

Listening in complex environments

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Outline

1. How knowledge and experience influence perception of noisy and ambiguous speech.
2. Cognitive factors such as attention influence perception of noisy and ambiguous speech.
3. What is listening effort?

Knowledge guides and informs perception –
perception is an inference (unconscious)
based on evidence...



Alhazen



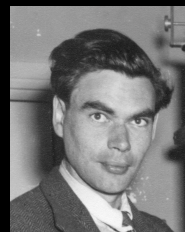
Ptolemy



*von
Helmholtz*



Rock

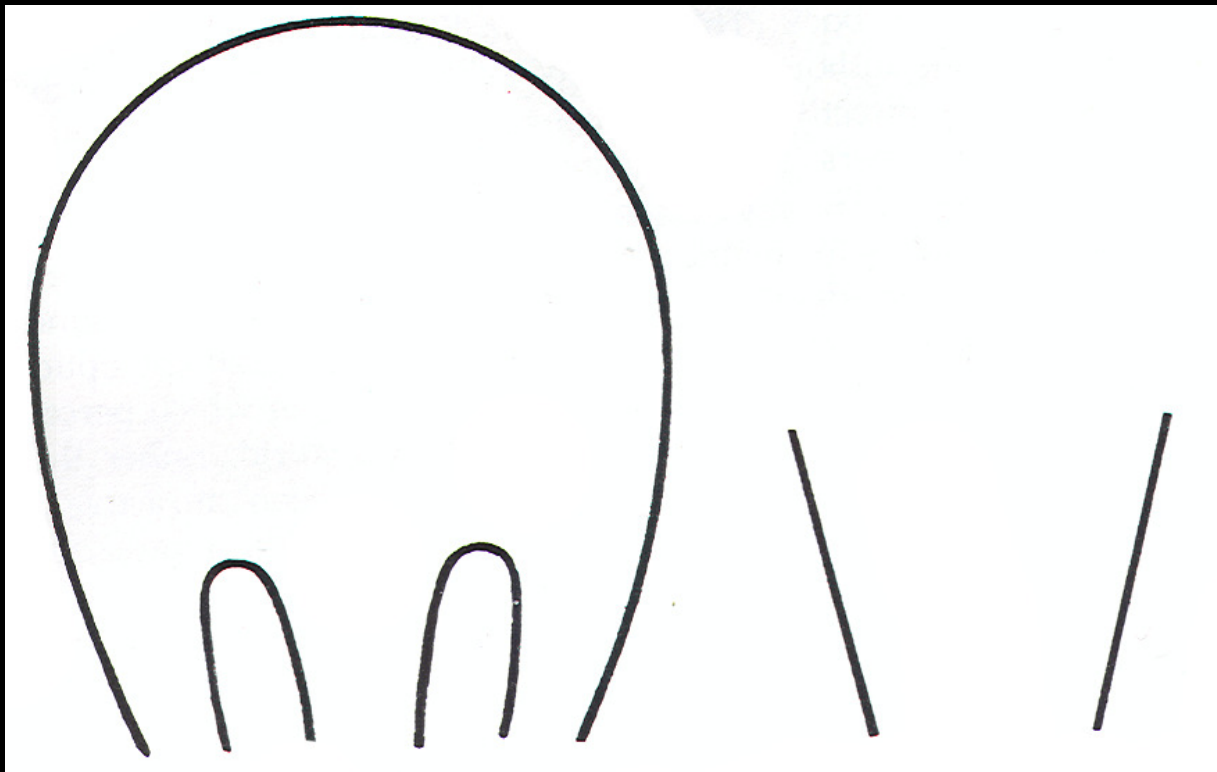


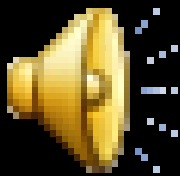
Gregory



Barlow

What is this?

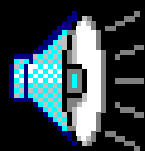
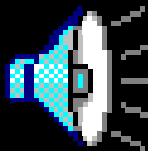
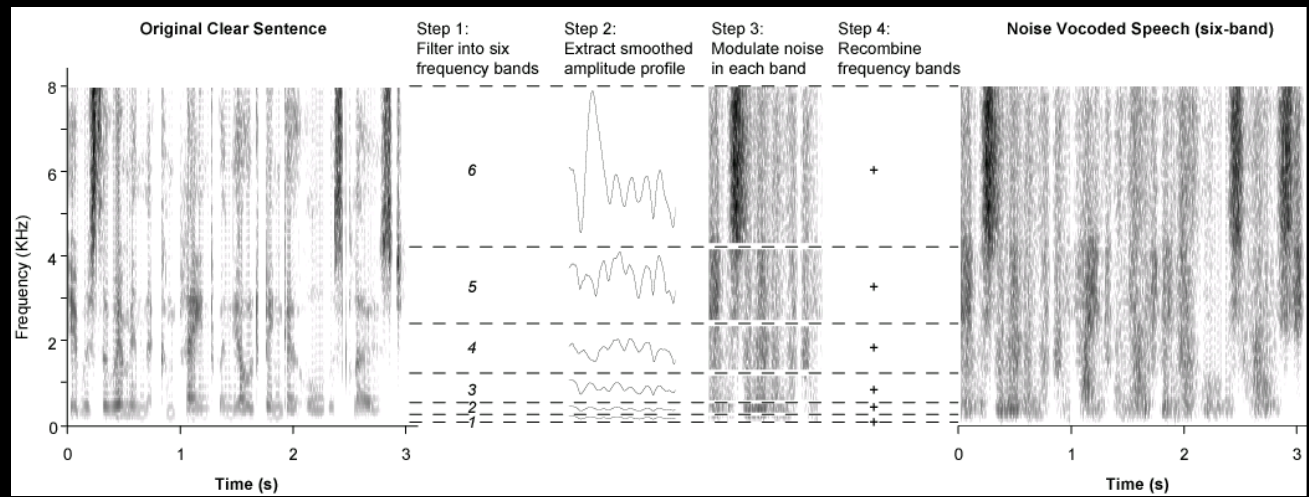




...and take a cast net and your oil clothes and go down there, go down over that bank at Lance Cove, and catch that tub of caplin and bring it up on the bank and get a smoke, and then put it on your back, in the dark, coming across the hills, all those rocks that you went through....

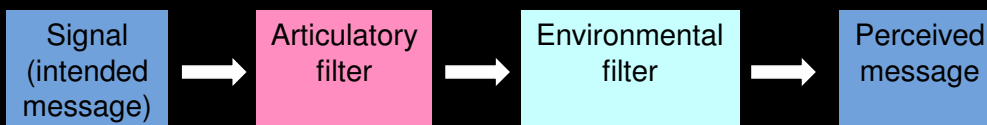


Noise-Vocoded Speech



Shannon et al., (1995)

Sources of knowledge in speech perception



Topic
World Knowledge
Lexical knowledge
Syntax
Dialect
Talker identity (ideolect, etc)
•
•

Talker identity
Sex/Size
Accent
Visible speech
•
•

Physics of sound and reverberation
Room acoustics
Knowledge of interfering talkers
Sound correlates of visible sources
•
•

Knowledge may:

Improve segregation of sources
Increase effective SNR
Help “fill in” missing information

Does talker familiarity enhance intelligibility?

How much do older listeners benefit when hearing naturally familiar voices?

How do they use what they know about a familiar voice?

Coordinate response measure (CRM) task

“Ready (Call Sign) go to (Color) (Number) now”.

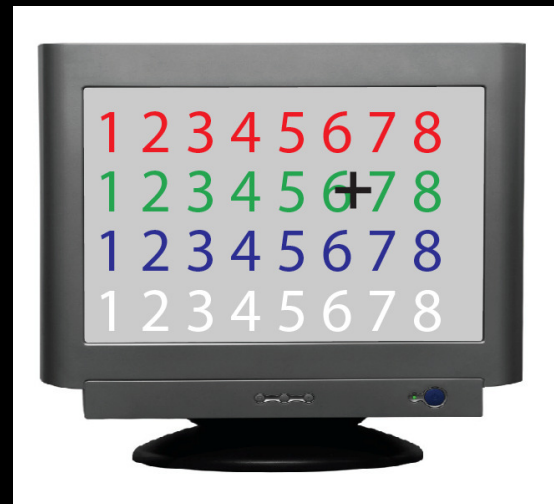
Target: Call Sign = “Baron”

TMR (-6, -3, 0, 3, 6 dB)

