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Department of Surgery

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Spectral degradation affects the efficiency of sentence processing: evidence from measures of pupil dilation


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INTRODUCTION

Prediction

is a fundamental aspect of cognition. [1,2]

In Speech Perception,
prediction is driven by:

Acoustics
Coarticulation lets you predict upcoming sounds [3,4]

Knowledge of a talker
You have ideas about what a talker should sound like [5]

Context
Words are easier to recognize when preceded by relevant context [6,7]

Context helps us predict and understand what we are *about to hear*

"Sweep the floor with a *broom*"

"Stuart thought about a *broom*"

High-context sentences are more intelligible than **low-context** sentences

Context facilitates faster word recognition

Questions in this study:

1. Does context reduce *listening effort*?
   (i.e. do you get "effort release" from context?)
2. If so, how quickly does it occur?
3. Does it occur in people with cochlear implants?
   (i.e. does spectral degradation interfere with effort release?)

Can people with CIs USE and benefit from context as quickly and effectively as people with normal hearing?

They report disproportionate reliance on context ....

... but the signal isn't delivered with good clarity, so the context might not be utilized optimally

METHODS

PARTICIPANTS: 21 young listeners with normal hearing (ages 19 – 32 y)
12 listeners with cochlear implants (ages 40– 67 y)

STIMULI: **Revised speech-in-noise (R-SPiN) sentence lists** [6]
Each list contains 25 high-context and 25 low-context sentences.

SPECTRAL RESOLUTION:
Four testing blocks alternated in **sound quality** between normal (clear) speech and degraded (8-channel vocoded) speech.

PROCEDURE:
Listen to & repeat sentences while fixating on a monitor

(3 s silence) Stimulus (2 s silence) Response
"Stir your coffee with a spoon"

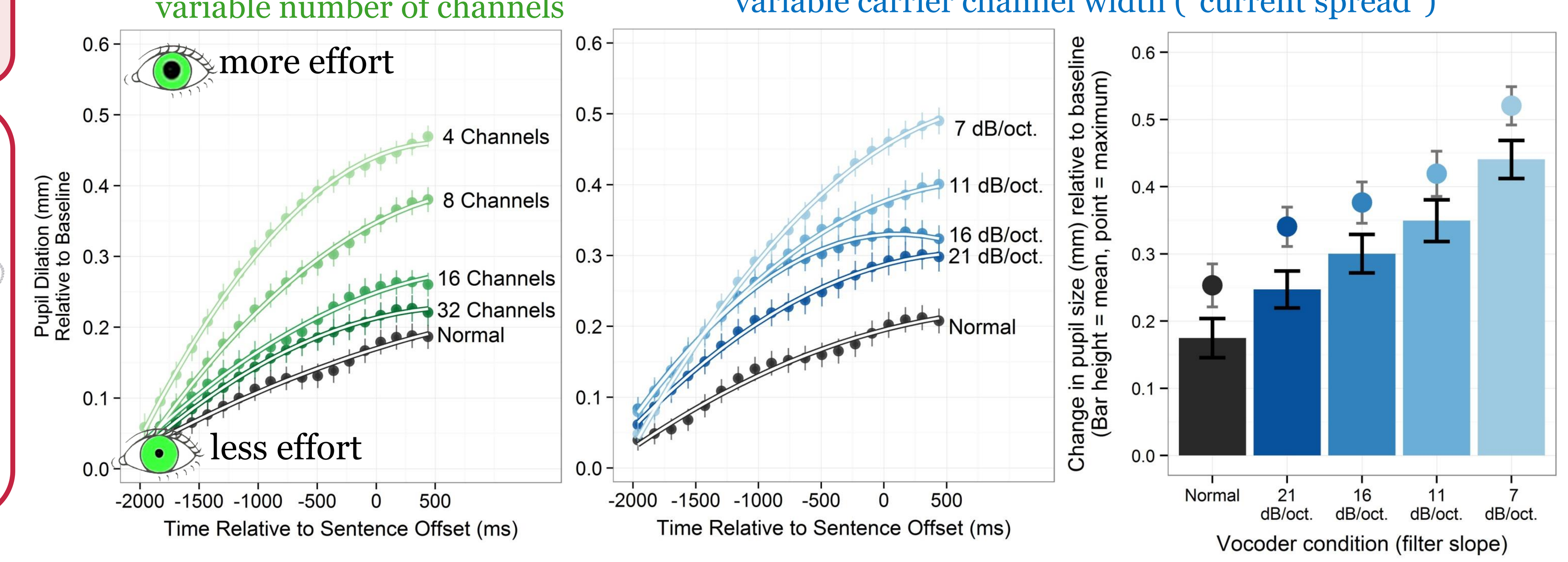
INTELLIGIBILITY: scored by hand during testing

	NH		NH vocoded		CI	
	high-context	low-context	high-context	low-context	high-context	low-context
% of sentences with errors on "context"	2	2	16	22	9	15
% of sentences with target-word errors	3	3	11	38	8	32
% of target word errors preceded by "context" errors	1	1	8	9	5	6

