

Cognitive resources for successful speech comprehension in old age

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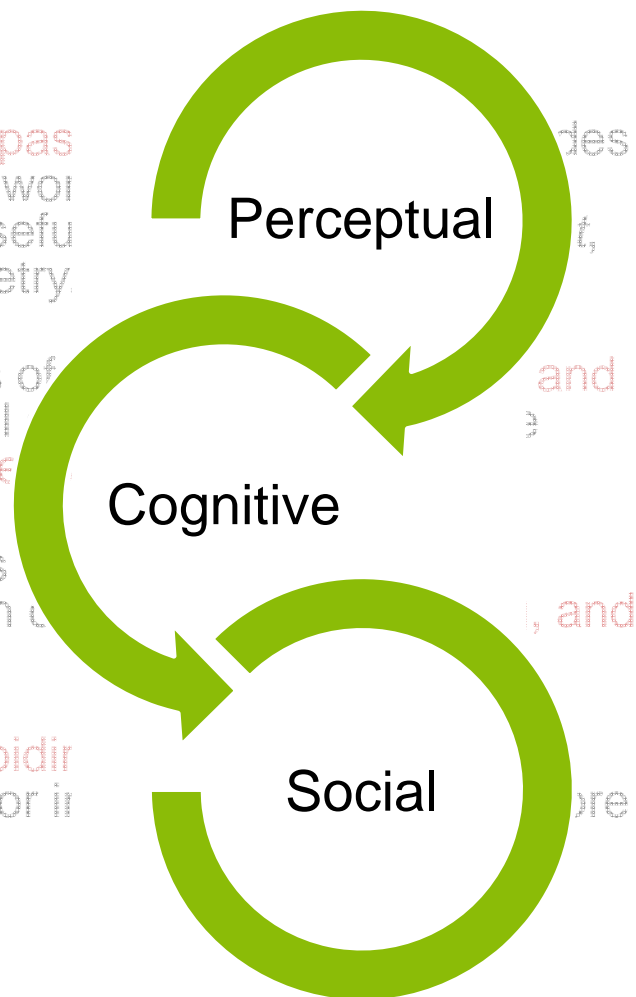
Advances in audiology, Las Vegas, Dec 2-5, 2012

PHONAK
life is on

Consensus statement (Kiessling et al., 2003)

International Classification of Functioning, Disability and Health, WHO 2001

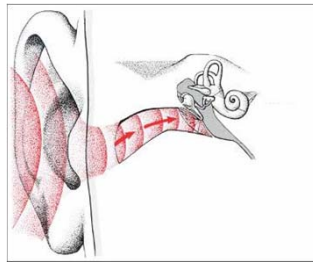
- **Hearing** is essentially a **passive** process that provides access to the auditory world; it is primarily useful for **communication**, typically using audiometry.
- **Listening** is the process of **selective attention** for purposeful communication, involving expenditure of **mental energy**.
- **Comprehending** follows **bidirectional** reception of sound and involves **interpretation** of the message, **intent**.
- **Communicating** is the **bidirectional** exchange of information, meaning, or ideas between people.



Basic
sensory
information

Sensory-
cognitive
processing

A complex process:
from vibrations of air [sound]
to linguistic representation in the brain [speech]



Continuously varying sounds made up
of spectrotemporal patterns of
differential complexity ...



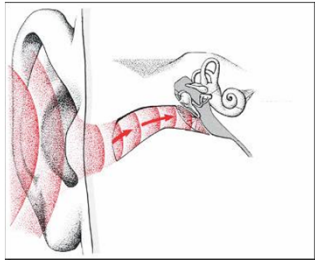
Have to be recognized as speech and
transferred to higher language
processing ...



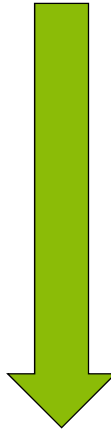
So that we are able to generate a
linguistic representation in the brain
and understand a spoken utterance.

...all of this with speech running at a rate of 2 to 3 words per second !!!

Bidirectional processing



The better the quality of the signal....



... the better the chances for successful speech comprehension.

BUT: Adult-onset hearing loss is extremely prevalent, with about **25% of people aged 45 and over experiencing hearing loss** (Lopez et al. 2006).

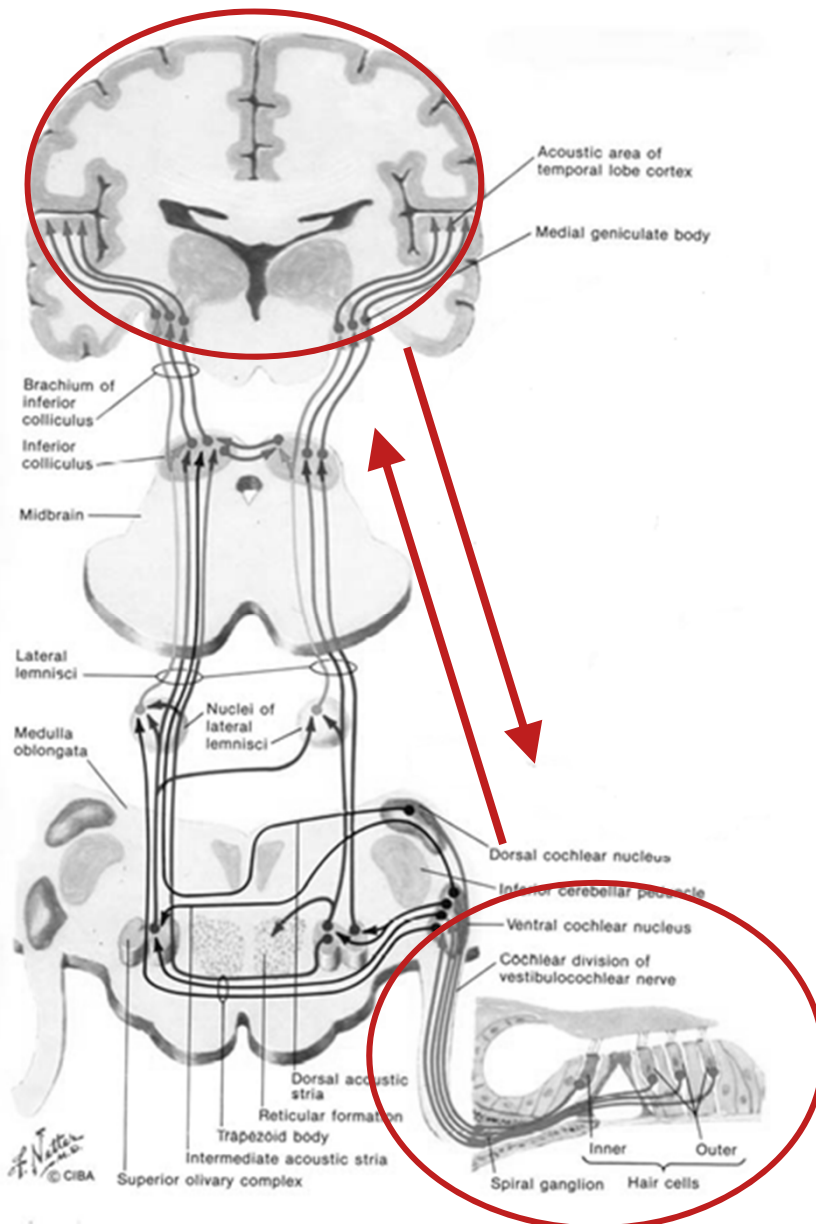
...the better the chances to understand.



