TED

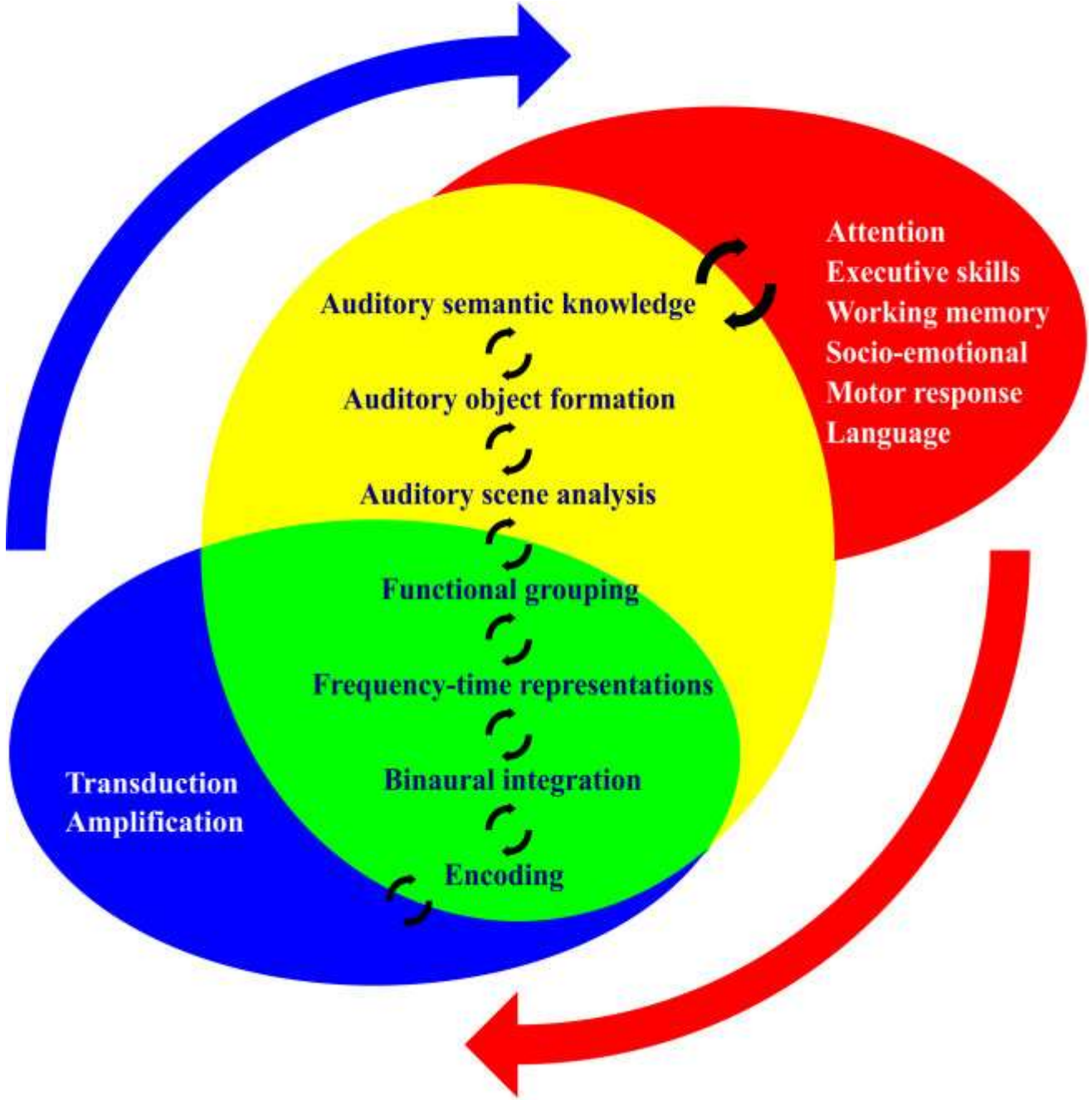
AUDITORY PROCESSING HIERARCHY AND INTERPLAY WITH GENERAL COGNITIVE FUNCTIONS

General cognitive functions

Auditory cognition
auditory cortex and cerebral connections

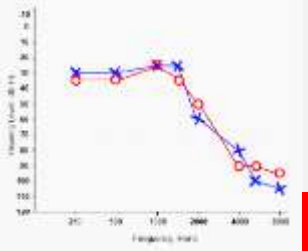
Precognitive auditory processing
auditory brainstem

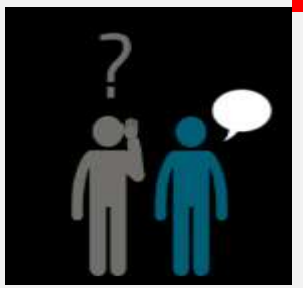
Peripheral hearing
cochlea and auditory nerve



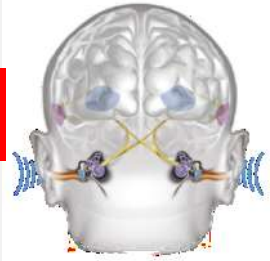
Consequences of an untreated hearing loss

Hearing loss

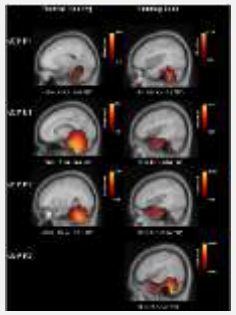




Signals to the brain have lower quality



The brain will reconstruct and compensate

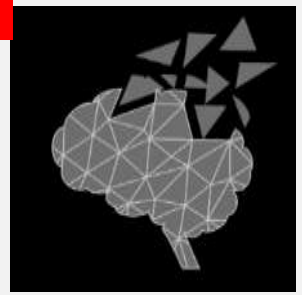


Campbell & Sharma, 2014

Fatigue and social withdrawal

Acceleration of health problems

(e.g. depression and dementia)



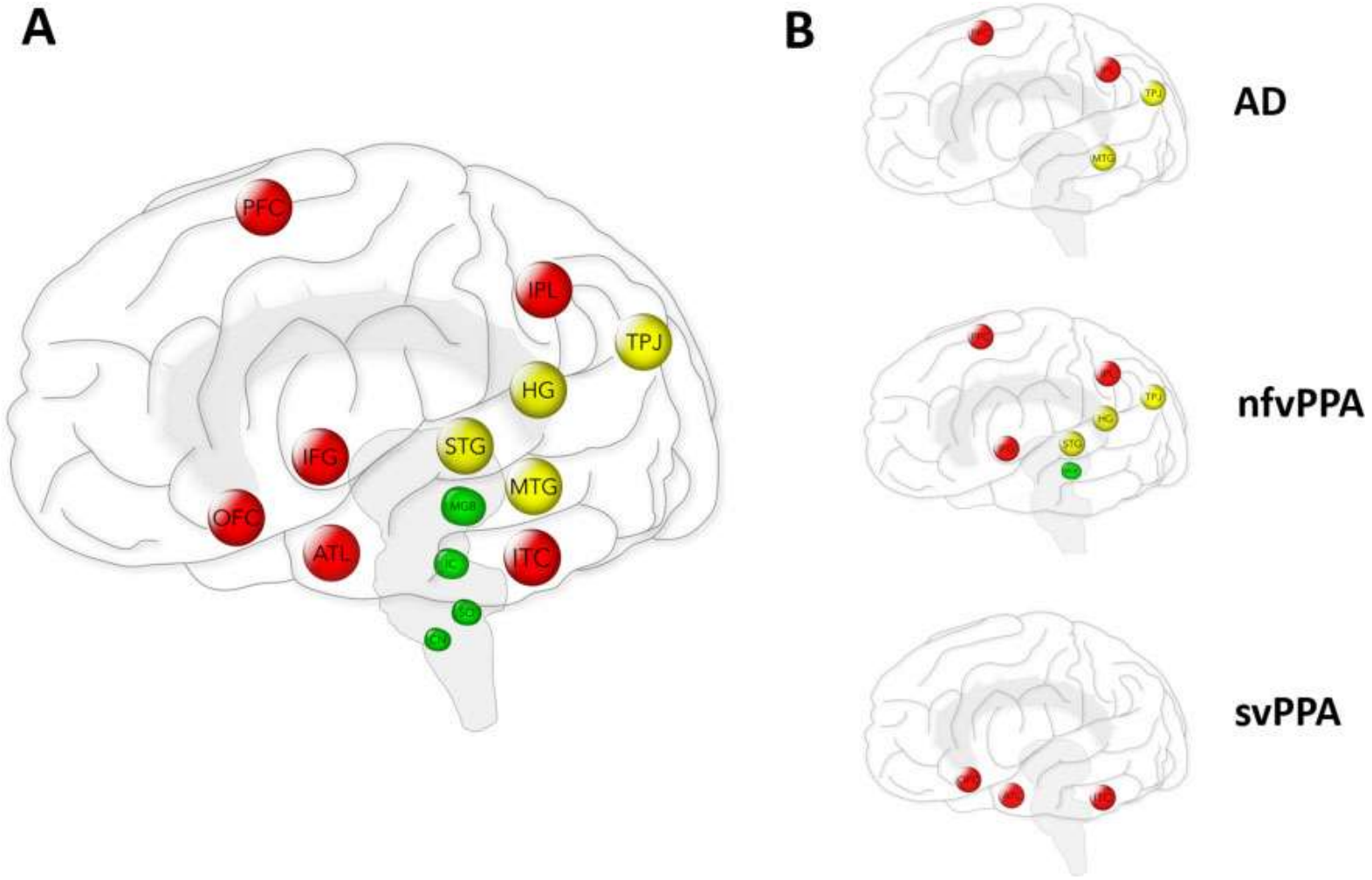
AUDITORY BRAIN IN HEALTH AND NEURODEGENERATIVE DISEASE

Anatomical regions that mediate the processes underpinning hearing as spheres:

precognitive auditory processing in brainstem pathways;

auditory cognition in auditory cortices;

general cognitive processes in connected cerebral regions.



Fondazione Caript

16° CONVEGNO NAZIONALE SUI CENTRI DIURNI ALZHEIMER

16-17 ottobre 2026
Montecatini Terme
Teatro Cinema Imperiale
Piazza Massimo D'Azeglio 5

GRUPPO ITALIANO CENTRI DIURNI ALZHEIMER

Centri Diurni Monteoliveto
Pistoia

PROGRAMMA PRELIMINARE

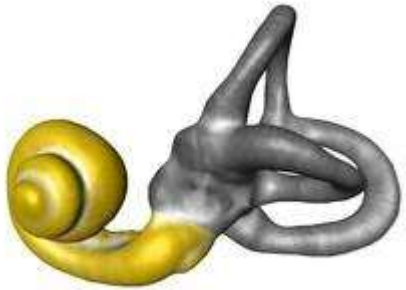
Ipoacusia e deficit cognitivo nell'anziano: come riconoscerla, come intervenire

VIS Vestibology Italian Society

Rudi Pecci

Bárány Society
The International Society for Neuro-otology

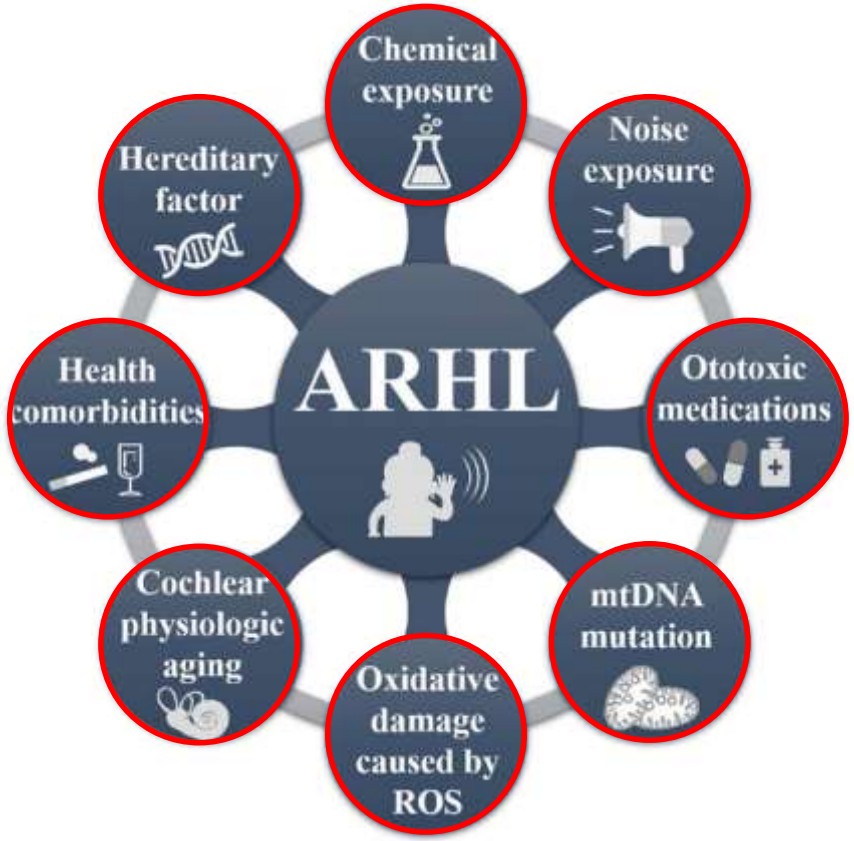
Dipartimento oncologico e di chirurgia ad indirizzo robotico
SOD di Audiologia e Otorinolaringoiatria
Azienda Ospedaliero-Universitaria Careggi
Università degli Studi di Firenze



Age Related Hearing Loss (ARHL)

