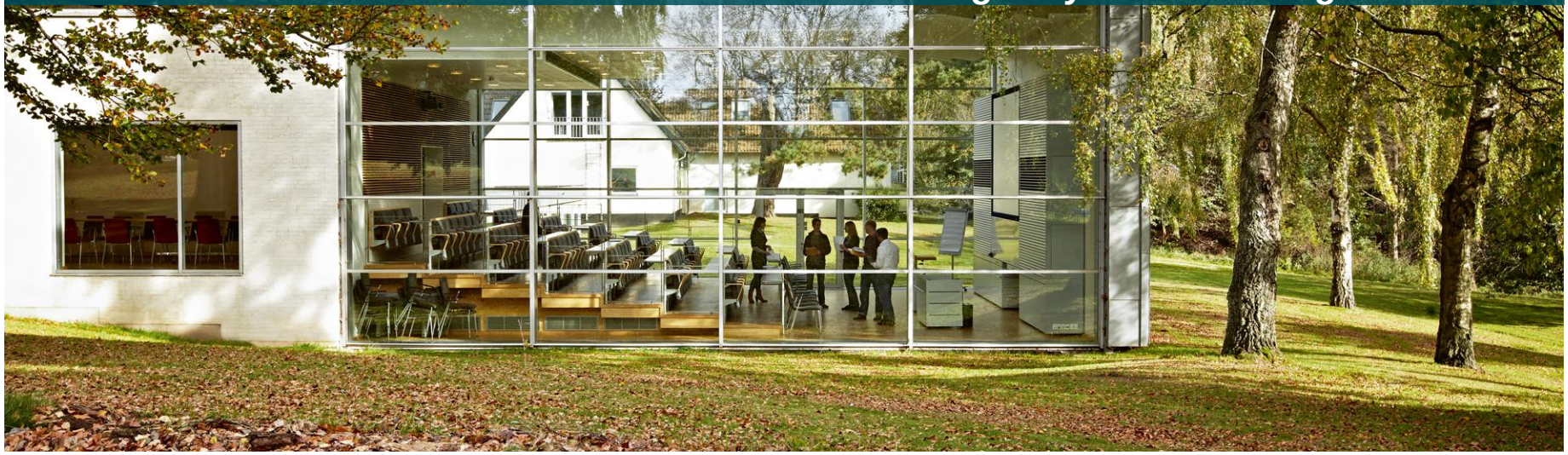
Beyond speech intelligibility testing

A memory test for assessment of signal processing interventions in ecologically valid listening situations



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Mary Rudner
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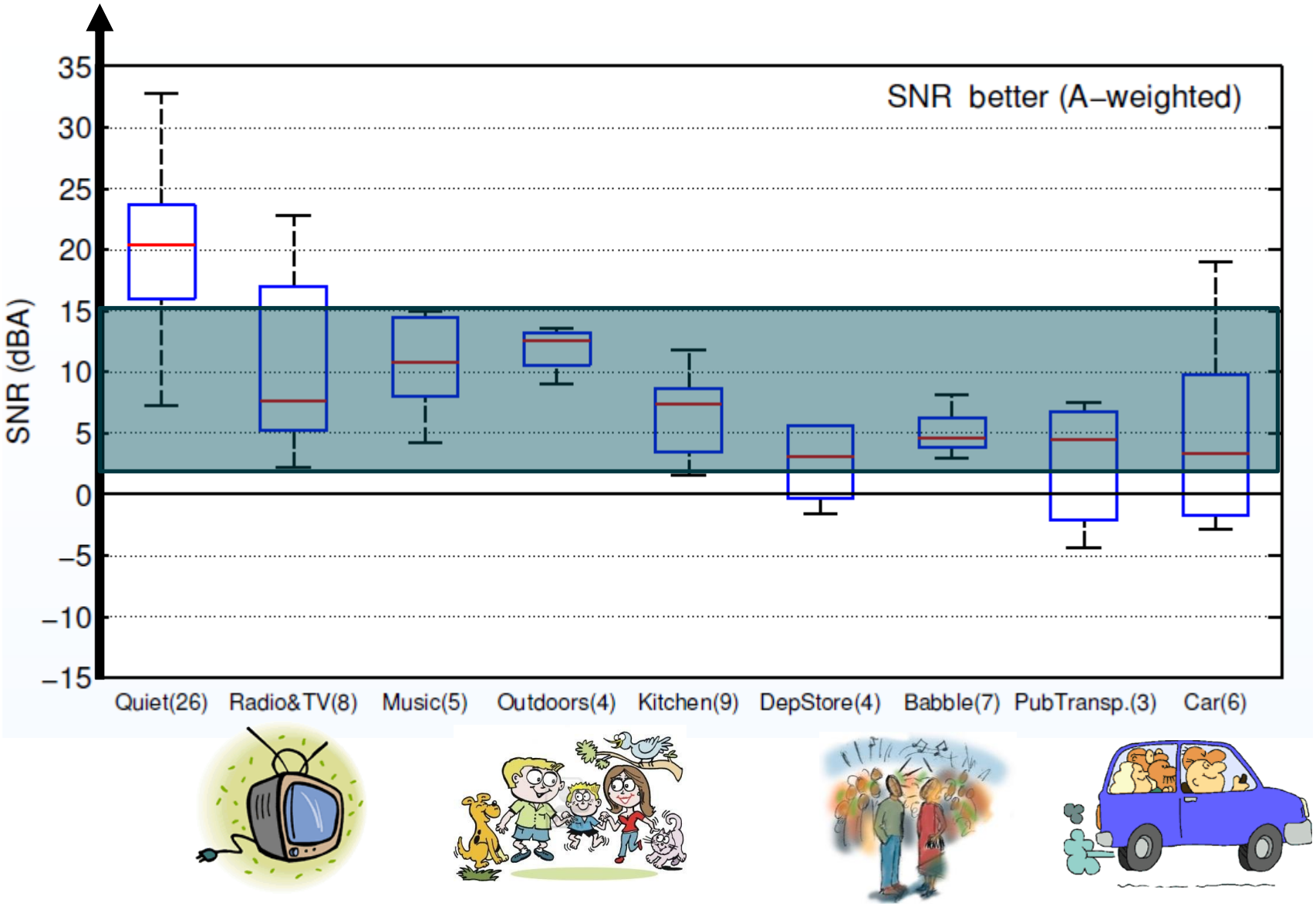
Introduction

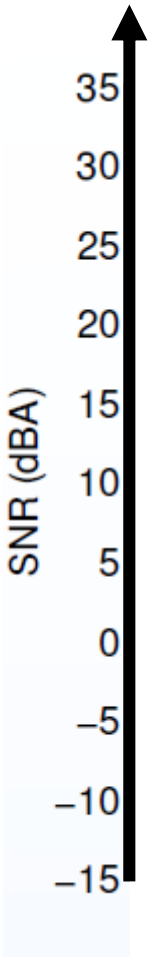
- *Speech in noise testing at Ecological SNRs*
- *Need for new tests at Ecological SNRs*
  - *Ecology for NR systems (in this case)*
  - *Tests other than speech intelligibility…*

Outline

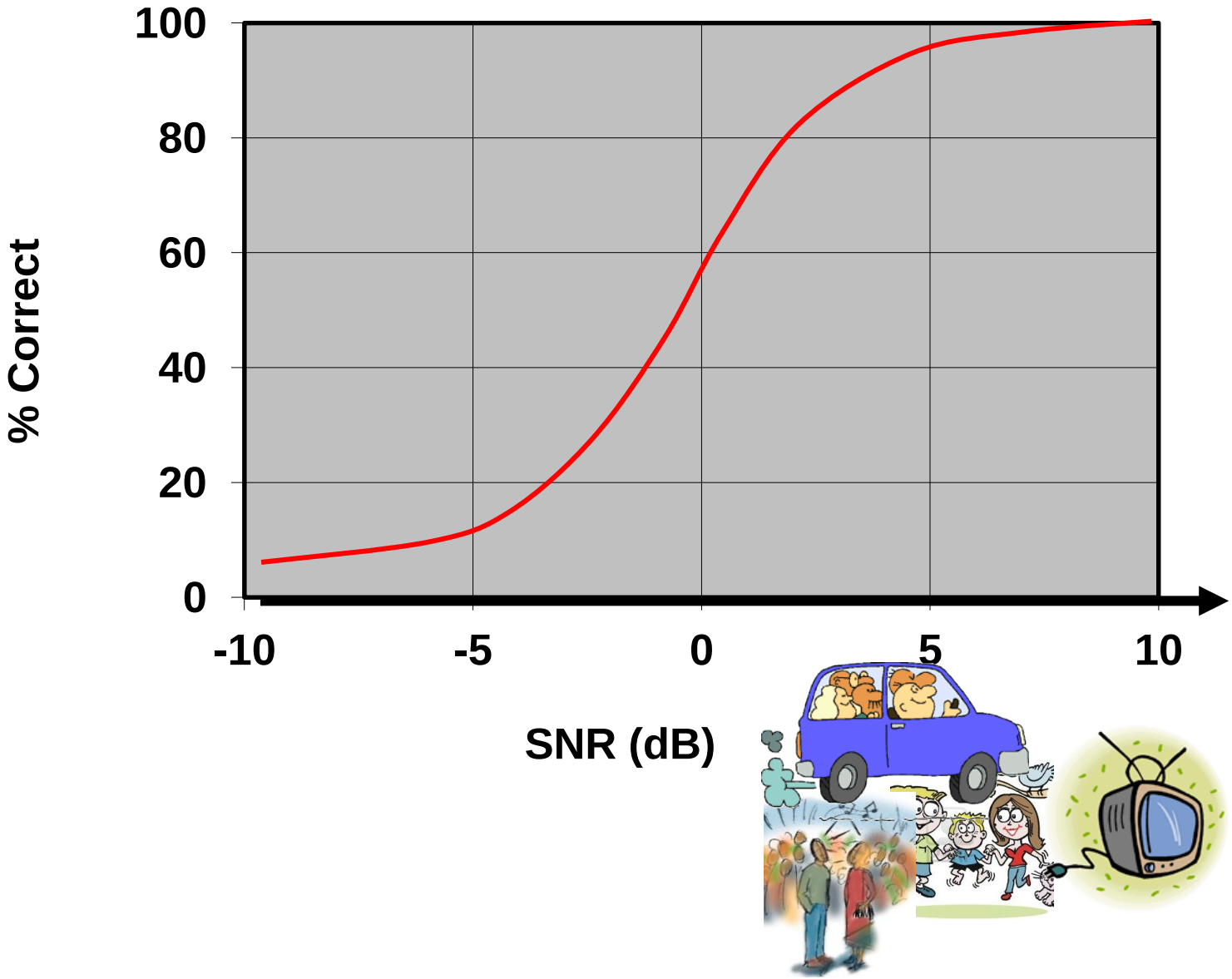
- Motivation for ecological SNRs
- About working memory and hearing impairment
- Memory test
- Noise reduction scheme
- Two experiments