The better the cognitive resources...

BUT: Cognitive resources are limited. A limited amount of processing «capacity» is allocated and shared between a number of tasks according to priorities. (Welford, 1952; Broadbent, 1958; Moray, 1967; Kahneman 1971; Allport, 1980; Norman & Shallice, 1986).

Continuous bottom-up ↔ top-down interaction

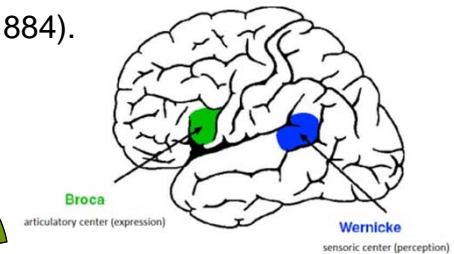
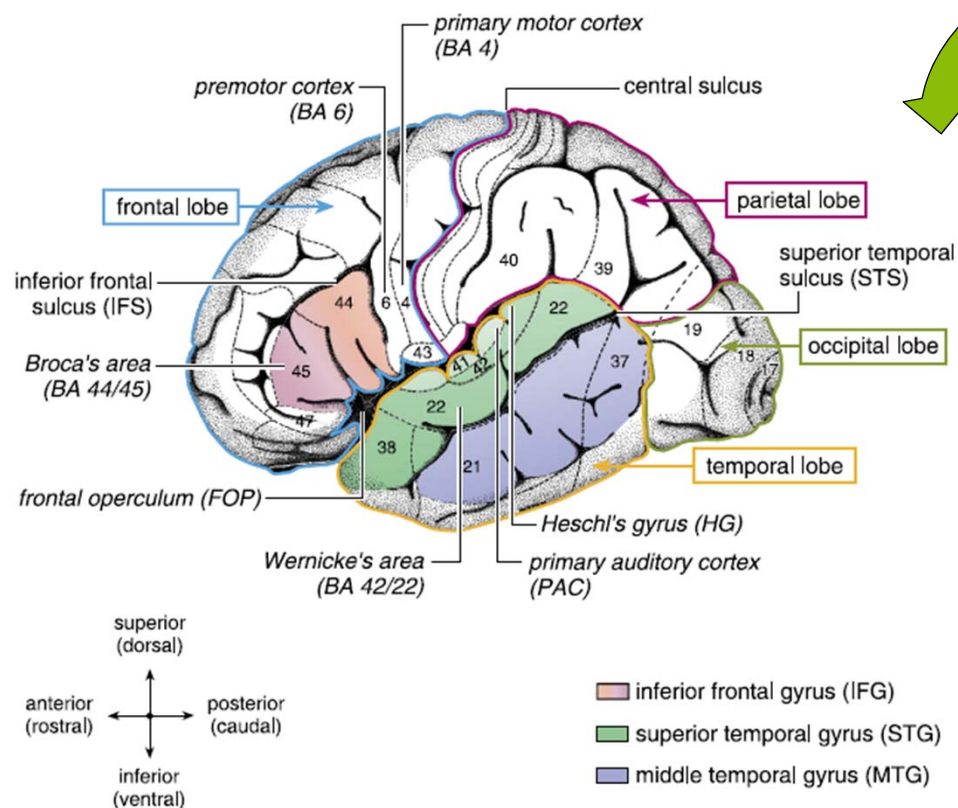


- **Bottom-up processing:** from the acoustic signal to e.g. phonemes, lexical-semantics, words, phrases, and sentences.
- **Top-down processing:** Perception of speech is facilitated by linguistic context and expectations of listeners
- Speech represents a **continuous bottom-up-top-down interaction**. This is the reason why speech can be processed as rapidly as it is.
- Words can be recognized in fluent speech long before their full acoustic duration has been completed or in hindsight (Marslen-Wilson, 1987)

Cortical organization of speech processing

Traditional model → Extended network model

Traditional models of language organization in the brain focused on the existence of two localized speech centers in the **left** human hemisphere, namely **Broca's area and Wernicke's area** (Wernicke-Lichtheim Model 1884).



Anatomical and cytoarchitectonic details of the left hemisphere. **Major language relevant gyri (IFG, STG, MTG)** are color coded. **Broca's area** consists of the pars opercularis (BA 44) and the pars triangularis (BA 45). Located anterior to Broca's area is the pars orbitalis (BA 47). The frontal operculum (FOP) is located ventrally and more medially to BA 44, 45. The premotor cortex is located in BA 6. **Wernicke's area** is defined as BA 42 and 22. The primary auditory cortex (PAC) and Heschl's gyrus (HG) are located in a lateral to medial orientation.

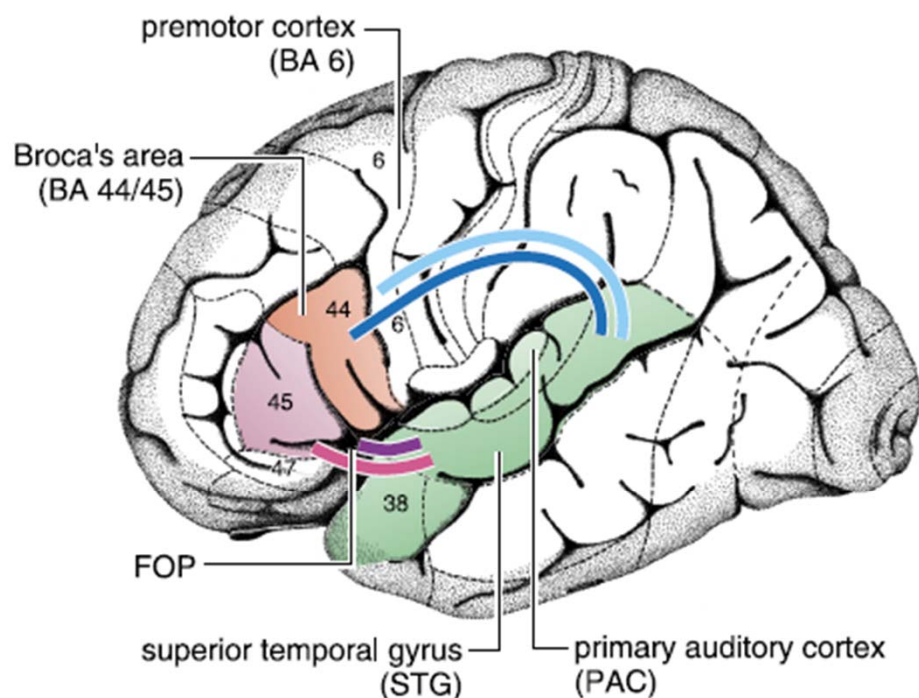
Friederici (2011)

Dual-stream model of the functional anatomy of language

Hickok & Poeppel, 2000, 2004, 2007; Saur et al. 2008, 2010; Friederici, 2011

Long-range structural connections were identified connecting the language-relevant regions of tempopral and frontal cortex (DTI, diffusion tensor imaging tractography)

Glasser & Rilling (2008)