Peripheral ARHL
presbycusis

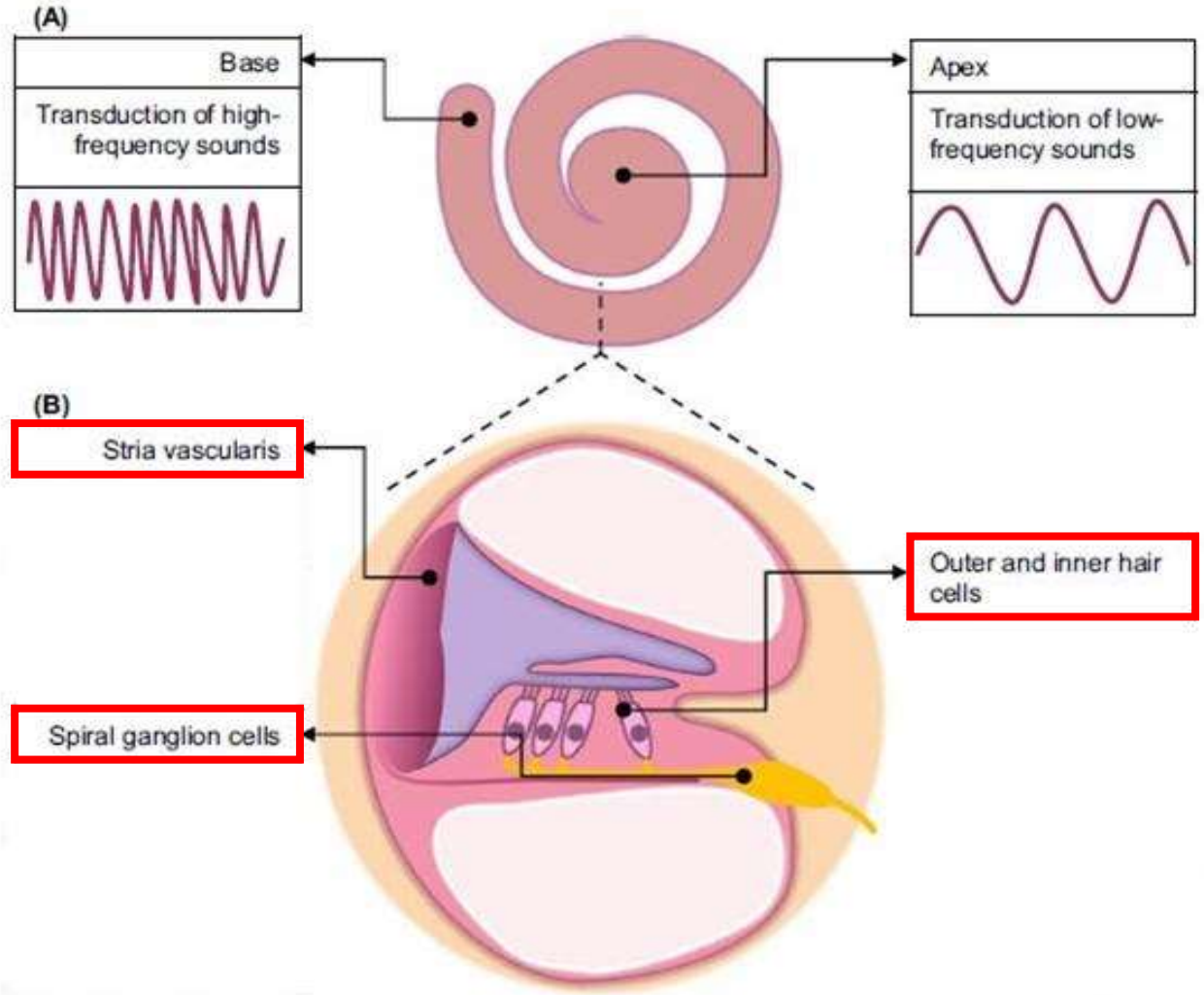
Increased
hearing threshold



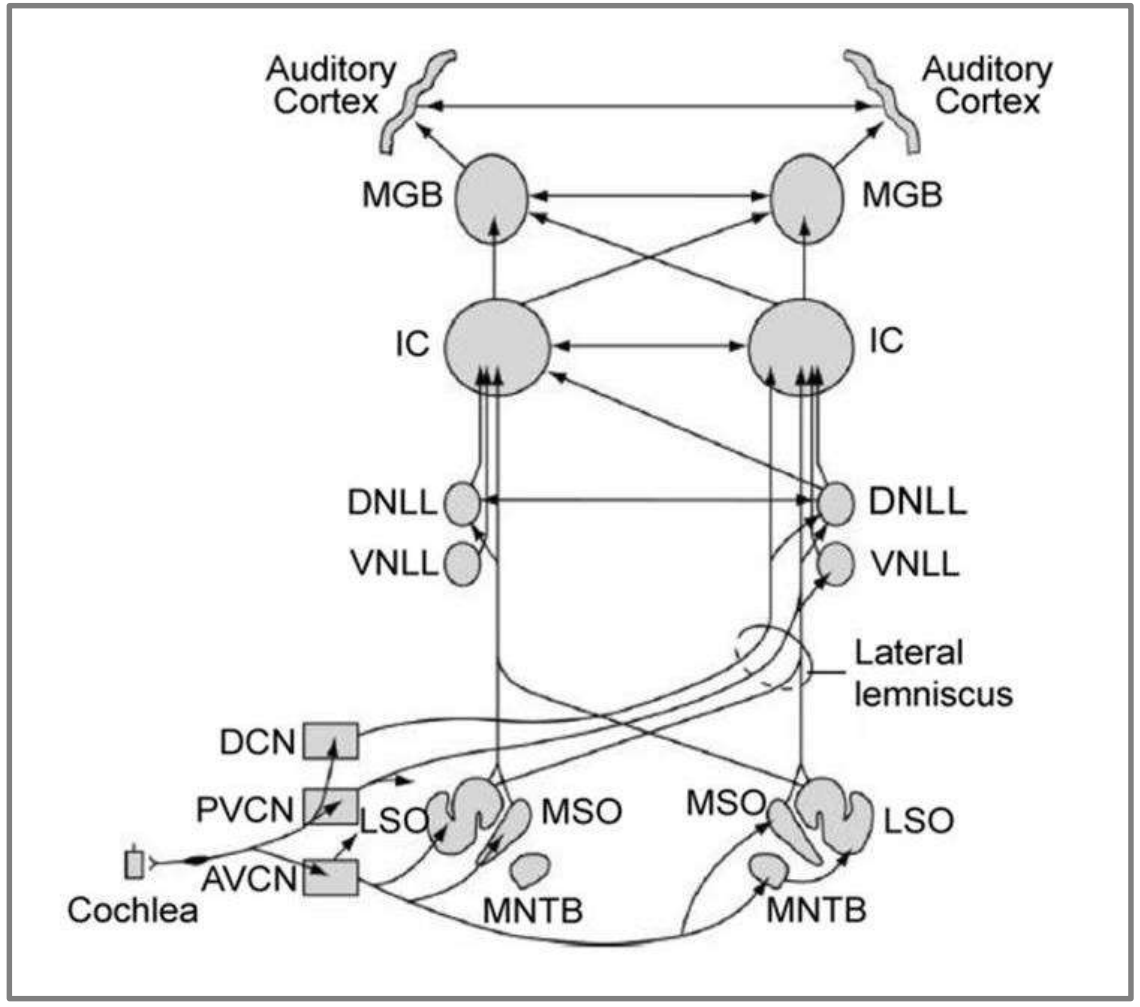
Central ARHL
central auditory
processing disorders

Impaired
speech understanding

The Mechanisms of Aging in the Peripheral Auditory System



The Mechanisms of Aging in the Central Auditory System



Changes in the central auditory pathway due to healthy aging:

reduction in both gray and white matter volumes

cortical thinning

decrease in glutamate and N-acetyl aspartate levels

increase in lactate levels

lower GABA concentrations

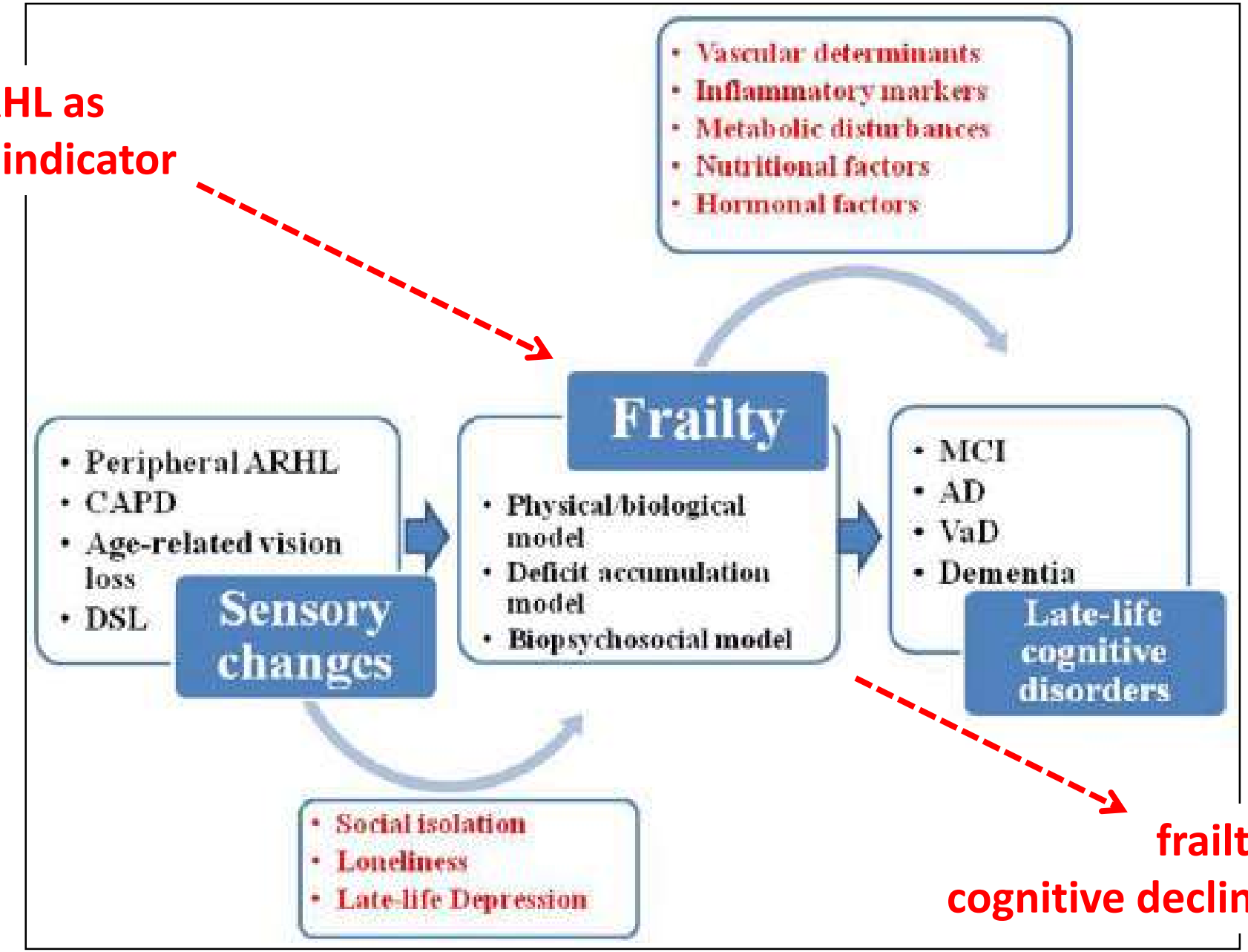
HYPOACUSIS
“older age frailty marker”

FRAIL
ELDERLY

Aspecific state of vulnerability, reduced multisystem physiological reserve and decreased resistance to stressors

Increased risk of falls, institutionalization, hospitalization, disability, and death

ARHL as frailty indicator

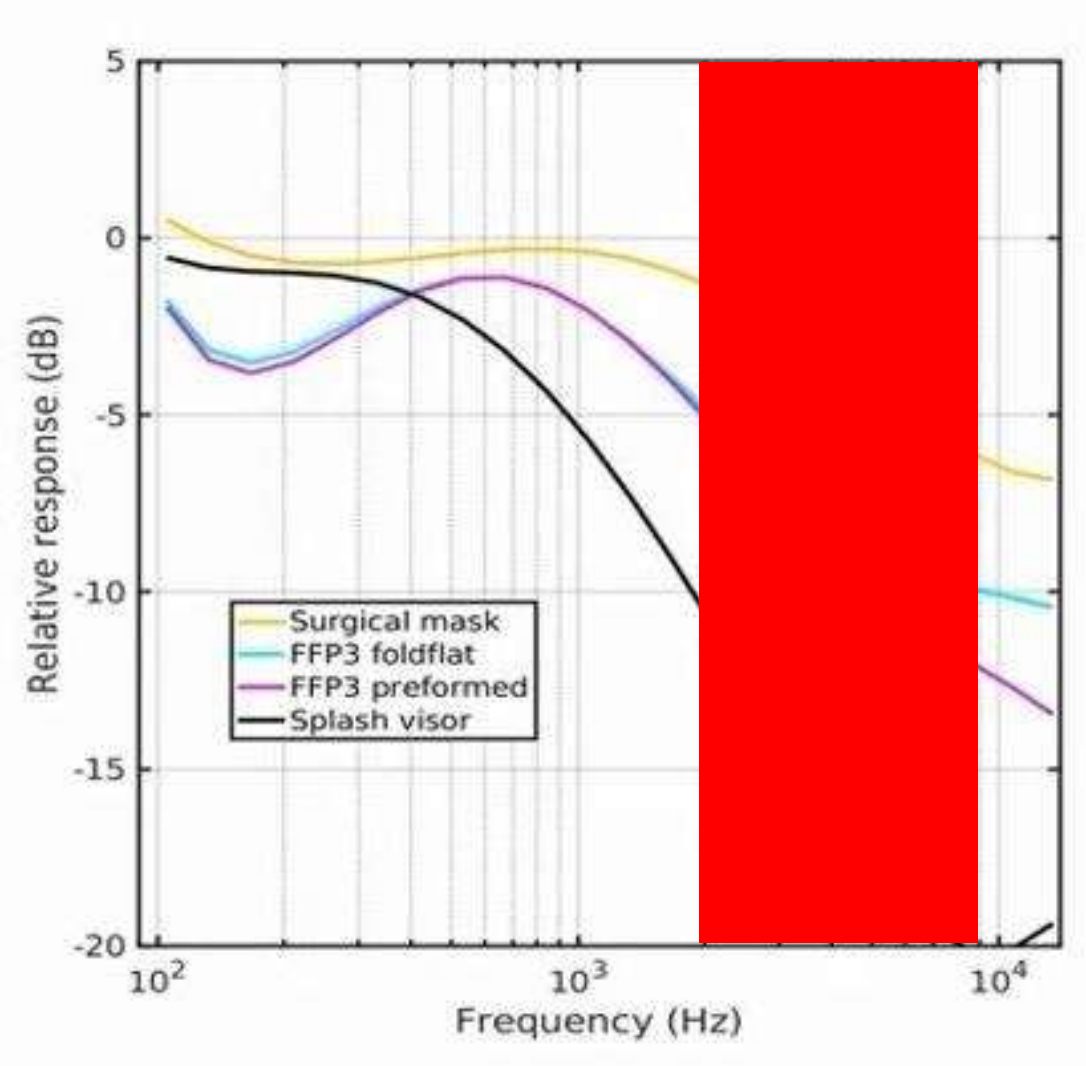


frailty as cognitive decline determinant

11 MARZO 2020
Pandemia da SARS-CoV2

World Health Organization

Uso delle mascherine



ATTENZIONE

Audio

Download

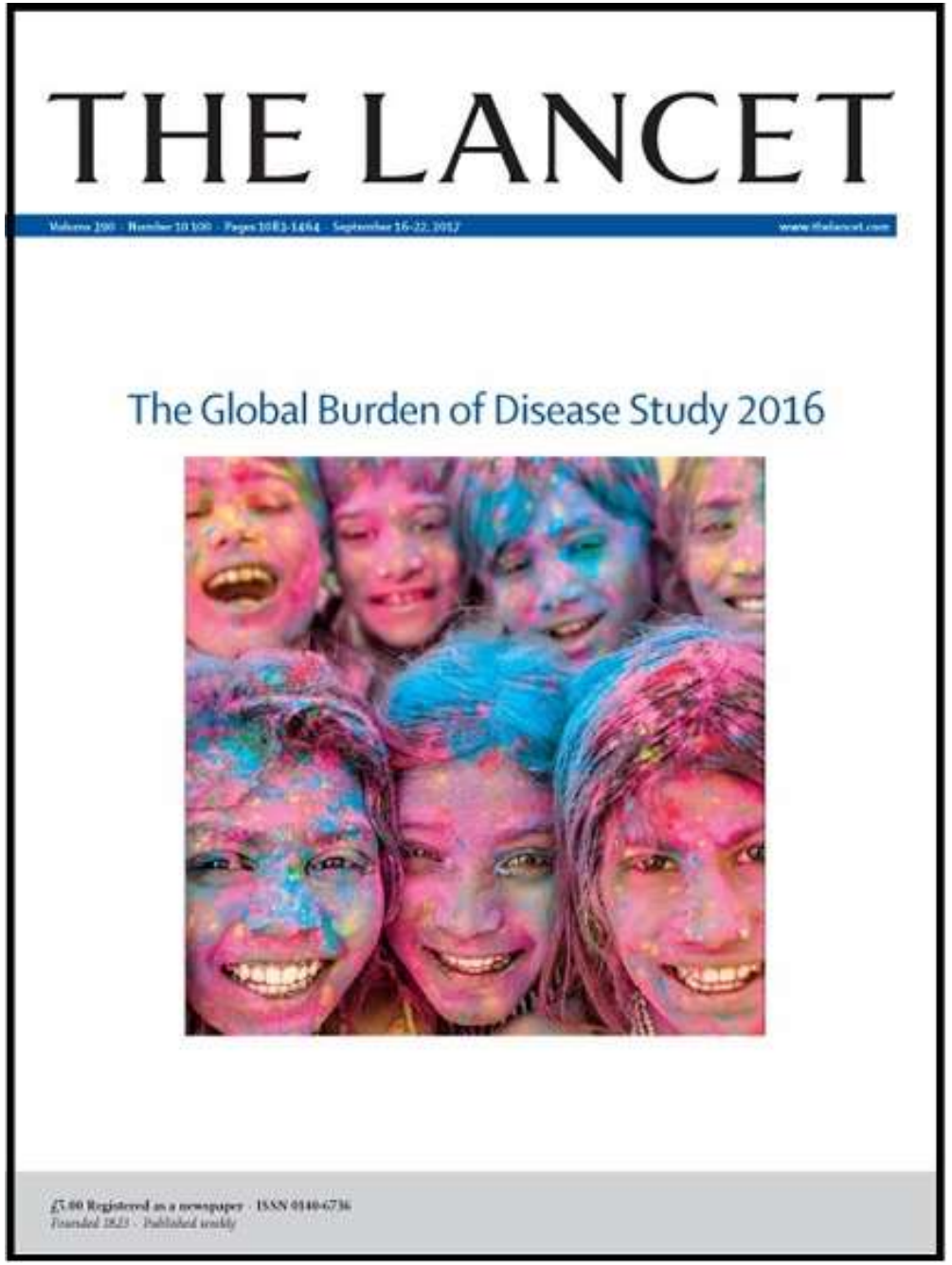
Global Burden of Disease 2016: The Lancet: September 16, 2017

In this special podcast we talk to GBD guru Chris Murray, representatives from exemplar countries Ethiopia, Nepal, and Peru, and *The Lancet*'s editor Richard Horton.

GLOBAL BURDEN OF DISEASE

1 **Hearing loss has become the *third leading cause of years lived with disability (YLDs)* and a major concern for global health, especially in the elderly population.**

2 **The attention to Age-Related Hearing Loss has been growing from the perspective of its *relation with cognition*.**



Alzheimer's Association International Conference (AAIC) 2017

A novel lifespan-based model of dementia risk was reported by the Lancet Commission on Dementia Prevention, Intervention, and Care and simultaneously published in Lancet.

