Developing a new test-bench for screening effective next-generation speech processing algorithms for cochlear implants.

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1. Introduction

Improving cochlear implant (CI) user's speech performance with new signal processing algorithms is a significant challenge faced by CI manufacturers. Clinical studies are used to test new proposals and determine whether they should be integrated into products. However, conducting such studies for every new proposal is not feasible due to time and cost constraints[1].

To address this issue, **we propose another approach** featuring an **evaluation test-bench** that helps to **compare new CI signal processing designs by predicting speech performance improvements using intelligibility models.**
Our evaluation test-bench aims to have a first set of metrics that may reflect the performance of CI users for speech in noise.

2. Materials

Total 114 audio files

- 19 tracks of clean speech
- 3 different languages
- Male and female speakers

Speech in / SNR	Babble noise	White noise	Traffic noise	Reverb & babble noise	Reverb & white noise
5dB SNR	x	x			x
10dB SNR	x		x	x	

3. Method

Used Metrics

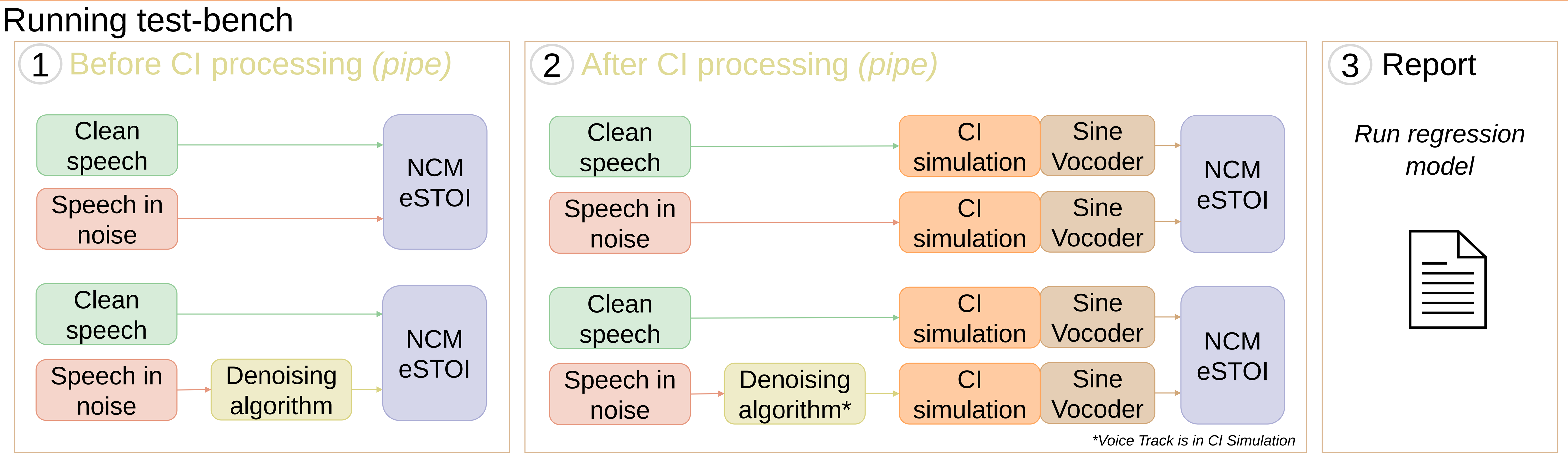
- eSTOI[2]: extended Short-Time Objective Intelligibility
- NCM[3]: Normalized Covariance Metric

Mixed effect logistic regression model

$$\boxed{\begin{matrix} eSTOI \\ NCM \end{matrix}} = \boxed{\begin{matrix} denoising\ algorithm\ + pipe + pipe * denoising\ algorithm \\ denoising\ algorithm\ + pipe + pipe * denoising\ algorithm \end{matrix}} + \begin{matrix} (1|\,\boxed{noise}:\boxed{clean\ speech}) \\ (1|\,\boxed{noise}:\boxed{clean\ speech}) \end{matrix}$$