Smeds et al. (IHCON, 2012)

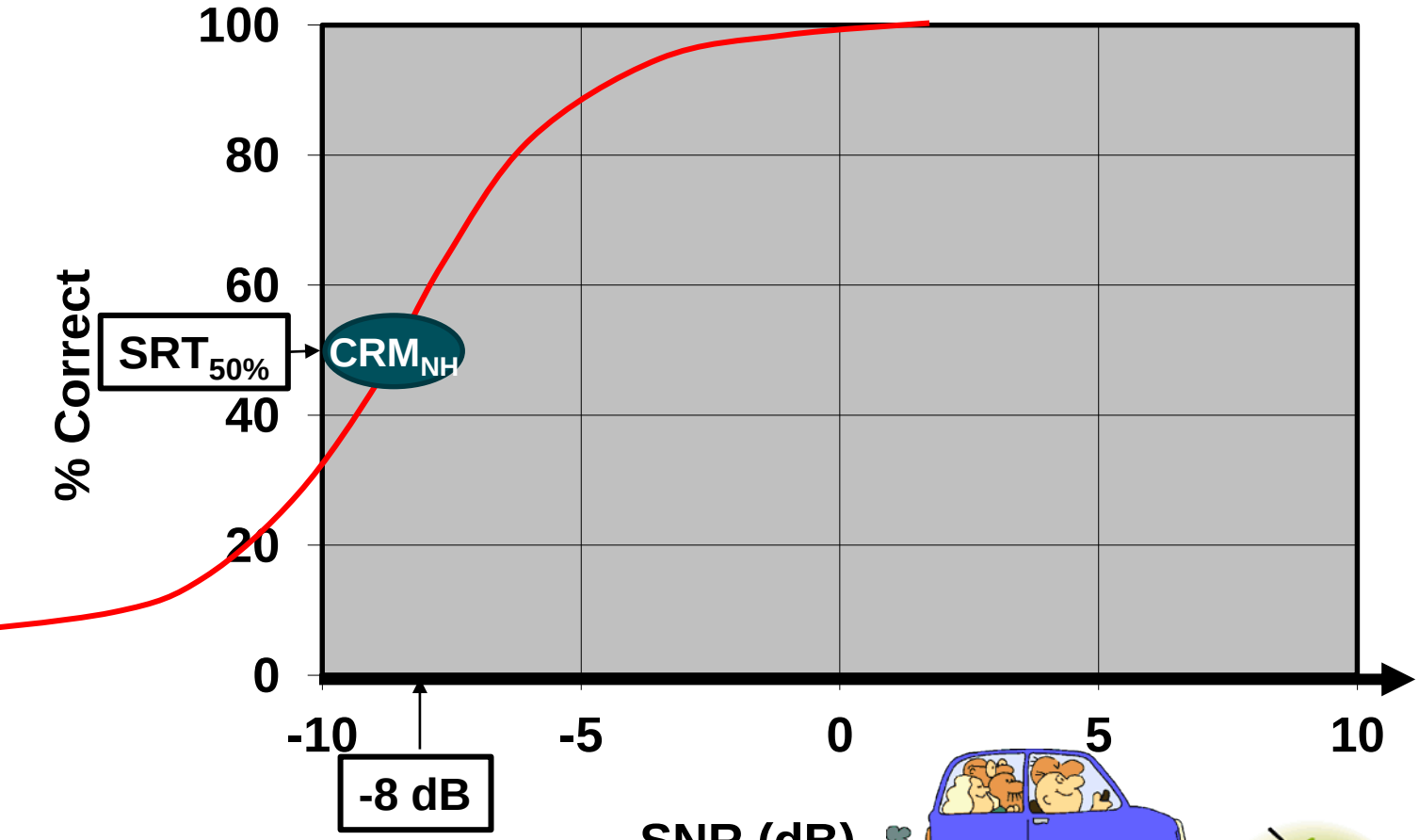


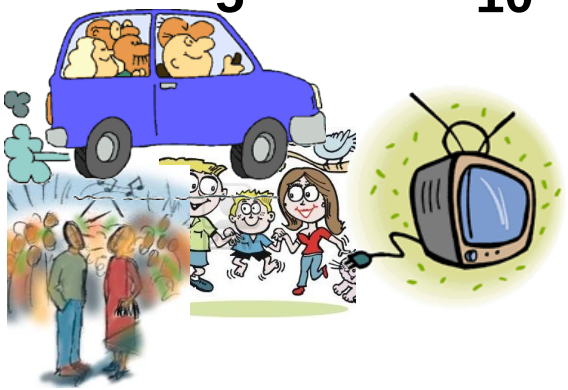

SNR (dBA)
35
30
25
20
15
10
5
0
–5
–10
–15

Speech in noise testing…

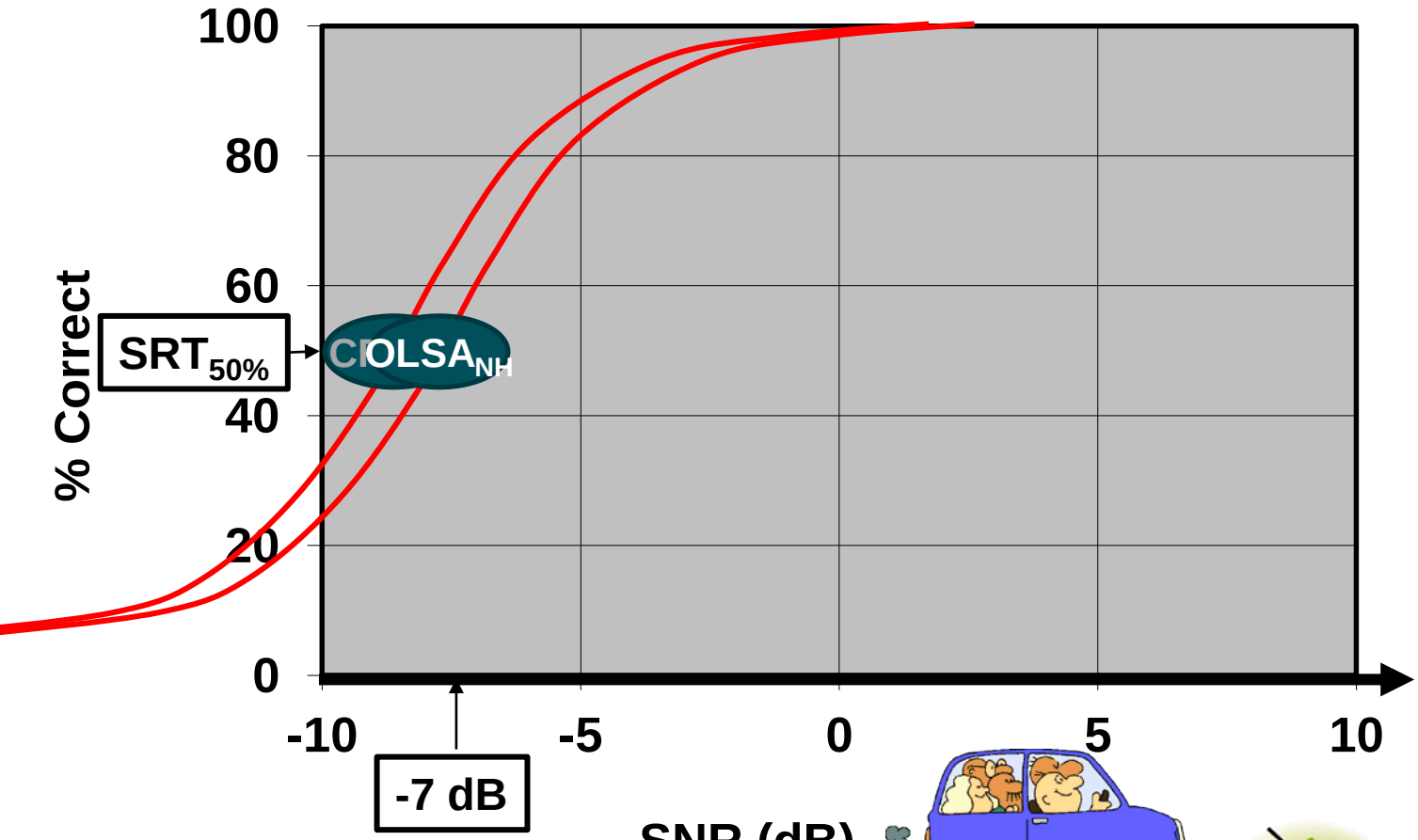


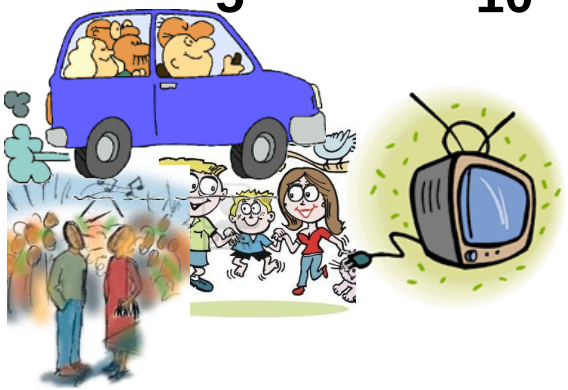
Speech in noise testing…



