SPEECH INTELLIGIBILITY INDEX MODEL:

A Key Aspect to a Child's Development of Speech and Language

THE UNIVERSITY OF IOWA

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Outline

1. Importance of the study
2. Introduction to hearing
3. Methods for imputation
4. Construction of SII Model
5. Analysis of Imputations
6. Concluding Remarks

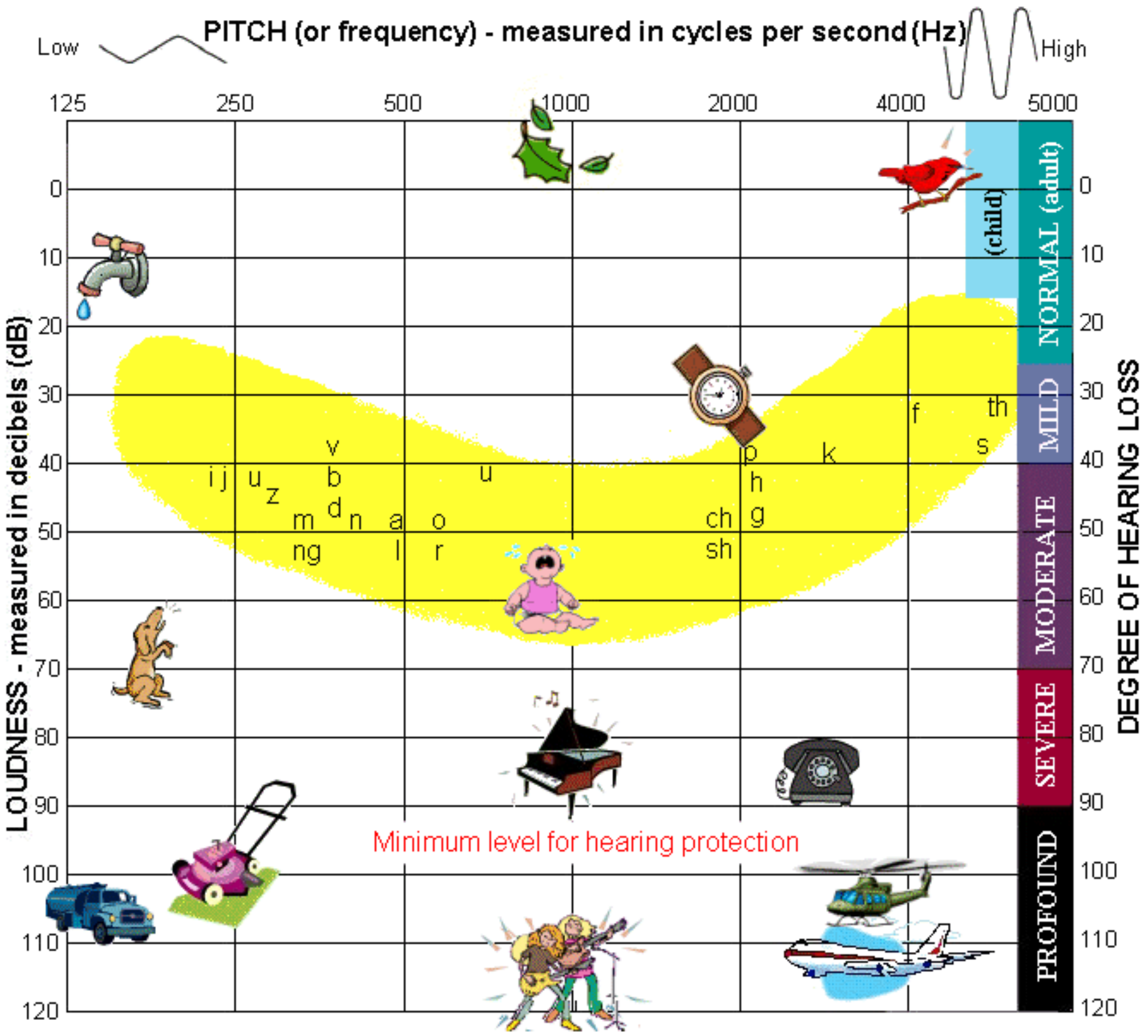
Importance

- The development of speech and language in children is critically impacted by the child's ability to hear
    - OCHL Grant