Dependent variables — Fixed factors, with interaction — Random factors

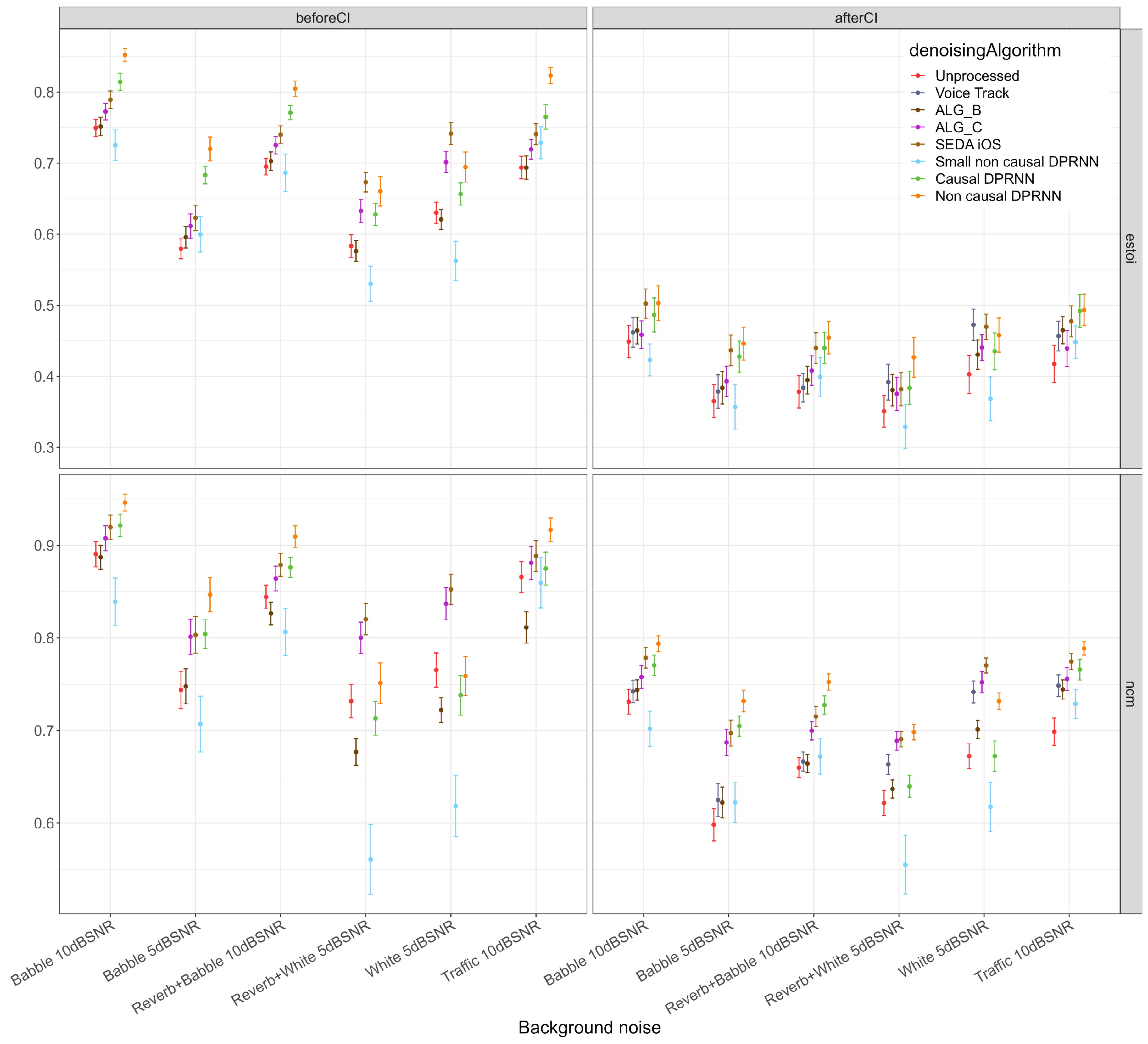
Running test-bench



4. Results

Denoising algorithms

- Voice Track: Oticon Medical denoising solution for Neuro2 product[4].
- SEDA iOS: denoising solution designed by York-Sound company[5] .
- Non causal DPRNN: non-causal Deep Neural Network (DPRNN)[6-7].
- Small DPRNN: non-causal DPRNN[6-7] with small number of parameters and small training data set.
- Causal DPRNN: 5ms delay causal DPRNN[6-7].
- ALG_B, ALG_C: Anonymized algorithms.



Regression model

eSTOI:

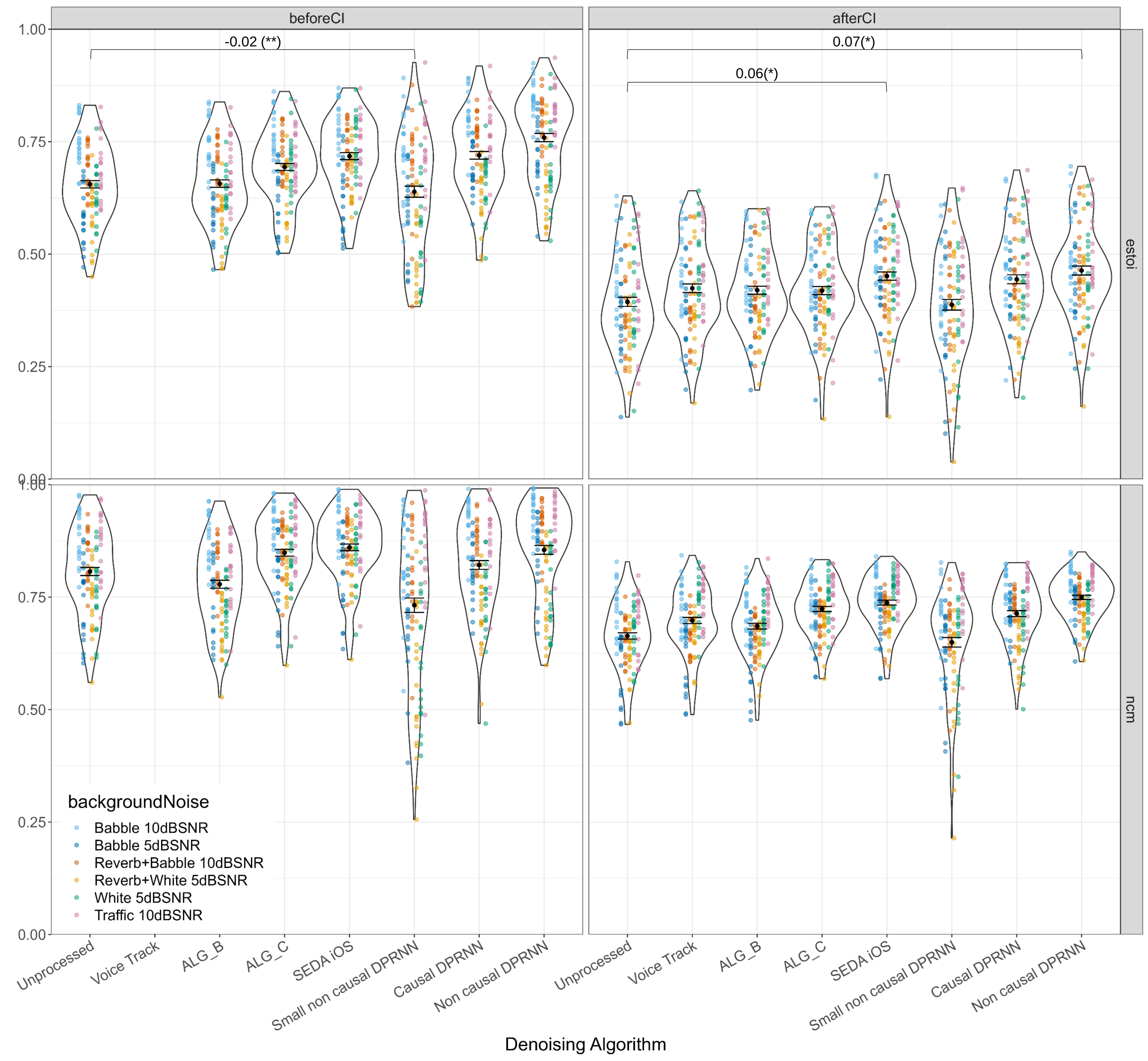
Denoising algorithm (χ^2=78.5, df=7, **p<0.001**), pipeline (χ^2=1078.2, df=1, **p<0.001**), denoising and pipeline (χ^2=40,0, df=6, **p<0,001**).

- **Small DPRNN is significantly worse than unprocessed before CI (β=-1.69, se=0.59, p<0.01).**
- **SEDA iOS is significantly better than unprocessed after CI (β=0.09, se=0.04, p<0.05).**
- **Non causal DPRNN is significantly better than unprocessed after CI (β=0.08, se=0.04, p<0.05).**

NCM:

Denoising algorithm (χ^2=98,2, df=7, **p<0.001**).

- Small DPRNN is significantly worse than unprocessed (β=-2,1, se=0.5, p<0.001).



5. Discussion

Preliminary conclusion

- Although eSTOI and NCM are not designed for CI, they are often used[7-8], and we can see a **coherency of the results** between before and after CI:
  - Results indicate non causal DPRNN and SEDA iOS as the algorithms with significantly better intelligibility marker than Unprocessed
  - Results confirm Voice Track good performance with static noise
- In the current state, test bench can be used for **algorithms comparison but not to predict patient performance**
- eSTOI and NCM limitations:
  - Vocoders add variability (see poster M63: [1605])
  - Markers not necessary linked to subjective preferences

Improving the current test-bench

To increase the statistical power regression model:

- Need to generate more audio files
- Improve grouping of background noise to decrease the number of comparisons

To improve robustness of the test-bench:

- More objective measures such as distortion
- Increase the variability of background noise
- Add MUSHRA subjective evaluation
- Run test-bench with different vocoders

Future work

- Better **understand the result variability** (eSTOI vs NCM, Before vs after CI)
- Confirm the approach by comparing test-bench results with **listening tests on normal hearing** using vocoders
- Validate the approach by comparing test-bench results with **listening tests on CI users**
- Next generation Oticon Medical CI sound processor will implement the noise reduction selected with this test-bench

References

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Because sound matters

Poster M64: [1636]

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