2 Same-sex talkers:

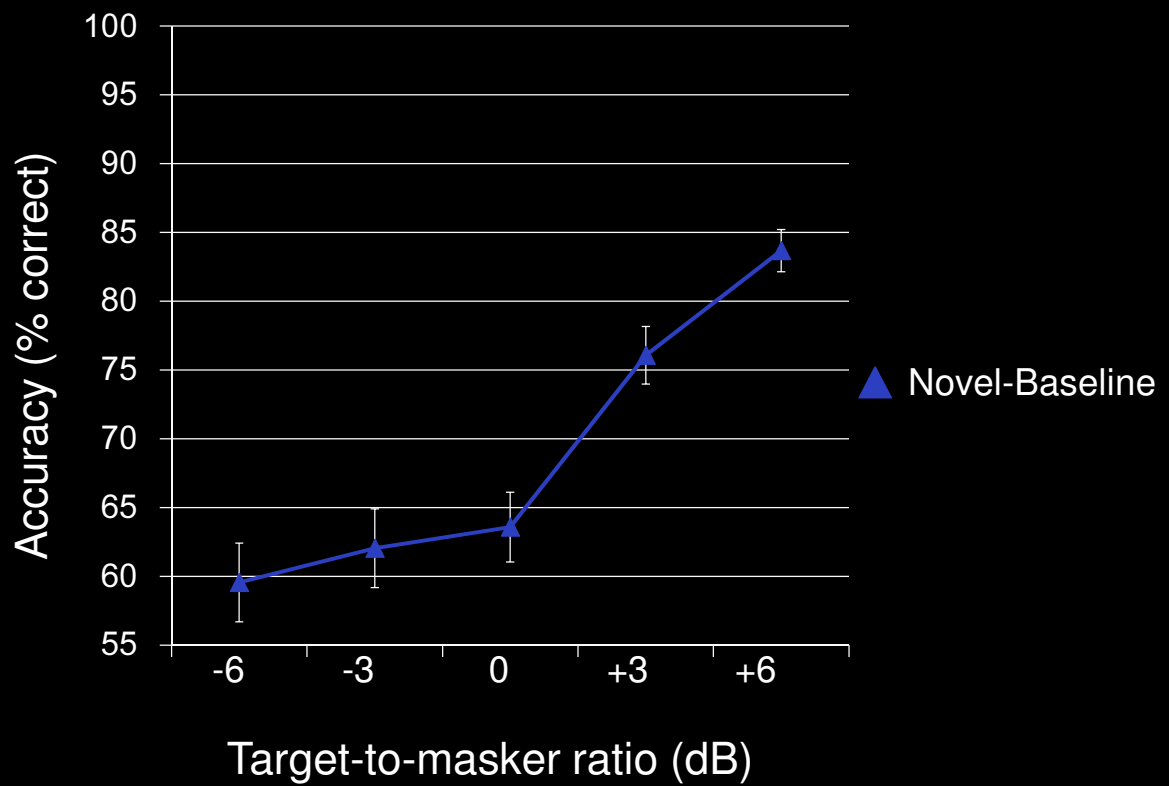


Condition	Target voice	Masker voice
Familiar-Target	Familiar	Novel 1
	Familiar	Novel 2
Familiar-Masker	Novel 1	Familiar
	Novel 2	Familiar
Novel-Baseline	Novel 1	Novel 2
	Novel 2	Novel 1



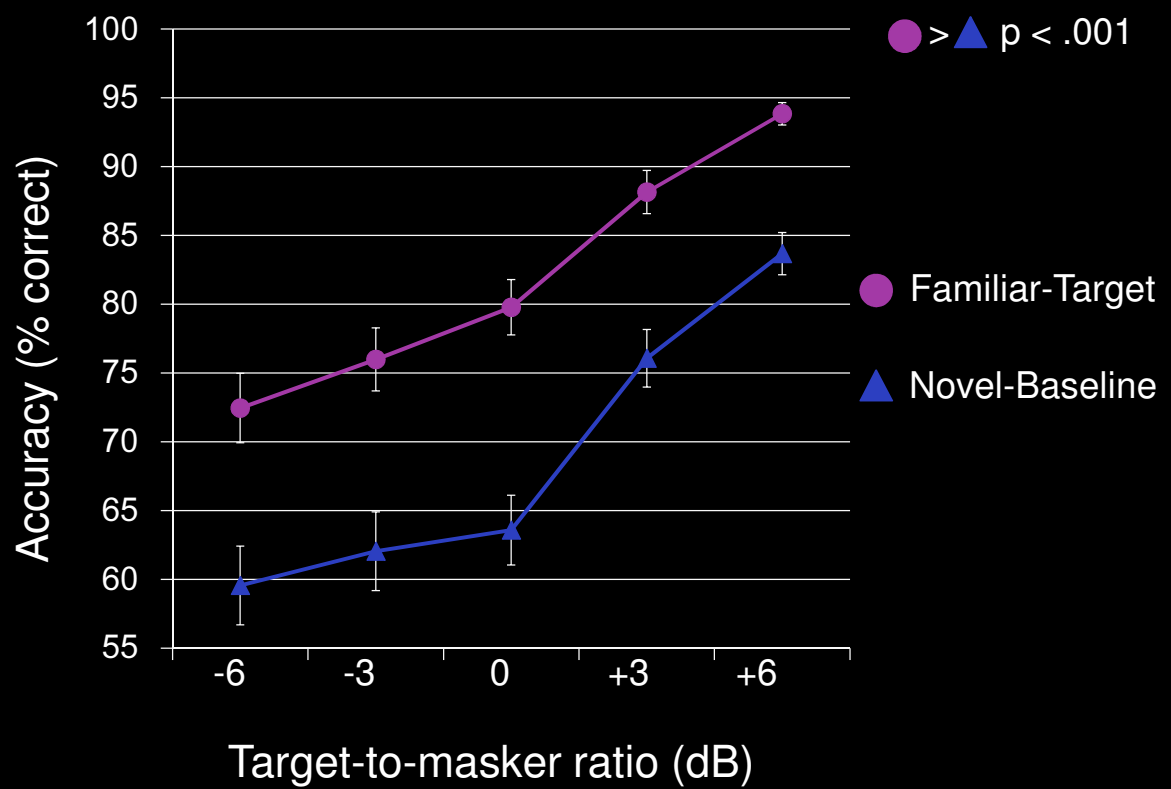
Bolia et al (2000). J Acoust Soc Am. 107: 1065-1066.
 Brungart (2001). J Acoust Soc Am. 109: 2276-9.
 Darwin et al (2003). J Acoust Soc Am. 114: 2913-22

Performance by condition



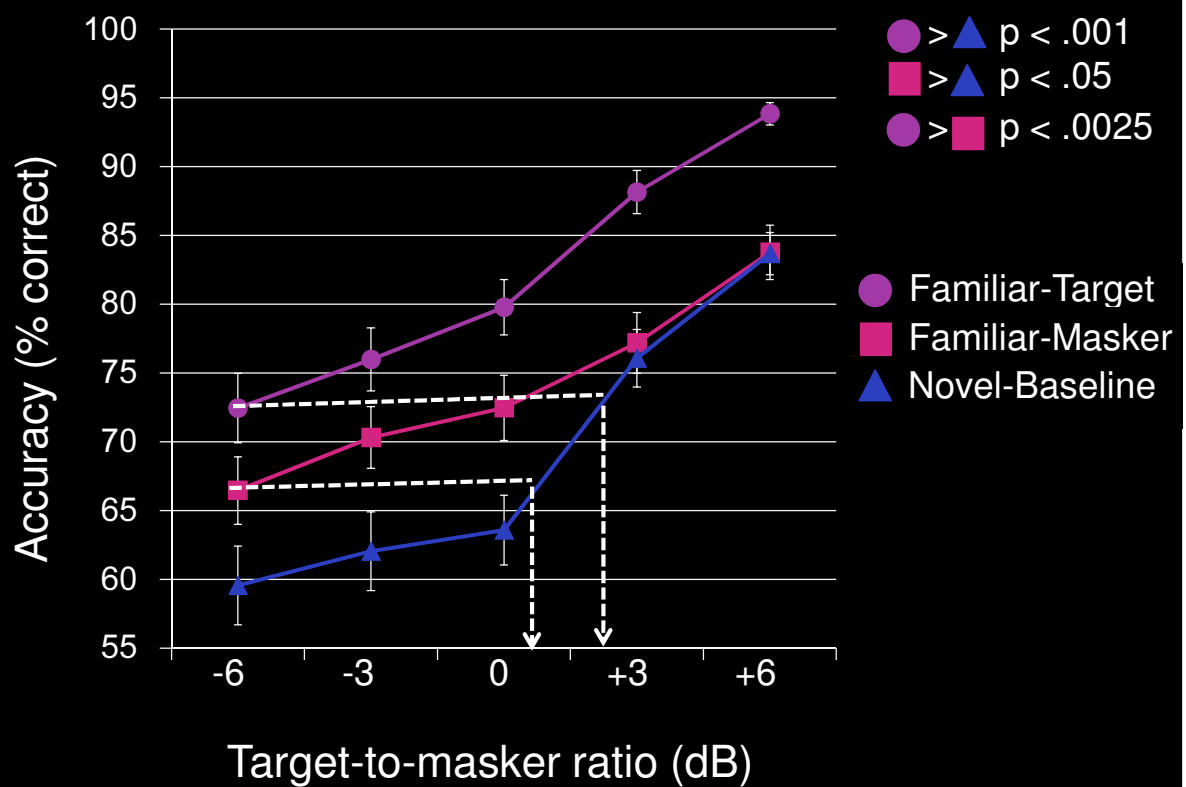
Johnsrude et al (2013) Psychological Science