Dorsal stream: sound to action

maps sensory or phonological representations onto articulatory motor representations

Ventral stream: sound to meaning

maps sensory or phonological representations onto lexical conceptual representations

Dorsal Pathway I

Light blue box: pSTG to premotor cortex via AF/SLF

Dorsal Pathway II

Dark blue box: pSTG to BA 44 via AF/SLF

Ventral Pathway I

Pink box: STG to BA 45 via EFCS

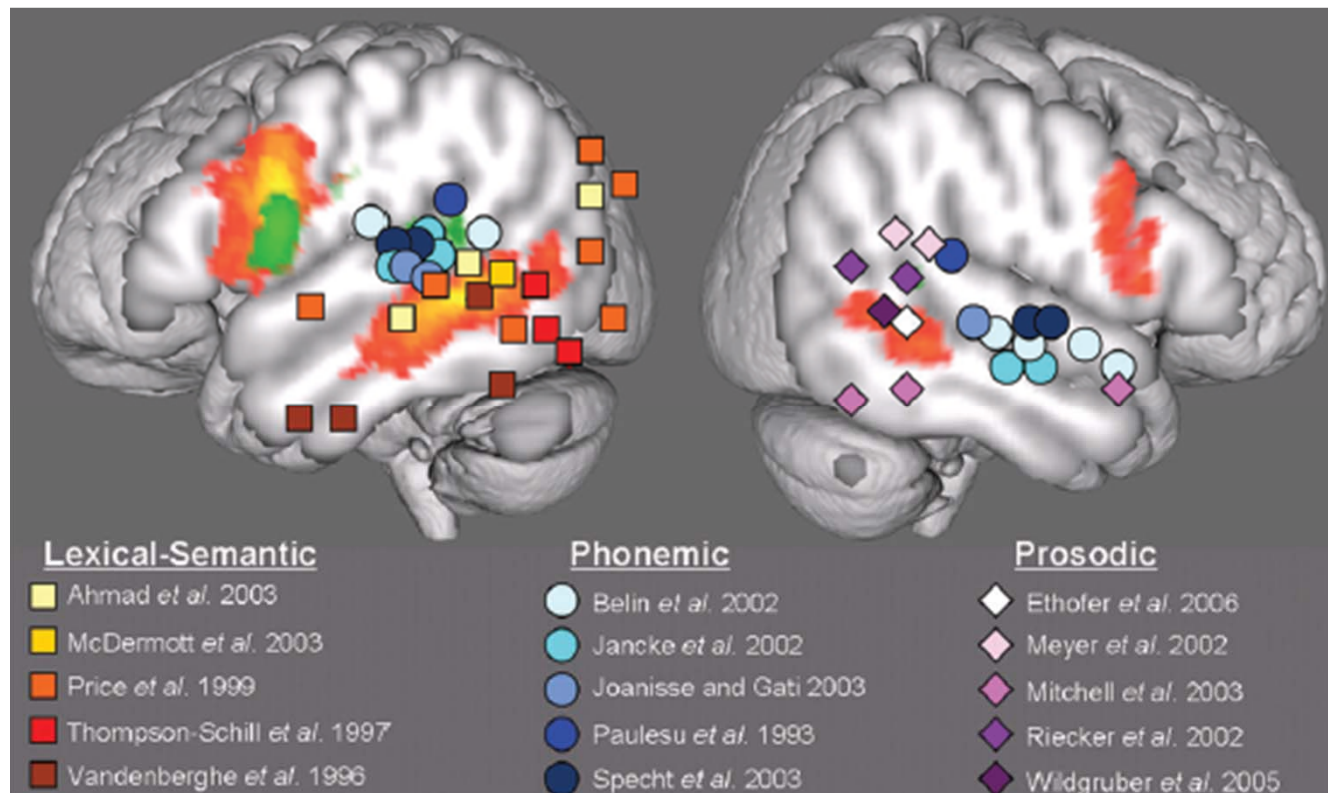
Ventral Pathway II

Purple box: antSTG to FOP via UF

STG - superior temporal gyrus
 AF - arcuate fascicle
 SLF - superior longitudinal fascicle
 EFCS - extreme fiber capsule system
 FOP - frontal operculum
 UF - uncinate fascicle

Cognitive neuropsychology

- Neuropsychology studies **structure and function** of the brain as they relate to psychological processes and behaviors such as speech comprehension
- Speech processing: where -> what -> how ?

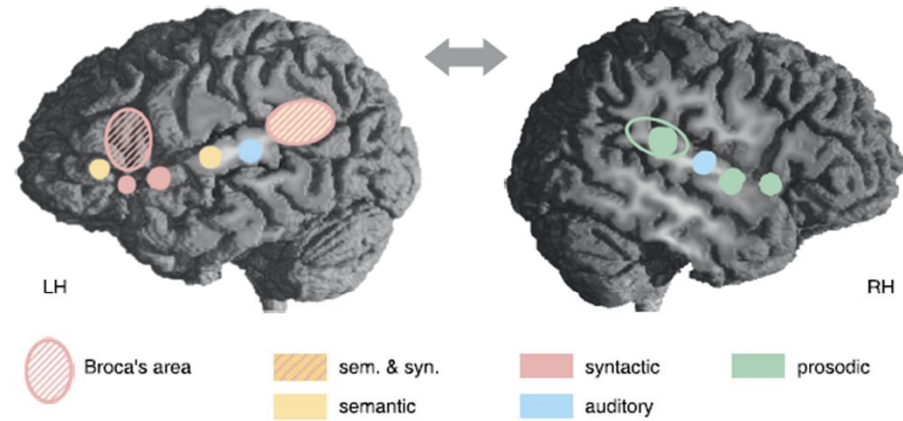


Glasser & Rilling (2008):
Functional activations overlaid on average tractography results, in standard space.