- It has been found that children with hearing loss, who fail to seek proper help, have a delay in their speech development

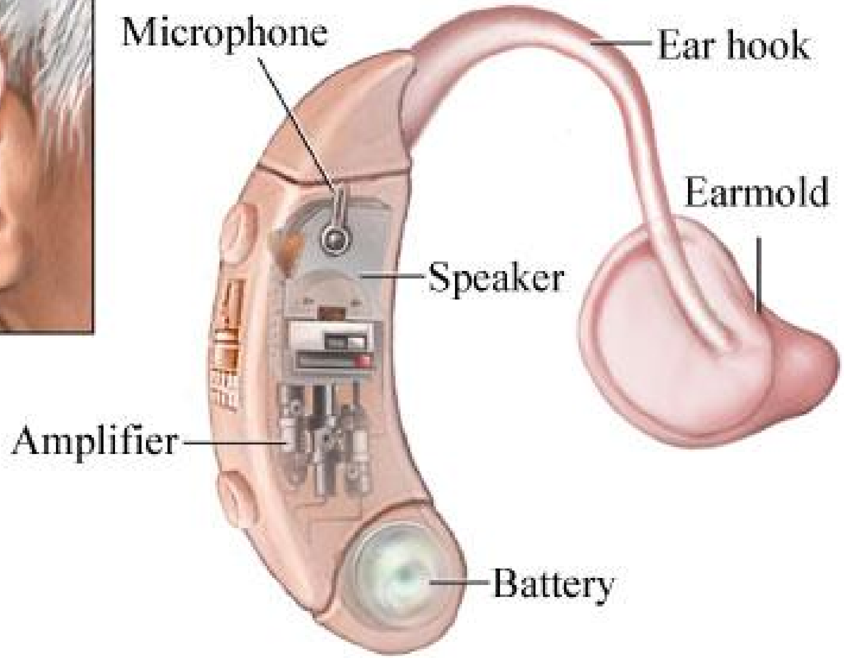
Hearing

- “Speech Banana”
- Shows the pitches and levels of loudness for which certain sounds and speech are heard