Performance by condition



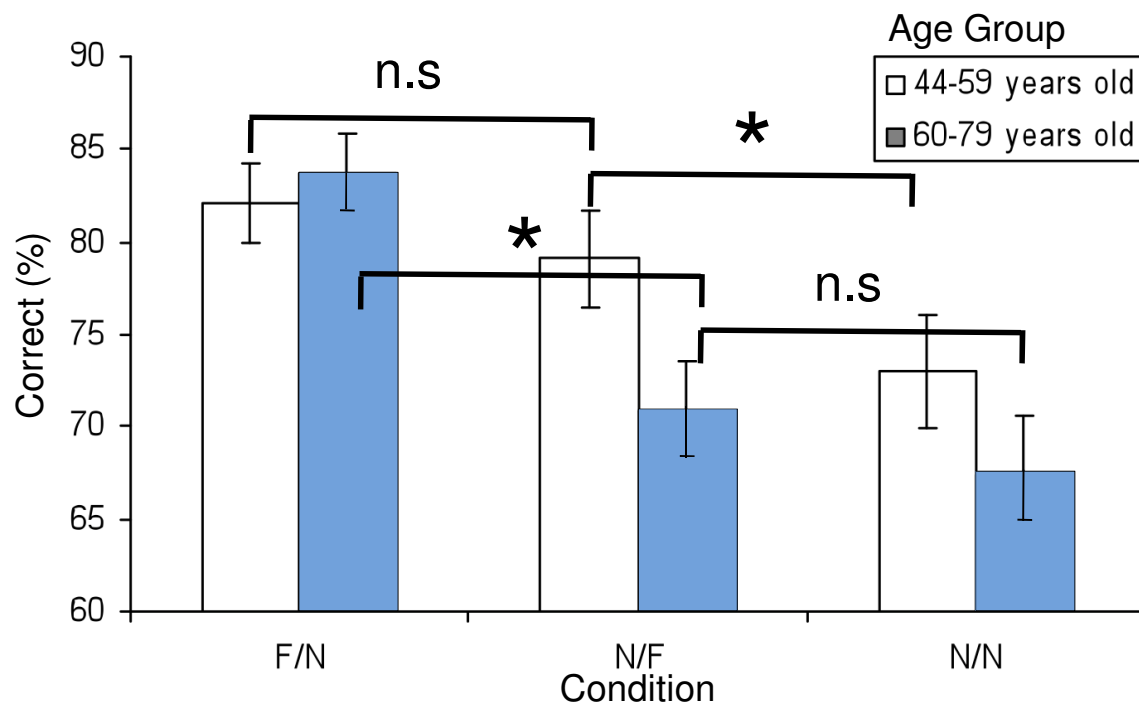
Johnsrude et al (2013) Psychological Science

Performance by condition



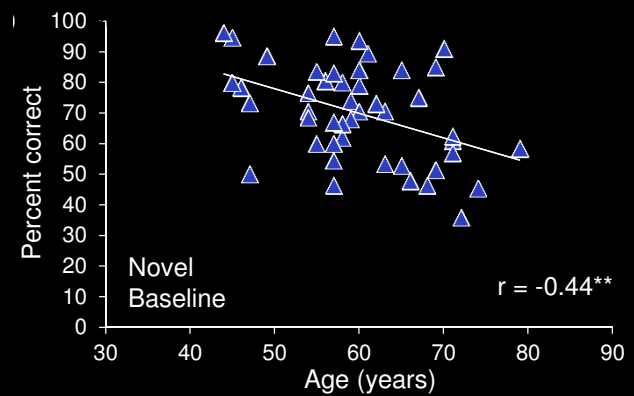
Johnsrude et al (2013) Psychological Science

Middle aged (but not older) people benefit from having their spouse as competing voice



Johnsrude et al (2013) *Psychological Science*

Condition by age interaction

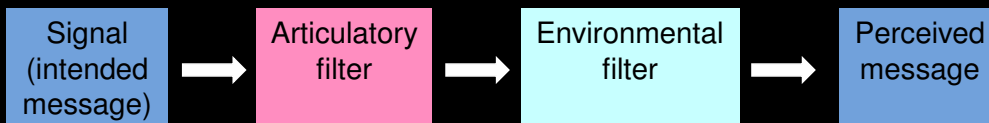


Johnsrude et al (2013) Psychological Science

Conclusions – Knowledge of a talker

- *Effective benefit of $\sim +6-9$ dB SNR for these materials*
- *A familiar target voice helps listeners compensate for age-related changes in hearing and cognition.*
- *Older subjects do not benefit from having the spouse voice as masker.*
 - *Age-related changes in cognition?*

Sources of knowledge in speech perception



Topic
 World Knowledge
 Lexical knowledge
 Syntax
 Dialect
 Talker identity (ideolect, etc)
 ●
 ●

Talker identity
 Sex/Size
 Accent
 Visible speech
 ●
 ●
 ●

Physics of sound and reverberation
 Room acoustics
 Knowledge of interfering talkers
 Sound correlates of visible sources
 ●
 ●
 ●

Knowledge may:

Improve segregation of sources

Increase effective SNR

Help “fill in” missing information

- the match ended as a tie
- the star had many fans who came to all his concerts
- a spade was not the suit that the card player wanted

Sentences with ambiguous words (homophones)

- the **match** ended as a **tie**
- the **star** had many **fans** who came to all his concerts
- a **spade** was not the **suit** that the **card** player wanted



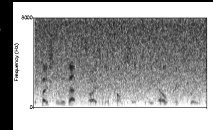
Lexical ambiguity
is ubiquitous



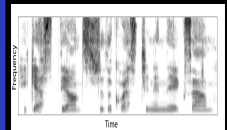
Semantic ambiguity in sentences

- High-ambiguity sentences
*“the **shell** was **fired** towards the **tank**”*
at least 2 ambiguous words

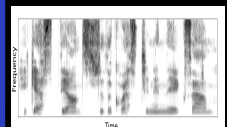
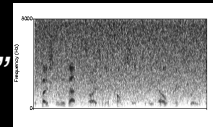
In Noise



Clear

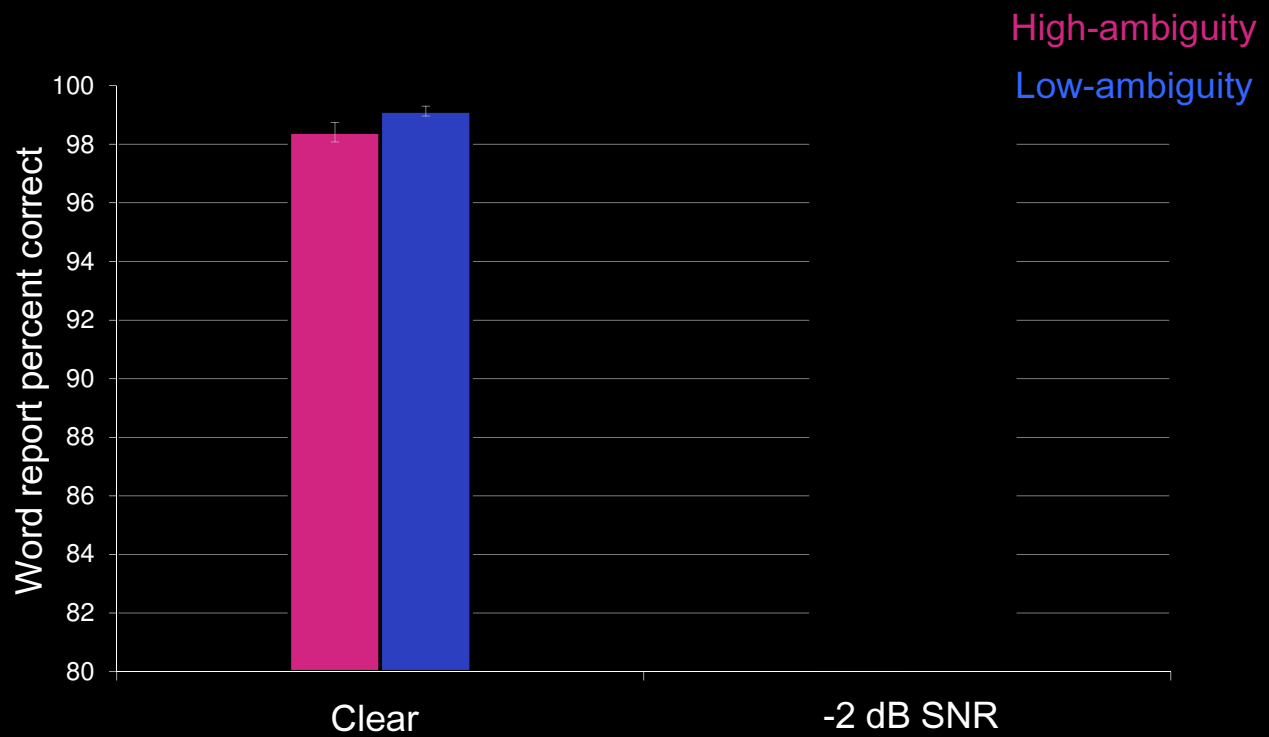


- Low-ambiguity sentences
“her secrets were written in her diary”