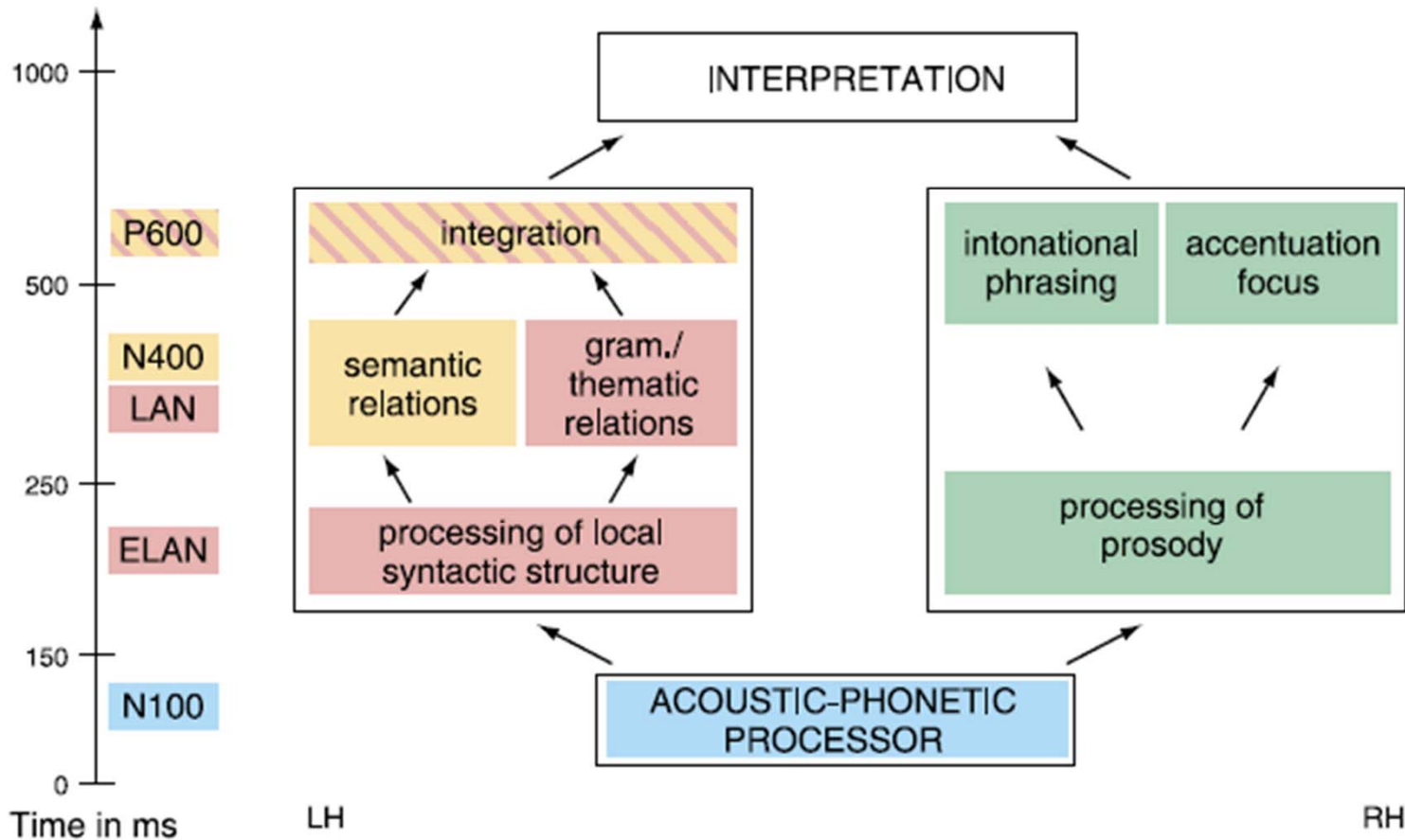
Each study in each hemisphere is represented by a different color. Lexical-semantic tasks are represented as squares, phonemic tasks are represented as circles, and prosodic tasks are represented as diamonds.

Friederici, 2011: Model of auditory sentence comprehension

B The brain basis of auditory language comprehension

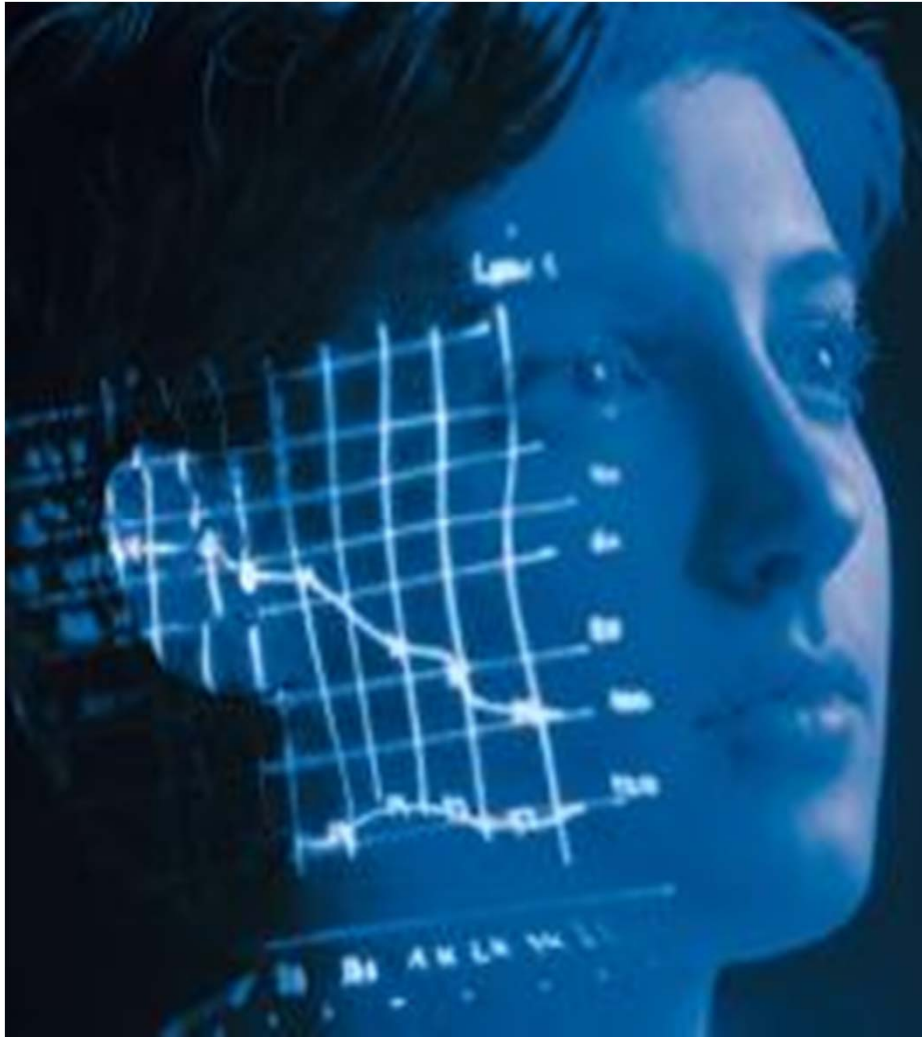


A Auditory language comprehension model

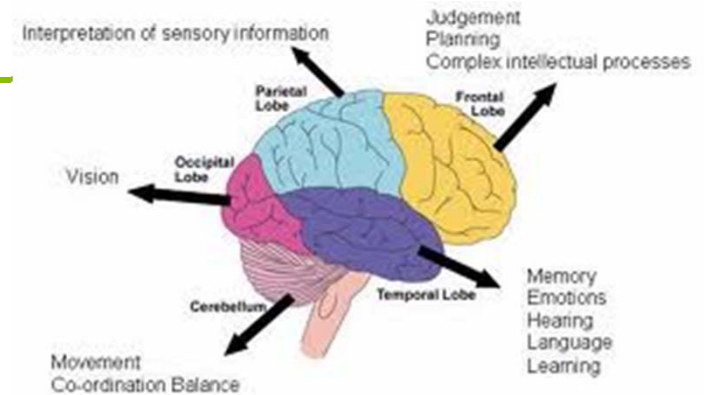


What's more to hearing?