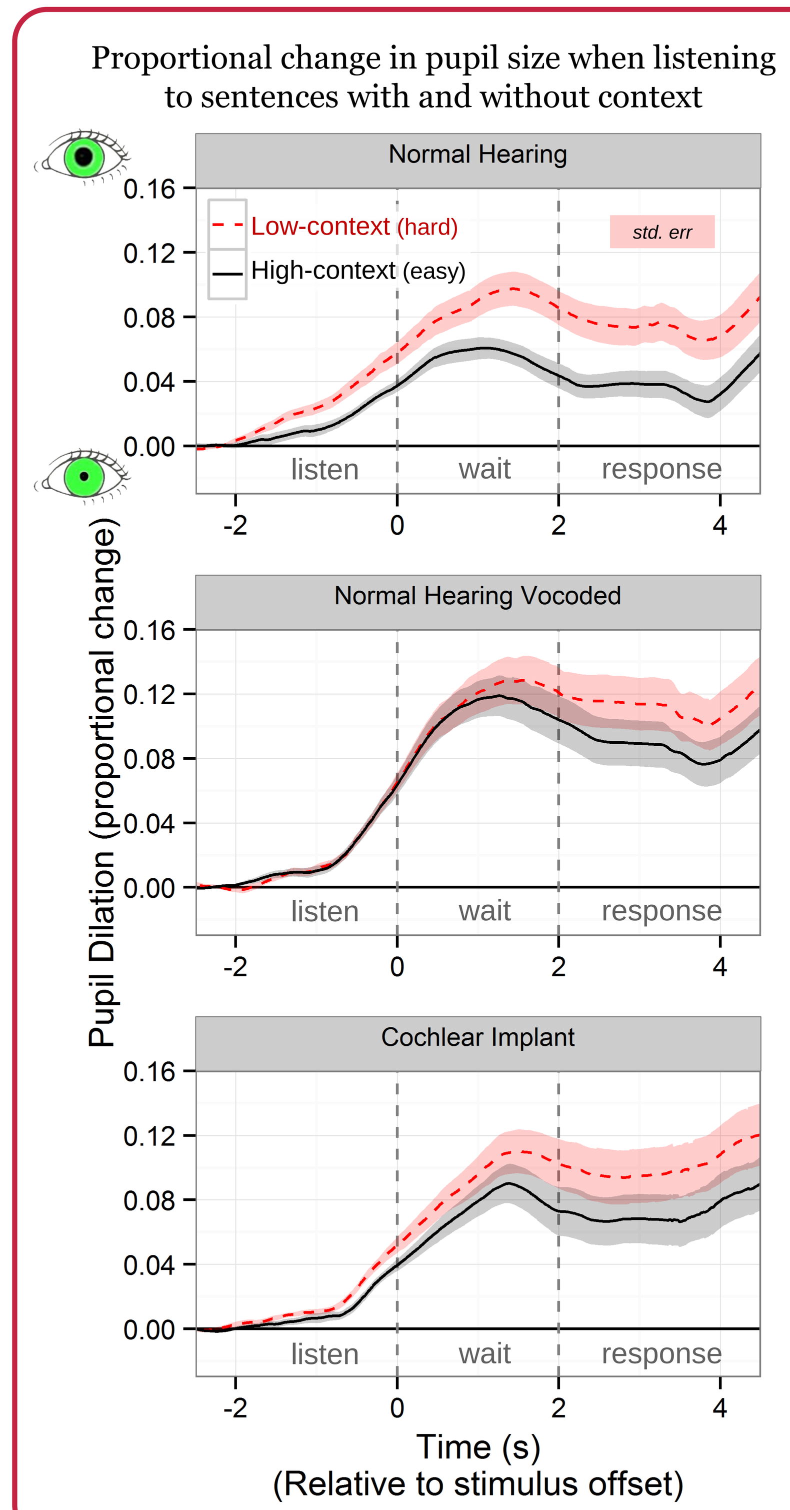
MEASUREMENT OF LISTENING EFFORT:
High-speed **eye tracking** was used to measure pupil dilation during each trial.
Greater pupil dilation indicates increased listening effort [8, 9]

WHY MEASURE PUPIL DILATION?

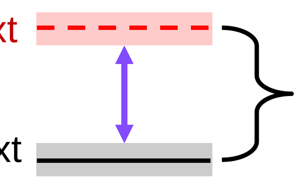
Pupil dilation is affected by relevant factors such as spectral resolution [10].
We want to observe the growth of effort *during* the perceptual process.