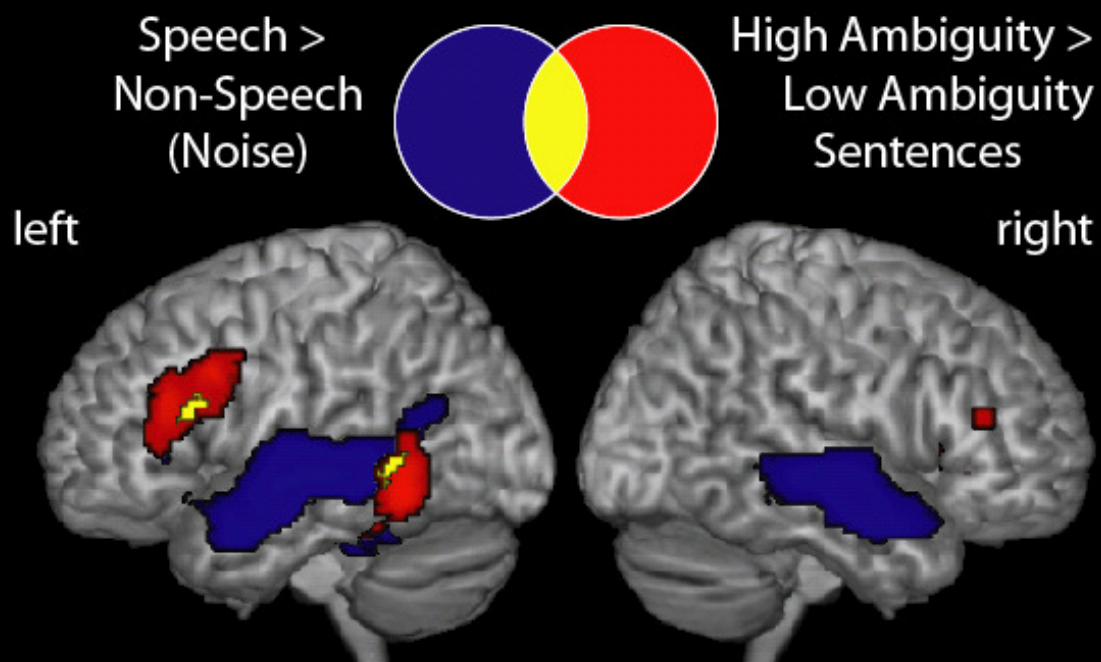


Johnsrude, Rodd, & Davis (in prep)

High-ambiguity sentences are less intelligible in noise

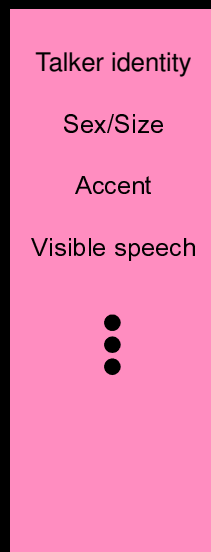
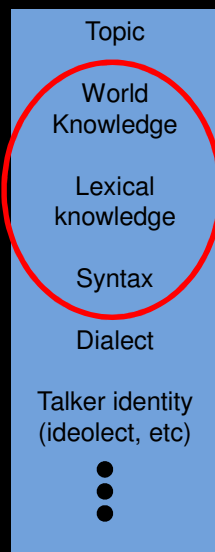
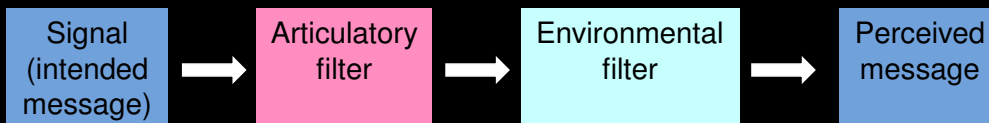


More activity for sentences with ambiguous words



Rodd et al (2012) Cerebral Cortex
Davis et al (2007) PNAS
Rodd et al (2005) Cerebral Cortex

Sources of knowledge in speech perception



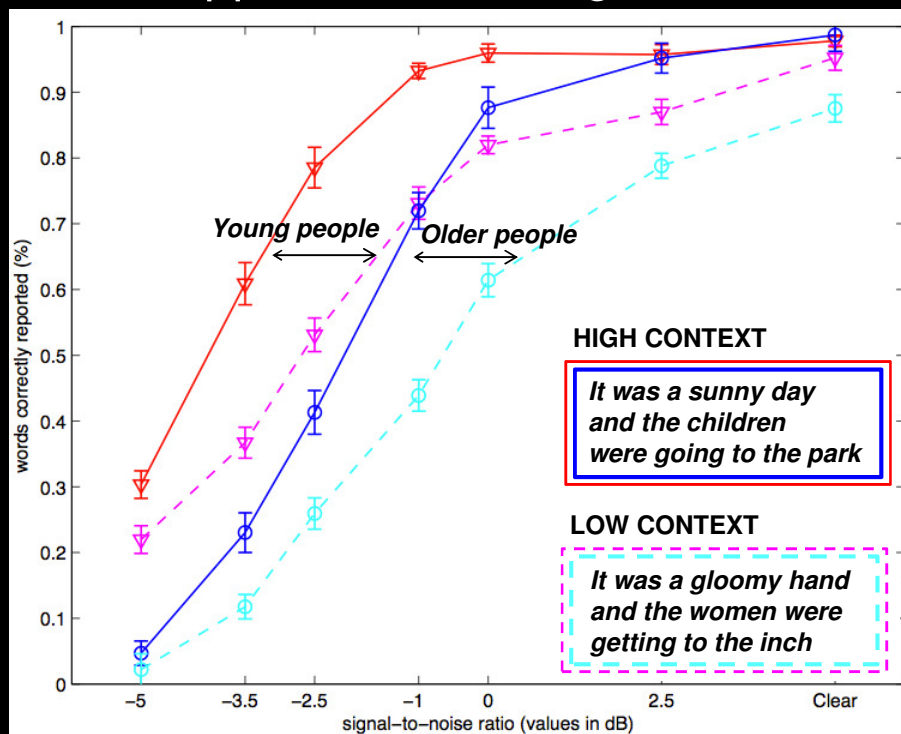
Knowledge may:

Improve segregation of sources

Increase effective SNR

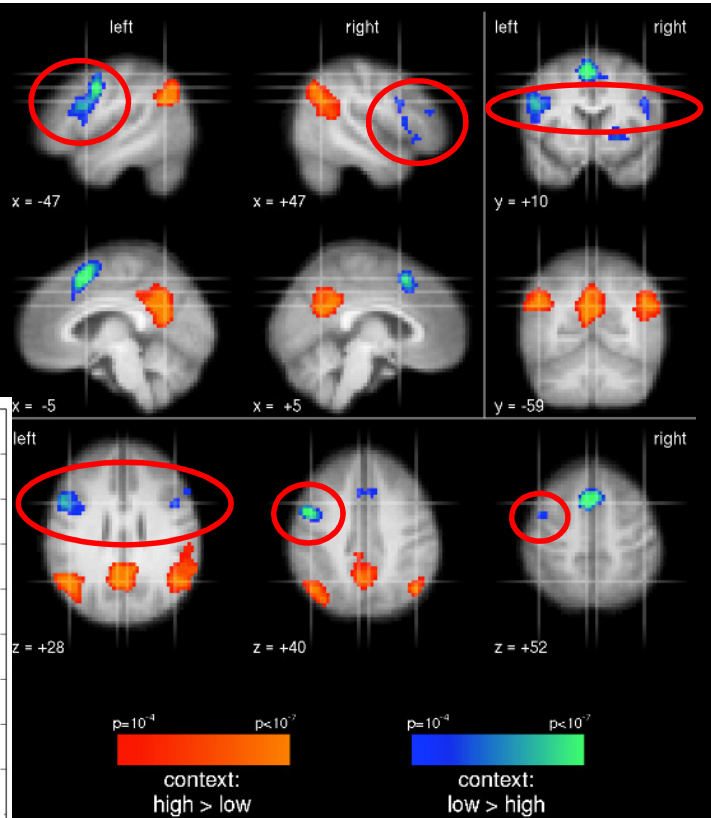
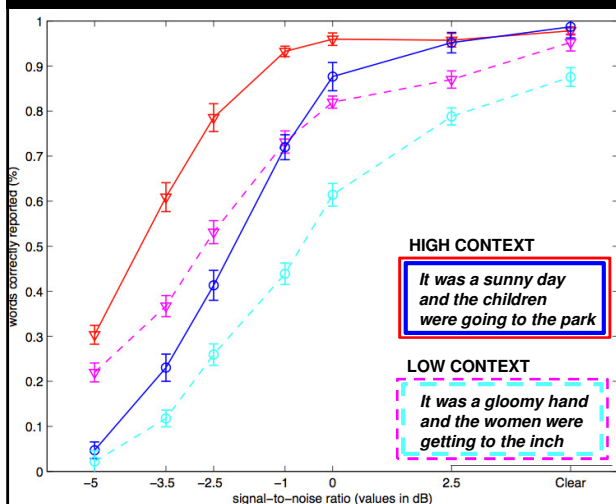
Help "fill in" missing information