From hearing to listening, comprehending, and communicating



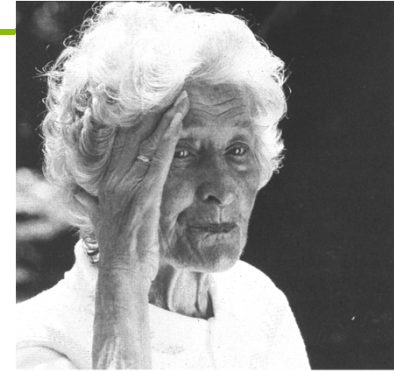
Cognitive abilities required for listening and comprehending



- ***Listening*** is the process of hearing with intention and attention for purposeful activities demanding the expenditure of mental effort.
Asking for abilities of:
 - intention, purpose (incl. motivation, planning, expectations)
 - selective, focused attention
 - expenditure of mental effort
 - incl. allocation of attention, executive control
 - incl. short term and working memory for holding and manipulating information
- ***Comprehending*** follows and is defined as the unidirectional reception of information, meaning, and intent.
Asking for abilities of:
 - interpretation of meaning
 - based on semantic knowledge, vocabulary and
 - knowledge of social rules, social emotional experience

Typical difficulties in old age

- **General slowing in speed information processing**
- **Executive functions:** cogn. processes that regulate, control, and manage other cognitive processes
 - mental flexibility
 - planning, initiation
 - monitoring of actions
- **Difficulties in processing parallel, interfering information**
 - effort to concentrate
 - divided attention
 - inhibition, task switching
- **Reduced capacity of certain types of memory functions,**
 - working memory capacity
 - episodic memory (esp. delayed free recall, tempo of learning)
 - Semantic memory (word fluency, word finding)



Cognitive age changes

Cross-sectional large scale results

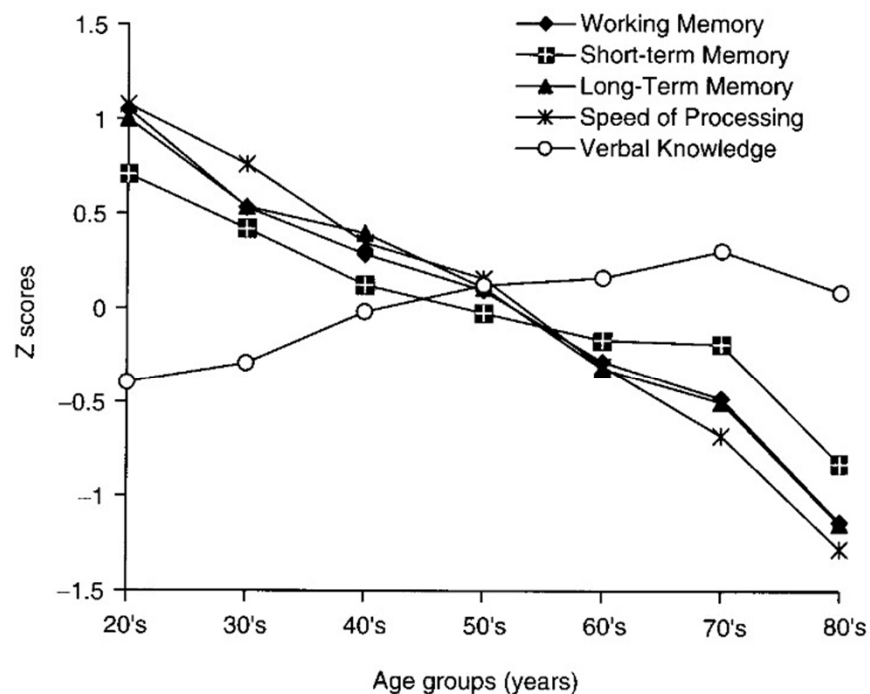


Figure 10.2 A cross-sectional data collection using measures of speed of processing, short-term memory, working memory, and long-term memory. Adapted from Park et al. (2002), with permission.

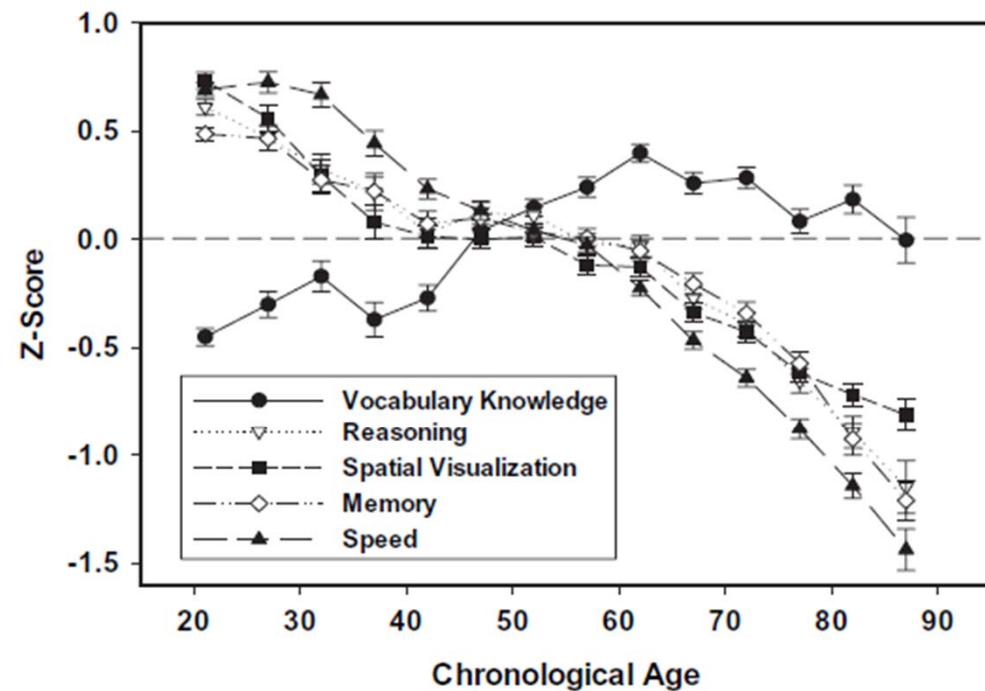
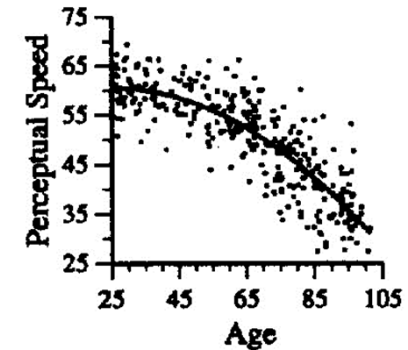
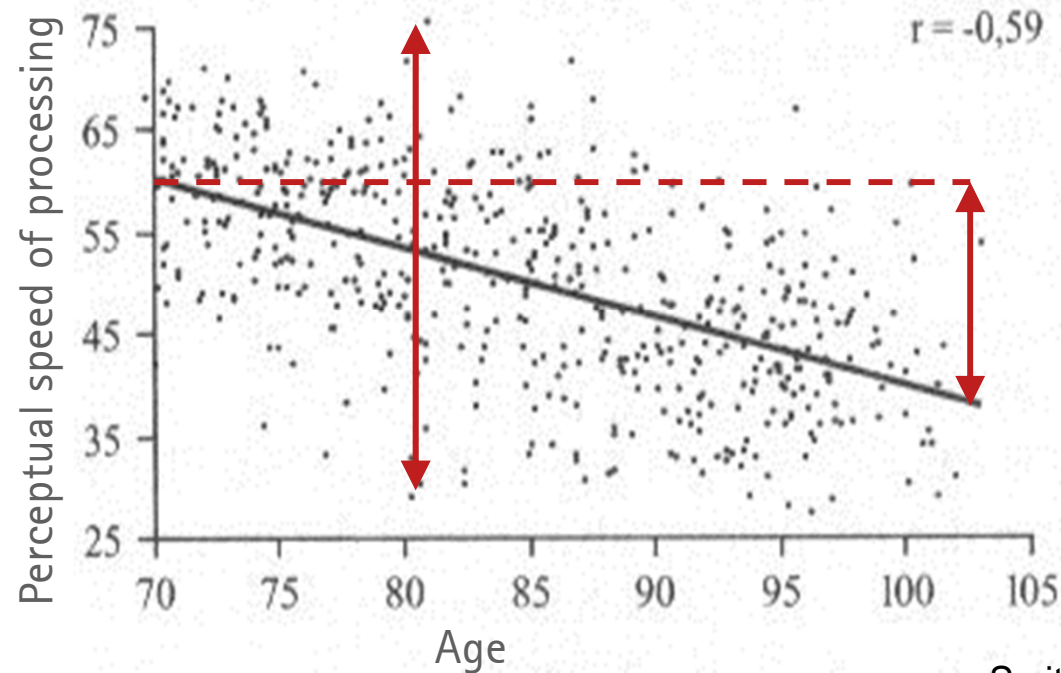


