

An Examination of the Effect of Natural Background Noise on Spontaneous Speech Intelligibility in Parkinson's Disease

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Introduction

Background noise (BN) impacts both speaker and listener during spontaneous speech. However, the full functional impact for speakers with Parkinson's Disease (PD) in natural environments is unclear. There is a significant difference in conversational spontaneous speech intelligibility (C-SSI) in the natural environment between PD and healthy volunteer (HV) speakers.¹ A strong relationship between background noise intensity and C-SSI has been found for PD speakers.¹ Other characteristics of the natural BN (BN_N) are yet to be studied.

Goals

(1) To analyze naturally occurring background noise and spontaneous speech with a conversational partner, and 2) To improve our understanding of the effect of the intensity and other characteristics of background noise on intelligibility of people with PD.

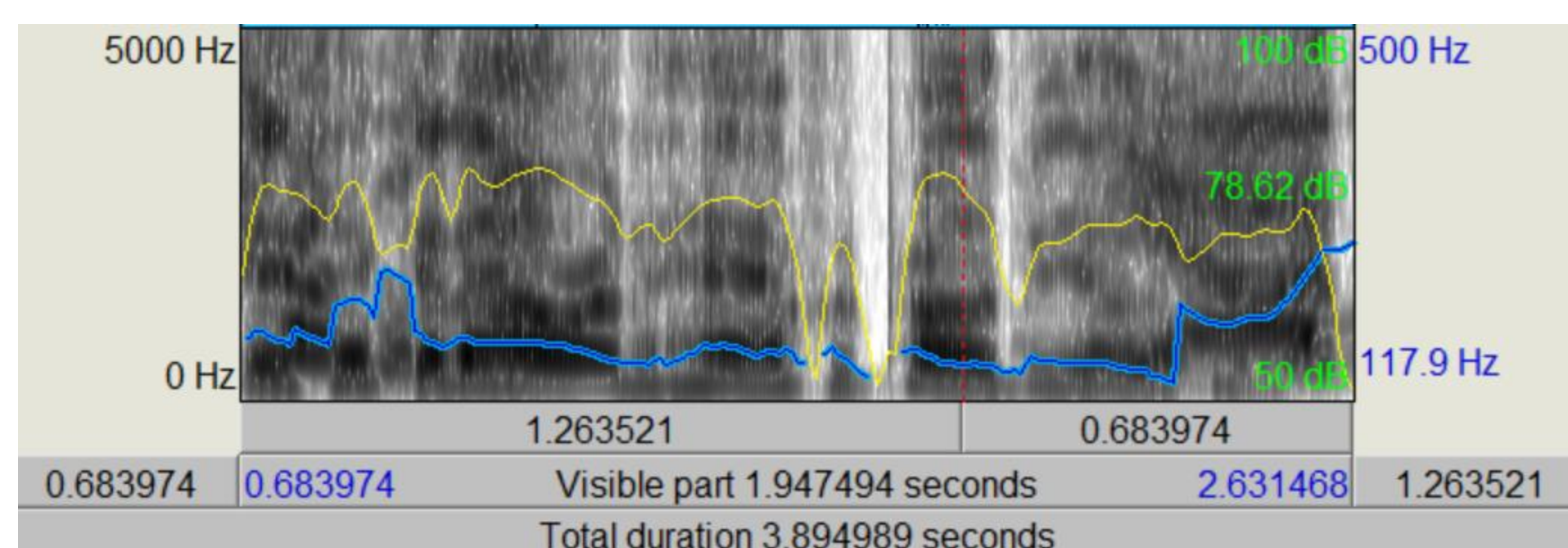
Methods

Part 1

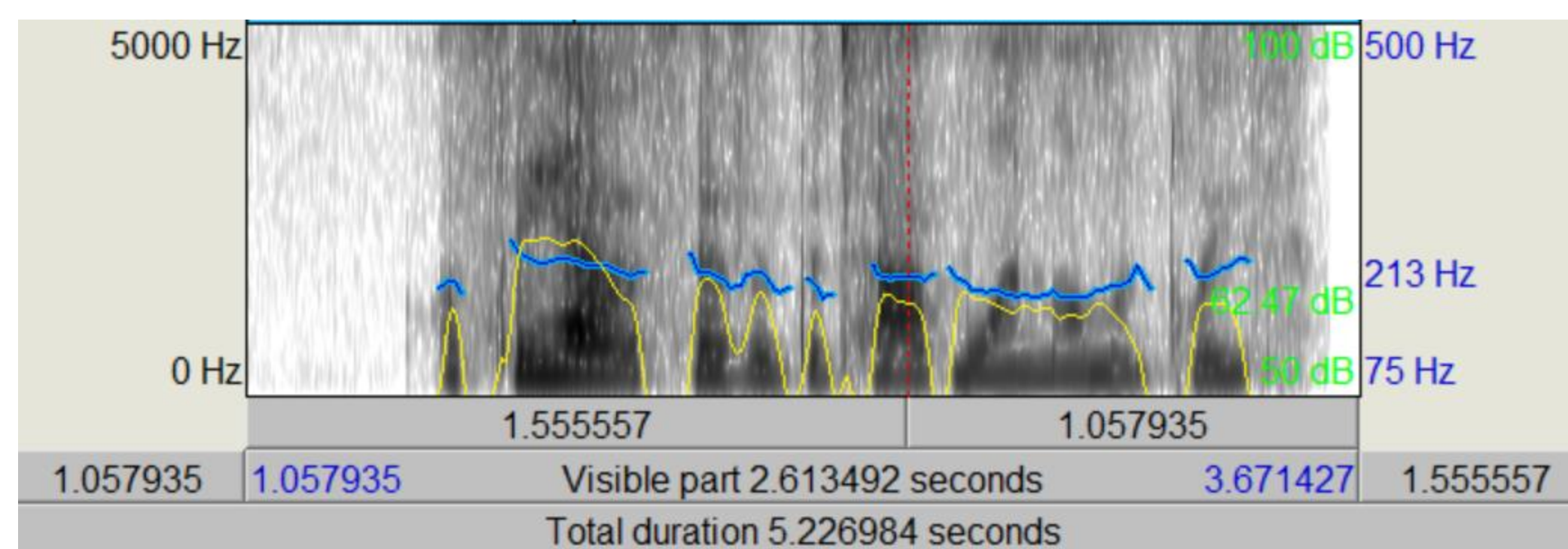
- 13 participants with PD (9 male, 4 female; ages 55-74; \bar{x} =66.9) and mild to moderate speech impairments characterized by hypokinetic dysarthria completed the study.
- Participants wore the LENA™ speech recorder² for 15 hours across 2 days to capture spontaneous speech and environmental background noise.
- 10 sentences were randomly selected from the recordings for each speaker and transcribed by 3 novel listeners, 130 sentences in all. The transcripts were compared to a key generated by researchers to determine percent of words intelligible for the variable of interest, C-SSI.