Intelligibility better when sentences contain supportive, meaningful context



Trang et al (in preparation)

Left lateral frontal regions
more active for low,
compared to high,
context



Trang et al (in preparation)



Outline



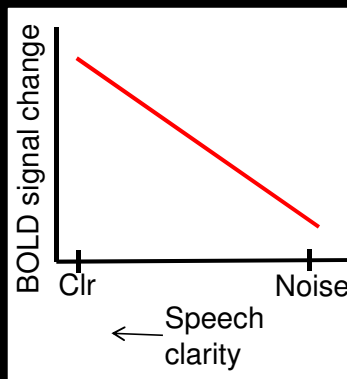
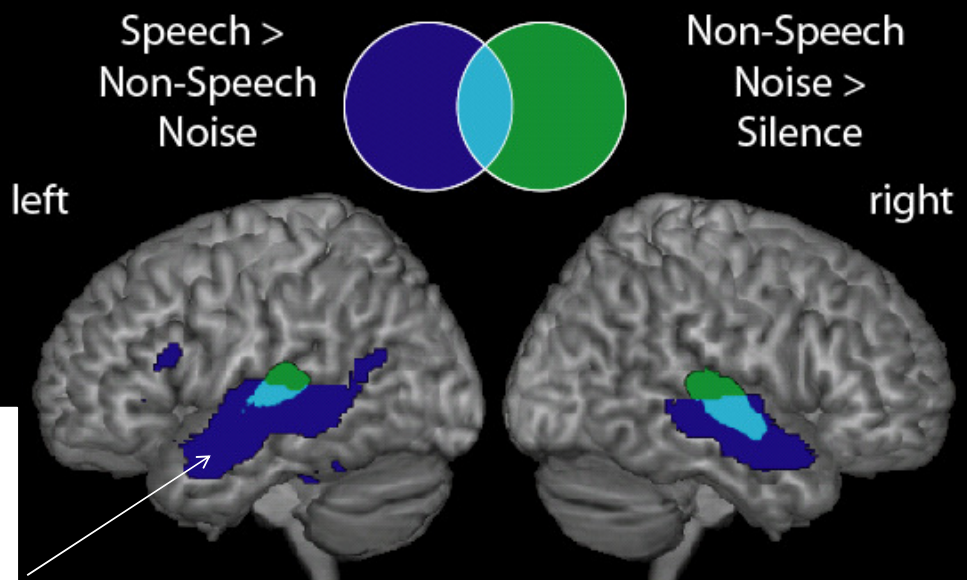
1. *How knowledge and experience influence perception of noisy and ambiguous speech.*

- *having a familiar voice in a mixture helps not just “hear” that voice better but may help a listener to “hear” the other voice too.*
- *knowledge of words and their meanings helps, but can also hinder-*
- *visual and semantic context help.*

2. Cognitive factors such as attention influence perception of noisy and ambiguous speech.

3. What is listening effort?

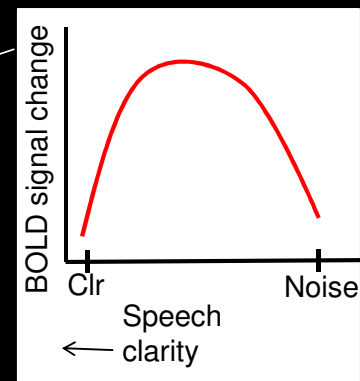
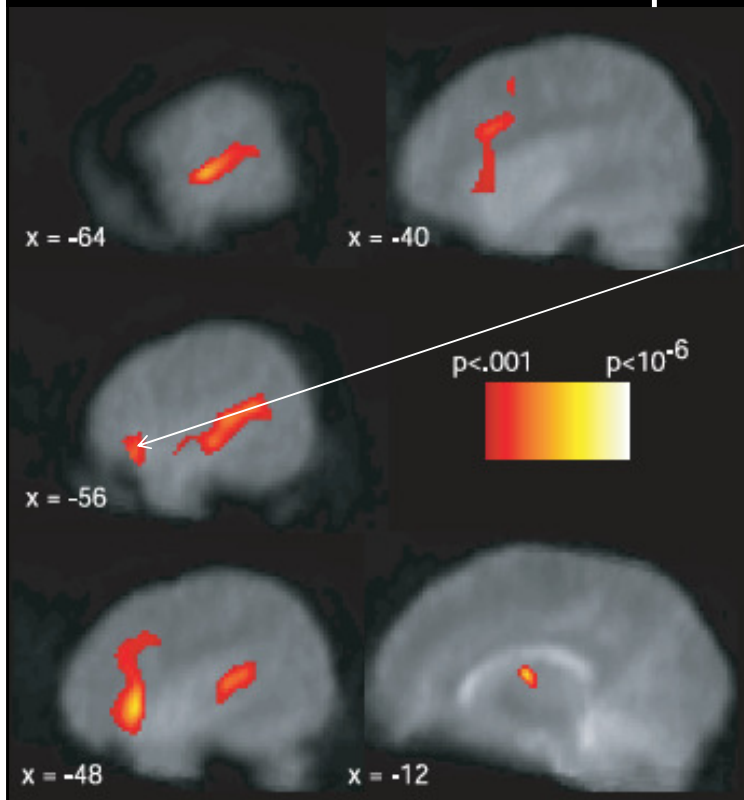
How well can degraded speech be processed outside the focus of attention?



“Intelligibility response”

Davis & Johnsrude (2003) J Neurosci
Rodd et al (2005) Cerebral Cortex


“Distortion-elevated Response”


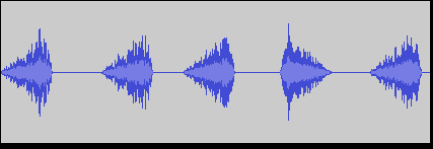
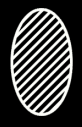


Davis & Johnsrude (2003) J Neurosci
Davis et al (2011) J Cog Neurosci
Hervais-Adelman et al (2012) Lang
Cog Proc
Johnsrude et al (in preparation)

How well can degraded speech be processed outside the focus of attention?

4 Speech Types X 3 Attention conditions


1. Clear speech
2. High-intelligibility NV speech (6-band) 
3. Lower-intelligibility NV speech (6-band, envelope-compressed)
4. Rotated 6-band NV speech

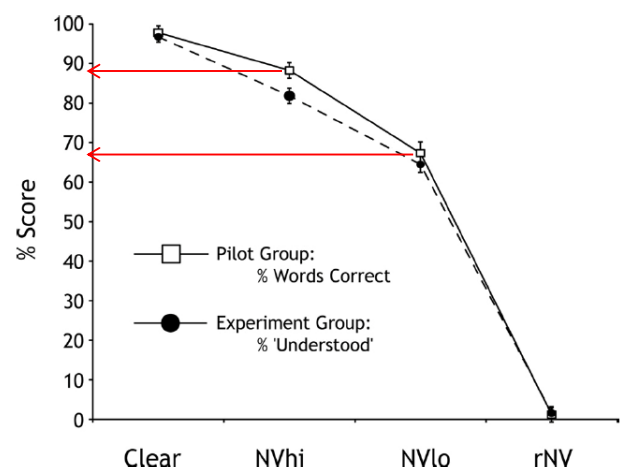
1. Attend to **speech**
- Binary decision: understood, or not
2. **Auditory Distraction** 
- Binary decision: target present?

3. **Visual Distraction** 
- Binary decision: target present?