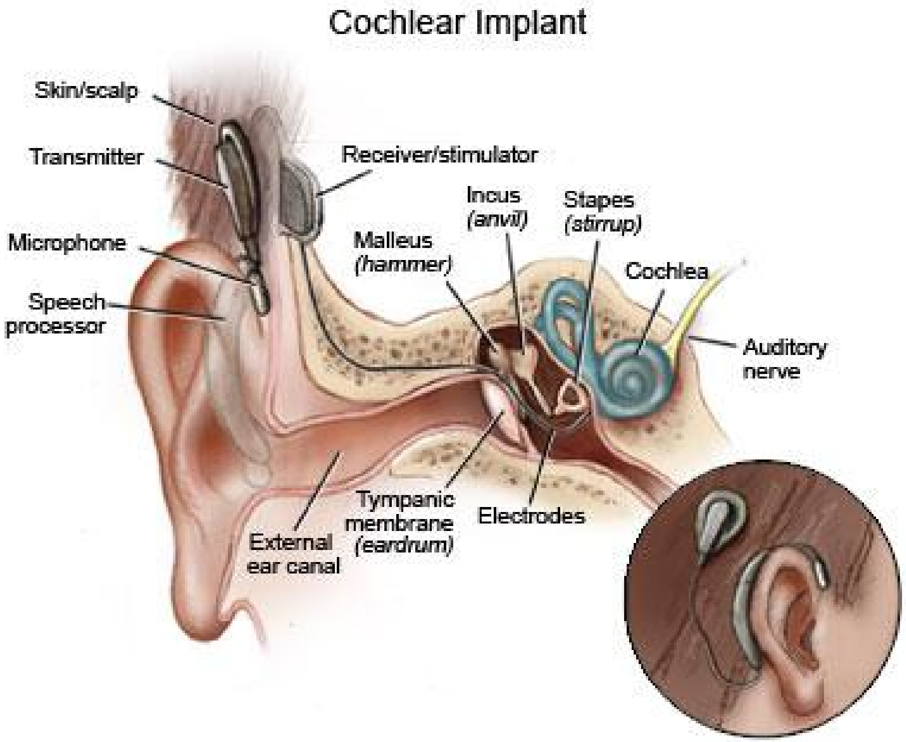
Hearing Aids

- Amplifies sound
- Patients have mild to moderate hearing loss



Cochlear Implants

- A Surgically implanted electronic device
- Patients damaged hair cells in cochlea
- Severe to complete hearing loss
- How it works?
    - Microphone captures sound from environment
    - Noise is filtered and converted to electric impulses



What is Speech Intelligibility Index?

- Measure between 0 and 1
  - 0: no understanding of speech
  - 1: speech information is audible and usable (normal hearing)
- Unable to be measured in individuals with cochlear implants
- No other way of obtaining this value

Goal of the Study

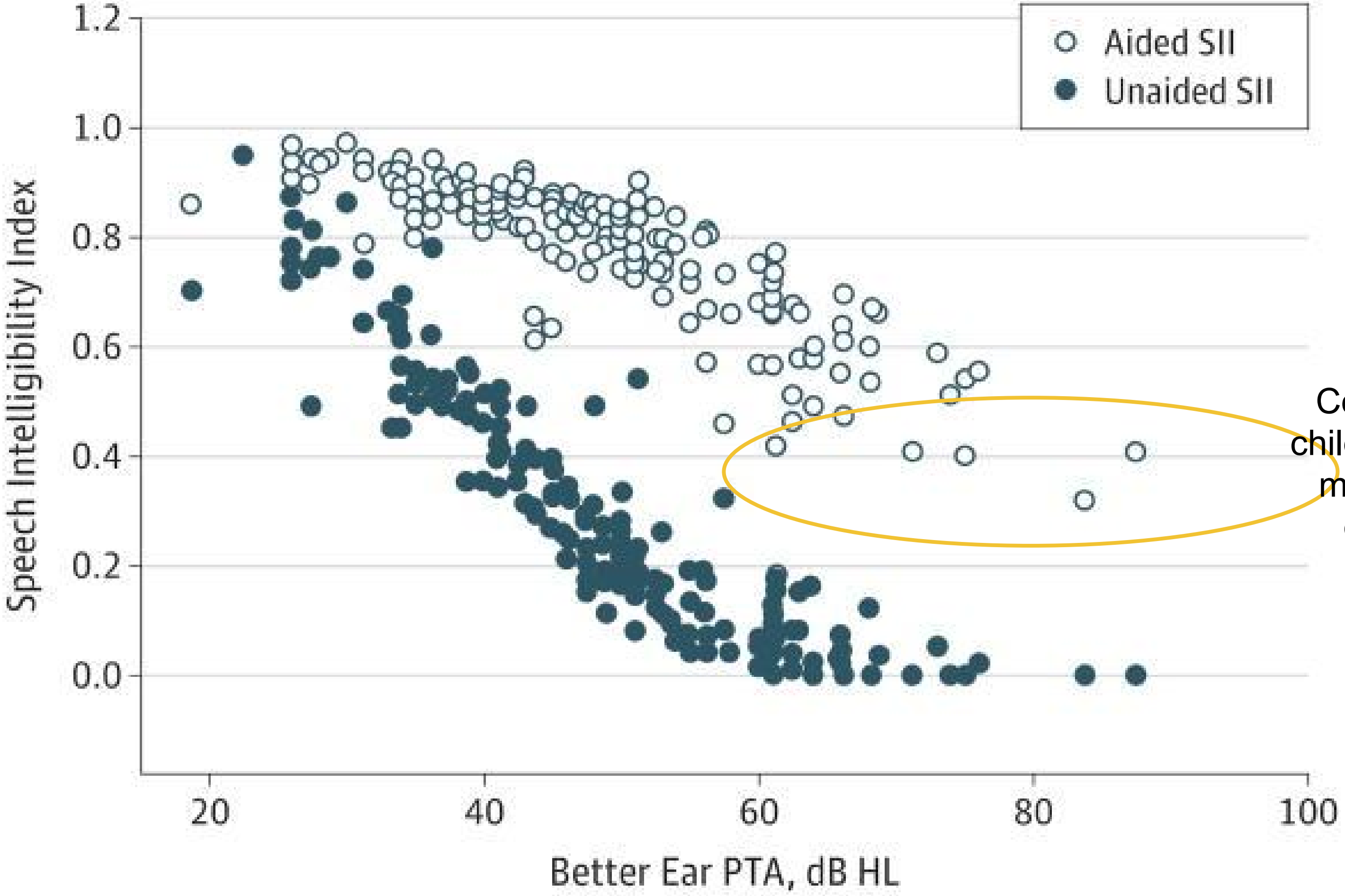
- Find a model that predicts “functional” Speech Intelligibility Index (SII) for a child with a cochlear implant