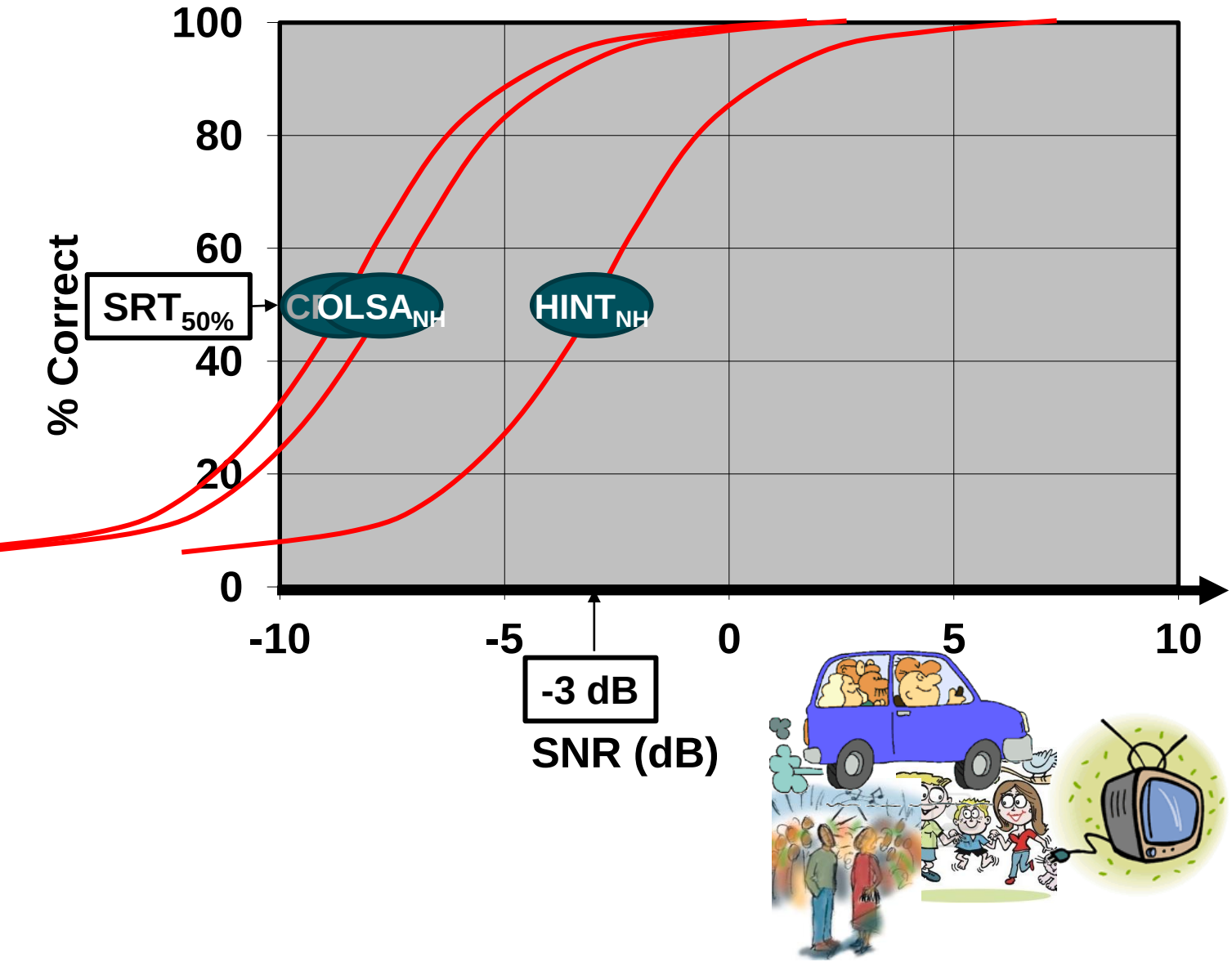


Speech in noise testing…

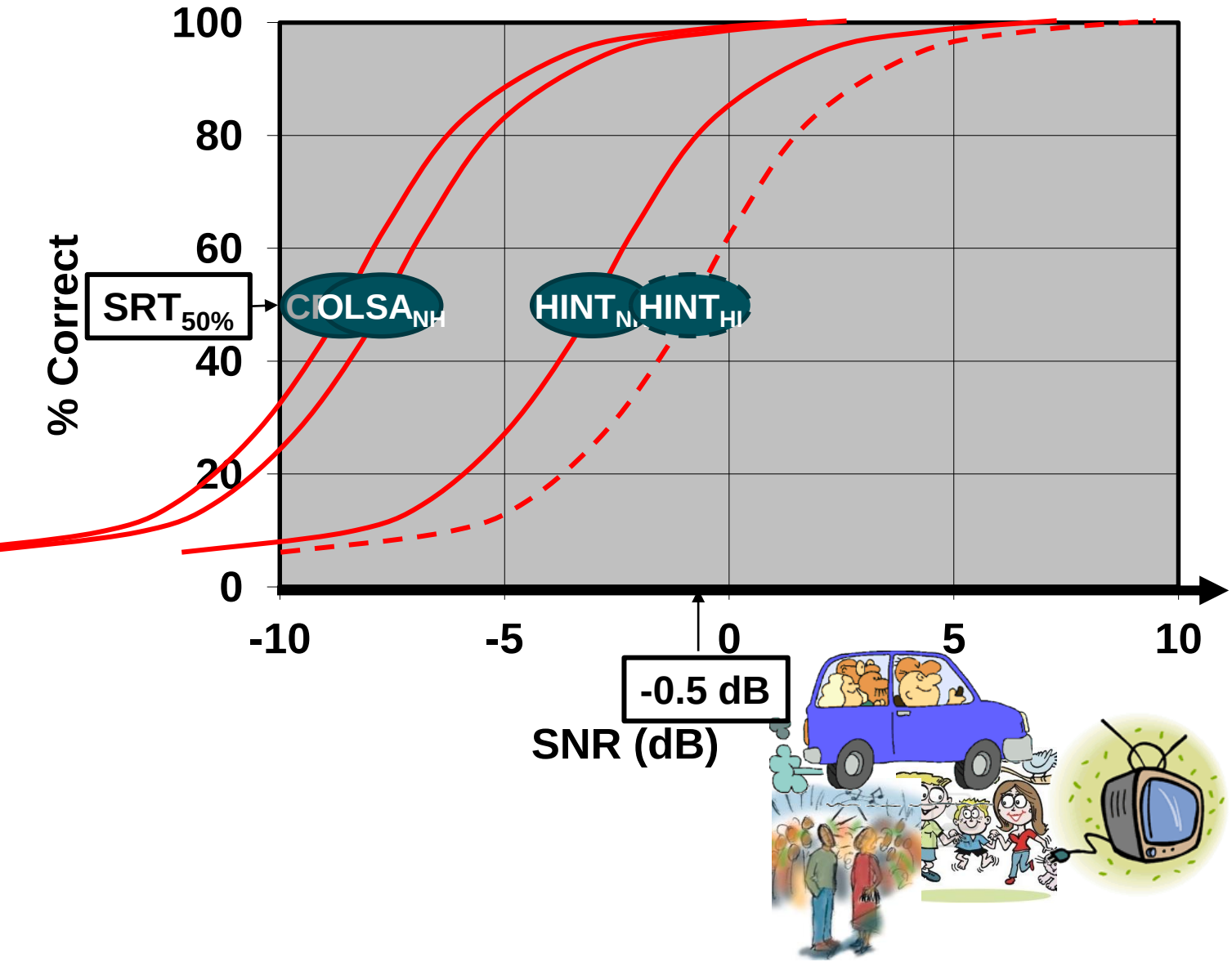




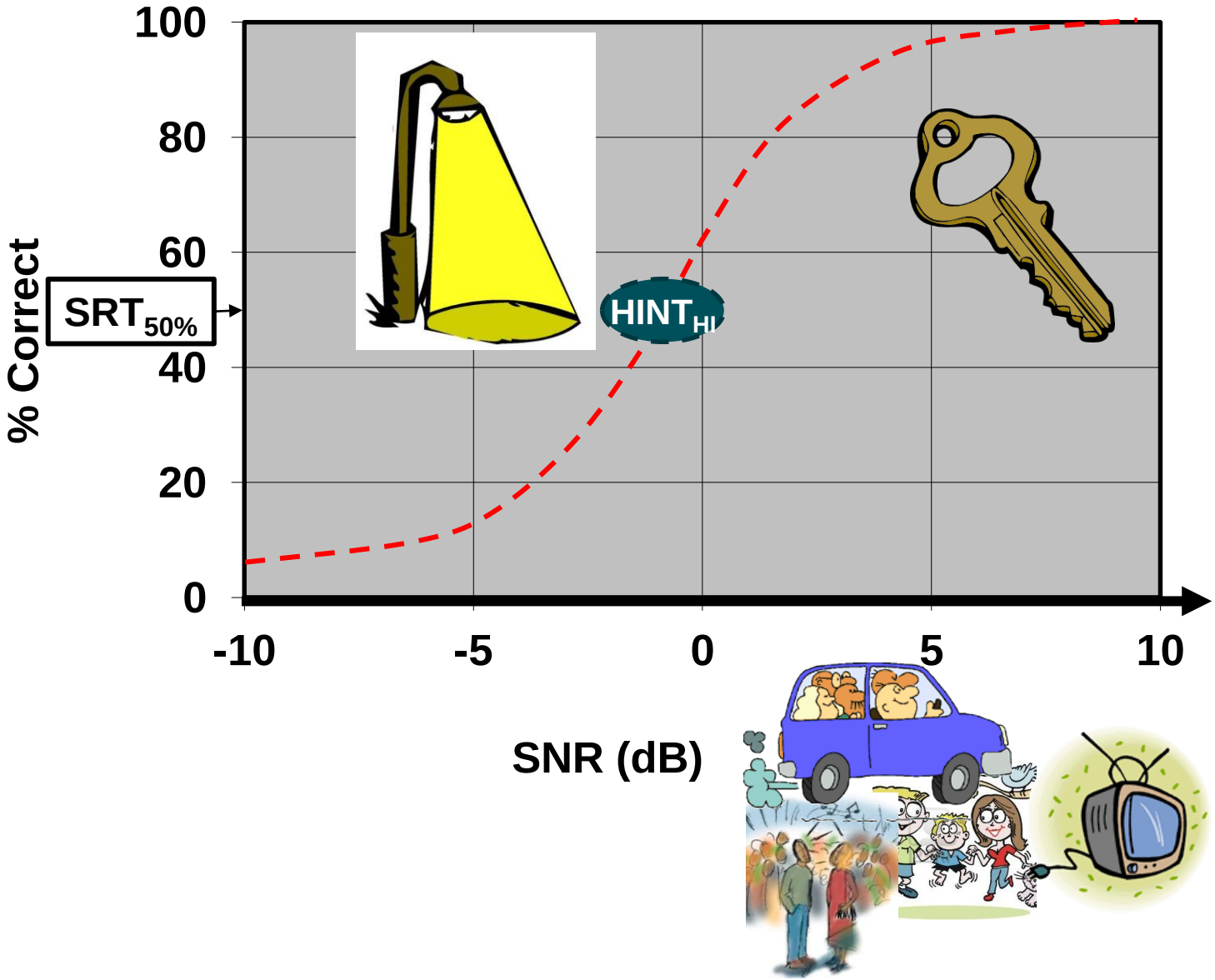
Speech in noise testing…



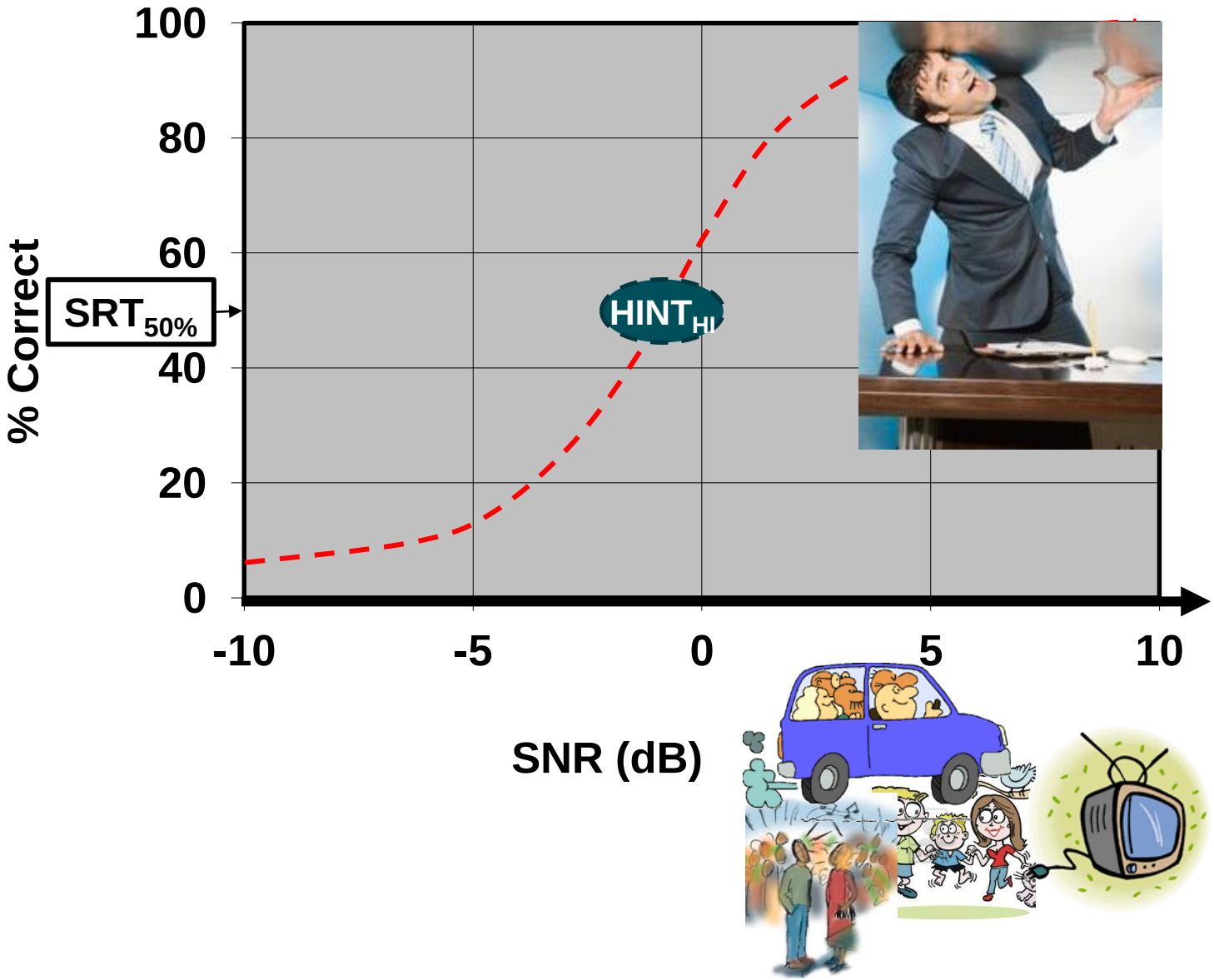
Speech in noise testing…



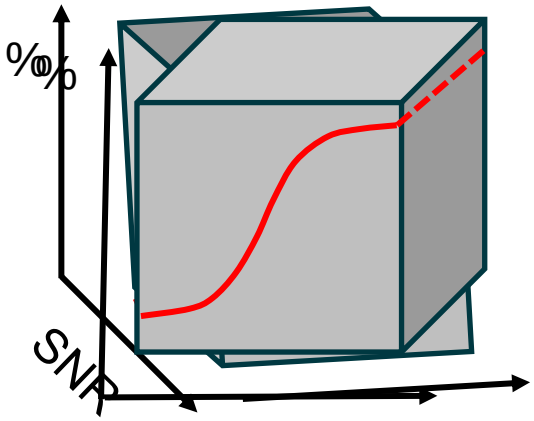
Speech in noise testing…