Fig. 1. Means and standard errors for composite scores in five abilities as a function of age based on data from studies by Salthouse and colleagues (e.g., Salthouse, 2009a). Sample sizes ranged from 2369 to 4149.

Speed of information processing



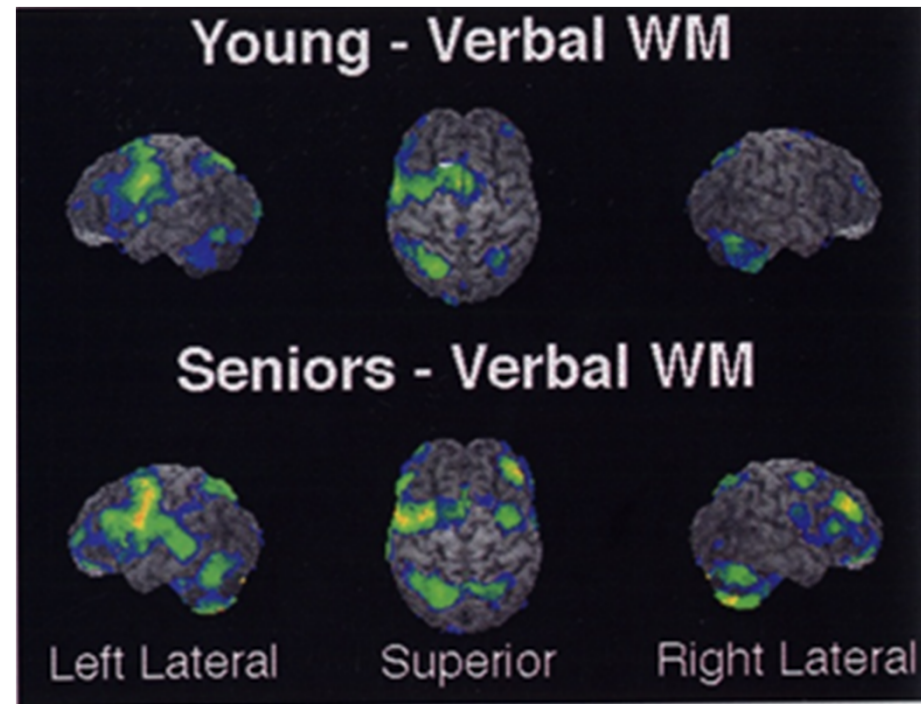
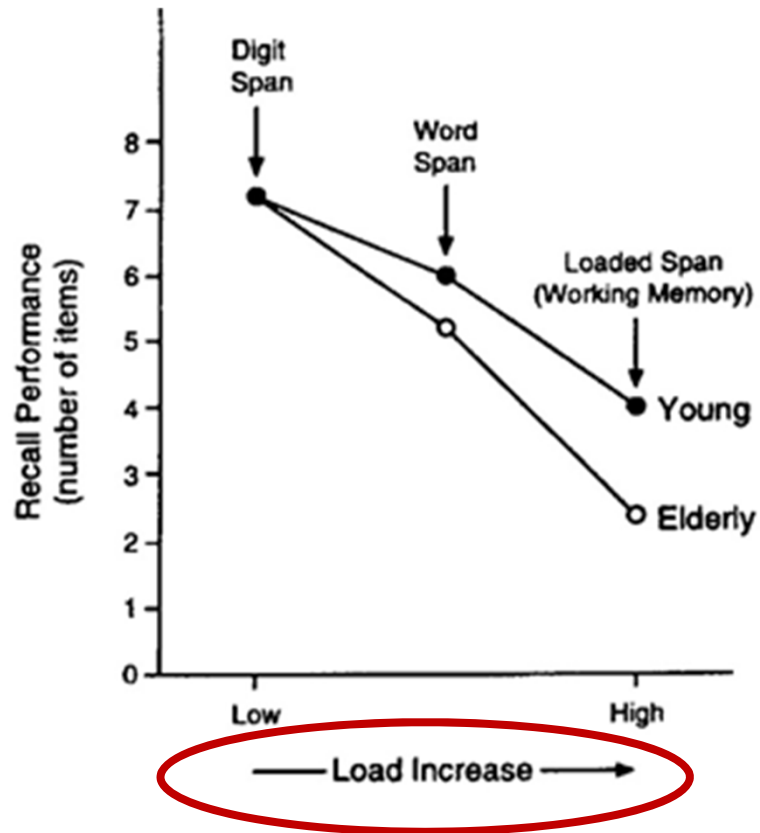
- There are big inter-individual differences between elderly people



Smith & Baltes, 1996

Often differences are bigger between two persons in the same age group than between persons of different age groups.

Working memory capacity



Wingfield et al. 1988: Younger and older adults were tested for their ability to recall **lists of spoken digits** (digit span), **lists of words** (word span), and **the final words of sets of sentences** presented for comprehension (loaded span).

Reuter-Lorenz et al.: Brain regions of activation in younger and older adults during a **verbal working memory** condition. WM-related activity is in **frontal cortex** (BA 44, 6, 46) and parietal cortex (BA 7, 10).

Compensation hypothesis:

Even when performing at the same level (here in a memory tasks) **brain activity is more widespread and less lateralized in PFC of older** compared to younger participants. (Cabeza et al., 2002, 2005; Reuter-Lorenz et al. 2000)

Same performance level can be realized in different ways.



Figure 2. PFC activity during source memory was right lateralized in Young and Old-Low participants but bilateral in Old-High participants.

Compromised auditory signal processing

Listening becomes effortful when perception is compromised by **signal degradation** (such as in competing background noise) or when **deficits in auditory processing** reduce the clarity of the input signal, or both (Pichora-Fuller, 2003).