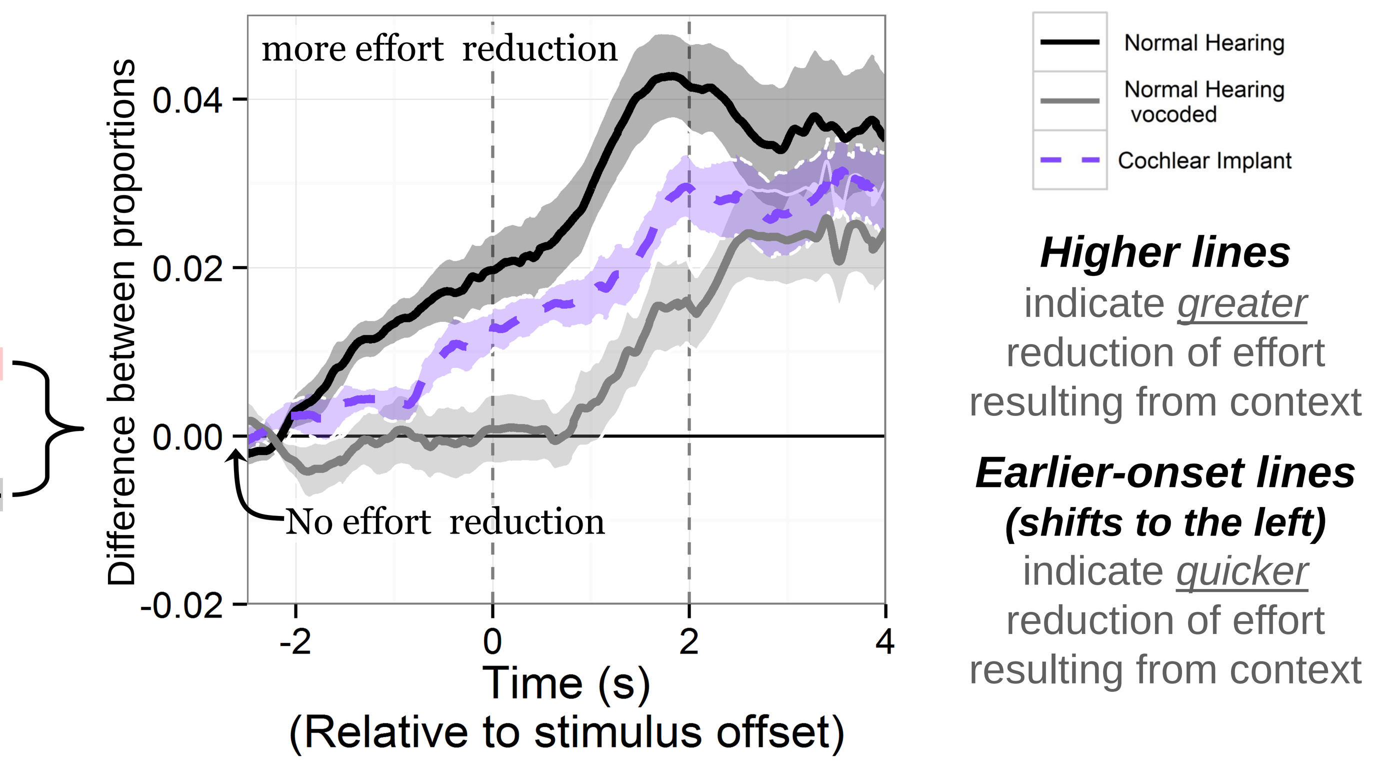


RESULTS: The effect of context on listening effort



Context-driven Effort Release





Higher lines indicate *greater* reduction of effort resulting from context

Earlier-onset lines (shifts to the left) indicate *quicker* reduction of effort resulting from context

Analysis

Difference between curves was modeled using a 3-parameter sigmoidal function to describe the *degree* and *latency* of reduction in pupil dilation in high-context sentences

$$\text{Effort release} = \frac{(max * group)}{1 + e^{(Time \times (-slope * group) + shift * group)}}$$

** xxxx denotes interaction*

	$Max \;/\; 1 + e^{(Time + shift) \times -slope}$
NH listeners:	
Normal speech: *immediate online* benefit of context, *before* the sentence is over	$0.040 \;/\; 1 + e^{(Time - 0.16) \times -1.25}$
Vocoded speech: *post-hoc* benefit of context, *after* the sentence is over	$0.025 \;/\; 1 + e^{(Time + 1.62) \times -2.55}$
CI listeners: *delayed* benefit of context, and less benefit compared to NH listeners	$0.031 \;/\; 1 + e^{(Time + 0.50) \times -1.11}$

CONCLUSIONS

- Semantic context reduces listening effort *immediately* for NH listeners, and *after a slight delay (~ 1 second)* for CI listeners
  - Likely mechanism of this effect: narrowing the spread of activation in the semantic network, reducing the need for vigilance of *all* possibilities
- Context-driven effort release in CI users doesn't occur as late as that for NH listeners listening to vocoded speech, perhaps because of the differences between groups in terms of *experience* with degraded signals.
- Context can help to resolve a sentence *after* it has been spoken (i.e. "oh, that's what that word was..."), *but in conversational speech, we don't have lengthy silent pauses after sentences for listeners to catch up and recover context; a brief delay in processing could cause interference between the last sentence and the next sentence*

Speech perception is more than just recognition of isolated units like syllables and words:
Poor signal quality can cause disruption in the *ongoing process* of prediction and restoration of words based on context and other higher-level processes

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