- Determine when hearing loss is identified, which hearing corrective action approach would provide a child with the most long term advantages:
  -hearing aids or cochlear implants?

Data Set and Variables

- 77 Children, ages 7-9
  - 18 with Cochlear Implants (CI)
  - 59 with Hearing Aids (HA)

- 16 Variables
  - SII
  - Word Attack, Passage Score, Mother's Education, Pure-tone Average



Could these children benefit more with a cochlear implant?

Multiple Imputation

- A method used to predict missing data values
- Imputations of SII for children with CI and of missing values in explanatory variables
- Software package used: Multivariate Imputation by Chained Equations (MICE) in R
- A Markov-Chain Monte Carlo algorithm (MCMC) is used in this package

MCMC Example

SII	Word Attack Score	Passage Score	Mother's Education Level
0.90	90		3
0.884	122	125	4
		132	5
	115	120	5
	109	110	2

Iteration Order: 1. Word Attack→ Passage→ SII
…
200. Word Attack→ Passage→ SII

$$\theta_1^{*(t)} \sim P\left(\theta_1 \middle| Y_1^{obs}, Y_2^{(t-1)}, \dots, Y_p^{(t-1)}\right)$$

$$Y_1^{*(t)} \sim P(Y_1 | Y_1^{obs}, Y_2^{(t-1)}, \dots, Y_p^{(t-1)}, \theta_1^{*(t)})$$

$$\theta_P^{*(t)} \sim P\left(\theta_P \middle| Y_P^{obs}, Y_1^{(t)}, \dots, Y_{p-1}^{(t)}\right)$$

$$Y_P^{*(t)} \sim P(Y_P | Y_P^{obs}, Y_1^{(t)}, \dots, Y_p^{(t)}, \theta_P^{*(t)})$$

MCMC Example

SII	Word Attack Score	Passage Score	Mother's Education Level
0.90	90	120	3
0.884	122	125	4
0.86	117	132	5
0.57	115	120	5
0.77	109	110	2

Iteration Order: 1. Word Attack→ Passage→ SII

…

200. Word Attack→ Passage→ SII

$$\theta_1^{*(t)} \sim P\left(\theta_1 \middle| Y_1^{obs}, Y_2^{(t-1)}, \ldots, Y_p^{(t-1)}\right)$$

$$Y_1^{*(t)} \sim P(Y_1 | Y_1^{obs}, Y_2^{(t-1)}, \ldots, Y_p^{(t-1)}, \theta_1^{*(t)})$$

$$\theta_p^{*(t)} \sim P\left(\theta_p \middle| Y_p^{obs}, Y_1^{(t)}, \ldots, Y_{p-1}^{(t)}\right)$$