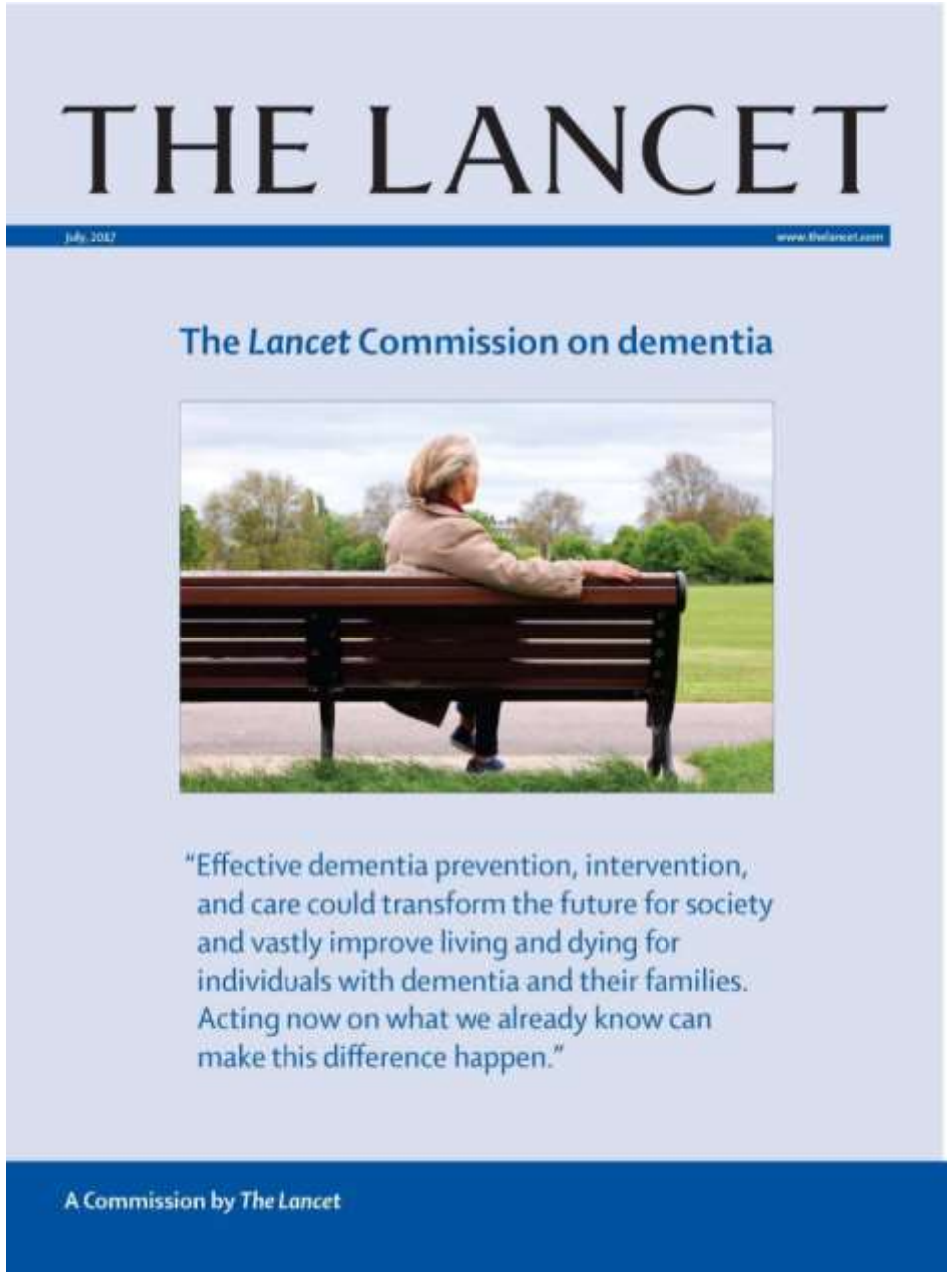
	Relative risk for dementia (95% CI)	Prevalence	Communality	PAF	Weighted PAF*
Early life (age <18 years)					
Less education (none or primary school only)	1·6 (1·26–2·01)	40·0%	64·6%	19·1%	7·5%
Midlife (age 45–65 years)					
Hypertension	1·6 (1·16–2·24)	8·9%	57·3%	5·1%	2·0%
Obesity	1·6 (1·34–1·92)	3·4%	60·4%	2·0%	0·8%
Hearing loss	1·9 (1·38–2·73)	31·7%	46·1%	23·0%	9·1%
Later life (age >65 years)					
Smoking	1·6 (1·15–2·20)	27·4%	51·1%	13·9%	5·5%
Depression	1·9 (1·55–2·33)	13·2%	58·6%	10·1%	4·0%
Physical inactivity	1·4 (1·16–1·67)	17·7%	26·6%	6·5%	2·6%
Social isolation	1·6 (1·32–1·85)	11·0%	45·9%	5·9%	2·3%
Diabetes	1·5 (1·33–1·79)	6·4%	70·3%	3·2%	1·2%

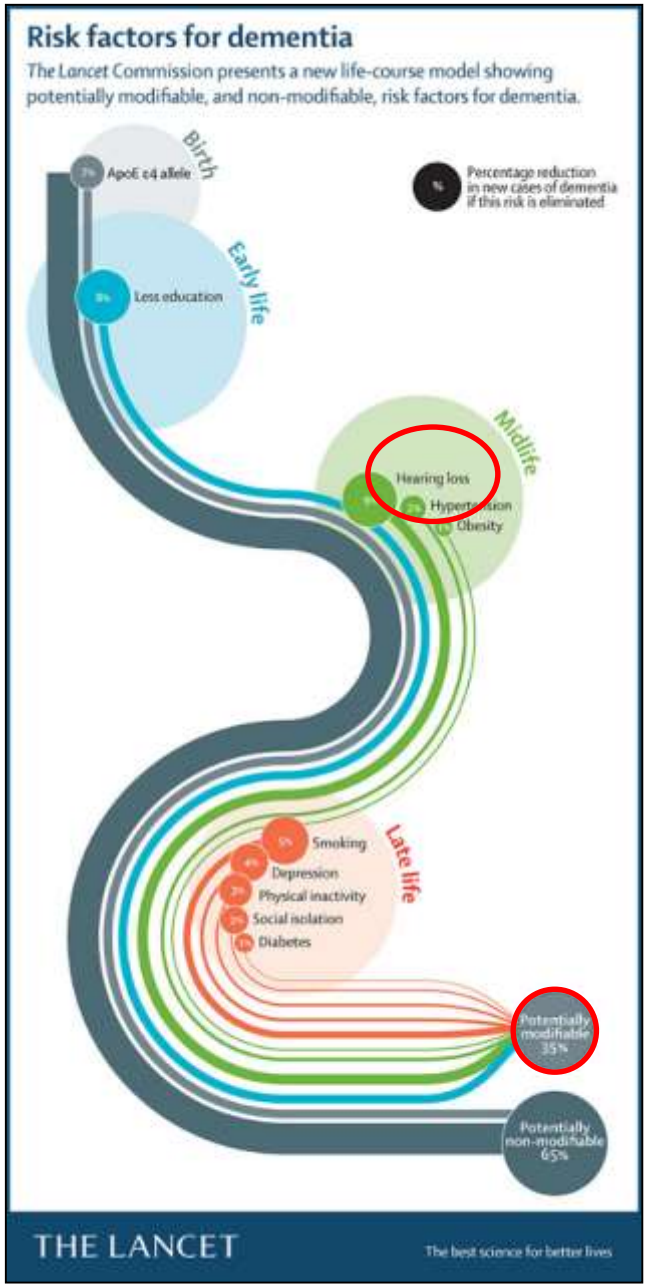
Data are relative risk (95% CI) or %. Total weighted PAF adjusted for communality =35·0%. PAF=population attributable fraction. *Weighted PAF is the relative contribution of each risk factor to the overall PAF when adjusted for communality.

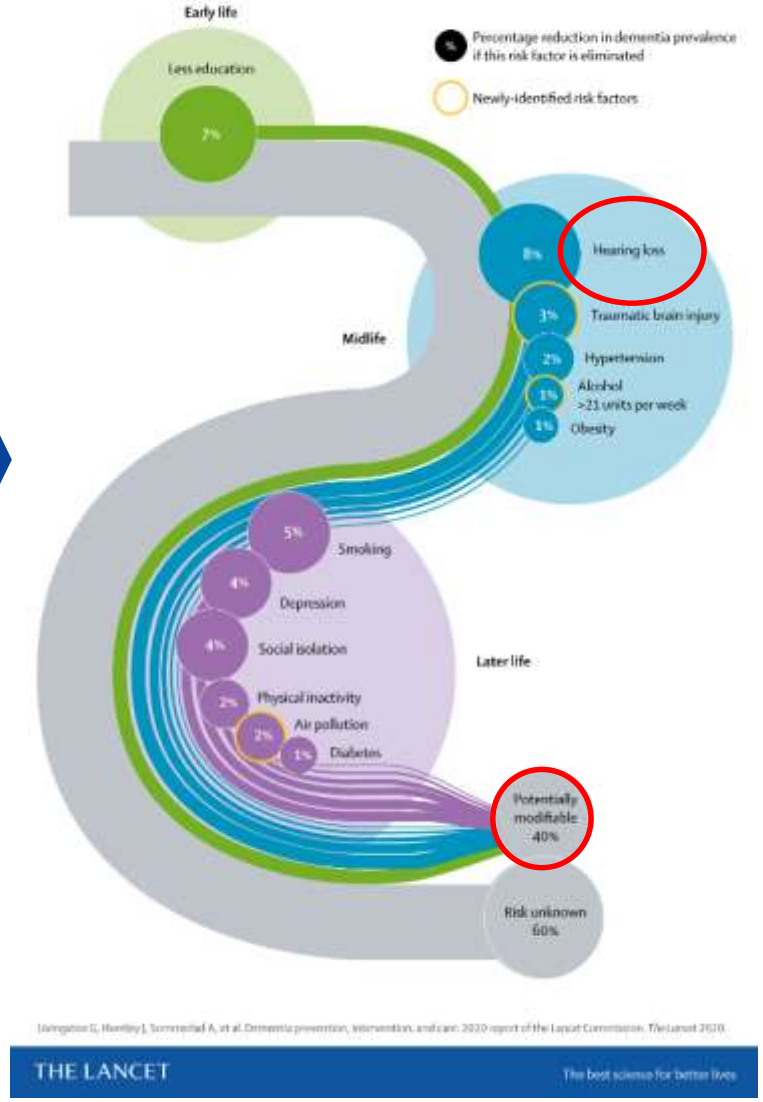
Table 1: Potentially modifiable risk factors for dementia

Hearing loss was positioned as *the largest potentially modifiable risk factor* for dementia among nine health and lifestyle factors.

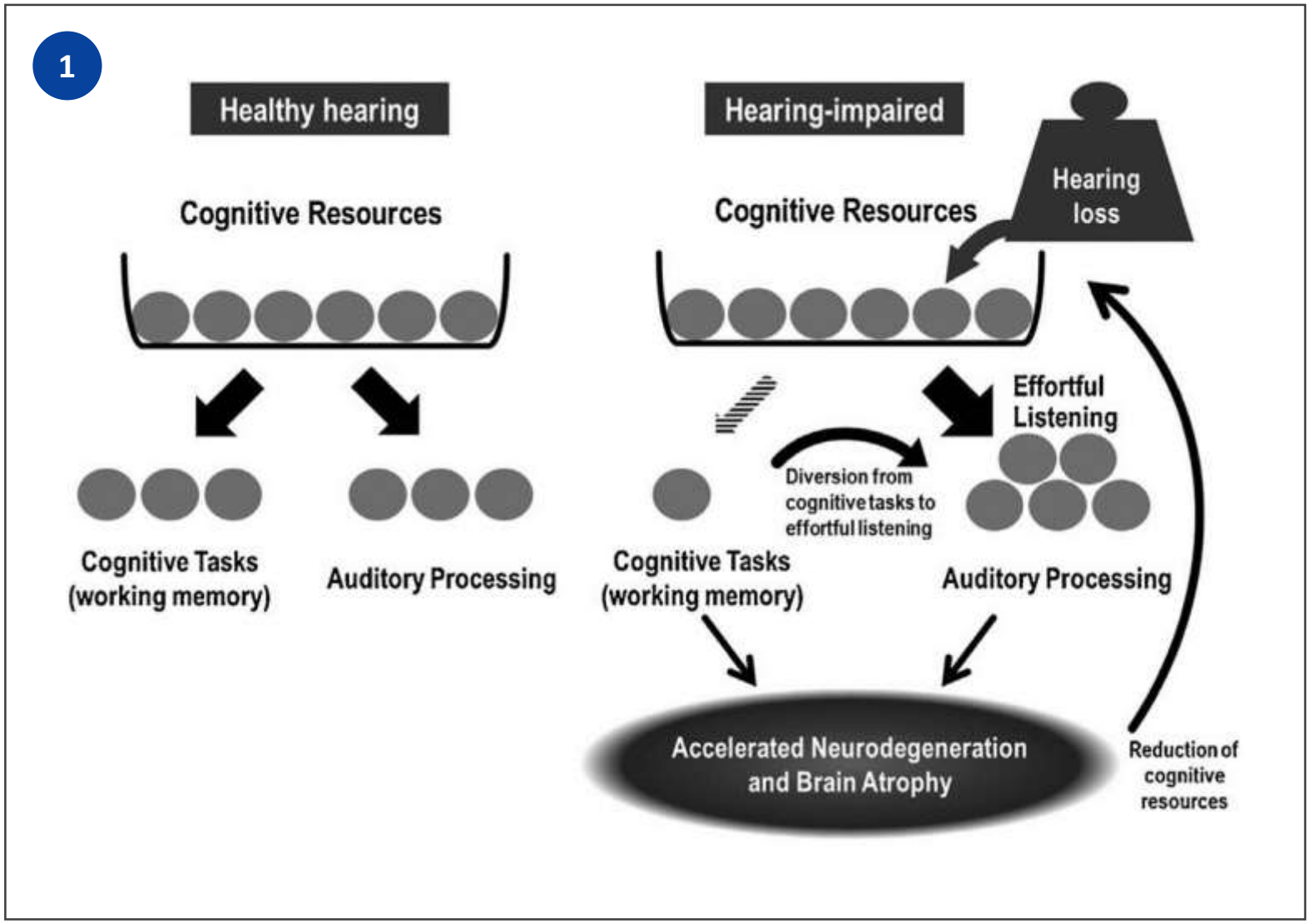
Mid-life hearing loss, if eliminated, might *reduce the risk of dementia by nine percent*.


THE LANCET
July, 2017
www.thelancet.com
The Lancet Commission on dementia
"Effective dementia prevention, intervention, and care could transform the future for society and vastly improve living and dying for individuals with dementia and their families. Acting now on what we already know can make this difference happen."
A Commission by The Lancet

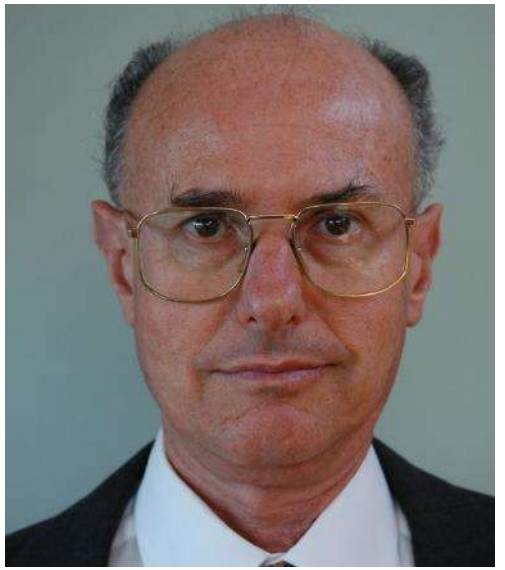

Risk factors for dementia
The Lancet Commission presents a new life-course model showing potentially modifiable, and non-modifiable, risk factors for dementia.
Birth
ApoE ε4 allele
Percentage reduction in new cases of dementia if this risk is eliminated
Early life
Less education
Midlife
Hearing loss
Hypertension
Obesity
Late life
Smoking
Depression
Physical inactivity
Social isolation
Diabetes
Potentially modifiable 35%
Potentially non-modifiable 65%
THE LANCET
The best science for better lives


Risk factors for dementia
An update to the Lancet Commission on Dementia prevention, intervention, and care presents a life-course model showing that 12 potentially modifiable risk factors account for around 40% of worldwide dementias
Early life
Less education
7%
Percentage reduction in dementia prevalence if this risk factor is eliminated
Newly-identified risk factors
Midlife
8%
Hearing loss
3%
Traumatic brain injury
2%
Hypertension
1%
Alcohol >21 units per week
1%
Obesity
Later life
5%
Smoking
4%
Depression
4%
Social isolation
2%
Physical inactivity
2%
Air pollution
1%
Diabetes
Potentially modifiable 40%
Risk unknown 60%
THE LANCET
The best science for better lives

Potential mechanisms linking ARHL and cognitive decline



COGNITIVE LOAD HYPOTHESIS



John Sweller
Educational Psychology
Emeritus Professor
New South Wales University
Sidney
2011

PUPILLOMETRY

objective measurement of listening effort

Potential mechanisms linking ARHL and cognitive decline

2

COMMON CAUSE HYPOTHESIS

Microcirculatory insufficiency:

vascular risk factors such as atherosclerosis, smoking, and diabetes have an impact on both hearing and cognition.

Genetic factors:

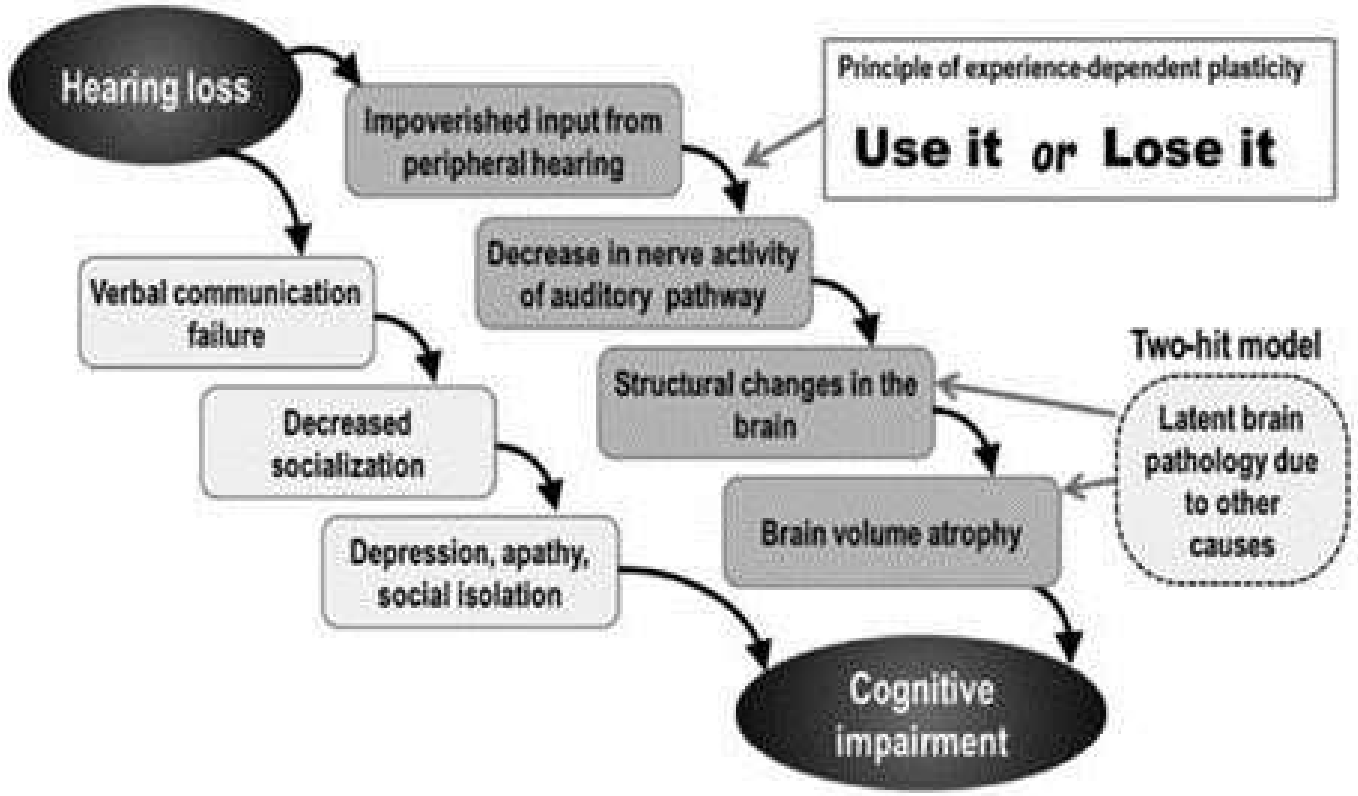
apolipoprotein E (APOE) ε4 allele, which predisposes a susceptibility to Alzheimer disease, is also associated with hearing loss.