Wild et al (2012) J Neurosci 32, 14010-21

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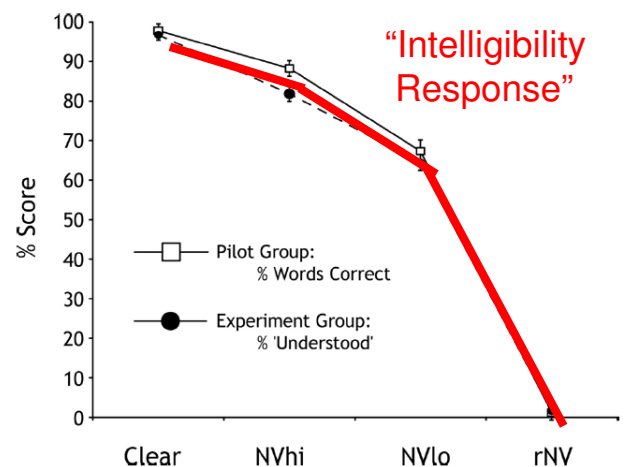


Wild et al (2012) J Neurosci 32, 14010-21

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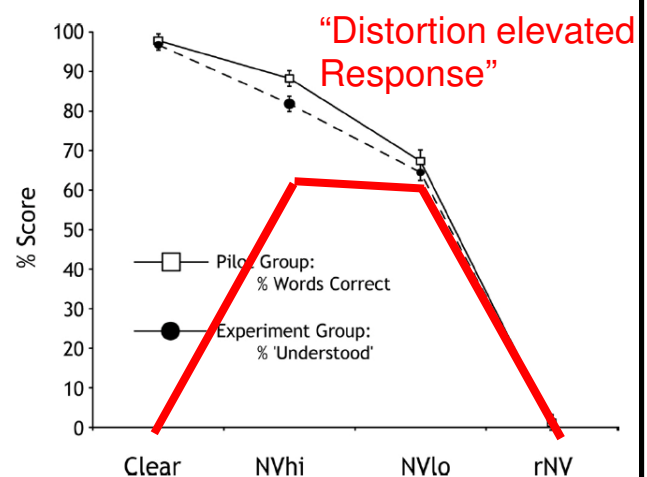


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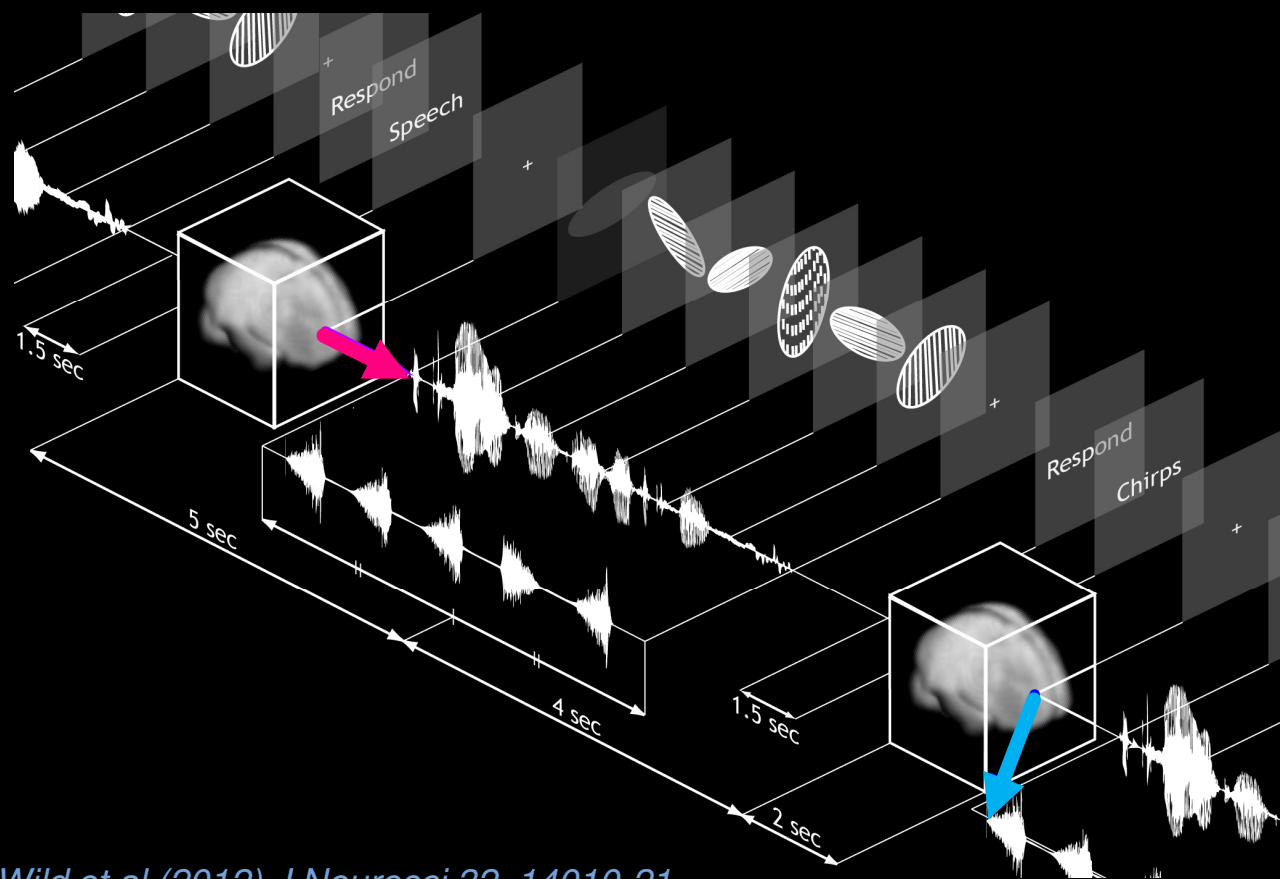
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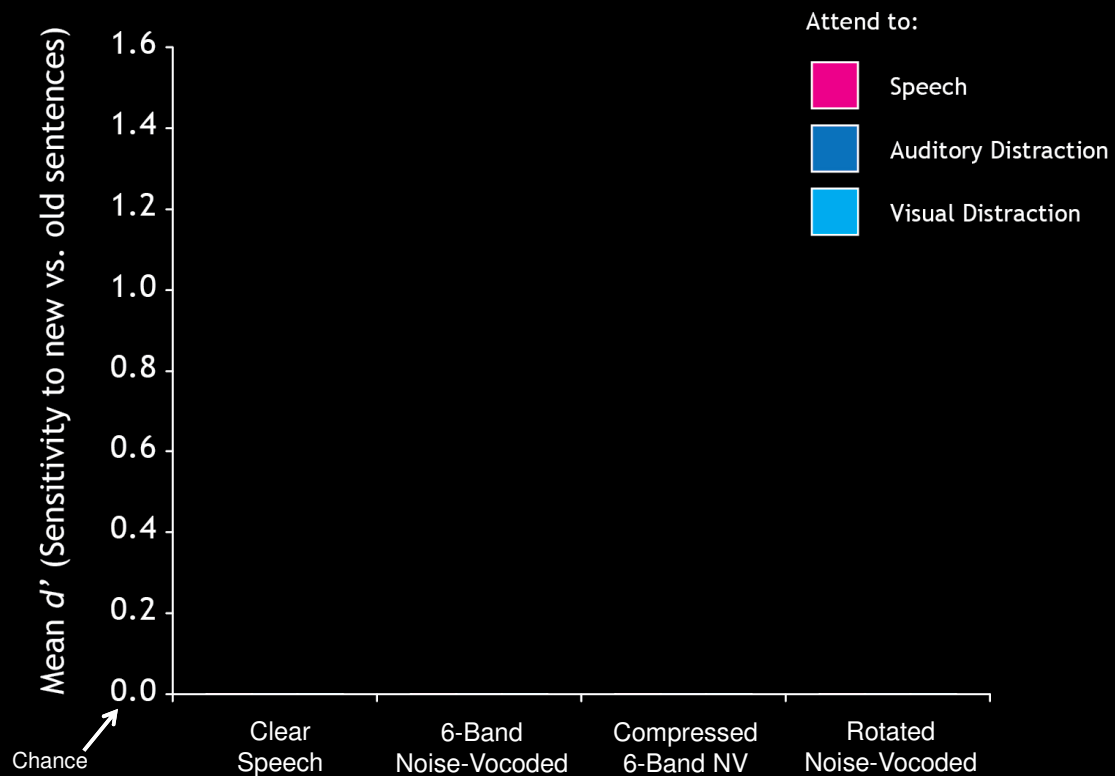
Wild et al (2012) J Neurosci 32, 14010-21