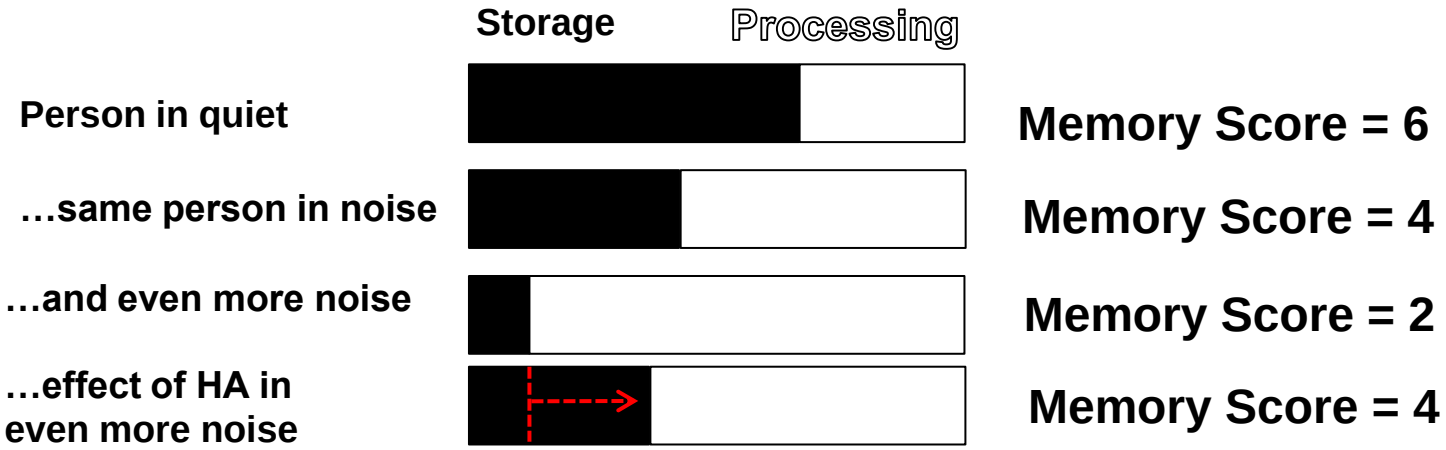
Speech in noise testing…



…a new axis with ~100% speech intelligibility



? **(Working) Memory**



Inspired by Pichora-Fuller (2006)

About Working Memory

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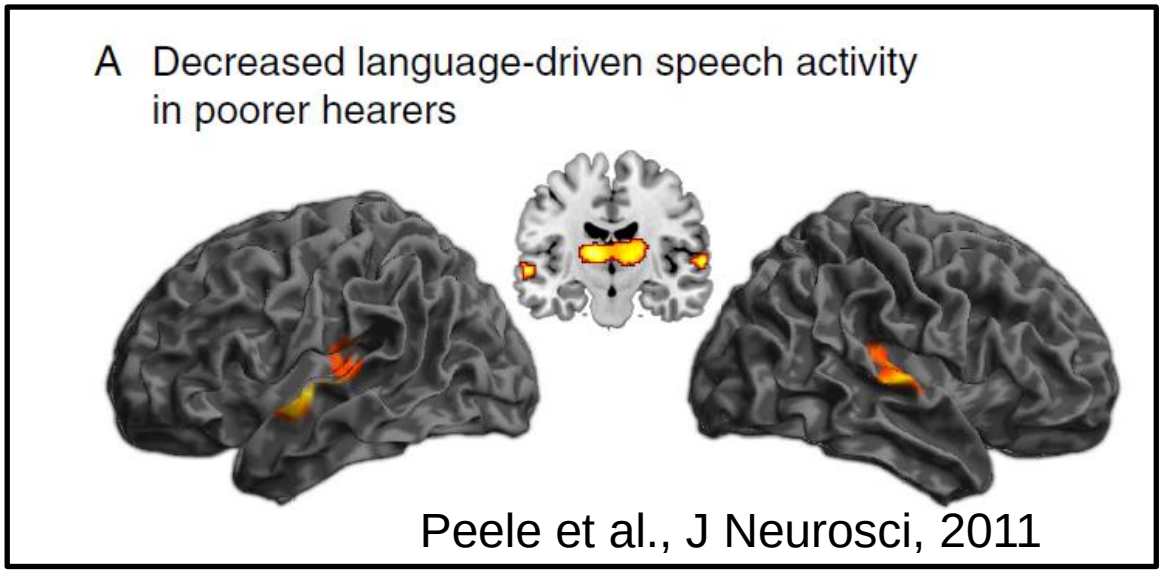
Hearing Loss & Cognitive Load

