The impact of spectral resolution on the efficiency of sentence processing


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INTRODUCTION

Semantic context
helps us understand speech

The old cabin was made of *logs*

The duck swam with the white *swan*

"duck" – you're thinking of birds
"swam" – related to duck, you're thinking about things in water
"white" – a white bird in the water is a ….
You know the last word (swan) even before you hear it

Sentences without context
can be more challenging

They did not discuss the *logs*
The woman considered the *swan*

"swan" is no longer predictable based on the first half of the sentence

Spectral resolution
(the ability to hear sound frequency distinctions)

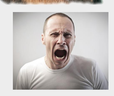
… is especially important for speech perception and is a major challenge for people who use cochlear implants (CIs).

CI listeners and other people with hearing impairment show disproportionate reliance on context

BUT if the contextual information is delivered with poor sound quality, it might not be as helpful.

The lion gave an angry *roar*.

If you heard "lion" as "man", then you are *less* likely to predict that the final word is "roar"



The sandal has a broken *strap*.

If you didn't *clearly* hear "sandal", then the context might not be exploited as quickly

Question in this study:
How does spectral degradation interfere with the ability to benefit from semantic context in speech perception?

METHOD

PARTICIPANTS: 6 young listeners with normal hearing (ages 19 – 32 y)

STIMULI: **R-SPiN sentence lists [1]**
Each list contains 25 sentences with context and 25 without context.

PROCEDURE: Participants were prompted to repeat the sentence following a 2-second delay.

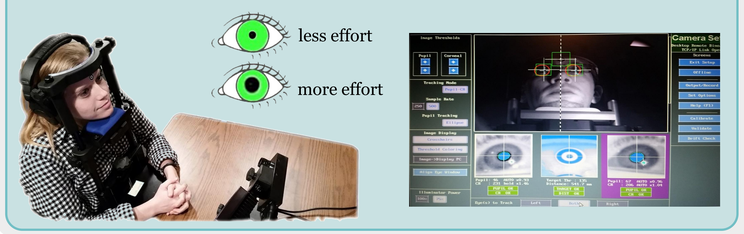
Lists were administered in half-blocks of 25 sentences each (mixed context types in each block)

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

ACCURACY: scored by hand during testing

High-speed **eye tracking** was used to measure pupil dilation during each trial.

Greater pupil dilation indicates increased *listening effort* [2, 3]

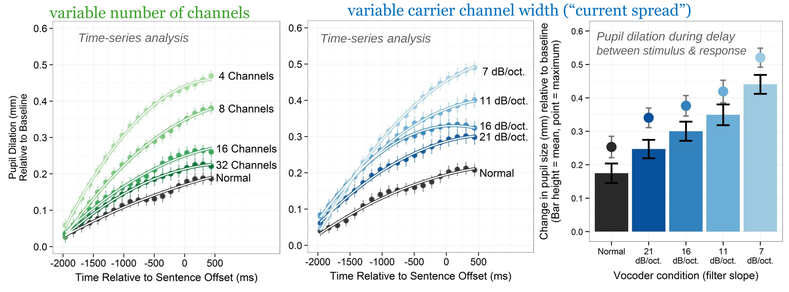


BACKGROUND: WHY MEASURE PUPIL DILATION?

Recent work (*Winn et al, Ear & Hearing [4]*) shows:
As spectral resolution becomes progressively poorer, pupil dilation increases.

1. Noise vocoder with variable number of channels

2. Noise vocoder with variable carrier channel width ("current spread")



Time-series growth curve analysis [5] reveals significant differences between each level in terms of slope of pupil dilation over time.

RESULTS

Error breakdown across sentence types

More word errors for degraded speech

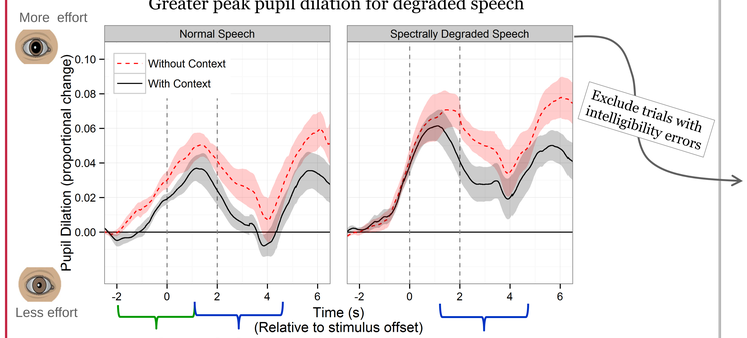
For degraded sentences with context…
Final-word errors were *not* attributable to errors earlier in the sentence (it only happened 7% of the time)

Normal speech	Early-sentence errors	Final-word errors	Percentage of final-word errors preceded by early-sentence errors
Without context	0 %	1 %	0 %
With context	0 %	0 %	0 %
Degraded speech			
Without context	35 %	39 %	13 %
With context	14 %	10 %	7 %

Numbers reflect the proportion of sentences that contained any errors
Data averaged from all participants

Pupil Dilation / Listening Effort

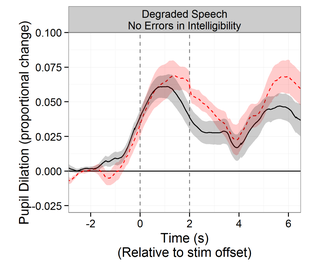
Main effect of spectral resolution:
Greater peak pupil dilation for degraded speech



For normal speech, listeners show *online* benefit of context that continues into the rehearsal and response

For degraded speech, context shows no effect until *after* the stimulus is completely over.

Long latency of context benefit for vocoded speech – is it because the "context" words were simply not intelligible?



For spectrally degraded speech, context benefit occurs late **even if the words were heard correctly.**

i.e. lack of context benefit wasn't because of lack of context.

CONCLUSIONS

- Degraded spectral resolution demands increased listening effort
- For speech with good spectral resolution, semantic context can reduce listening effort *during* the perception of the sentence
- **When resolution is poor, semantic context is not exploited as quickly**
- *In normal speech, there are rarely any lengthy pauses after sentences for listeners to catch up and recover valuable semantic context*
- Word recognition accuracy is a post-stimulus measure; changes in effort occur *online*
- Unknown: the influence of cognitive attributes such as working memory (*see poster PS-260*)

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