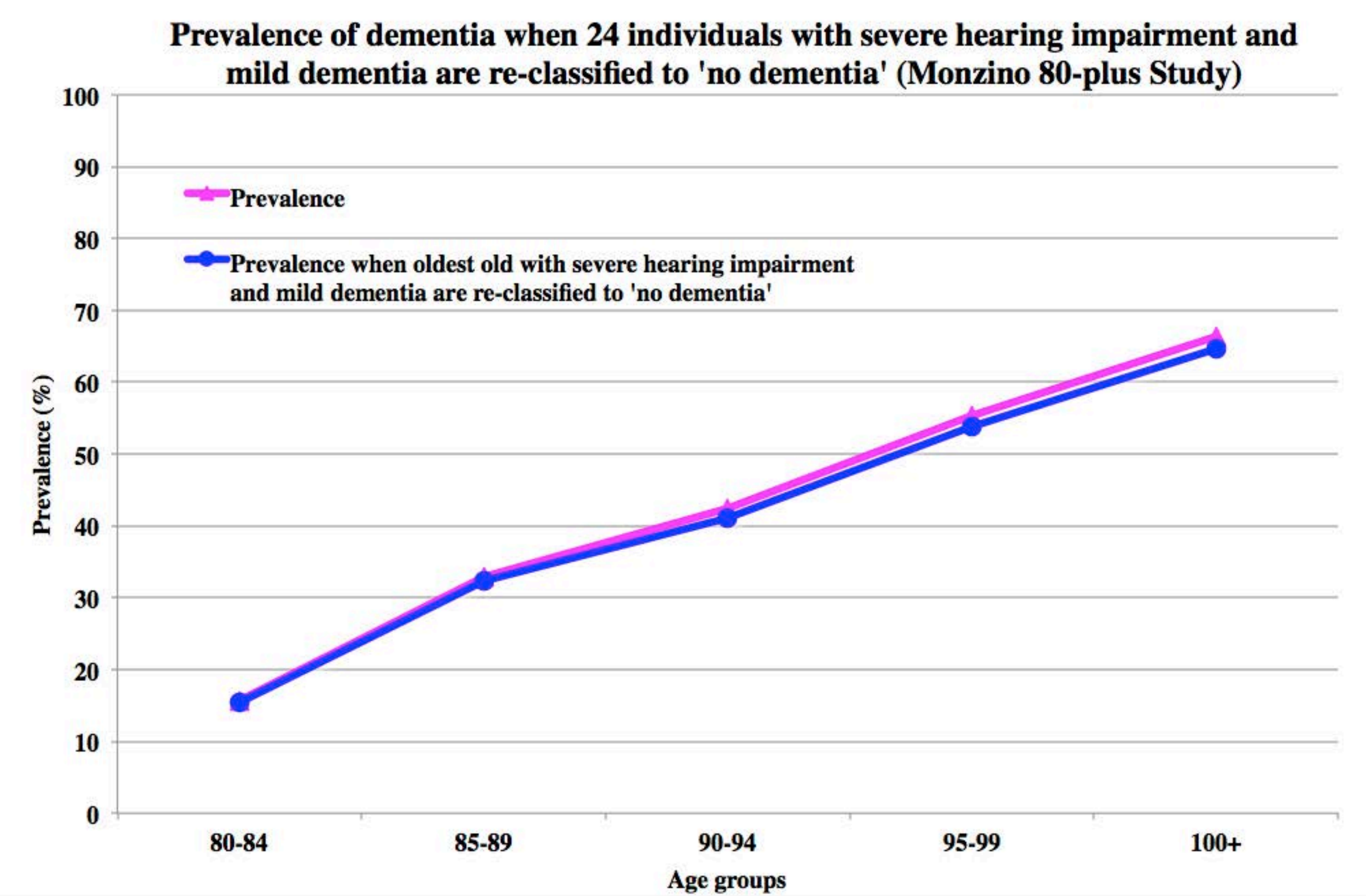

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Conclusions (1): the association with aging

Severe visual and hearing impairments continue to grow also in the very old.

Severe hearing impairment and measures of cognitive ability or cognitive competence are cross-sectionally associated in the oldest old but not in centenarians.

results not shown

The risk of incident dementia associated with a severe hearing impairment is slightly increased in the oldest old but not in centenarians.

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Conclusions (2): misclassification

In individuals with hearing impairment, "greater cognitive resources are required for auditory perceptual processing to the detriment of other cognitive resources such as working memory" (Lin and Albert 2014).
The presence of a severe sensory impairment unquestionably makes the assessment of cognition in the laboratory setting more difficult.