- A 10 ms clip of BN_N in close temporal proximity to the onset of speech for each sentence was captured. Intensity (dB-SPL) of this BN_N was measured in dB-SPL using Praat and compared to C-SSI by subject via linear regression per subject. Data was split into two naturally occurring and clinically relevant groups³, based on average overall C-SSI.
 - High Mean Intelligibility ($HIGH_{C-SSI}$) = $\bar{x}_{C-SSI} > 75\%$
 - Low Mean Intelligibility (LOW_{C-SSI}) = $\bar{x}_{C-SSI} < 75\%$
 - The difference between groups was measured with chi-square.

Part 2

- BN_N characteristics of interest emerged from literature searches and listening to the samples. A group of 5 listeners participated in choosing the following characteristics, chosen based on possible impact on both speakers and listeners.:
 - frequency potentially inclusive of speech frequencies in the F1 and F2 space ($FREQ_{SP}$)⁴,
 - consistent or continuous noise (CONS)^{5,6},
 - presence of human speech (HU)^{5,7}, and
 - presence of electronic noise (ELEC)⁸ such as a microwave, radio or fan.



Inconsistent noise: visible/audible as non-target voices with breaks



Consistent noise: visible/audible as white noise without breaks

- Characteristics of the BN_N in each sentence was initially analyzed independently by 2 listeners. Listeners could listen to each clip as many times as needed and were able to change their answers later. Interrater reliability (IRR) was calculated: 64.62% (ELEC), 76.92% (HU), 77.69% ($FREQ_{SP}$), 90.00% (CONS), typical of other perceptual measures.
- 2 authors reanalyzed the disagreements together to come to consensus. They independently spot-checked the agreements.
- Repeated Measures ANOVA was used to examine the characteristics of BN_N for the response variable C-SSI.