Oxidative stress:

the brain is susceptible to oxidative stress and, as well, reactive oxygen species play an important microcirculatory role in auditory processing, in the inner ear and the central auditory pathways.

Potential mechanisms linking ARHL and cognitive decline

3



CASCADE HYPOTHESIS

"Use it or lose it":

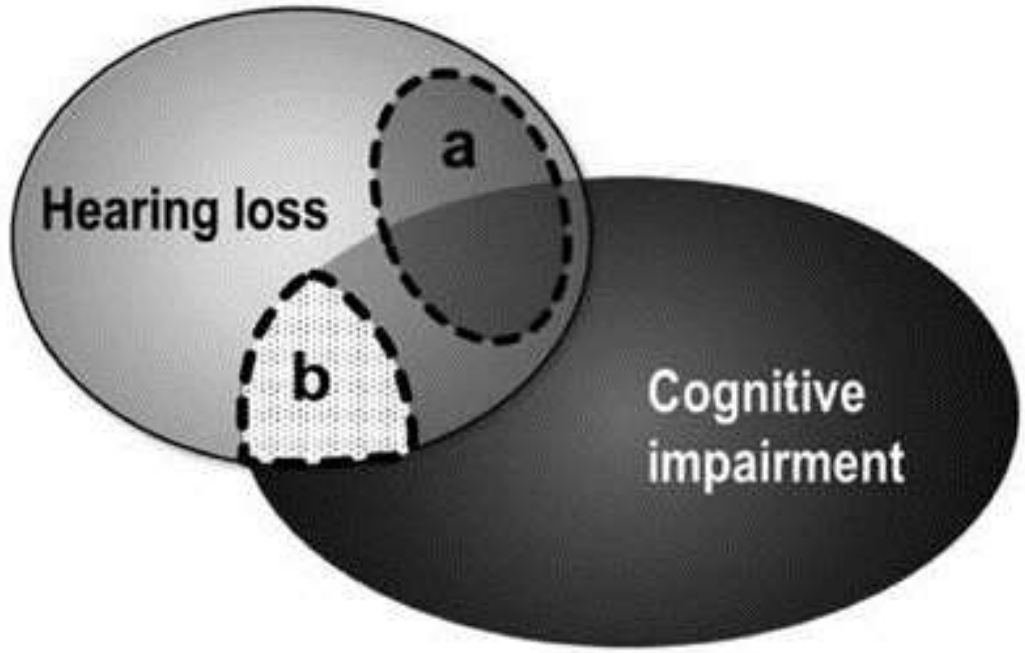
if one does not continue to use his or her listening and processing abilities, he or she might lose those abilities.

"Two hit model":

a less severe latent brain pathology (first hit) that is due to other causes (e.g., amyloid-beta accumulation, neurofibrillary tangles, and microvascular disease) may already exist in the brain, hearing loss representing the second hit.

Potential mechanisms linking ARHL and cognitive decline

4



OVERDIAGNOSIS OR HARBINGER HYPOTHESIS

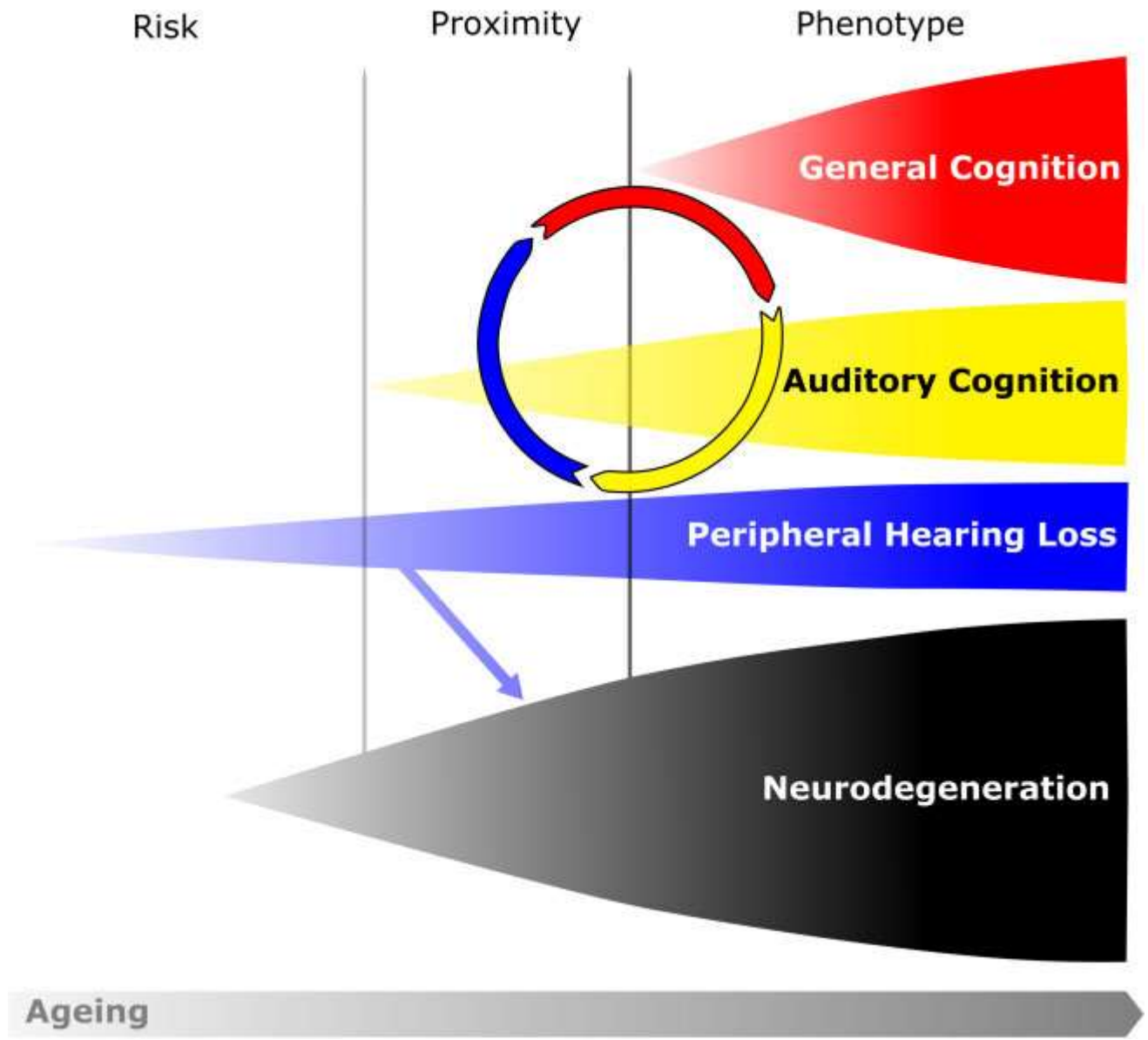
Area “a”:

overdiagnosis of cognitive impairment due to the effects of hearing difficulty on neurophychological test performance.

Area “b”:

hearing loss manifested as central auditory dysfunction can be a harbinger of Alzheimer dementia;

initial cognitive decline may be potentially concealed behind the symptoms treated as hearing loss.

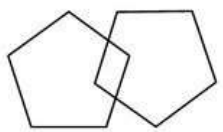

Risk
Proximity
Phenotype
General Cognition
Auditory Cognition
Peripheral Hearing Loss
Neurodegeneration
Ageing

Clinical Screening Tools
of Cognitive Decline Associated With Age-Related Hearing Loss

Questionnaires

Screening Tool: The Mini-Mental State Examination (MMSE)

Patient _____ Examiner _____ Date _____

Maximum	*Score*	
5		**Orientation** • What is the (year) (season) (date) (day) (month)?
5		• Where are we (state) (country) (town) (hospital) (floor)?
3		**Registration** • Name 3 objects: 1 second to say each. Then ask the patient all 3 after you have said them. Give 1 point for each correct answer. Then repeat until he/she learns all 3. Count trials and record. Trials _____
5		**Attention and Calculation** • Serial 7's. 1 point for each correct answer. Stop after 5 answers. Alternatively spell "world" backward.
3		**Recall** • Ask for the 3 objects repeated above. Give 1 point for each correct answer.
2		**Language** • Name a pencil and watch.
1		• Repeat the following "No ifs, ands or buts."
3		• Follow a 3-stage command: "Take a paper in your hand, fold it in half and put it on the floor."
1		• Read and obey the following CLOSE YOUR EYES.
1		• Write a sentence.
1		• Copy the design shown. 

_____ **Total Score**

ASSESS level of consciousness along a continuum _____

Alert Drowsy Stupor Coma

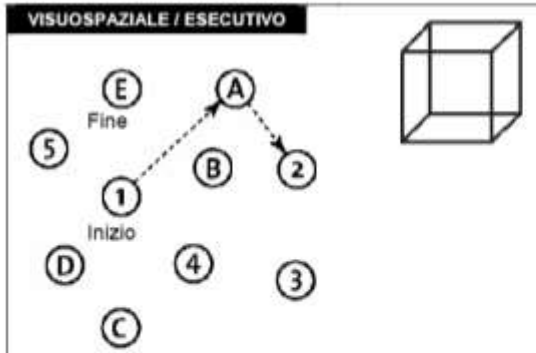
"Mini-Mental State." A Practical Method for Grading the Cognitive State of Patients for the Clinician. *Journal of Psychiatric Research*, 12(3): 189-198, 1975. Used with permission.

more information on reverse

MONTREAL COGNITIVE ASSESSMENT (MOCA)
- ITALIA -

NOME: _____
Scolarità: _____ Data di nascita: _____
Sesso: _____ DATA: _____

VISUOSPAZIALE / ESECUTIVO — **PUNTI**



Copi Il cubo

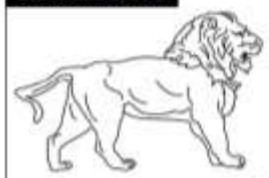
[ ] [ ]

Disegni un orologio (undici e dieci) (3 punti)

[ ] Contorno [ ] Numeri [ ] Lancette

__/ 5

DENOMINAZIONE



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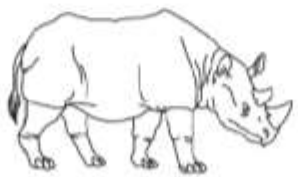

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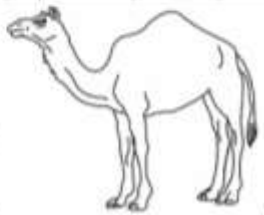


[ ]

__/ 3

MEMORIA — Leggere la lista di parole: il soggetto deve ripeterle. Fare le prime 2 prove di seguito e il " Richiamo " dopo 5 min.

	Faccia	Velluto	Chiesa	Margherita	Rosso
1°prova					
2°prova					

0 punti

ATTENZIONE

Leggere la serie di cifre (una cifra / sec.)
Il soggetto deve ripeterle [ ] 2 1 8 5 4
Il soggetto deve ripeterle in ordine inverso [ ] 7 4 2

__/ 2

Leggere la serie di lettere. Il soggetto deve dare un colpetto con la mano sul tavolo ad ogni lettera "A". 0 punti se ≥ 2 errori

[ ] F B A C M N A A G H L B A F A H D E A A A G A M O F A A B

__/ 1

Sottrazione di 7 partendo da 100 per 5 volte [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 o 5 sottrazioni corrette: 3 pt, 2 o 3 corrette: 2 pt, 1 corretta: 1 pt, 0 corretta: 0 pt

__/ 3

LINGUAGGIO — Ripeta:
So solo che oggi dobbiamo aiutare Giovanni. [ ]
Il gatto si nascondeva sempre sotto il divano quando c'erano cani nella stanza. [ ]

__/ 2

Fluenza / In 1 minuto, nomini il maggior numero possibile di parole che iniziano con la lettera "F". [ ] __ (N ≥ 11 parole)

__/ 1

ASTRAZIONE — Similitudini tra per es. banana / arancio = frutti; [ ] treno / bicicletta [ ] orologio / righello

__/ 2

RICHIAMO DIFFERITO — Deve ricordarsi le parole SENZA AIUTO

	Faccia [ ]	Velluto [ ]	Chiesa [ ]	Margherita [ ]	Rosso [ ]	Punti solo per ripetizione SENZA AIUTO
Opzionale — AIUTO: Categoria Semant.						
Opzionale — AIUTO: Scelta multipla						

__/ 5

ORIENTAMENTO [ ] Data [ ] Mese [ ] Anno [ ] Giorno [ ] Luogo [ ] Città

__/ 6

© Z. Nasreddine. Traduzione a cura di A. Pirani, C. Tulipani, M. Neri.
Versione 26 Luglio 2006
www.mocatest.org

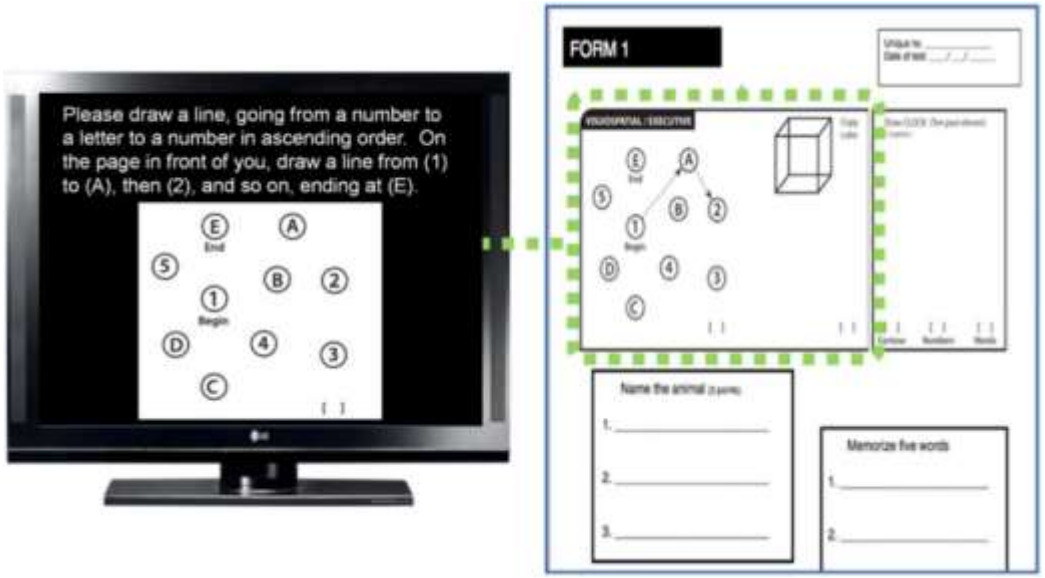
Normale: ≥ 26 / 30

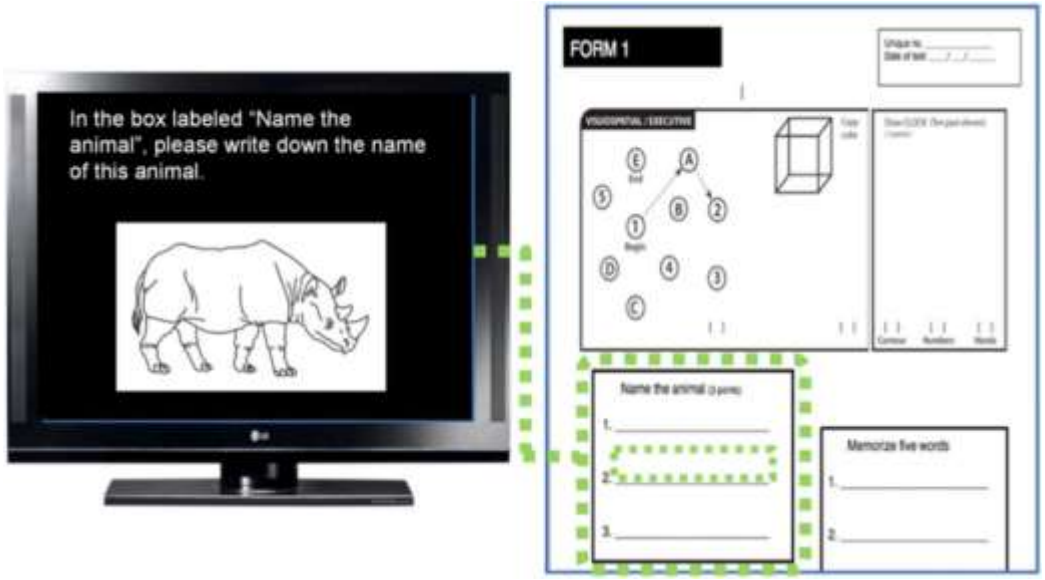
TOTALE __/30
Aggiungere 1 punto se ≤ 12 anni di istruzione