Imaging procedure



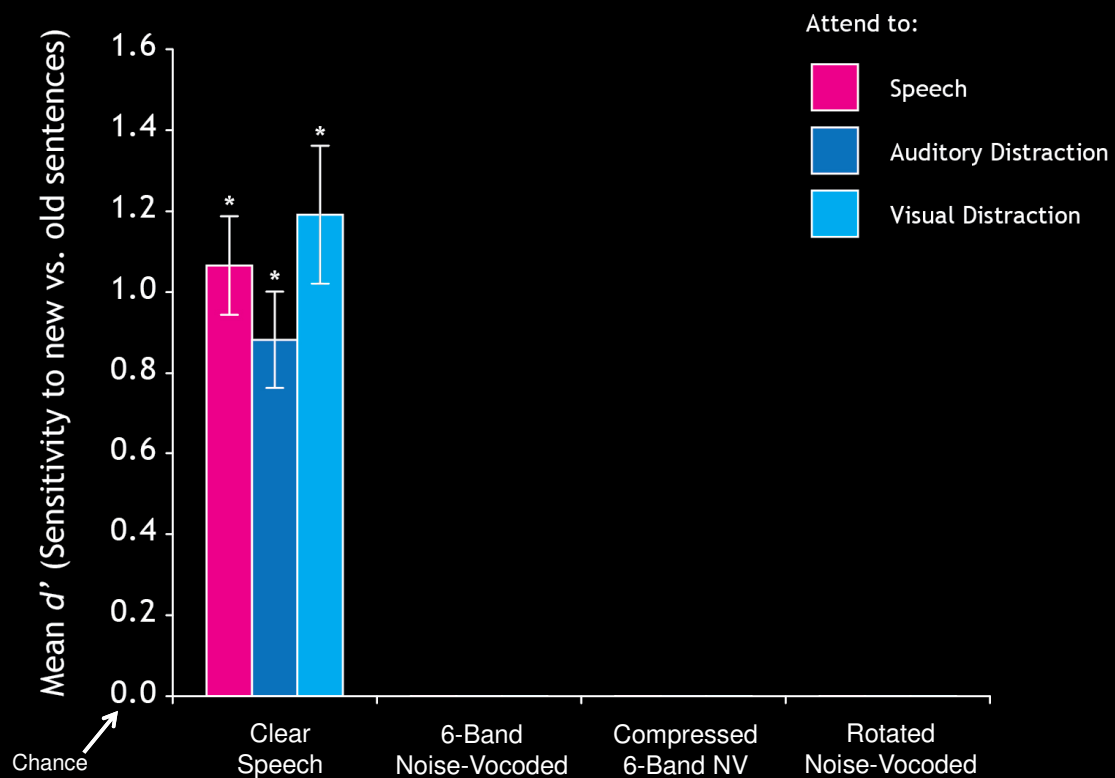
Wild et al (2012) J Neurosci 32, 14010-21

How well were sentences remembered?



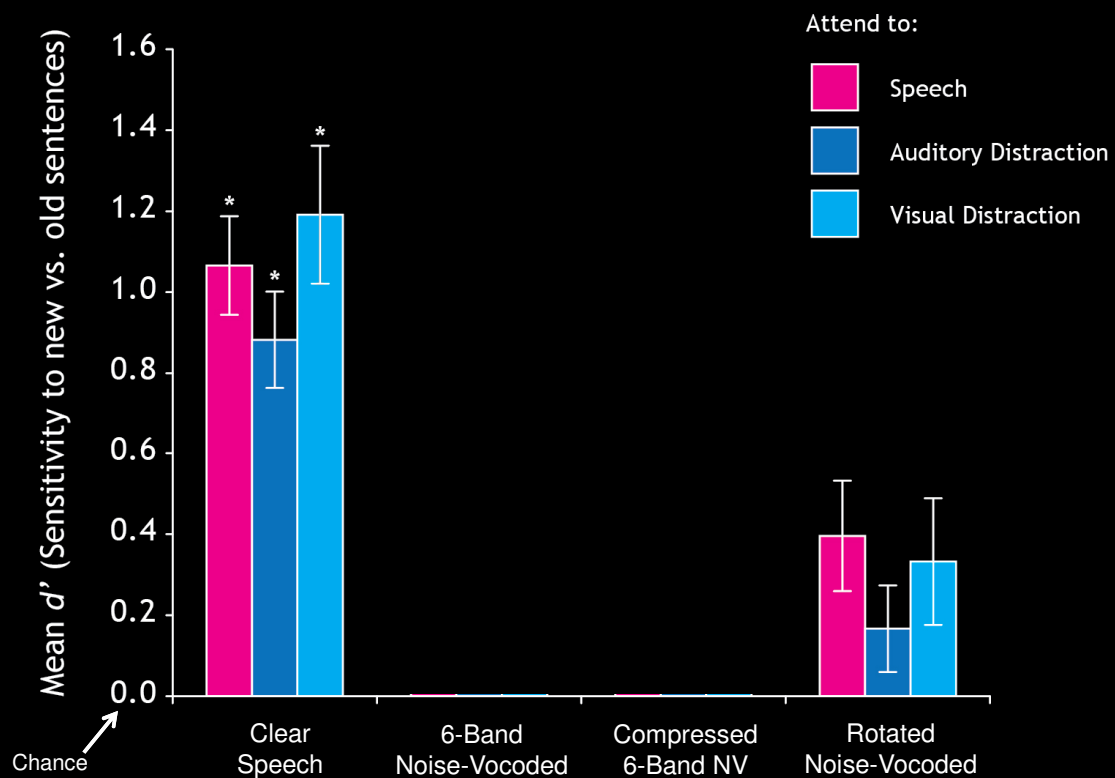
Wild et al (2012) J Neurosci 32, 14010-21

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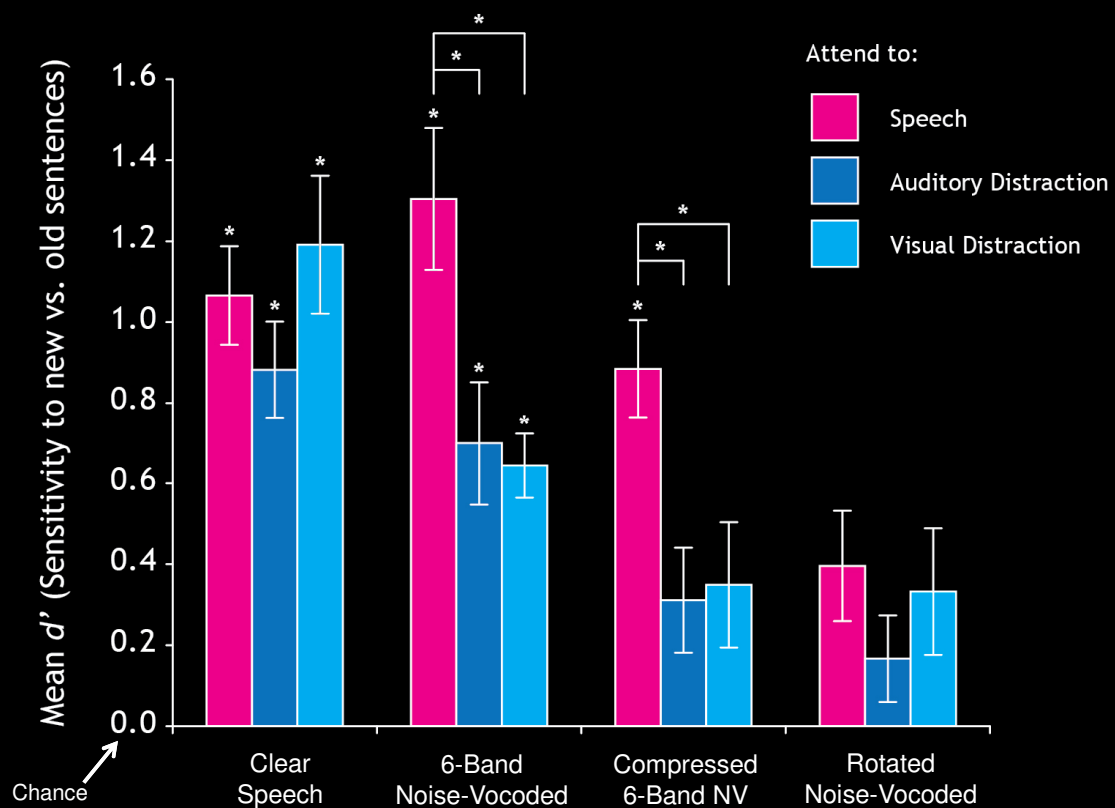
Wild et al (2012) J Neurosci 32, 14010-21

How well were sentences remembered?