References

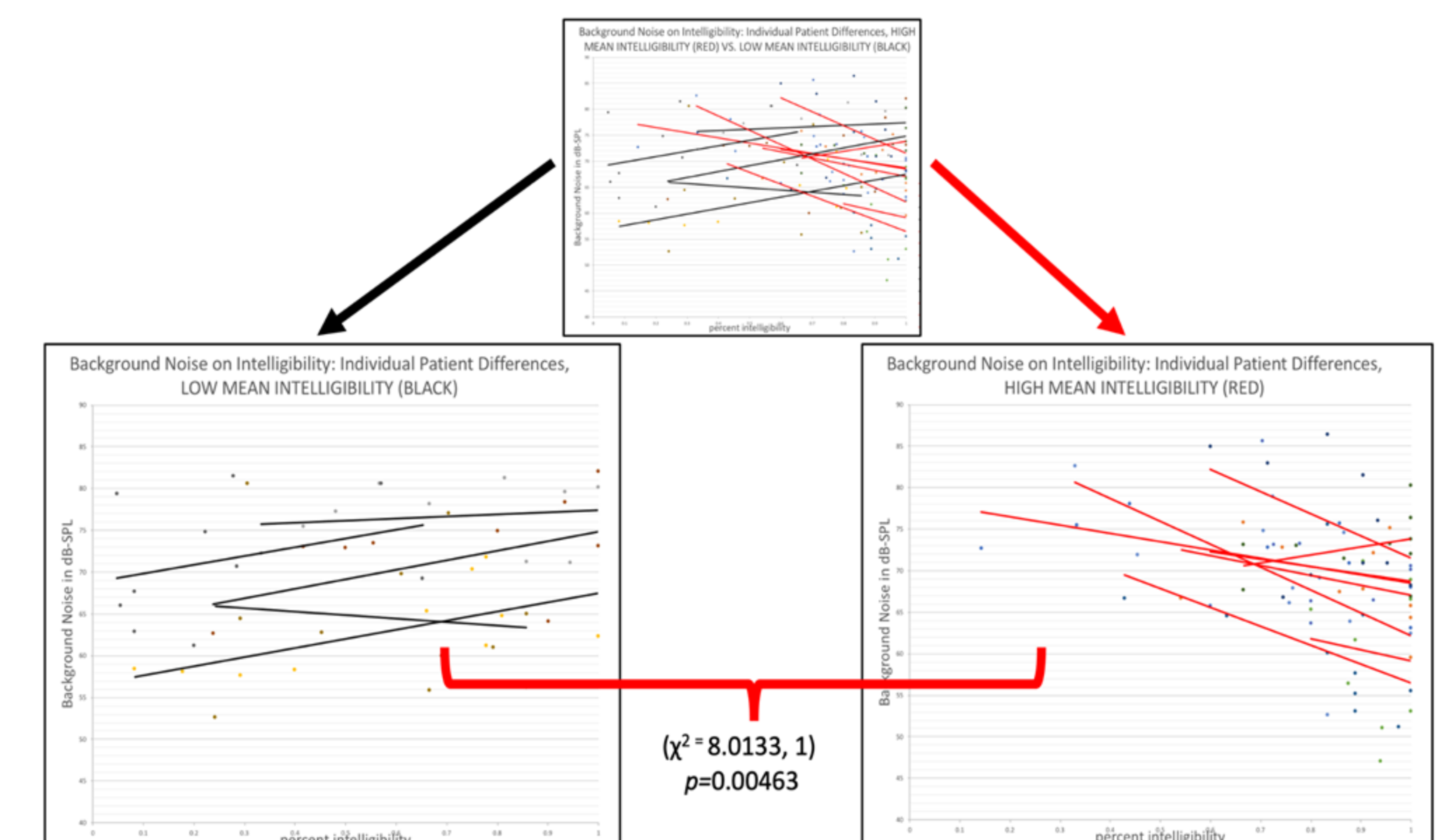
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Results

Part 1

There was no significant difference between or within subjects, but $HIGH_{C-SSI}$ and LOW_{C-SSI} groups responded differently to the BN_N dB-SPL ($p=0.00463$, $\chi^2=8.0133, 1$)

A Repeated Measures ANOVA was used to examine the intensity (dB-SPL) of the BN_N for the dependent variable C-SSI.