MoCA
MONTREAL
COGNITIVE ASSESSMENT

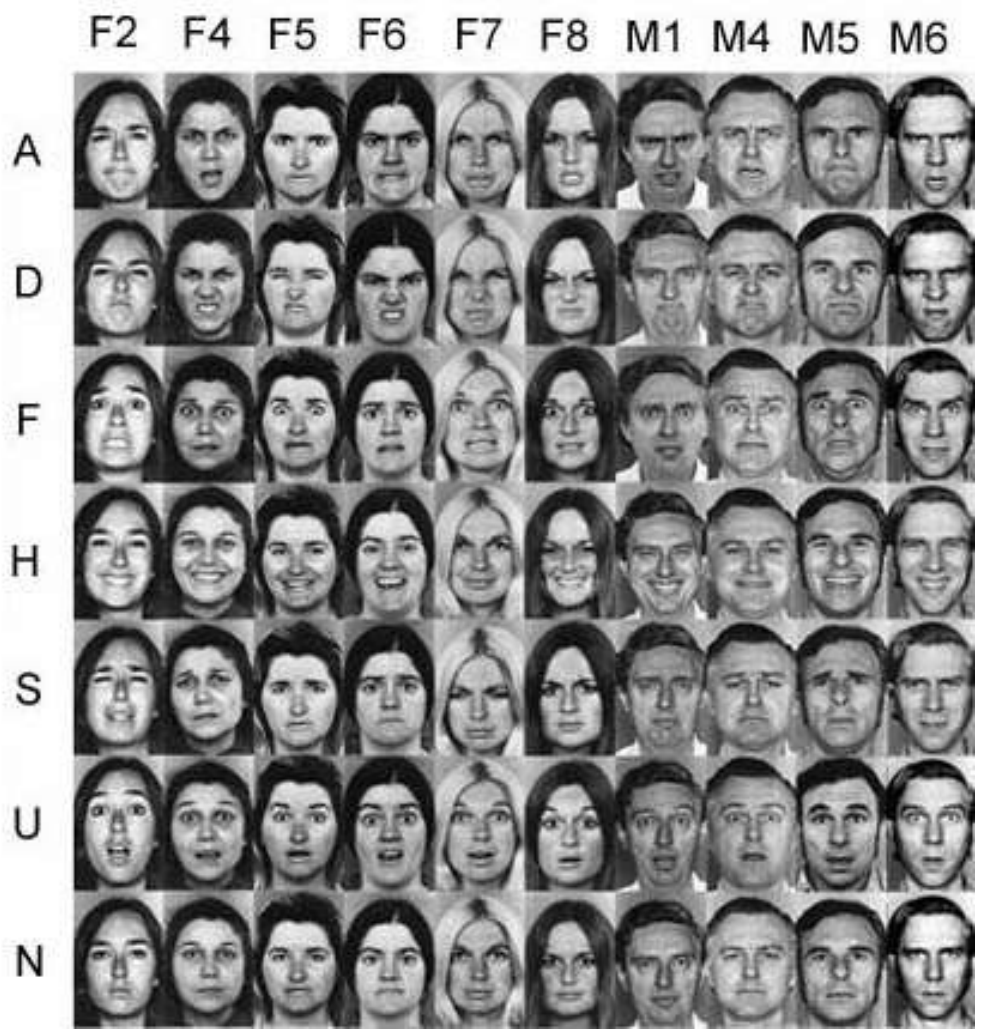
hearing loss
↓
decreased MoCA performance
↓
increased false-positive
↓
cognitive decline over-diagnosis

Hearing-Impaired MoCA (HI-MoCA)





FUTURE DIRECTIONS:
Social Cognition and Emotional Assessment



Photographs of facial expressions from

Ekman and Friesen *Pictures of Facial Affect (POFA)*

1976

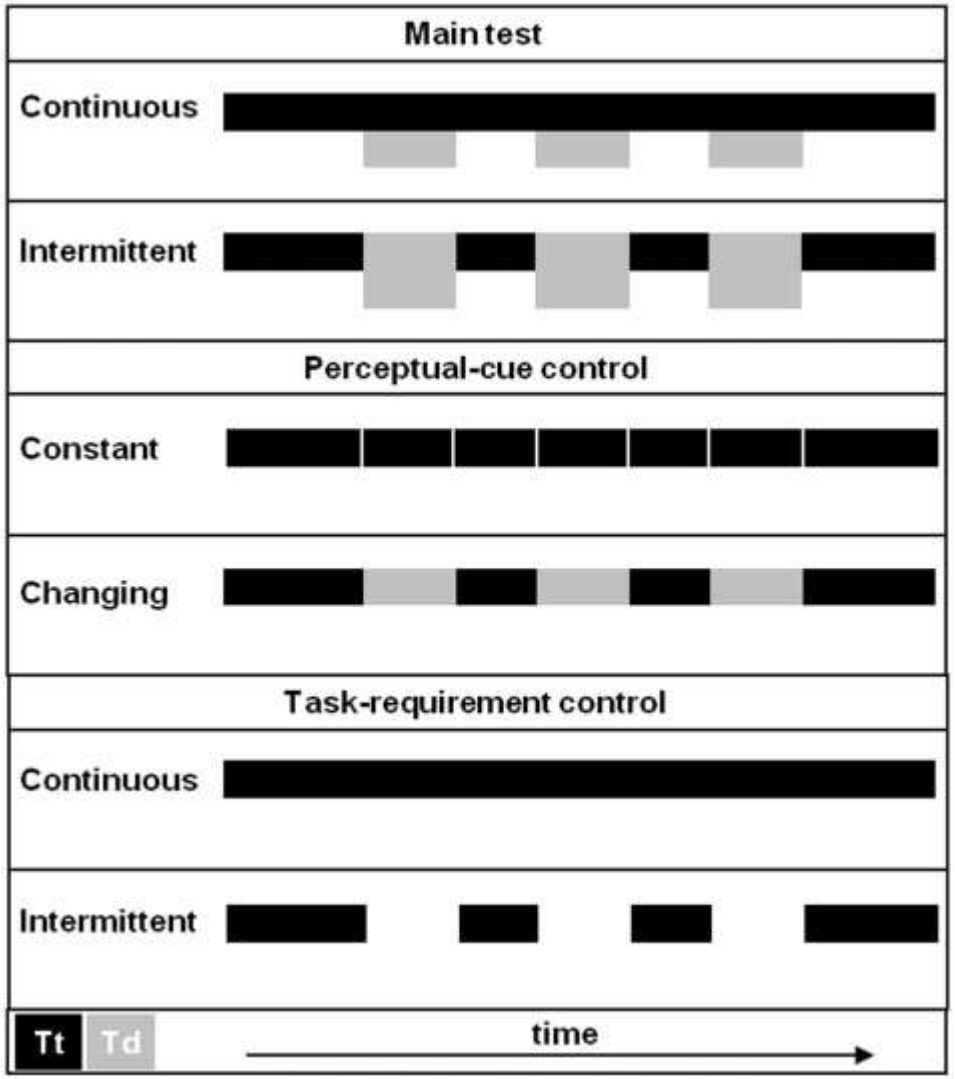
- There are emotional expressions of anger (A), disgust (D), fear (F), happiness (H), sadness (S) and surprise (U), and a neutral (N) pose for 6 female and 4 male models.
- The labels used to identify each of the models locate them in the Ekman and Friesen series (F2 = second female model in the series, M1 = first male model, etc.).
- **Facial Emotion Recognition (FER) decreases in ARHL associated with cognitive impairment (reduced performance in multiple cognitive domains, especially with semantic memory).**

FUTURE DIRECTIONS:
Auditory Phenotypes of Dementia Syndromes

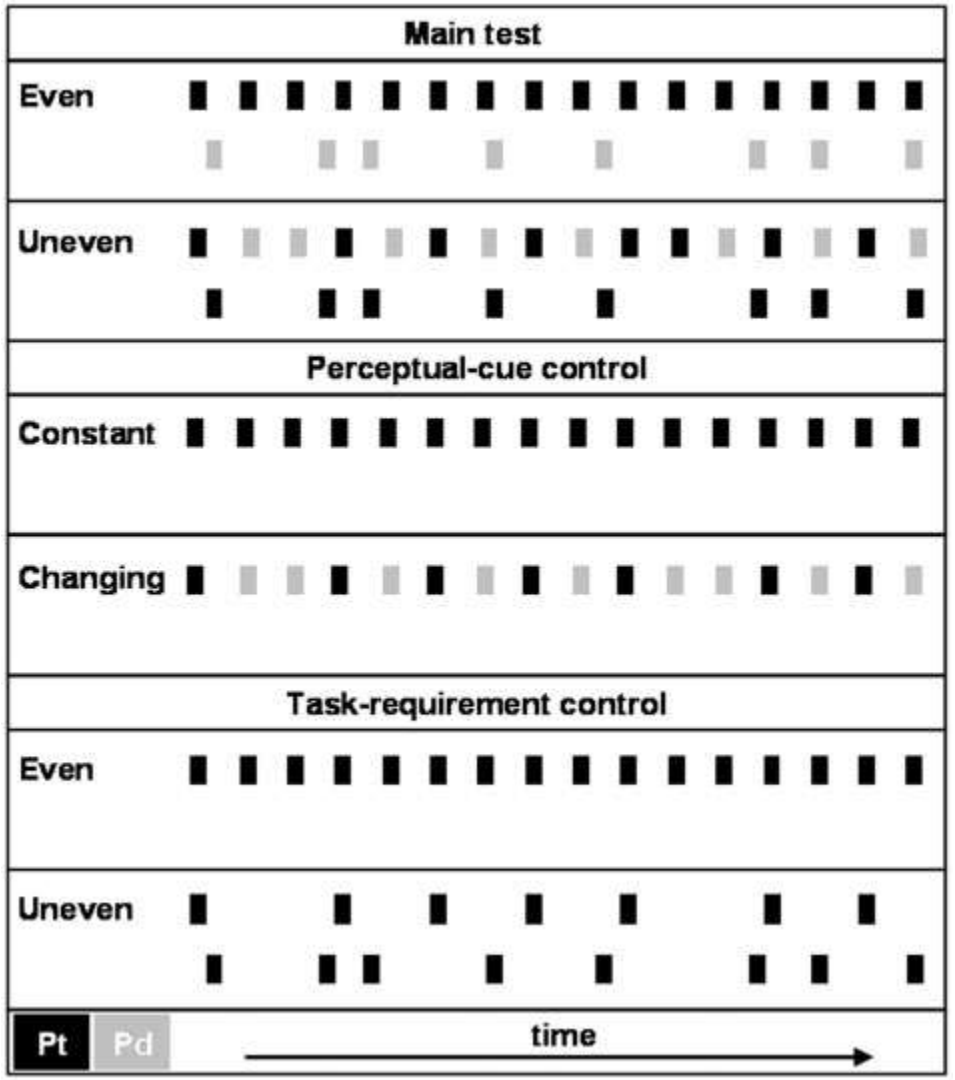
Syndrome	Core clinical features	Key auditory symptoms	Auditory deficits[a]	Proposed auditory diagnostic test[b]	Pathological neuroanatomy[c]
Alzheimer's disease					
Typical	Episodic/topographical memory loss, parietal deficits	Difficulty tracking sound sources/information in busy acoustic environments, auditory disorientation, difficulty understanding less familiar accents, auditory agnosia, increased sound sensitivity	Scene analysis, localization, attention, melody contour, accents, environmental sound recognition, working memory	Auditory stream separation, sound localization/motion detection[j], DLT[1,2,3,4]	Posterior cingulate, precuneus, lateral temporo-parietal cortex
LBD[e]	Fluctuating alertness/attention/executive deficits, visuo-perceptual deficits, visual hallucinations, REM sleep behaviour disorder, parkinsonism	Auditory hallucinations	Pure tone detection, complex tone perception, auditory scene analysis, rhythm perception, speech loudness perception	Sinewave speech comprehension[k,7,8]	Cortico-subcortical circuits
FTD					
bvFTD	Socio-emotional, executive dysfunction with disinhibition, apathy, loss of empathy, obsessions and rituals, dietary and other behavioural abnormalities	Sound aversion/musicophilia[g], phonagnosia[h]	Emotional recognition/reactivity, hedonic valuation, voice recognition[f], integration of semantic/affective information	Vocal emotion recognition[11]	Auditory/multimodal association cortex in anterior temporal lobe, orbitofrontal cortex, insula, anterior cingulate, striatal circuits