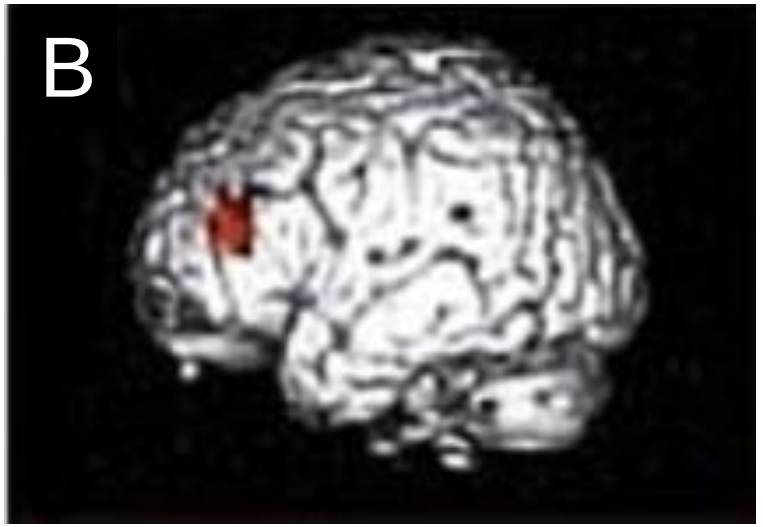
Poorer hearing is associated with:

A. Reduced language-driven activity in primary auditory pathways

B. Increased compensatory language-driven activity in pre-frontal cortical areas

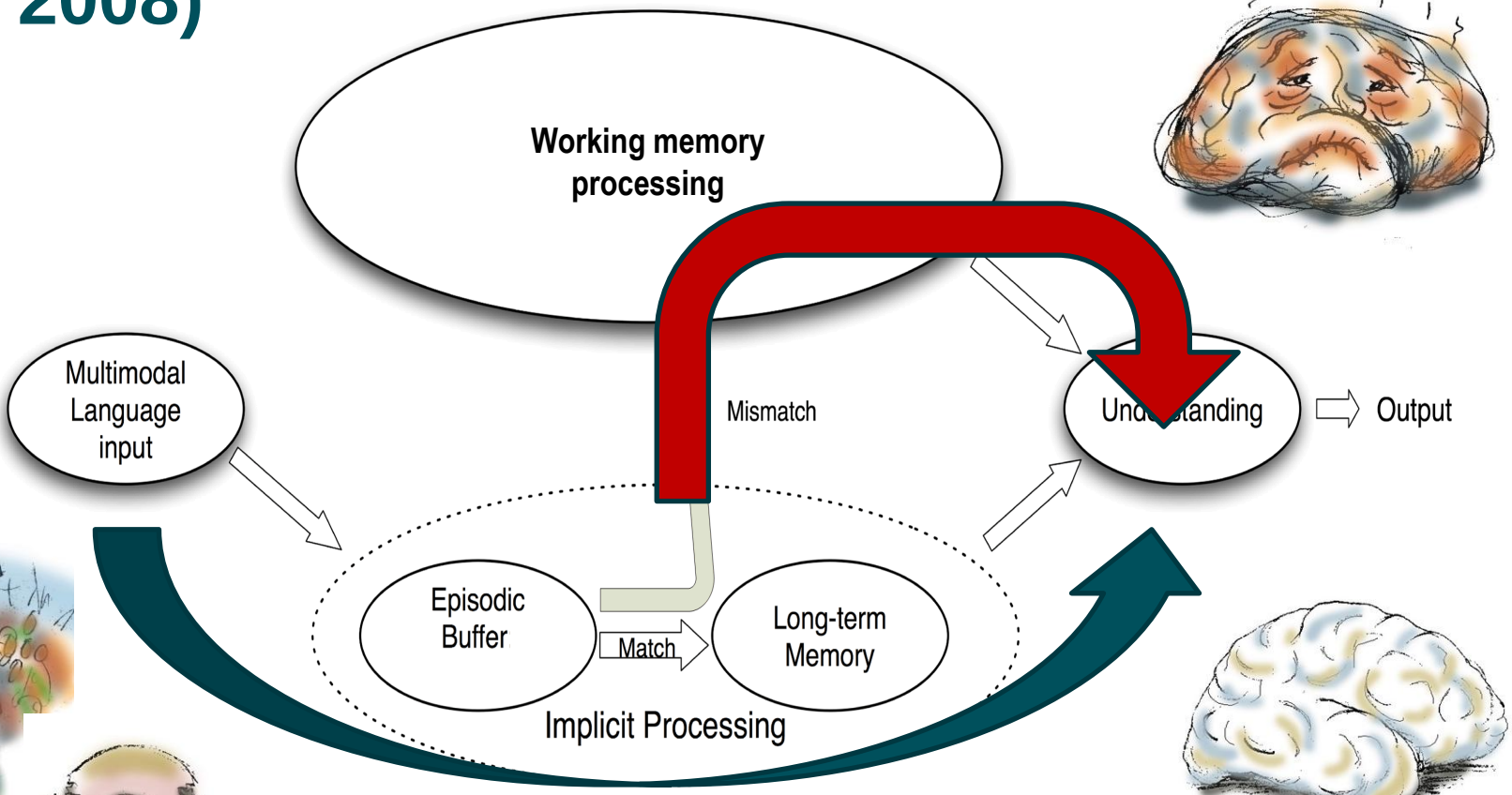


Peele et al., J Neurosci, 2011



Grossman et al., Brain Lang, 2002

A WM system for Ease of Language Understanding (ELU) (Rönnberg, Rudner, Foo & Lunner, 2008)



Individual working memory capacity
The Reading Span test

- *Instructions*
  - Read the sentence
  - Determine if the sentence makes sense or not (yes/no)
  - After a number of sentences you will be asked to recall either the last or the first word – from EACH sentence!