The notion that the **extra effort** that a hearing impaired listener must expend **to achieve perceptual success comes at the cost of processing resources** that might otherwise be available for encoding the speech content in memory. (McCoy et al., 2005)

Hearing loss



Degraded speech signal to the brain

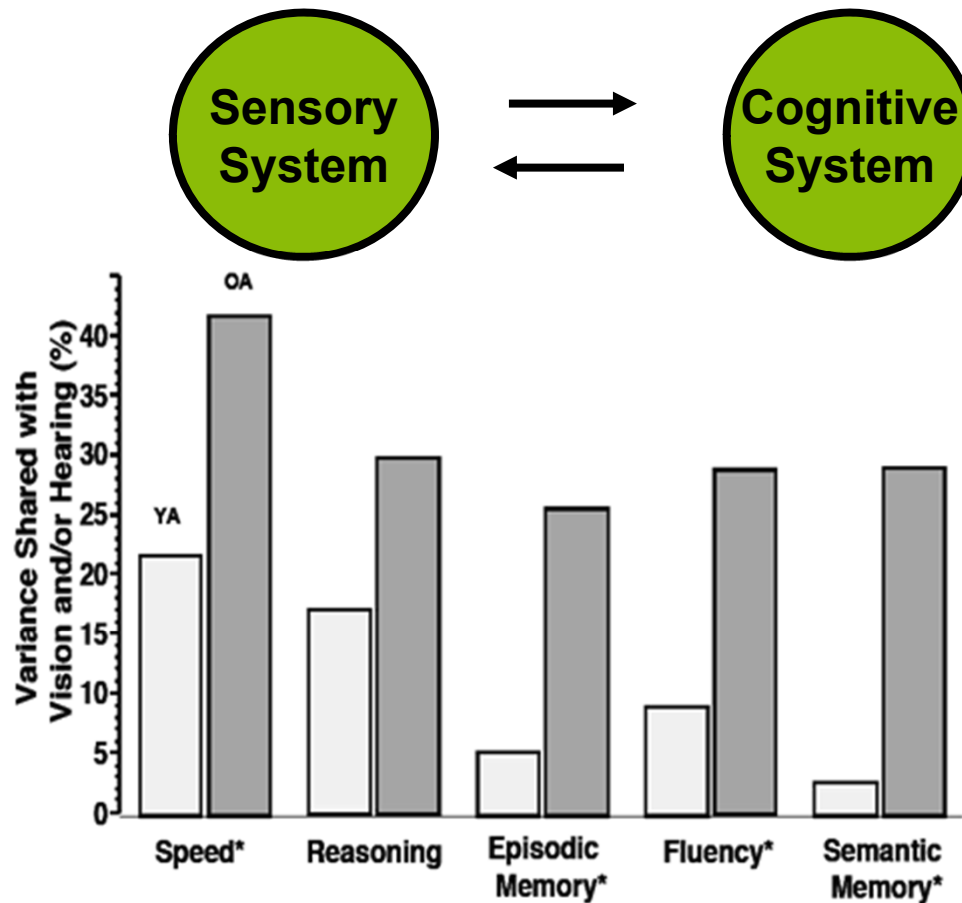


More cognitive resources applied to speech comprehension



Fewer cognitive resources available for other tasks

Shared variance between sensory and cognitive age changes (Baltes & Lindenberger, 1997)



YA = 25 - 69 (n = 171)

OA = 70 - 103 (n = 516)

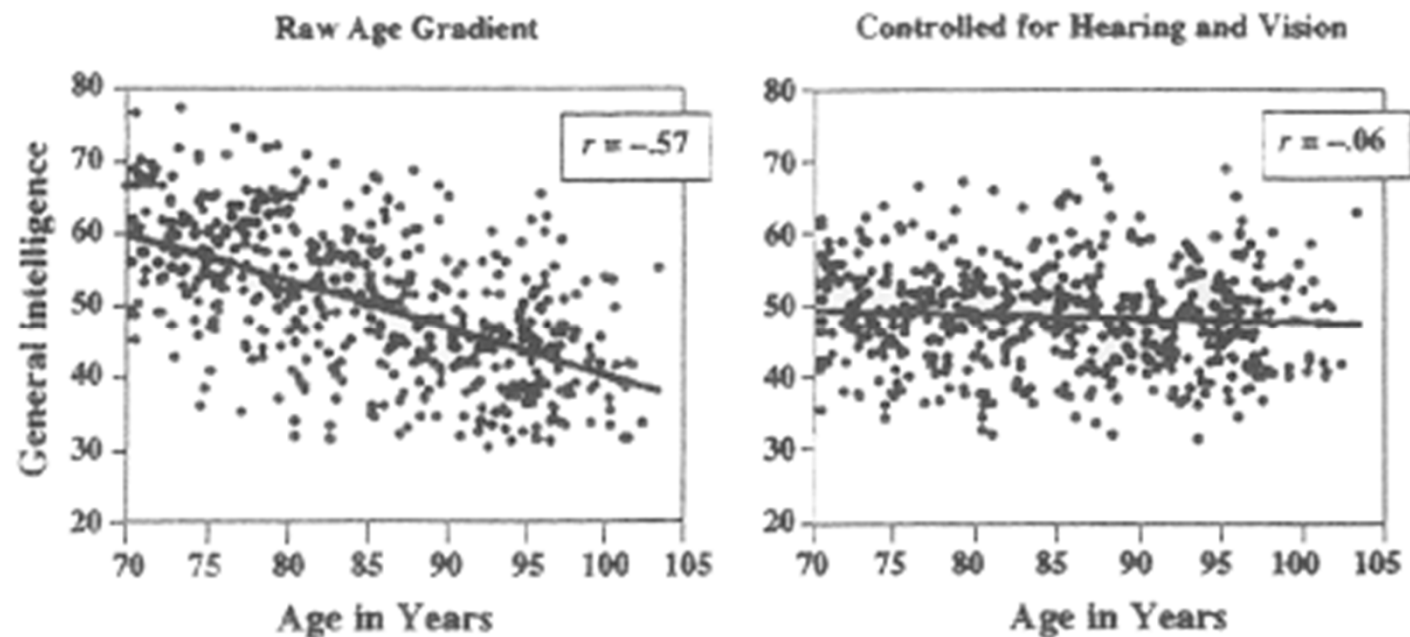
(Baltes & Lindenberger, 1997)

We do not know to what extent central slowing causes inefficient processing nor to what extent inefficient processing slows the system

We do not consider this to be a “chicken-and egg problem” as interaction in both directions is probable.