Auditory Scene Analysis

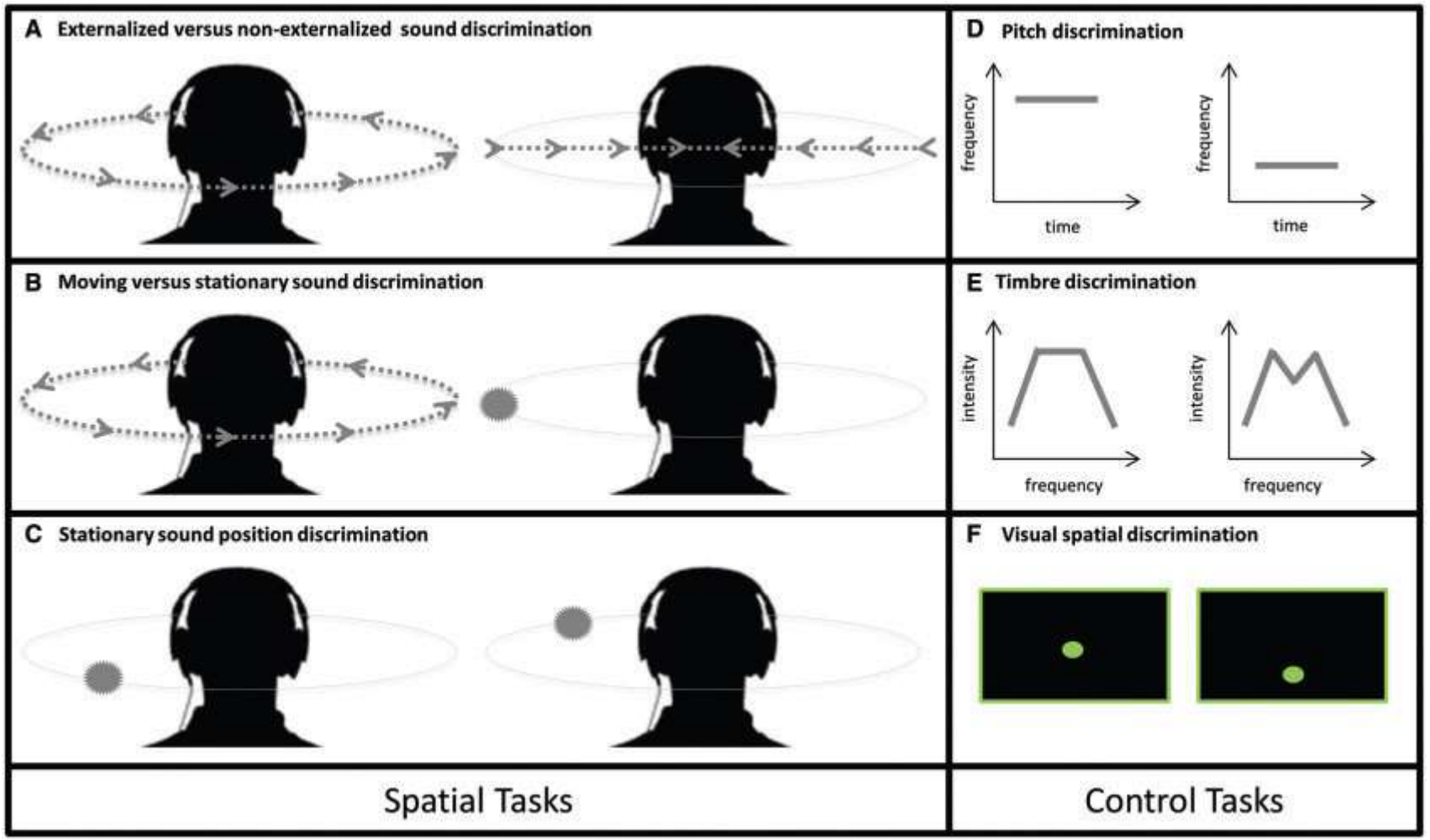
Auditory Scene Analysis segregation



Auditory Scene Analysis grouping

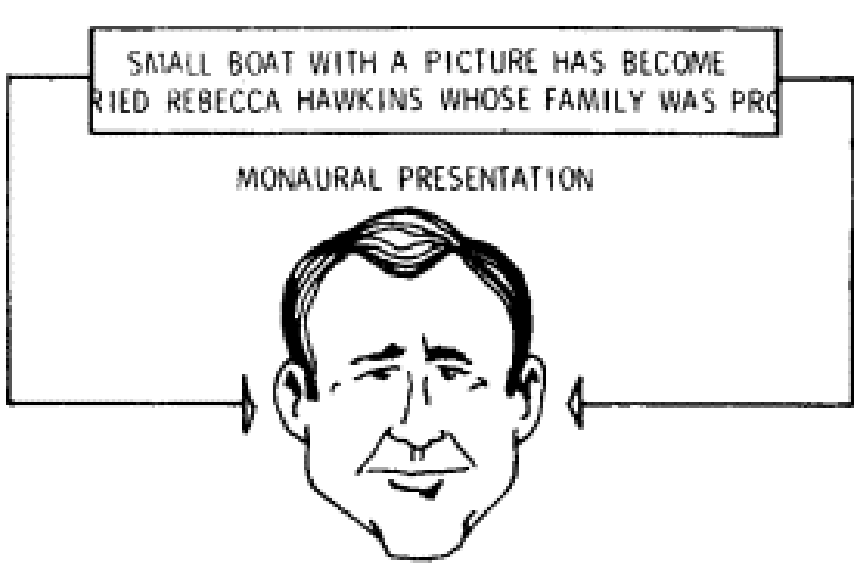


Auditory Spatial Processing

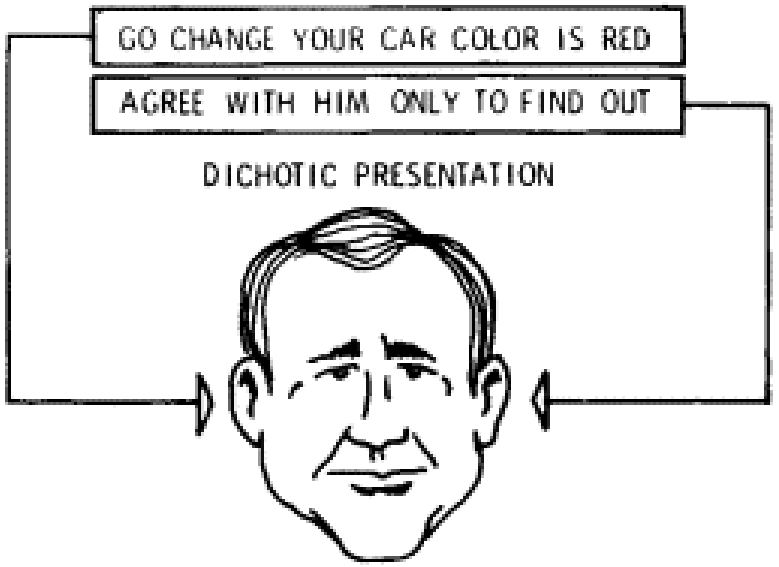


Central Auditory Processing

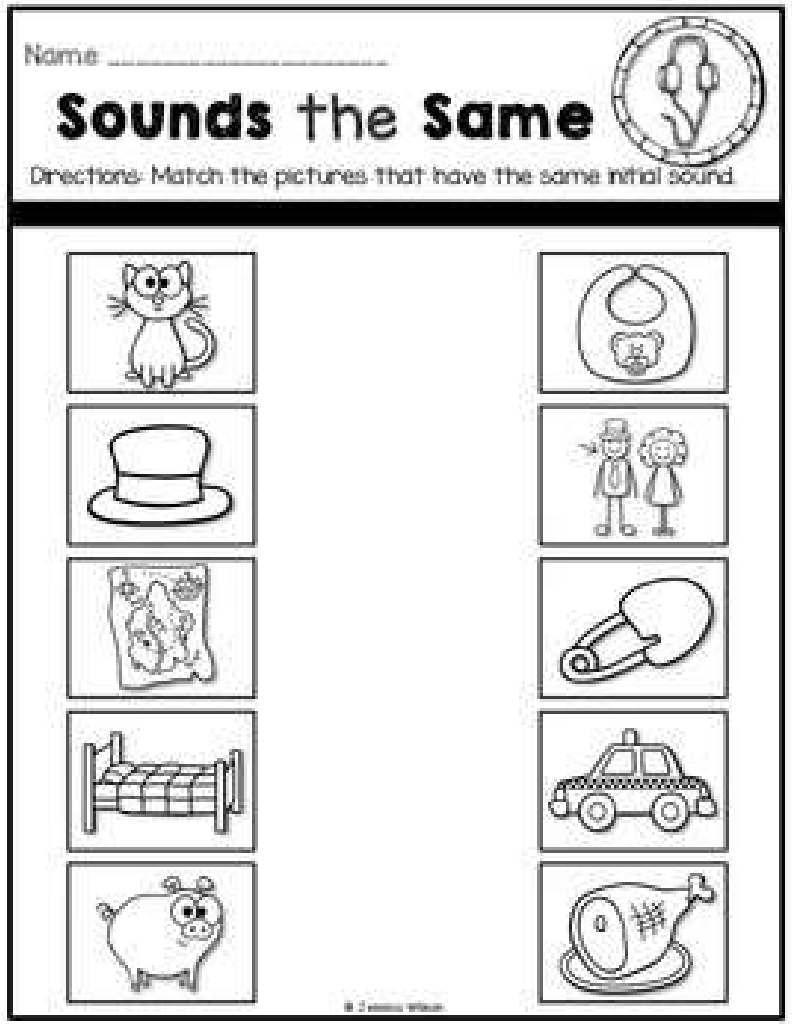
Synthetic Sentence with Ipsilateral Competing Message

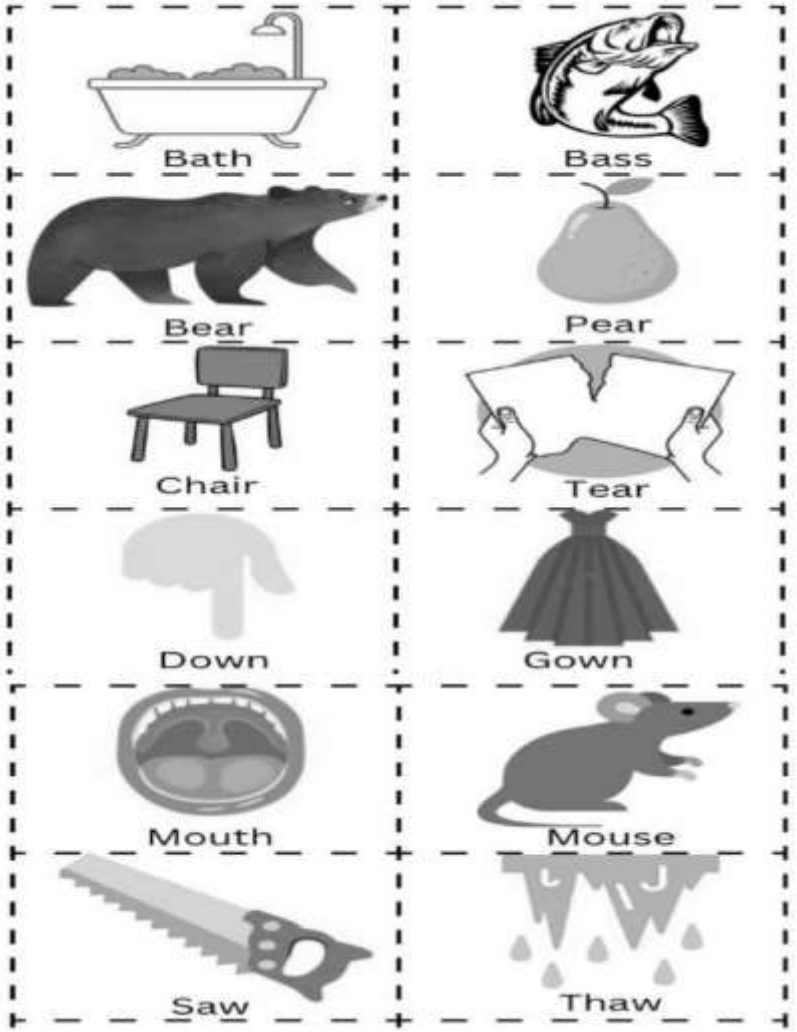


Dichotic Sentence Identification

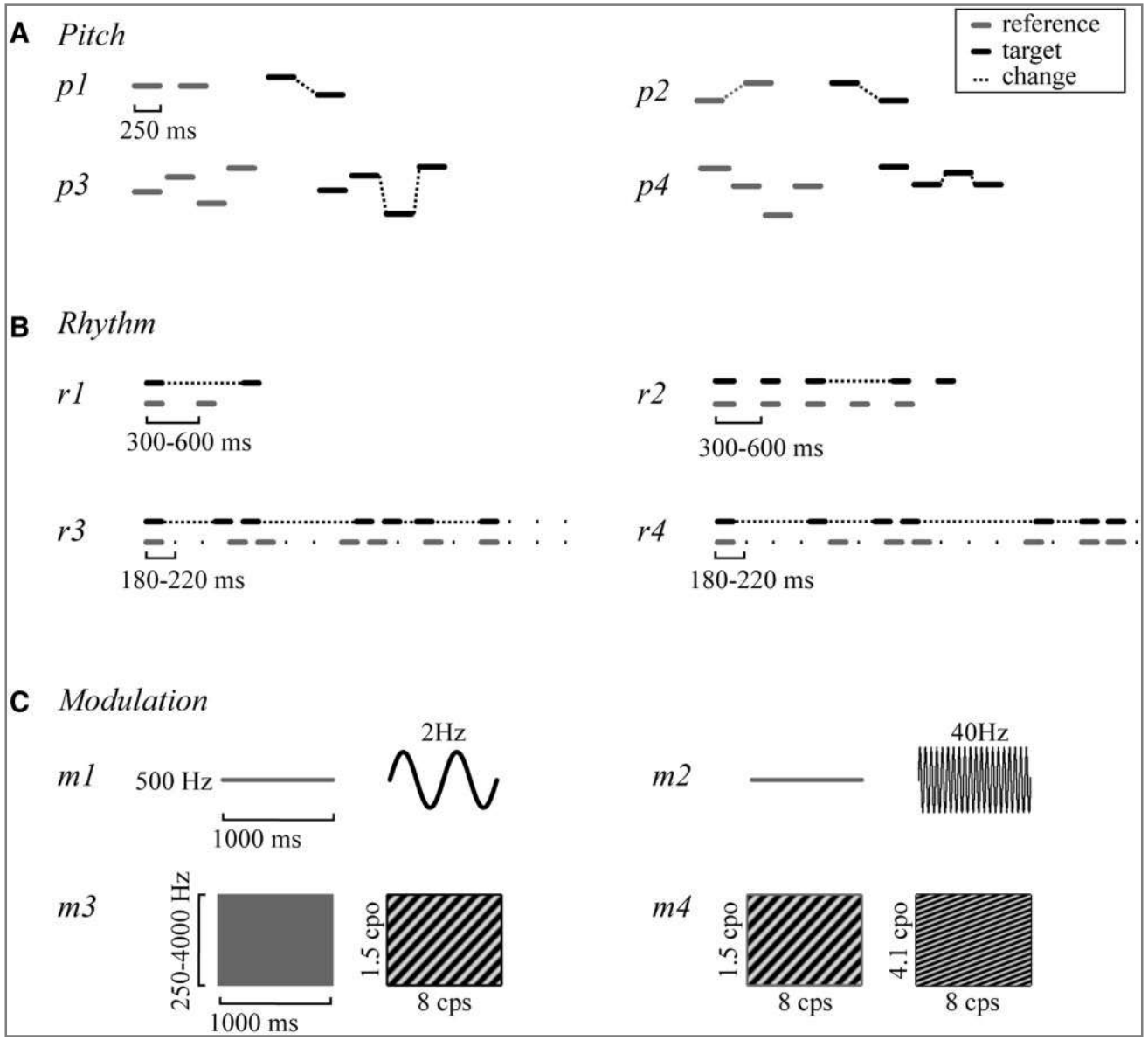


Phonemic Discrimination

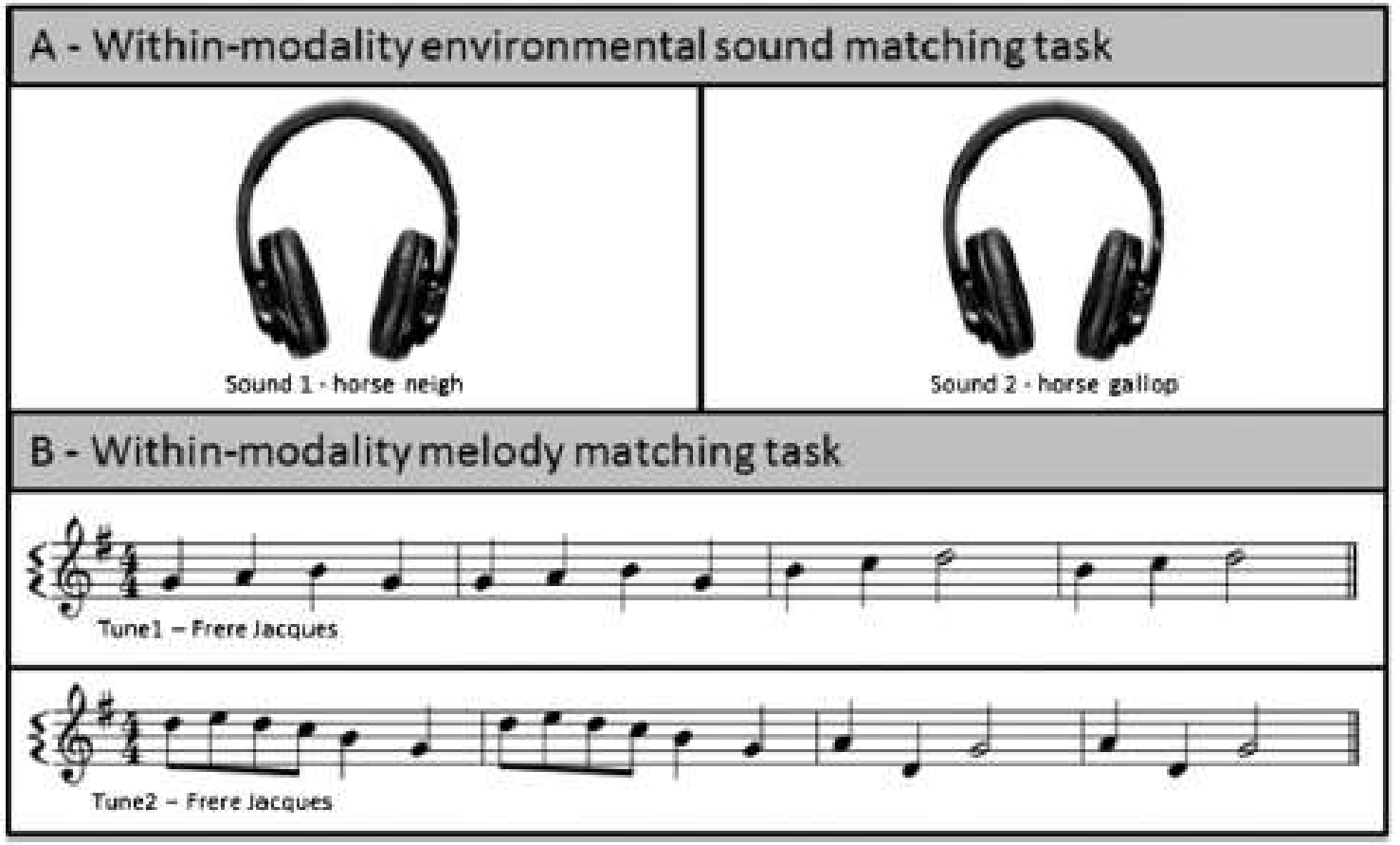




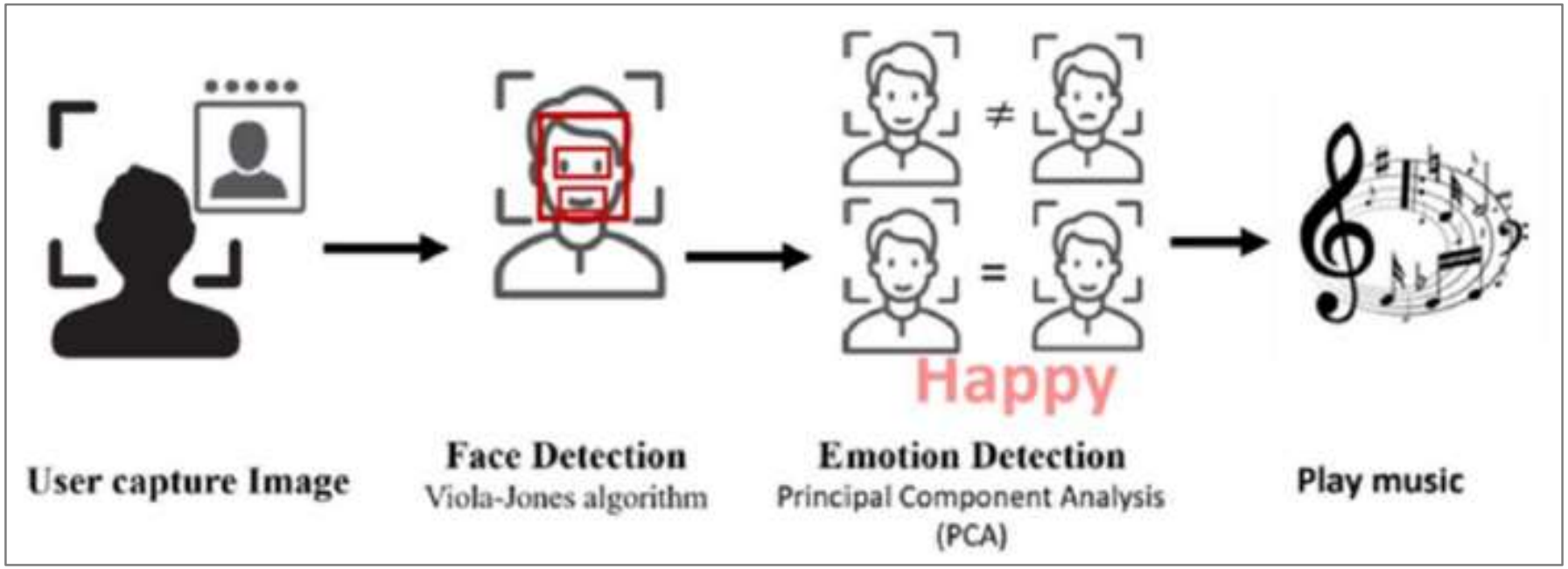
Core Auditory Processing



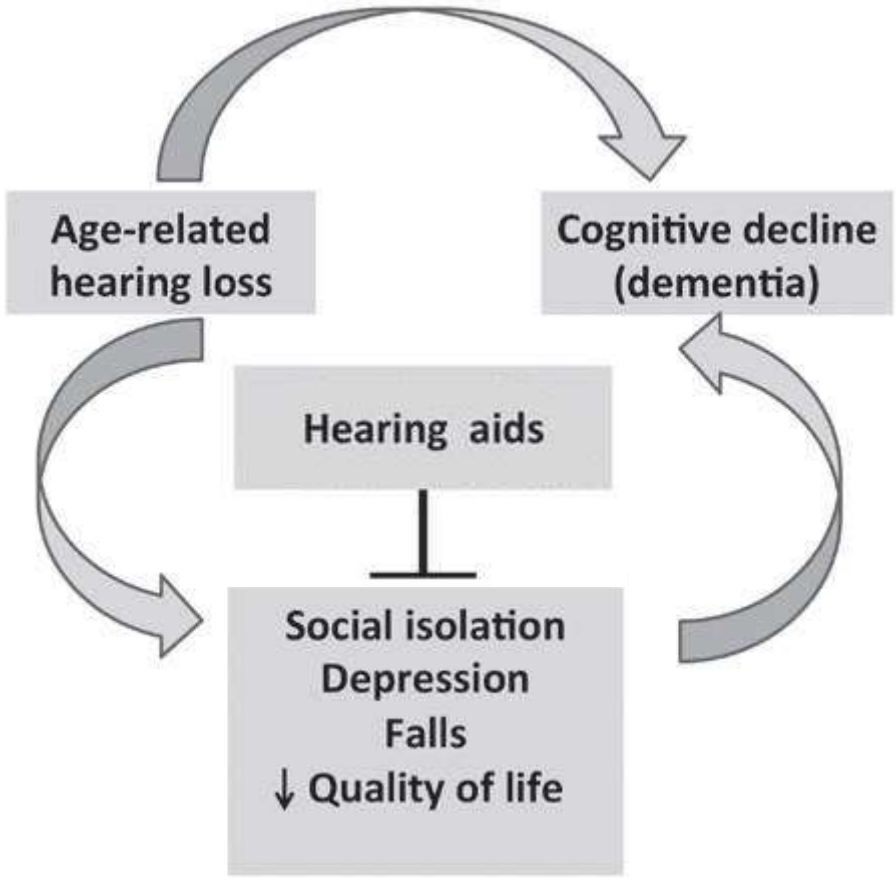
Environmental Sounds and Melodies Identification



Music Emotion Recognition



Impact of hearing aids on elderly deaf patients



Comparative Study > Lancet Public Health. 2023 May;8(5) [illegible]
doi: 10.1016/S2468-2667(23)00048-8. Epub 2023 Apr 14.