- ***Are you ready?***

The train sang a song

The captain saw his boat

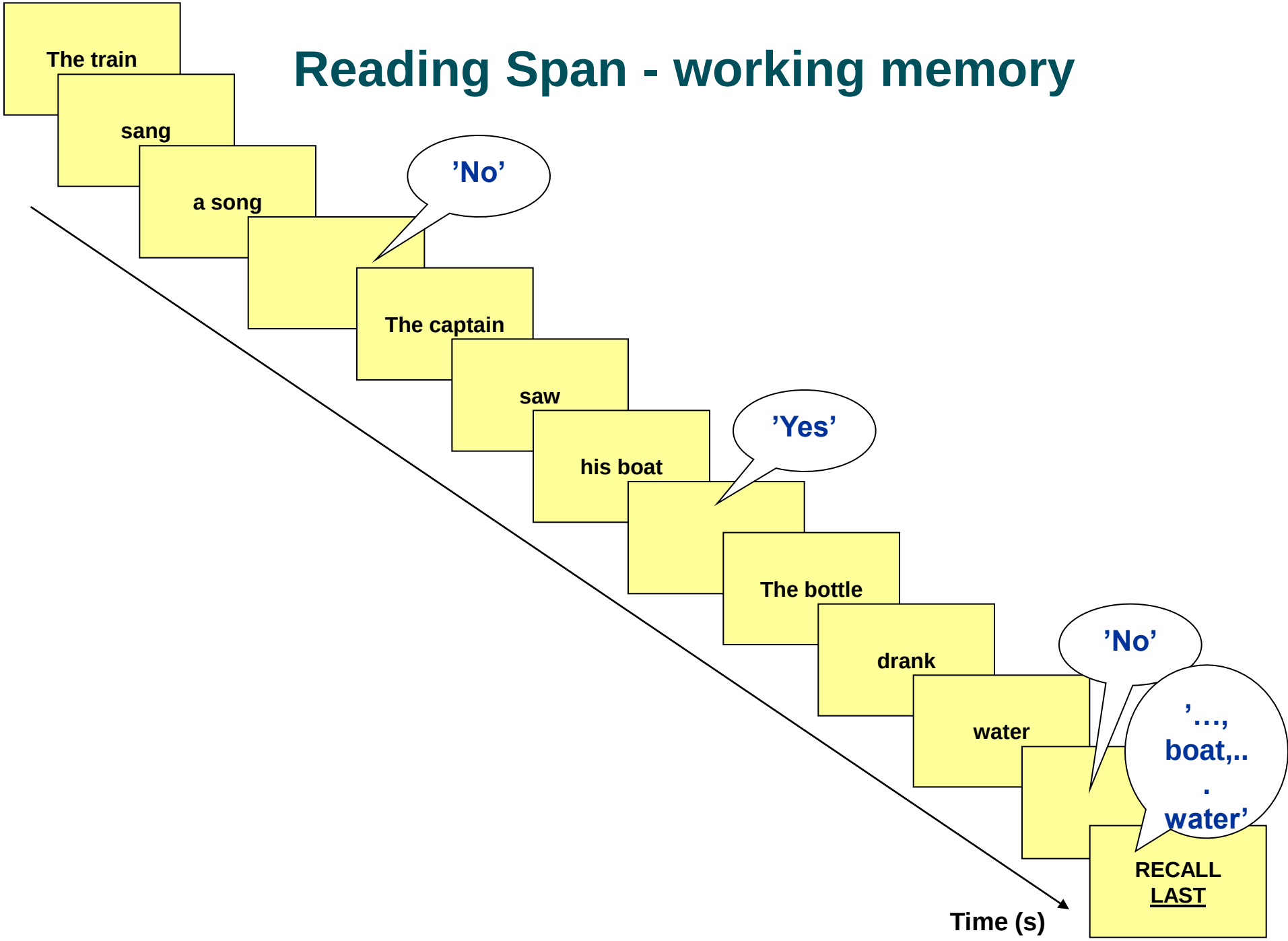
The bottle drank water

The priest drove a car

Recall the LAST word from each sentence

song
boat
water
car

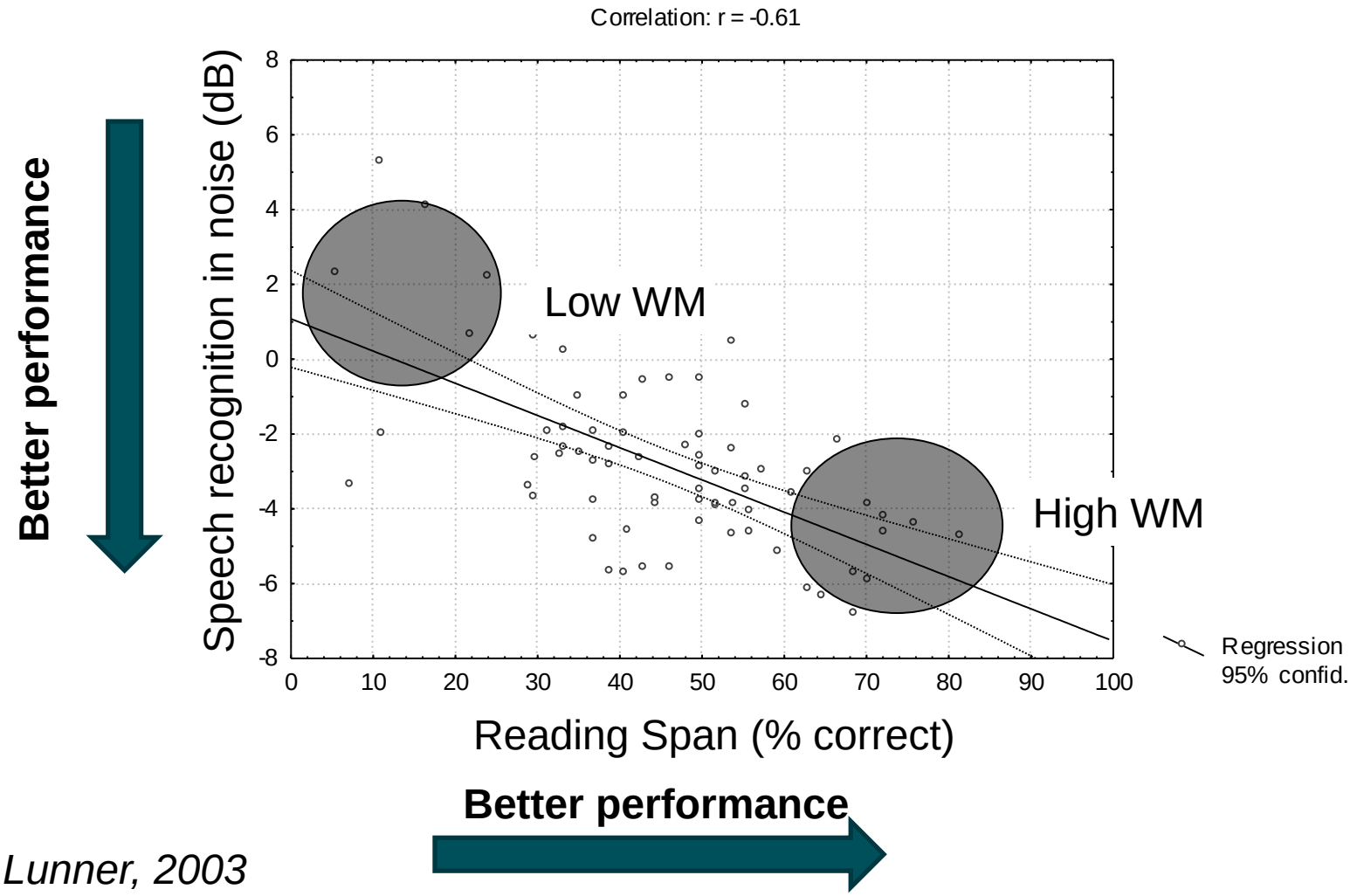
Reading Span - working memory



Why would Working Memory matter for the hearing impaired? For the normal-hearing?

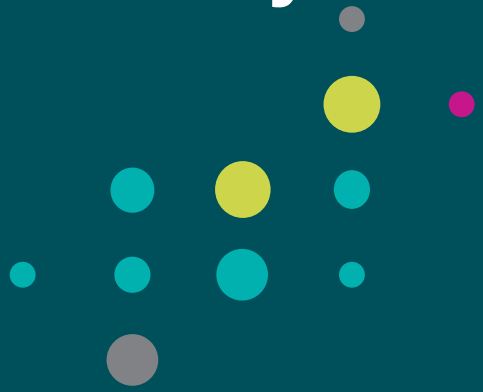
- Online processing abilities, here-and-now
- Guessing, keeping track, filling in
- Inhibit irrelevant information (e.g. competing talkers)

Individual differences: Speech recognition and Working Memory



Lunner, 2003

Memory test



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Memory task:

Sentence-final Word Identification and Recall (SWIR)

Sentence material

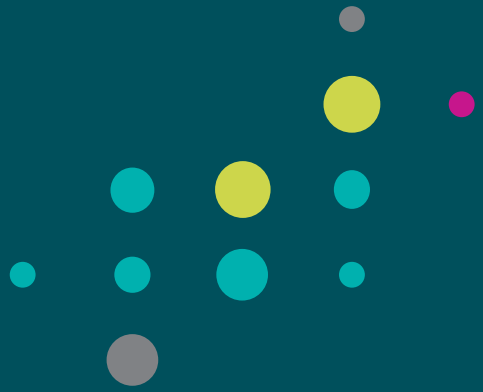
- Swedish HINT sentences

E.g. Pappa ska laga min fåtölj
Tanten handlar en gång i veckan
Rektorn tog fram kastrullen
Farmor åker till golfbanan
Golvet täcktes av en vit matta
Frukten packades i sex lådor
Plånboken låg kvar på isen

”Recall”

Inspired by Sarampalis et al., 2009

Noise reduction



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Aggressive noise reduction (NR)

- Aggressive noise reduction (binary mask processing) tries to enhance the talker and suppress competing noise/talkers

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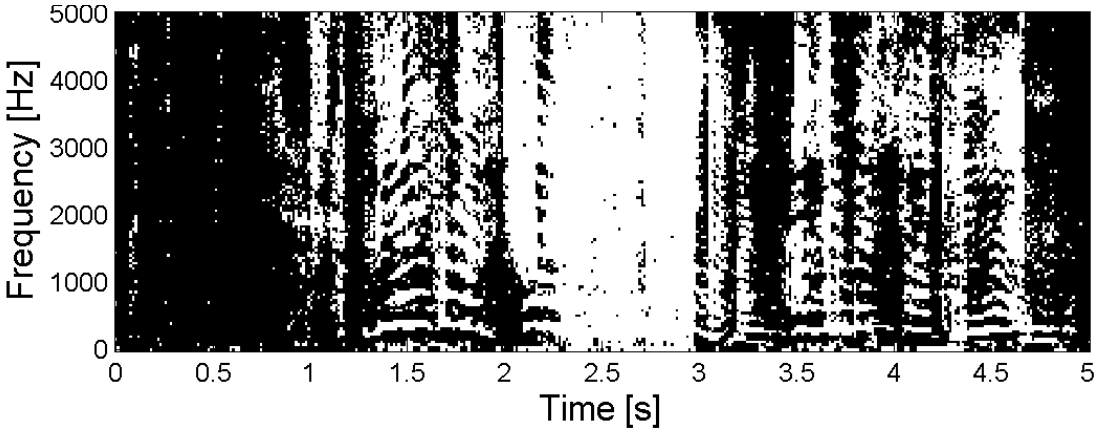
- Aggressive noise reduction (binary mask processing) tries to enhance the talker and suppress competing noise/talkers



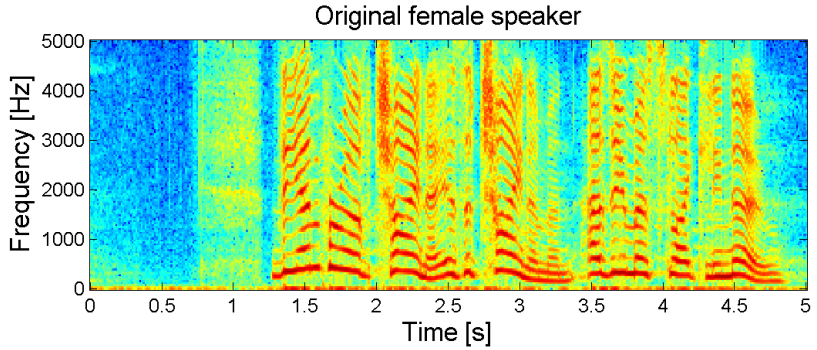
$$\mathrm{IBM}(t,f) = \begin{cases} 1 & \text{if } s(t,f) - n(t,f) > 0 \\ 0 & \text{otherwise,} \end{cases}$$

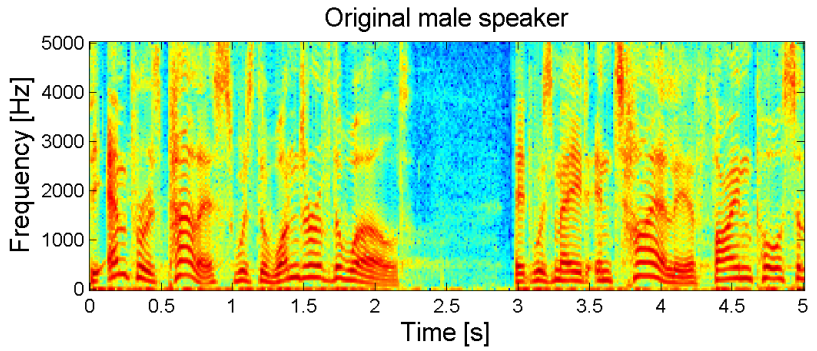
‘Signal’ talker

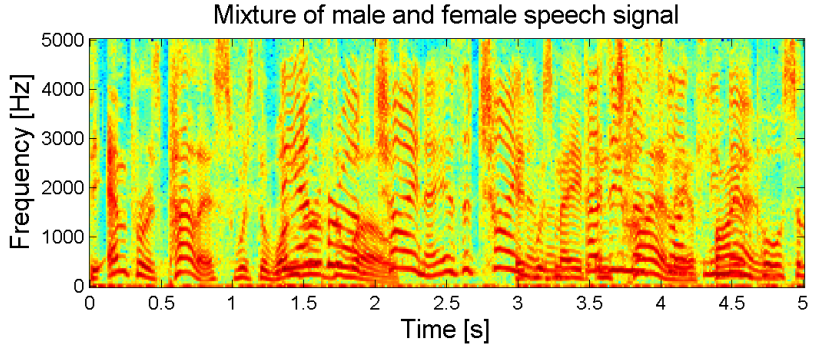
‘Noise’ talker

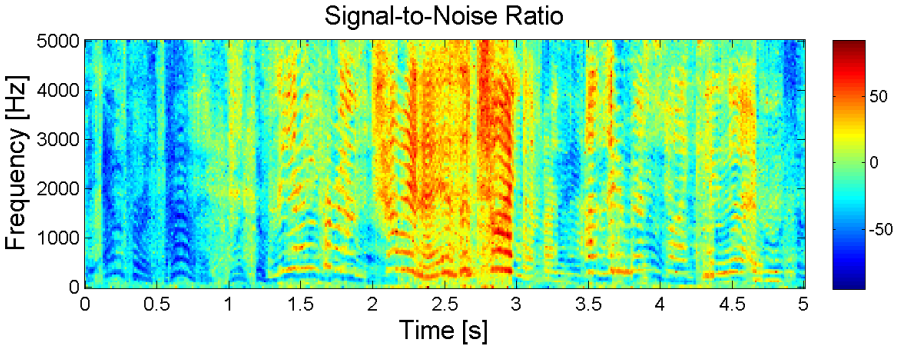
Mixture of ‘Signal’ and ‘Noise’