Part 2

A. Using the full data set and fitting the model with a set of eight independent variables consisting of six primary variables, intelligibility group ($HIGH_{C-SSI}$, LOW_{C-SSI}), dB-SPL, HU, ELEC, CONS, $FREQ_{SP}$; and two interactions, $FREQ_{SP}$ & HU, and CONS & HU.

- Only CONS had a significant effect on C-SSI ($F=7.966$, $p=0.00588$). Participants showed **decreased C-SSI** with consistent noise.

	HIGH/LOW	DB-SPL	HU	ELEC	CONS	$FREQ_{SP}$	$FREQ_{SP}:HU$	CONS:HU
C-SSI	NS	NS	NS	NS	$p=0.00588$	NS	NS	NS

B. Separating the data by group, $HIGH_{C-SSI}$ and LOW_{C-SSI} , fitting the model separately for each group, with seven independent variables consisting of all variables listed above except group:

- CONS was significant when the group was $HIGH_{C-SSI}$ ($F=4.337$, $p=0.0421$). Participants in the $HIGH_{C-SSI}$ group had **increased C-SSI** with consistent noise.
- Only dB-SPL was significant when the group was LOW_{C-SSI} ($F=4.329$, $p=0.0475$). Participants in the LOW_{C-SSI} group showed **increased C-SSI** with **increased dB-SPL**.

INTEL _{SPON}	DB-SPL	HU	ELEC	CONS	$FREQ_{SP}$	$FREQ_{SP}:HU$	CONS:HU
$HIGH_{C-SSI}$	NS	NS	NS	$p=0.0421$	NS	NS	NS
LOW_{C-SSI}	$p=0.0475$	NS	NS	NS	NS	NS	NS

C. To improve the viability of the normality assumption, fitting the same model as in above (1), transforming the response variable C-SSI, the results led to the **same conclusion**:

- Only CONS has significant effect on C-SSI ($F=8.584$, $p=0.00431$). Participants showed **decreased C-SSI** with consistent noise.

	HIGH/LOW	DB-SPL	HU	ELEC	CONS	$FREQ_{SP}$	$FREQ_{SP}:HU$	CONS:HU
C-SSI	NS	NS	NS	NS	$p=0.00431$	NS	NS	NS

Discussion

Part 1

Intensity of Natural Background Noise on Spontaneous Speech Intelligibility

- One of the first findings of this study was that the presence of more intense background noise during speech may positively impact speakers with lower intelligibility (LOW_{C-SSI}) but speakers with high intelligibility ($HIGH_{C-SSI}$) may not show the same benefit.
- Background noise (BN_N) has varying functional impact on spontaneous speech, depending on the severity of the speaker's dysarthria. The LOW_{C-SSI} group showed an increase in C-SSI when BN_N dB-SPL increased, while the $HIGH_{C-SSI}$ group showed a decrease in C-SSI.
- The LOW_{C-SSI} group may show increased sensitivity to the Lombard Effect, which results in an upregulation of the speech system (increased loudness, pitch and vowel duration, and duration of content words).
 - The $HIGH_{C-SSI}$ group's decreasing C-SSI with increasing dB-SPL may be due to the impact of noise on the listener.
- These findings led to considering other noise characteristics that may affect C-SSI.

Part 2

Characteristics of Natural Background Noise on Spontaneous Speech Intelligibility

- Consistent noise related to a decrease in intelligibility for the sample as a whole. However, speakers with high intelligibility increased intelligibility in the presence of consistent noise.
 - In the presence of consistent/continuous BN_N , and a high intelligibility speaker, listeners may be more likely to adjust for this consistent/continuous BN_N , to overcome and accurately transcribe the speaker's message more often.
 - This effect is strong enough in the $HIGH_{C-SSI}$ group to overcome the opposite effect in the sample as a whole.
- dB-SPL impacted only the LOW_{C-SSI} group, giving directionality and significance to Part 1
 - LOW_{C-SSI} speakers may show higher sensitivity to the Lombard effect.
- Of note, there were many variables that were hypothesized to have effect, given a review of the samples:
 - Noise overlapping common speech frequencies did not show a significant effect.
 - The presence of human voices did not show a significant effect, even when combined with $FREQ_{SP}$. This was hypothesized to cause a decrease in C-SSI based on perception of listener and speaker distraction in presence of other human speech.
 - The presence of ELEC BN_N did not show a significant effect. This was hypothesized to have an effect based on the Lombard Effect.

Limitations of the study

Small heterogeneous sample (most with mid-mod speech impairment), chaotic environmental recordings (but needed for ecological validity).