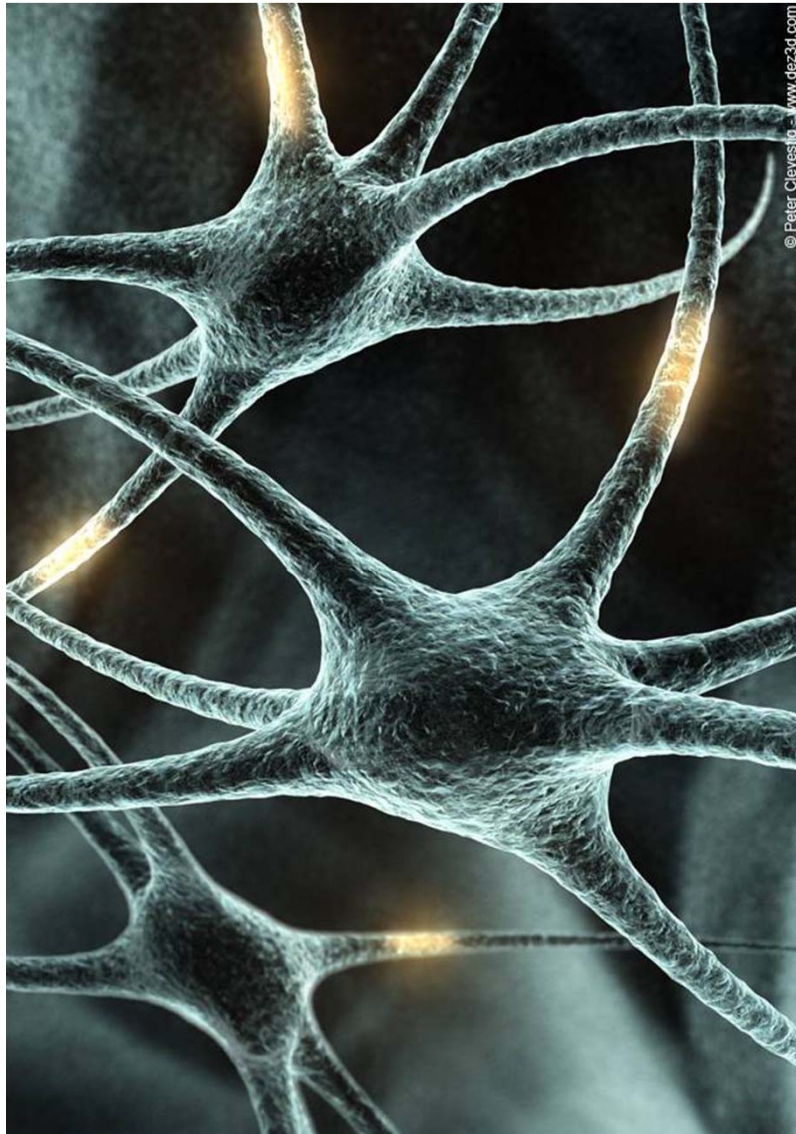
Powerful association of sensory with intellectual functioning in old age

- When measures of hearing, vision, and motor balance are used as covariates, the entire pattern of negative age differences in general intelligence disappears.
- The preferred explanation is to invoke **a common cause (third-variable hypothesis)** for this powerful association between sensorimotor and cognitive functioning that emerges in old age.
- Age-related changes in neurophysiological brain functioning are assumed to affect at the same time sensory, sensorimotor, and cognitive functioning.



Data from the Berlin Aging Study (Mayer & Baltes, 1996)

Age-related physiological changes in the healthy brain



- Moderate loss of brain mass esp. hippocampus, prefrontal cortex
- Reduced connectivity of neurons (but plasticity changes still possible!)
- Reduced concentrations of certain neurotransmitters, e.g. Dopamin, ACh
- Reduced blood flow in the brain
Review by Reuter-Lorenz, 2000

Cognitive aging

Lots of stability and even improvement

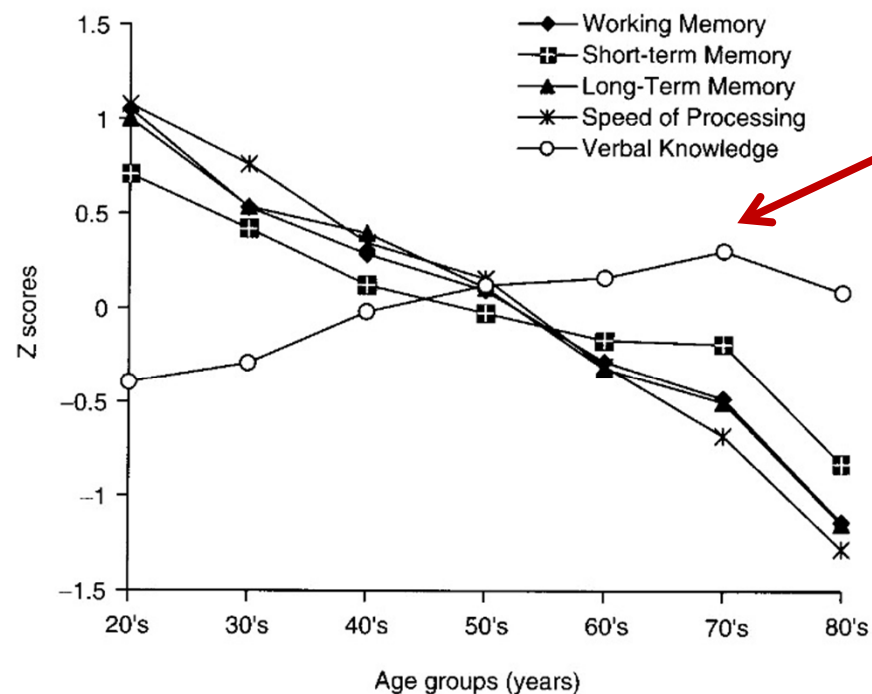


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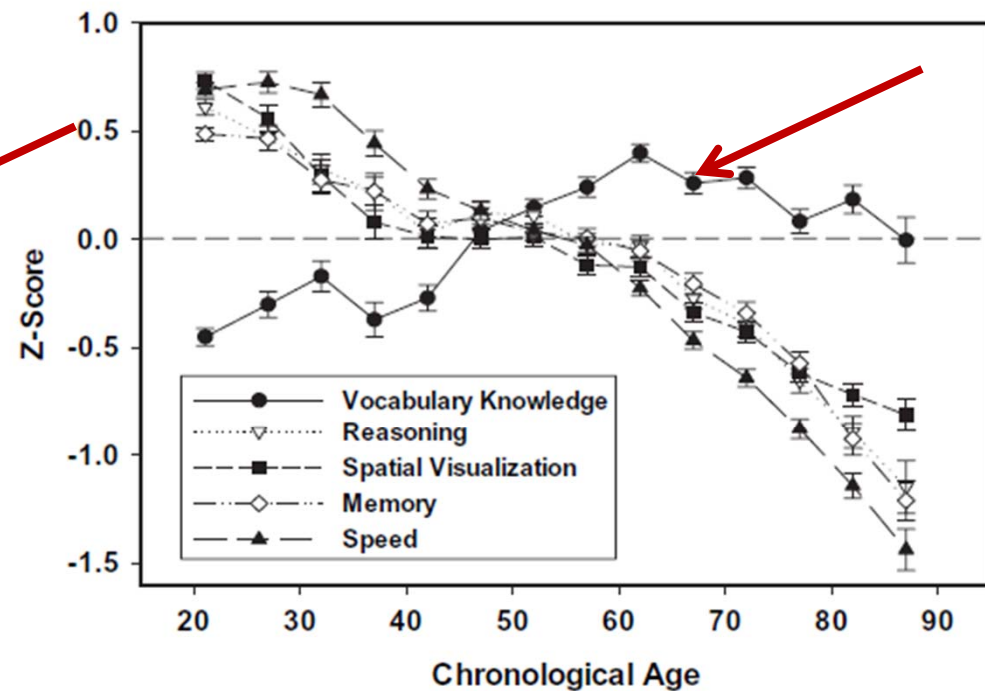


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Compensating resources for successful speech recognition in old age

- Broad experience with wide variety of social situations
- Broad semantic, linguistic knowledge, vocabulary
- Better use of listening strategies
- Better use of context information
- Better use of prosodic information (intonation, timing, stress)





THANK YOU



PHONAK
life is on