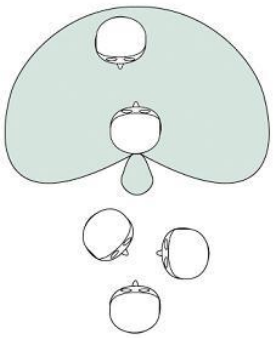
Local Signal-Noise Ratio







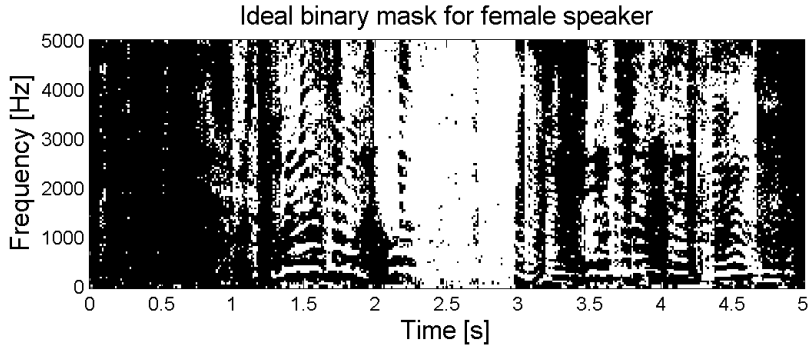


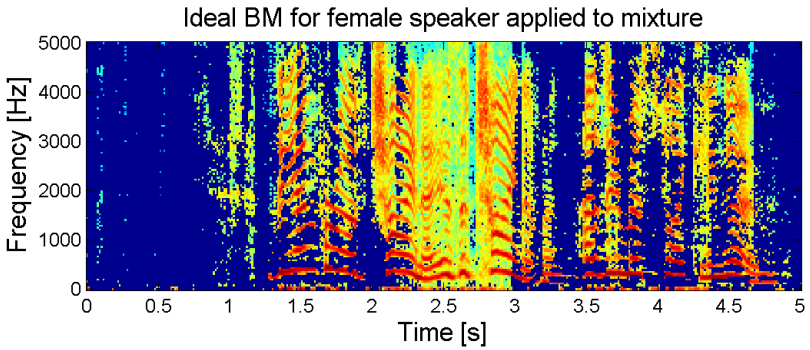


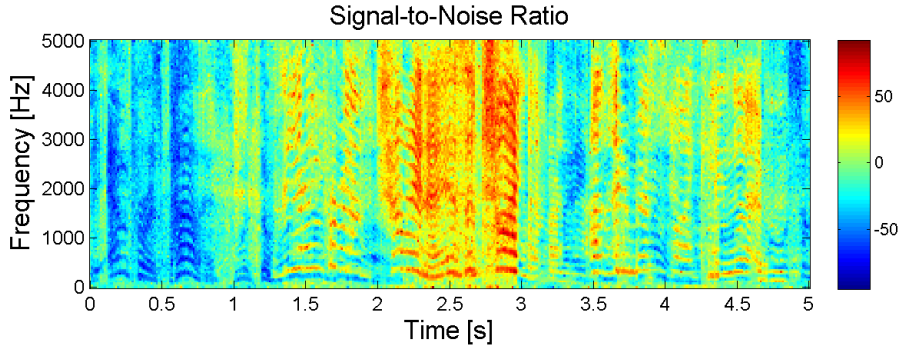
Binary gain pattern: Units where Signal is stronger than Noise

‘Signal’ talker extracted from mixture

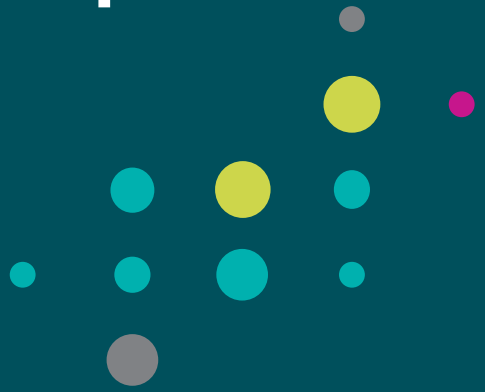
Local Signal-Noise Ratio







Experiments



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Experiment 1 (Ng, Lunner, Rudner, Rönnberg, submitted)

- 26 HI test persons, HA users, moderate hearing loss

Procedure:

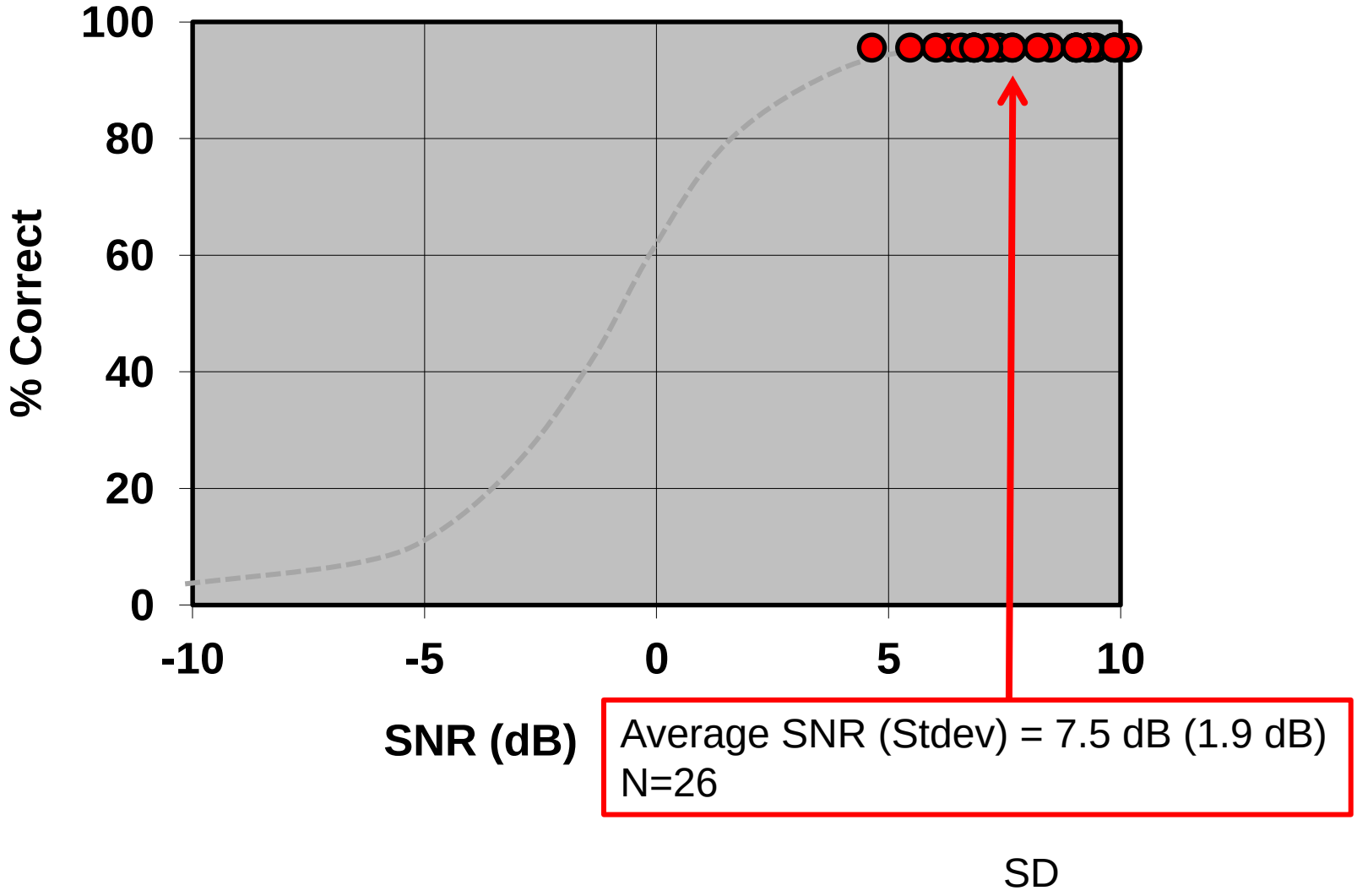
- **Prepare Experiment**
  - Assure audibility = No Processing condition (NoP). Linear gain with individually fitted frequency response to assure audibility up to 6.5 kHz
  - Adjust SNR to ~95 % correct HINT sentences for NoP in 4 talker babble
  - => SNR near ceiling

- **Proof of concept Memory test**

  Contrast:

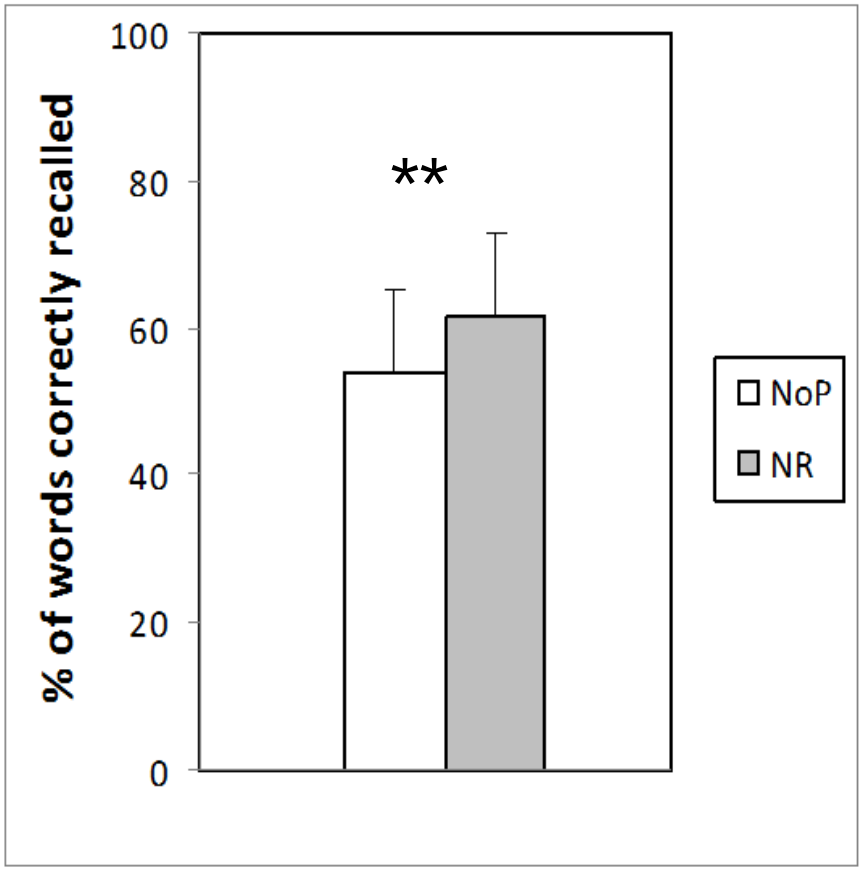
  NoP vs. Aggressive NR (binary mask processing) in 4 talker babble, 5 repetitions

SNR for 95% correct HINT sentences (NoP)



Result of memory test (SWIR)

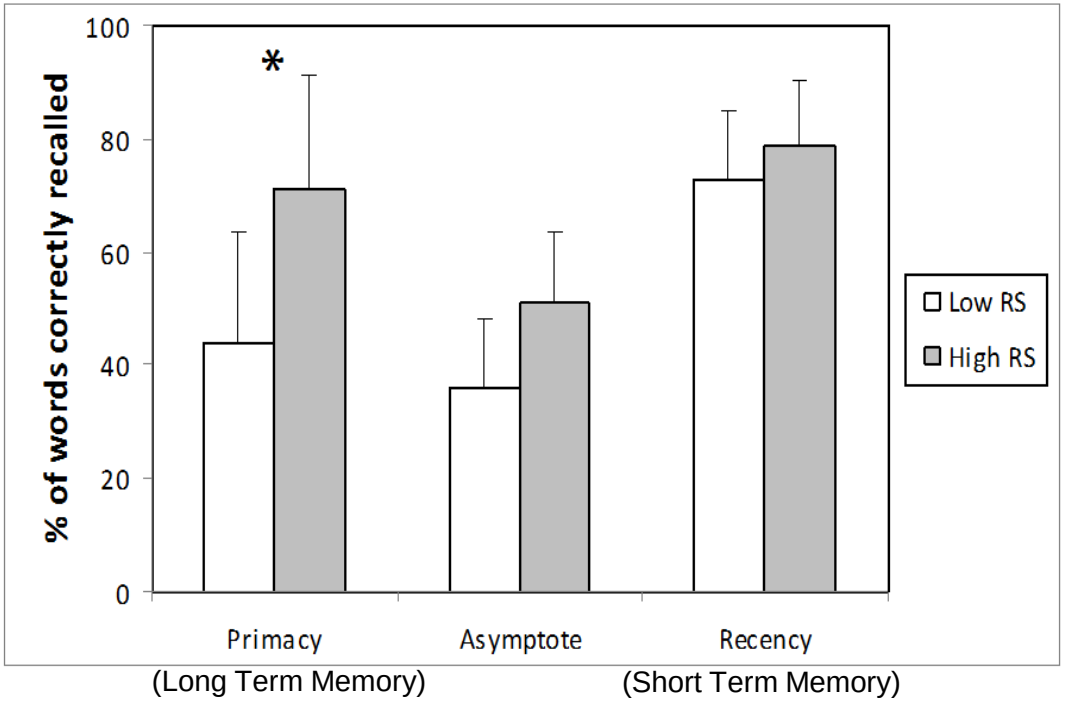
- Main effect of NR. Recall better for NR compared to NoP (*p<.01*)



Ng et al., in prep.

Result of memory test (SWIR)

- It looks as if high subjects with high WM performance (high RS) better encode into long-term memory



Experiment 2
Replication Experiment (Lunner, Grube Sorgenfei, Vatti, in prep)

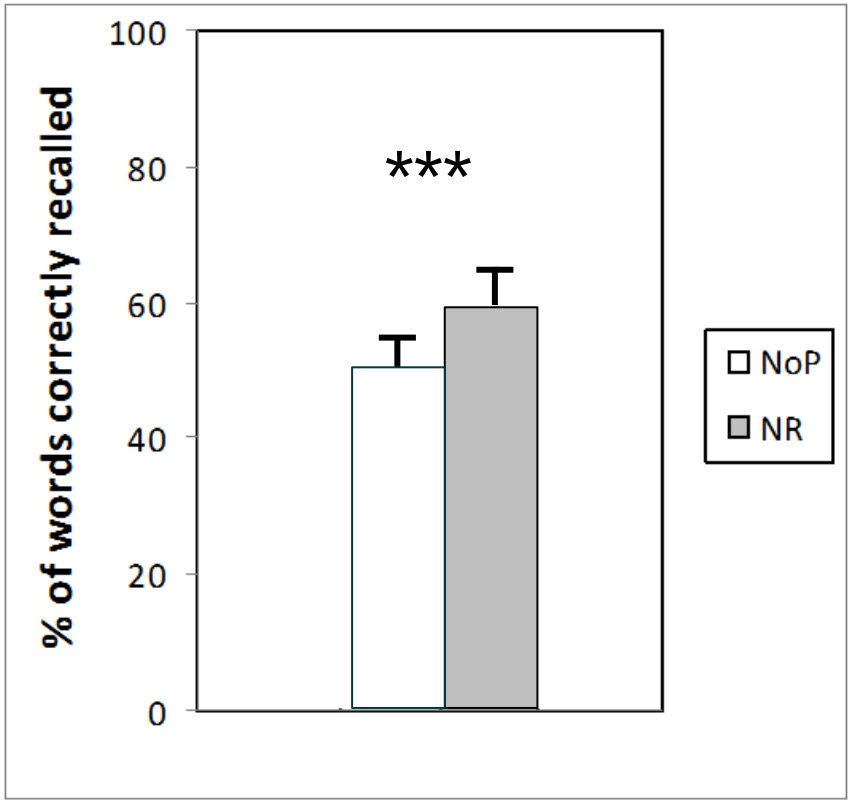
- 25 HI test persons, HA users, moderate hearing loss

Procedure:

- Identical to Ng et al. (submitted), *but new language* (Danish)

Result of replication experiment (Danish)

Main effect of NR. Recall better for NR compared to NoP (*p<.001*)

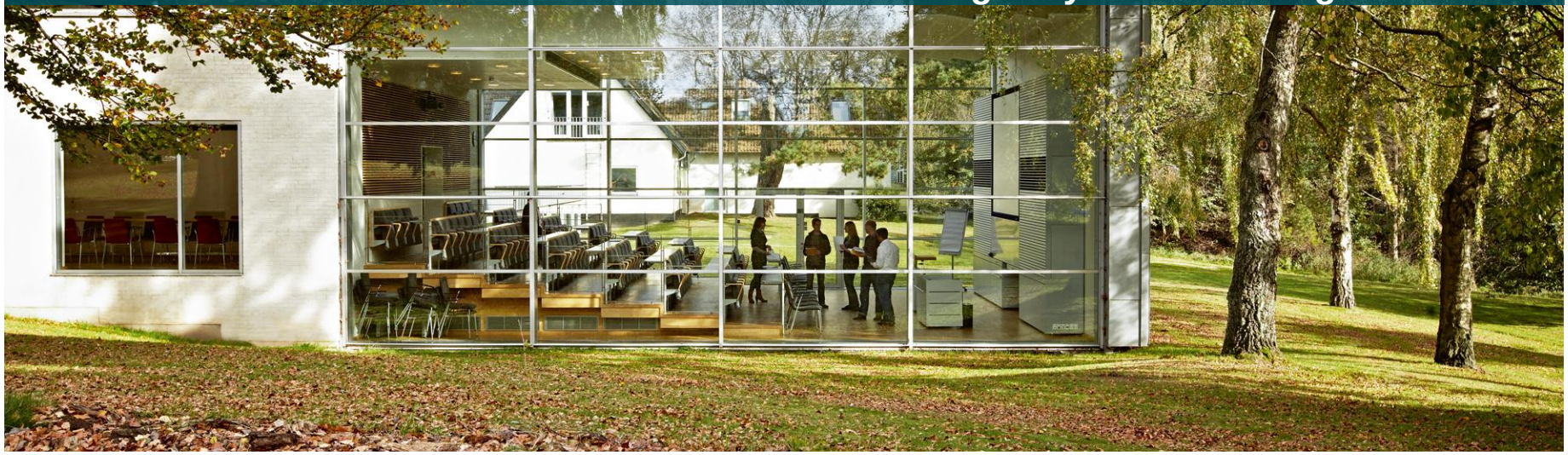


Summary: Proof of concept memory test at ecological SNRs

- Memory test inspired by Pichora-Fuller (2006) and Sarampalis et al. (2009)
- SNR for 95 % correct on average 7.5 dB (1.9 dB)
  - √ In line with Ecological SNRs according to Smeds et al. (2012)
- √ Possible to show improved recall for an experimental NR algorithm at ‘high’ SNRs
  - First study shown on hearing impaired
- √ Possible to replicate findings in a new language
- High WM subject better encode into Long-Term Memory

Beyond speech intelligibility testing

A memory test for assessment of signal processing interventions in ecologically valid listening situations



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