Wild et al (2012) *J Neurosci* 32, 14010-21

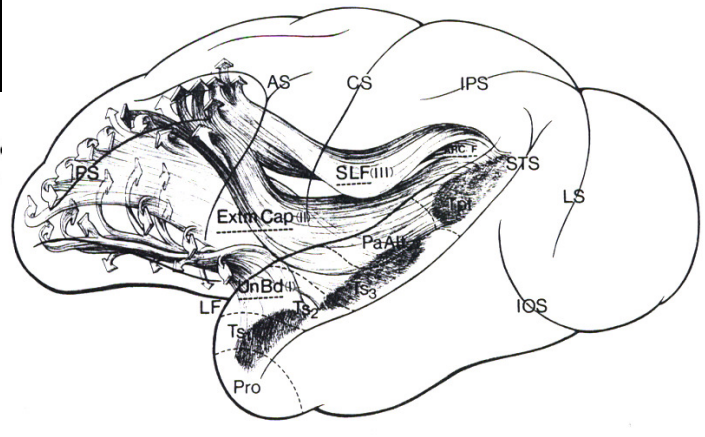
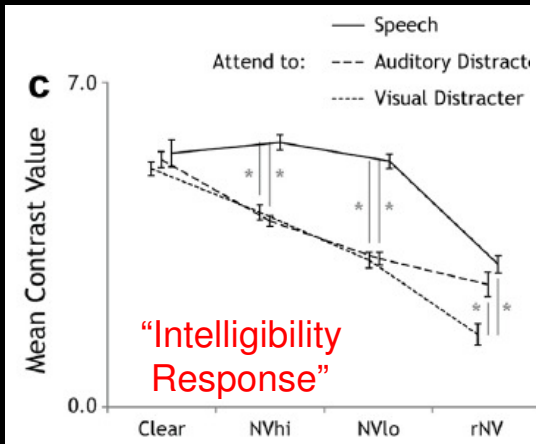
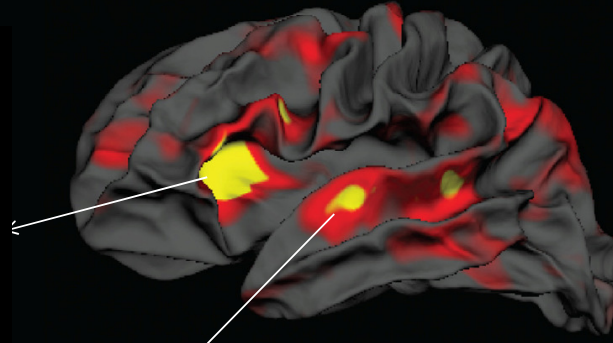
How well were sentences remembered?



Wild et al (2012) J Neurosci 32, 14010-21

Results: Interaction between speech type and attention

“Noise-elevated Response”



Petrides M & Pandya, DN (1988).
J Comparative Neurology, 273, 52-66

Outline

1. *How knowledge and experience influence perception of noisy and ambiguous speech.*

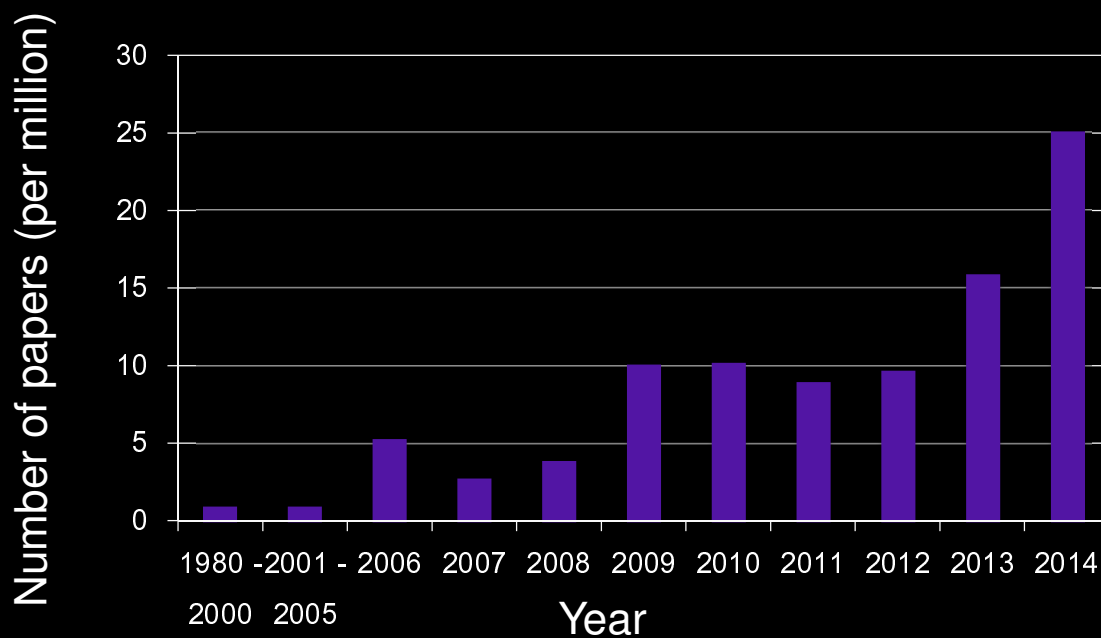
- *having a familiar voice in a mixture helps not just “hear” that voice better but may help a listener to “hear” the other voice.*
- *knowledge of words and their meanings helps, but can also hinder-*
- *visual and semantic context help.*

2. Cognitive factors such as attention influence perception of noisy and ambiguous speech.

- *attention is required to understand even quite intelligible degraded speech; more than for clear speech.*

3. What is listening effort?

“listening effort” or “effortful listening” or “ease of listening” on PubMed: 1980-2014



“auditory scene analysis”: 41

“hearing impairment” or deafness: 1160

hypertension: 16, 974

Listening effort

Despite equivalent performance, may explain variation in:

Fatigue (*e.g.*, Hétu *et al*, 1988; Hicks & Tharpe, 2002; Kramer *et al*, 2006; McGarrigle, 2014)

‘Downstream’ memory for spoken information
(*e.g.*, Rabbitt, 1968, 1991; Pichora-Fuller, 2003; Wingfield *et al*, 2005; Piquado *et al*, 2012)

Hearing aid use (bedside-table drawer problem)

(Chien & Lin, 2012; Öberg *et al*, 2012; McCormack & Fortnum, 2013)

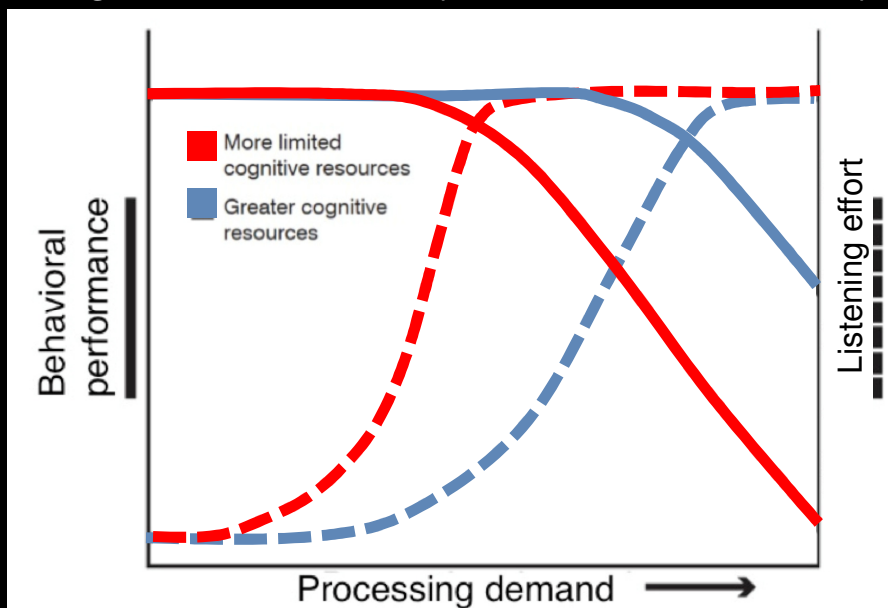
What is listening effort?

“The attention and cognitive resources required to understand speech”

(Hicks & Tharpe, 2002; Gosselin & Gagné, 2011; Fraser et al, 2011; Picou et al, 2011; McGarrigle et al, 2014).

What is “listening effort”?

Interaction between:
processing demands and
cognitive resources (individual differences)



Johnsrude, IS & Rodd JM (in press). Factors that increase the processing demands when listening to speech. In Neurobiology of Language (G Hickok and S Small, eds), Elsevier.

What is “listening effort”?

Interaction between:

cognitive resources (individual differences), and
processing demands of the listening situation.

Different types of processing demands:

1. *Perceptual demands*

e.g., adverse listening conditions; degradation caused by hearing impairment; distortion caused by CI or HA
processing strategy ; novel (compared to familiar) voices
and accents.

2. *Linguistic demands*

e.g., ambiguity; semantic and/or syntactic complexity;
lack of meaningful semantic context.

3. *Task demands*

e.g., concurrent task

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- *visual and semantic context help.*

2. Cognitive factors such as attention influence perception of noisy and ambiguous speech.

- *attention is required to understand even quite intelligible degraded speech; more than for clear speech.*

3. What is listening effort?

- *depends on:*
 - *the cognitive resources of the listener*
 - *the processing demands of the listening situation, which are met by cognition in different ways. Therefore – many different kinds of listening effort.*

Thanks to

Jennifer Rodd

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