Association between hearing aid use and all-cause and cause-specific dementia: an analysis of the UK Biobank cohort

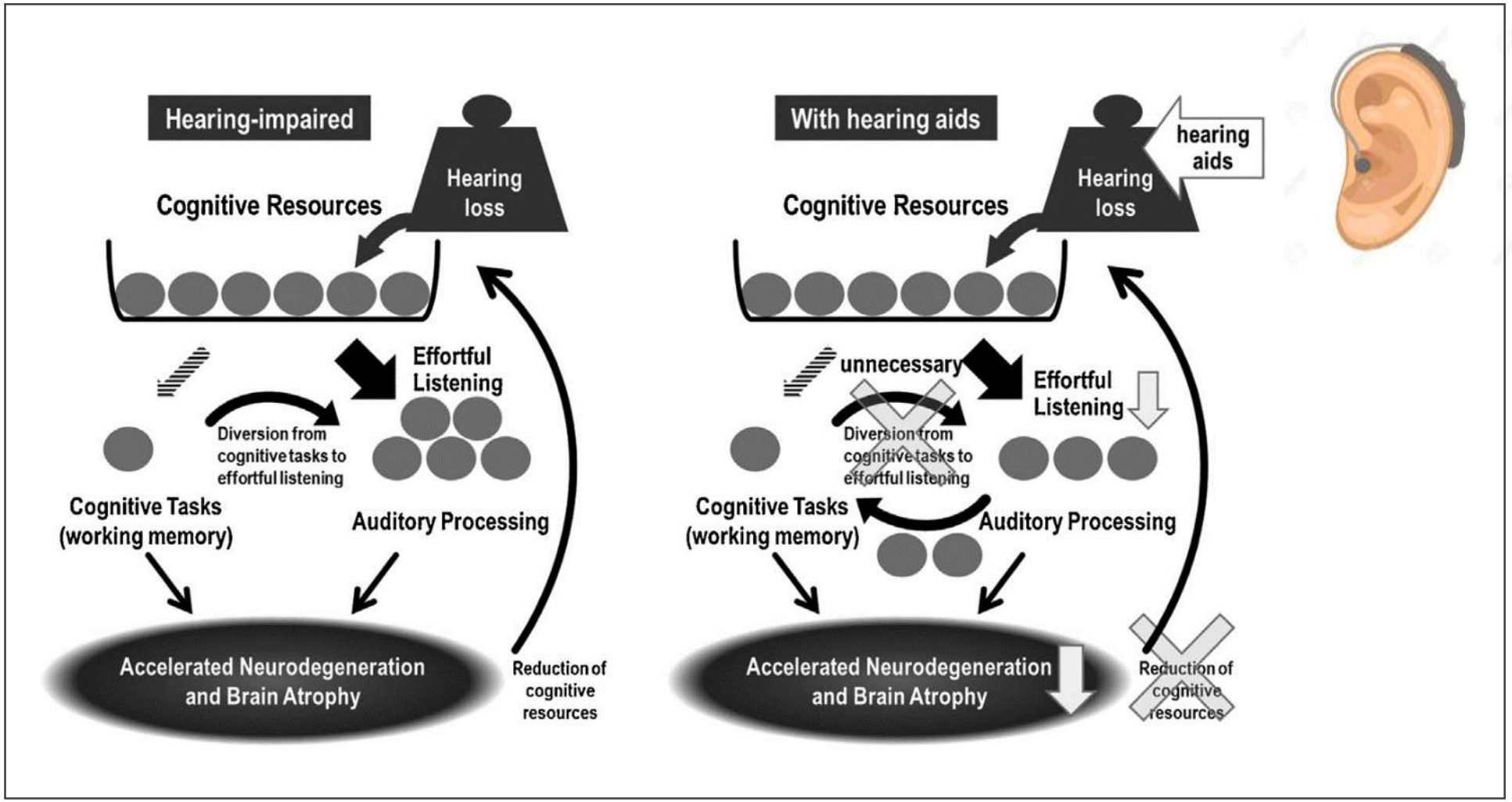
Fan Jiang [1], Shiva Raj Mishra [2], Nipun Shrestha [3], Akihiko Ozaki [4], Salim S Virani [5], Tess Bright [6], Hannah Kuper [7], Chengchao Zhu [illegible], Dongshan Zhu [8]