However, the possibility of mistaking severe hearing/visual impairment for incipient or mild dementia, though not impossible in principle, seems rather implausible; more so when, besides focused adaptation in test administration and scoring compensations, different sources of information are used to assess cognitive decline and dementia in the natural context of daily life.

In well conducted population-based studies in the oldest-old, the possible misclassification of dementia due to sensory impairment does not appear able to significantly modify the estimates of dementia occurrence and the relationship between dementia and ageing: the potential effect of misclassification seems thus overstated.

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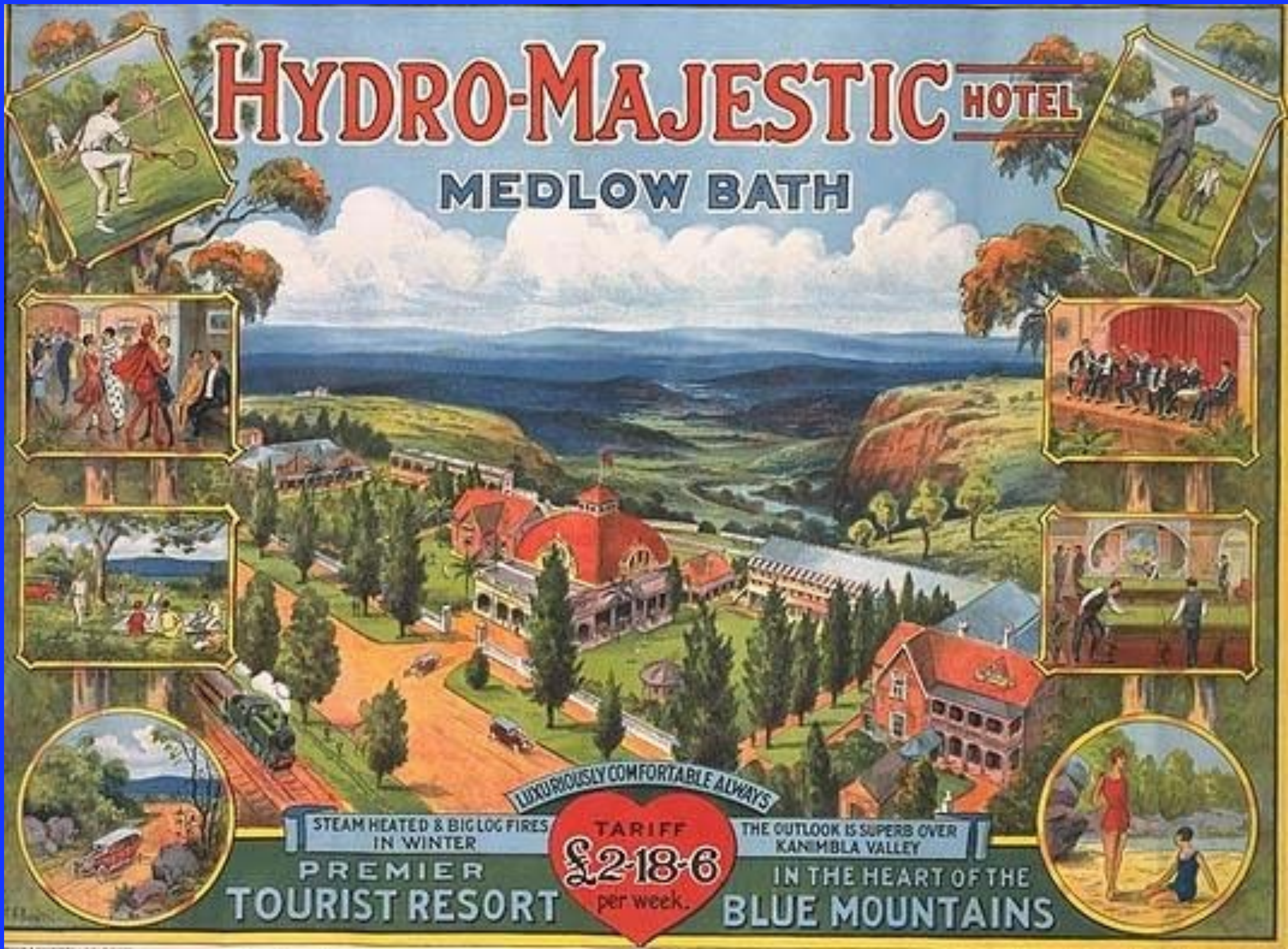
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