RETRACTED

Cognitive benefits of hearing aids in older adult with hearing loss

1

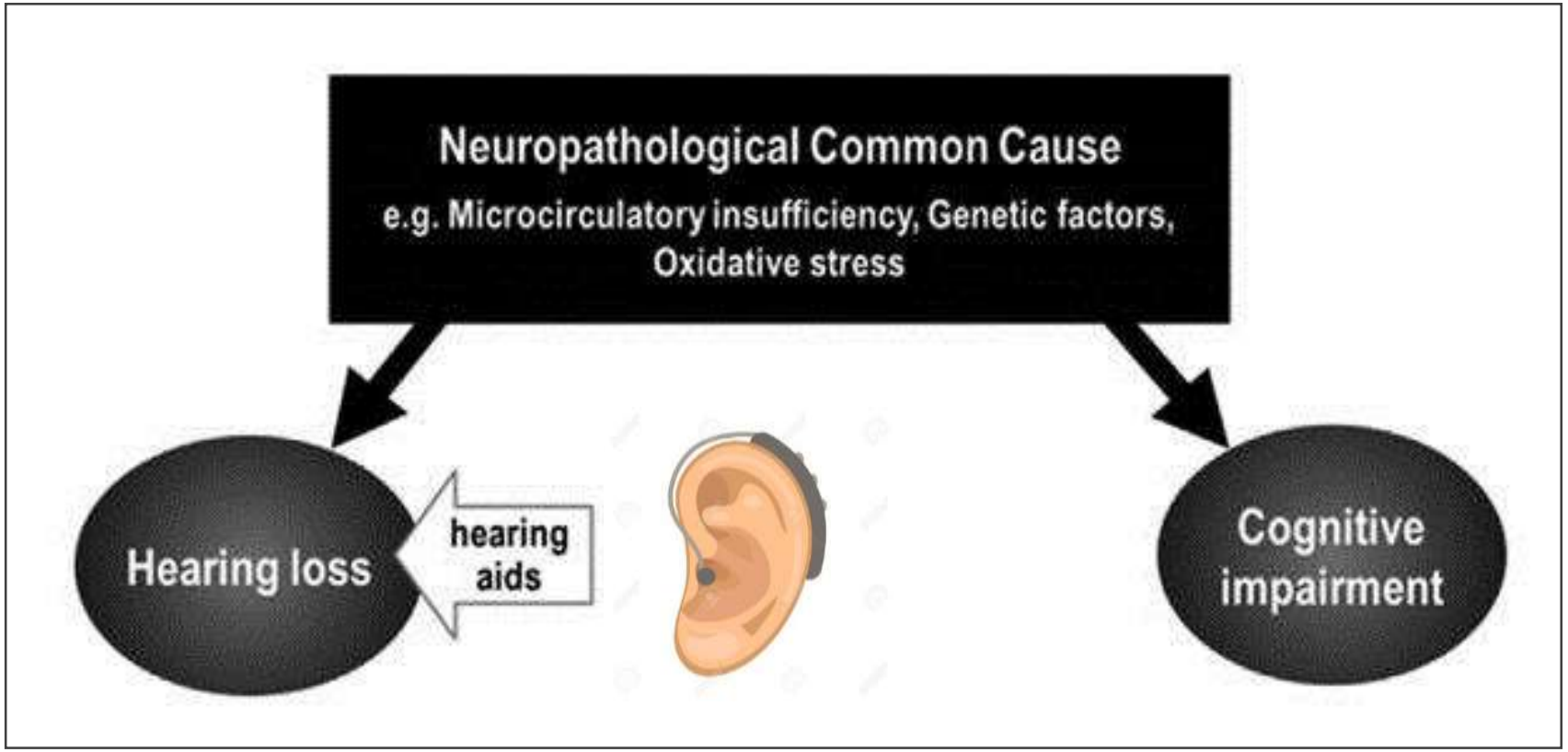
COGNITIVE LOAD HYPOTHESIS



Cognitive benefits of hearing aids in older adult with hearing loss

2

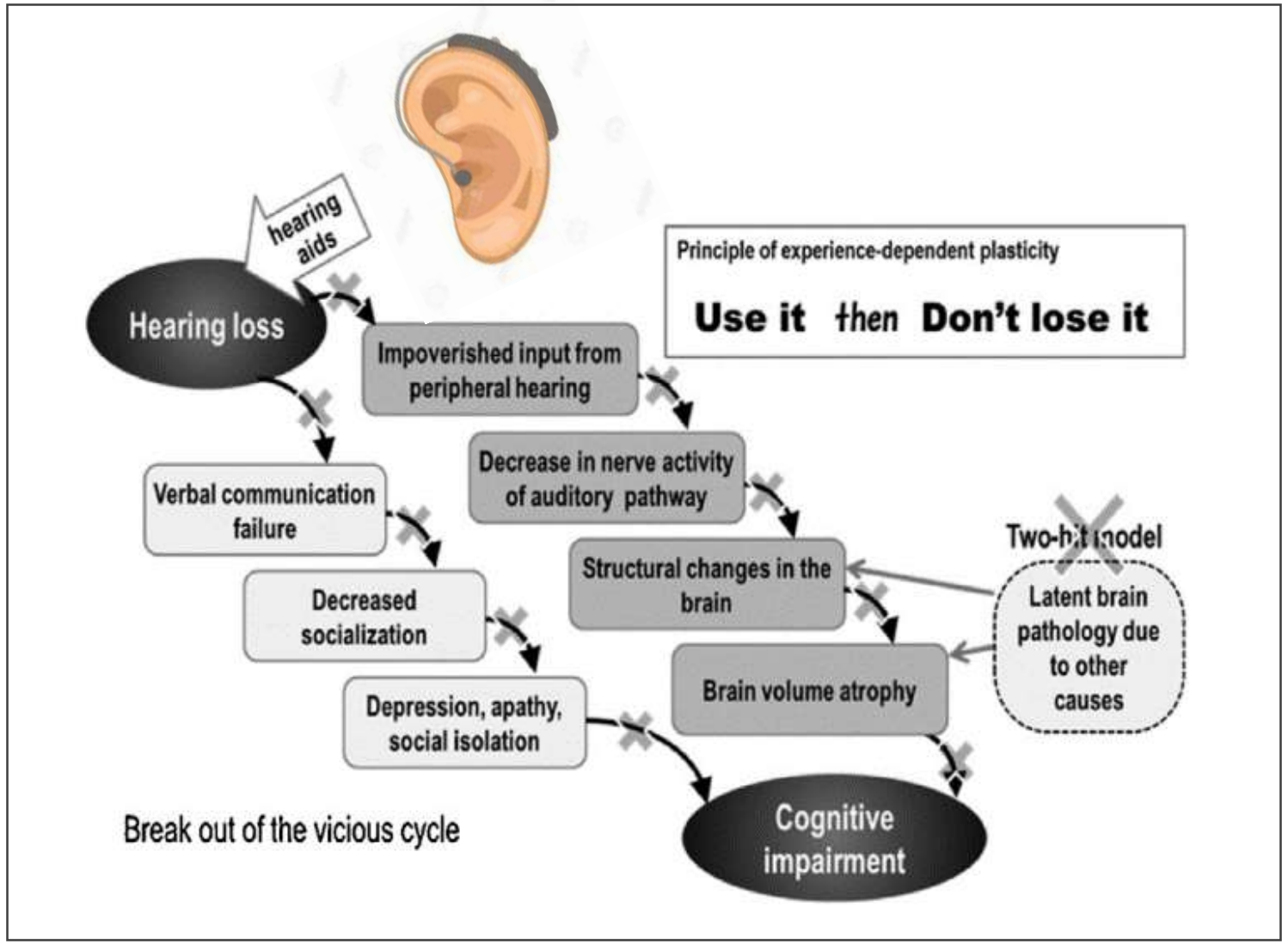
COMMON CAUSE HYPOTHESIS



Cognitive benefits of hearing aids in older adult with hearing loss

3

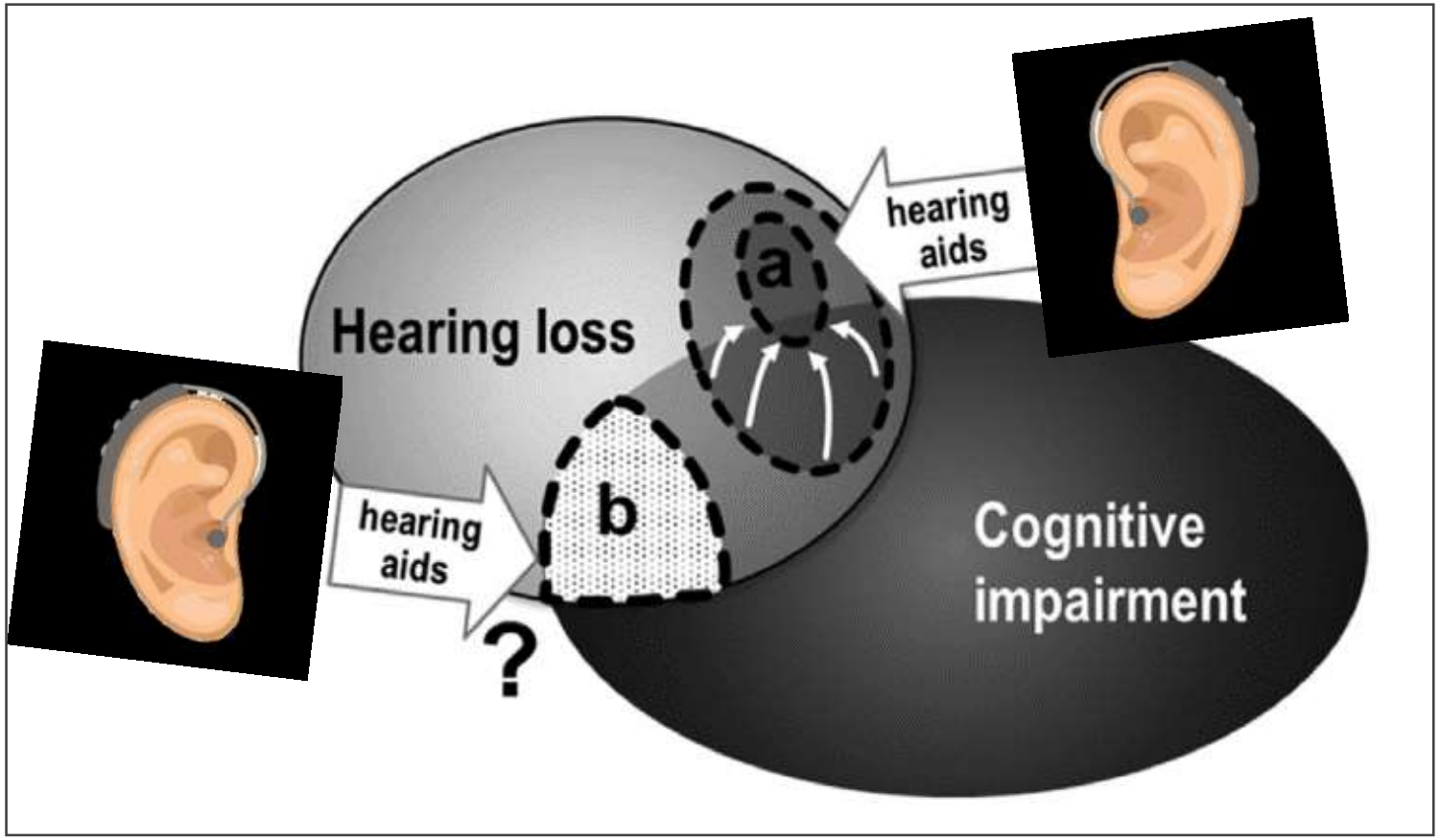
CASCADE HYPOTHESIS



Cognitive benefits of hearing aids in older adult with hearing loss

4

OVERDIAGNOSIS OR HARBINGER HYPOTHESIS

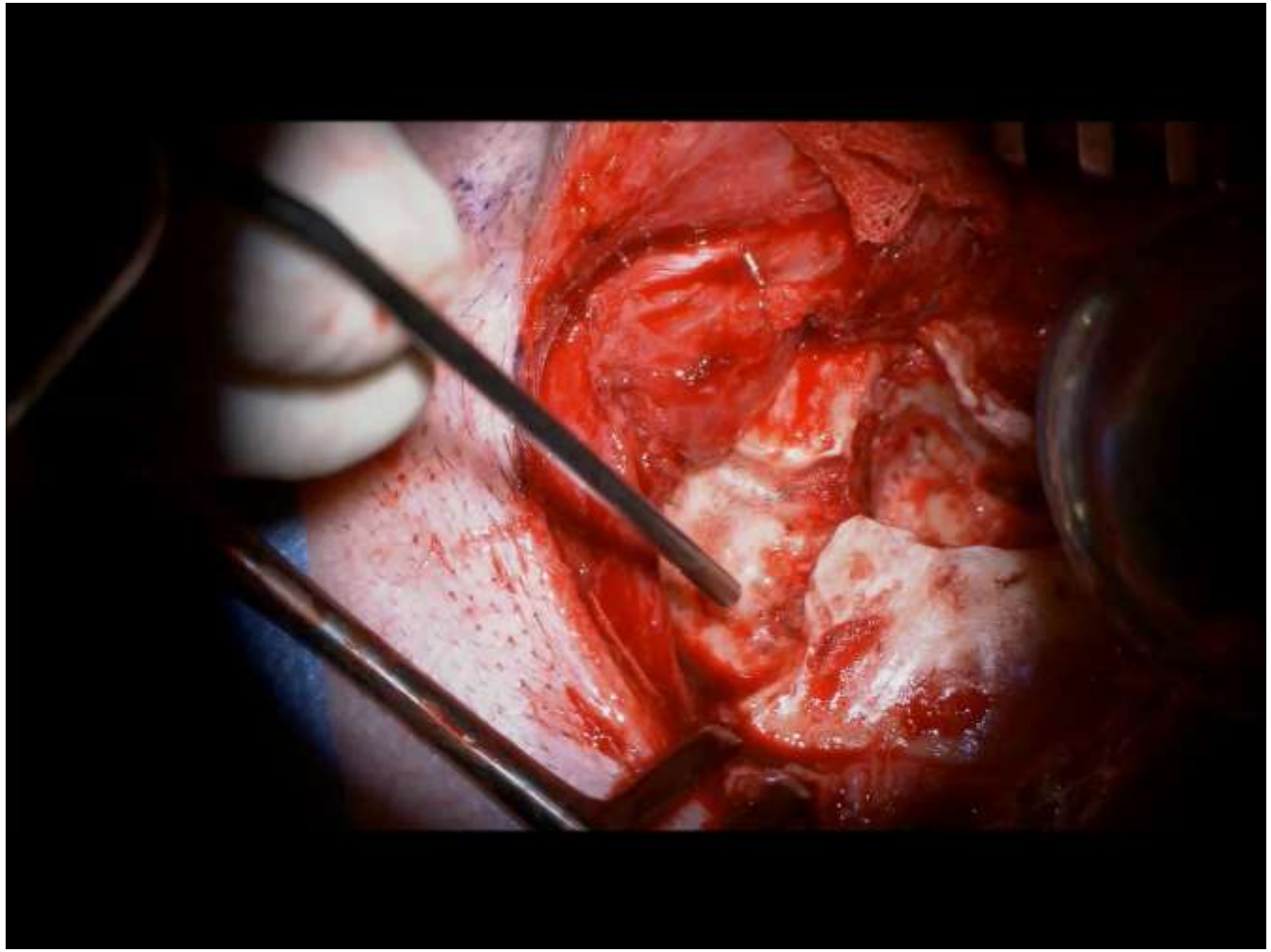


What does "hearing aids" mean?

It depends on
the severity of hearing loss!

For patients with
moderate-to-severe HRHL
and preserved speech discrimination

For patients with
severe-to-profound HRHL
and impaired speech discrimination



Conclusions

Listening - perception and understanding of sounds - is a highly active cognitive process, that collectively constitute “auditory cognition”, and critically depend on “auditory brain”.

Hearing impairment in later life is a leading association of cognitive decline, presenting significant potential opportunities for dementia diagnosis, treatment and prevention.

Patterns of brain degeneration anticipate the differential involvement of particular auditory functions, so that there exist different “auditory phenotypes” of cognitive disorders.

Hearing loss amplifies the effects of cognitive impairment and may confound or delay diagnosis of dementia.

Conversely, diagnosis of hearing loss and compliance with hearing aids are hindered by cognitive impairment.

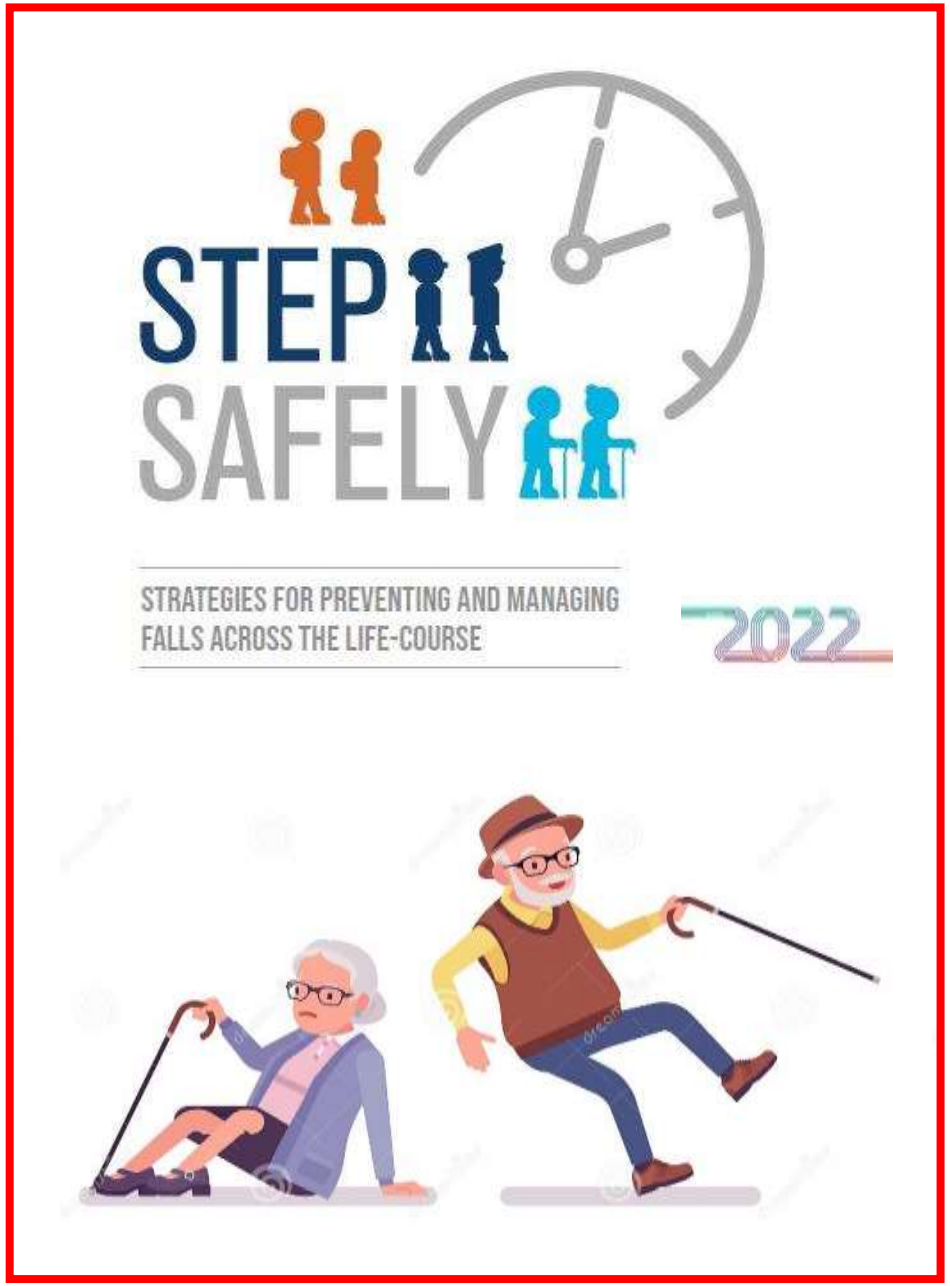
Inter-professional teamwork

should be hopefully organized so that

hearing information can guide cognitive healthcare and

information about cognitive status could guide hearing healthcare.

World Health Organization



Predictors of falls

Gait Speed

Timed-Up and Go

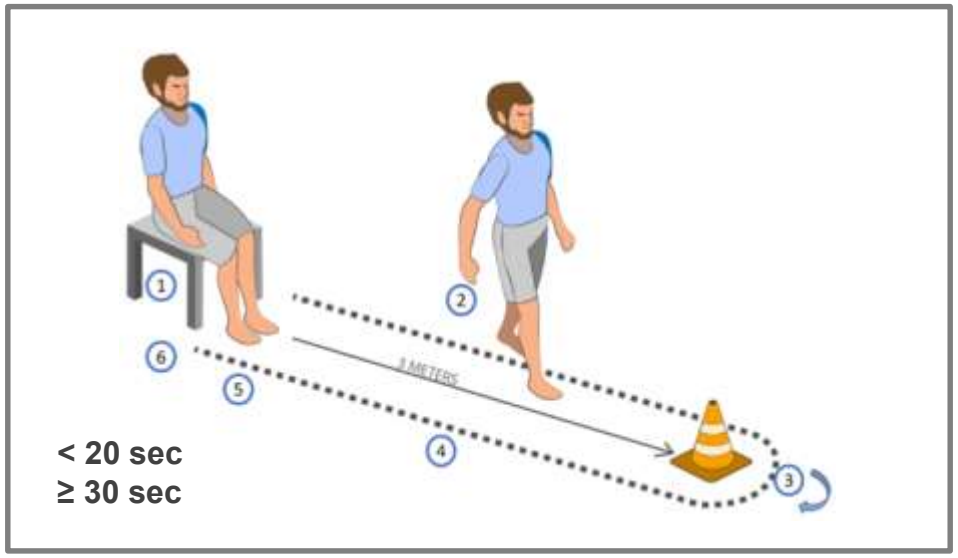
Stop Walking when Talking

Gait Speed

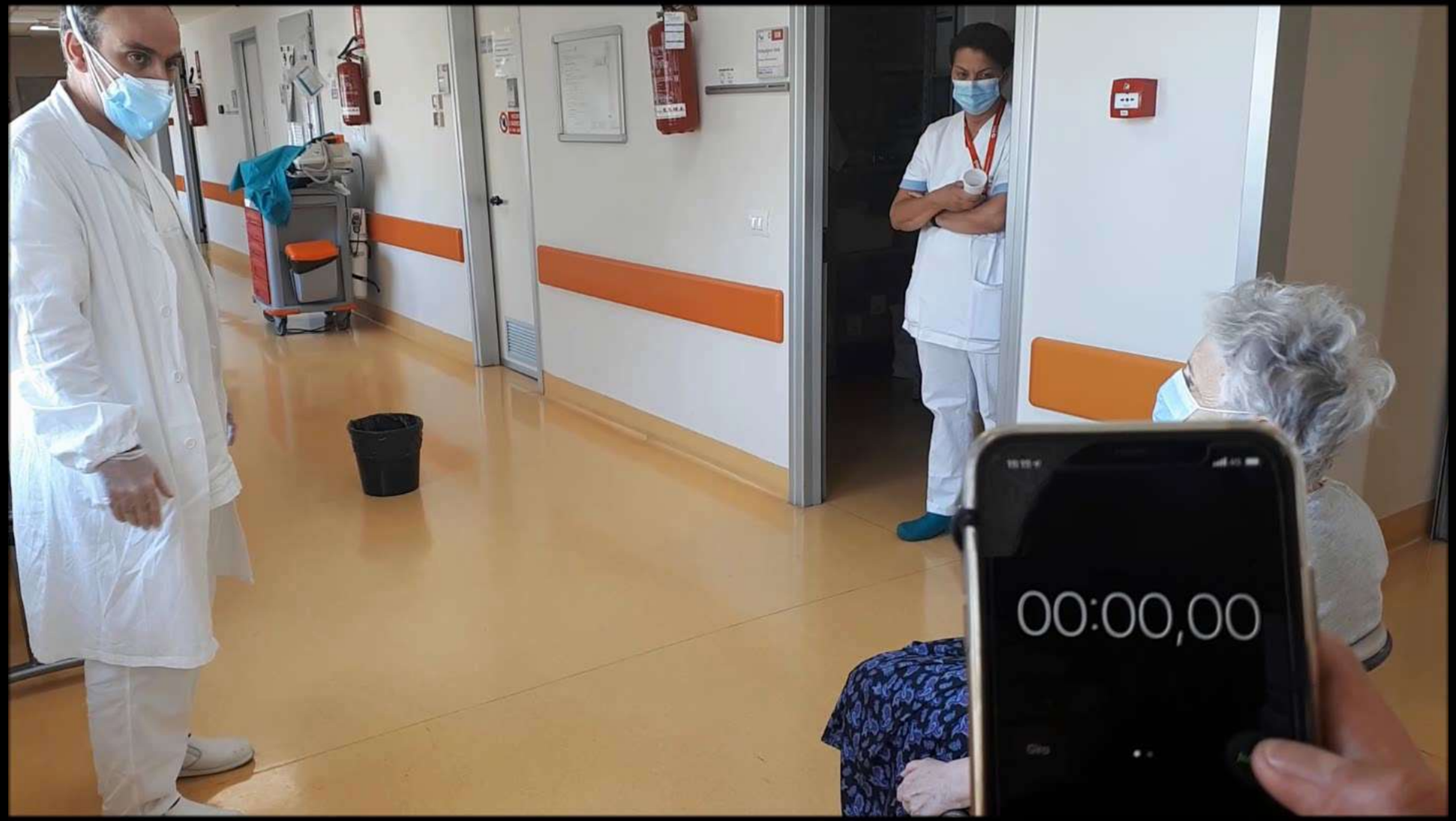
< 0.67m/sec
≥ 1.1m/sec

Gait Speed

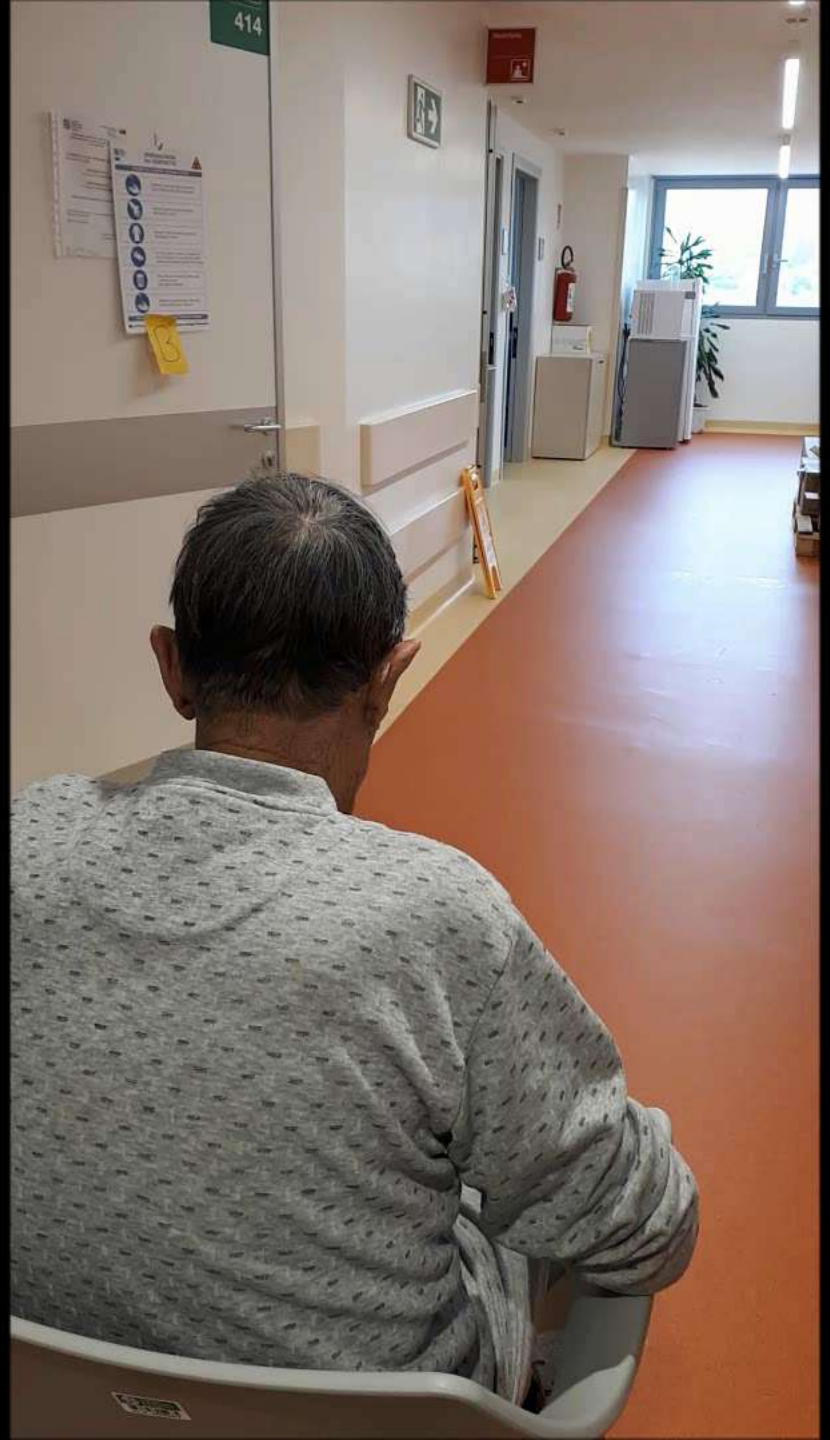
Timed-Up and Go



Timed Up and Go -1



Timed-Up and Go -2

Stop Walking when Talking

Stop Walking when Talking