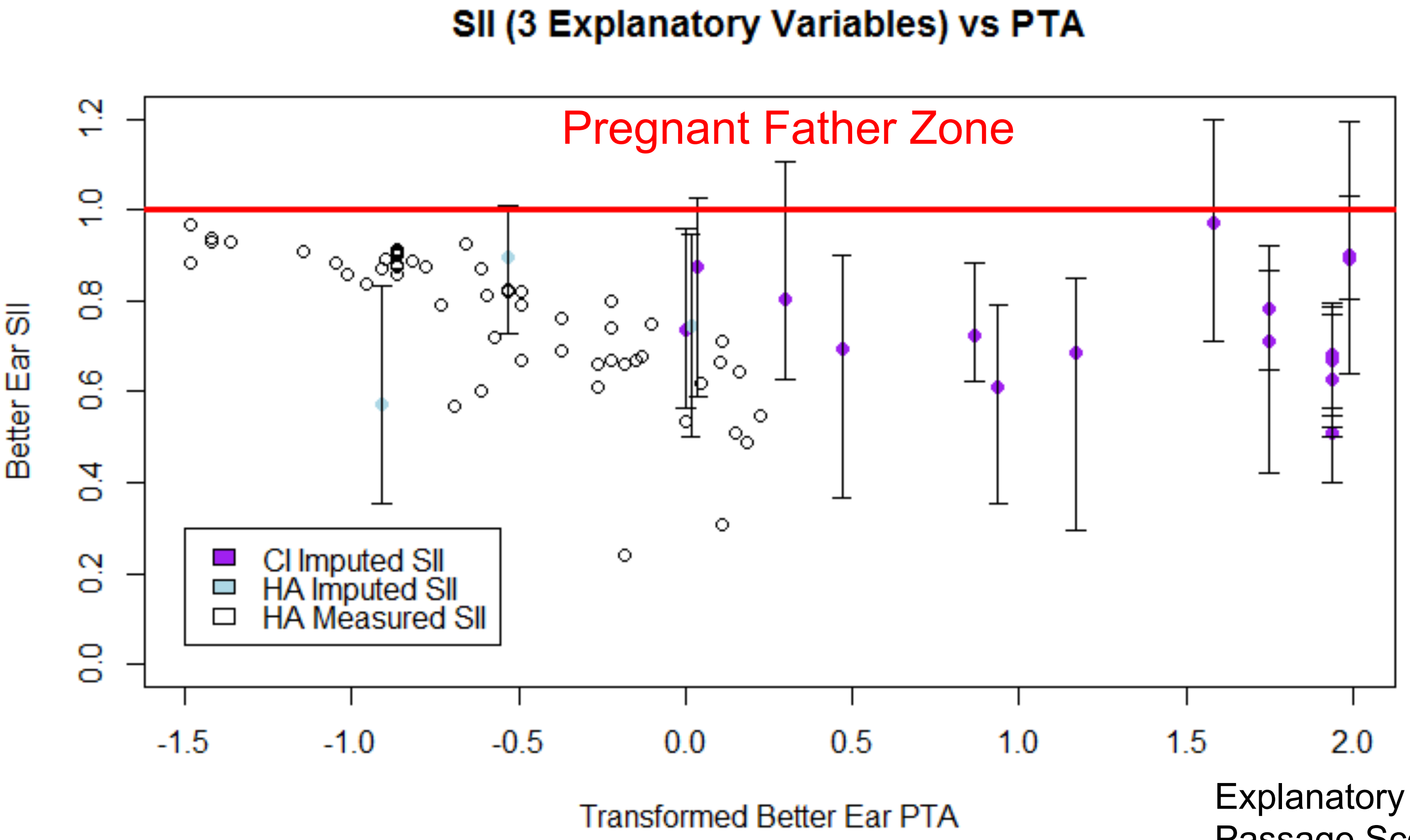
$$Y_p^{*(t)} \sim P(Y_p | Y_p^{obs}, Y_1^{(t)}, \ldots, Y_p^{(t)}, \theta_p^{*(t)})$$

Model Assumptions

- To perform multiple imputation, response variables are supposed to be “Missing at Random” (MAR). Is SII for CI children MAR?

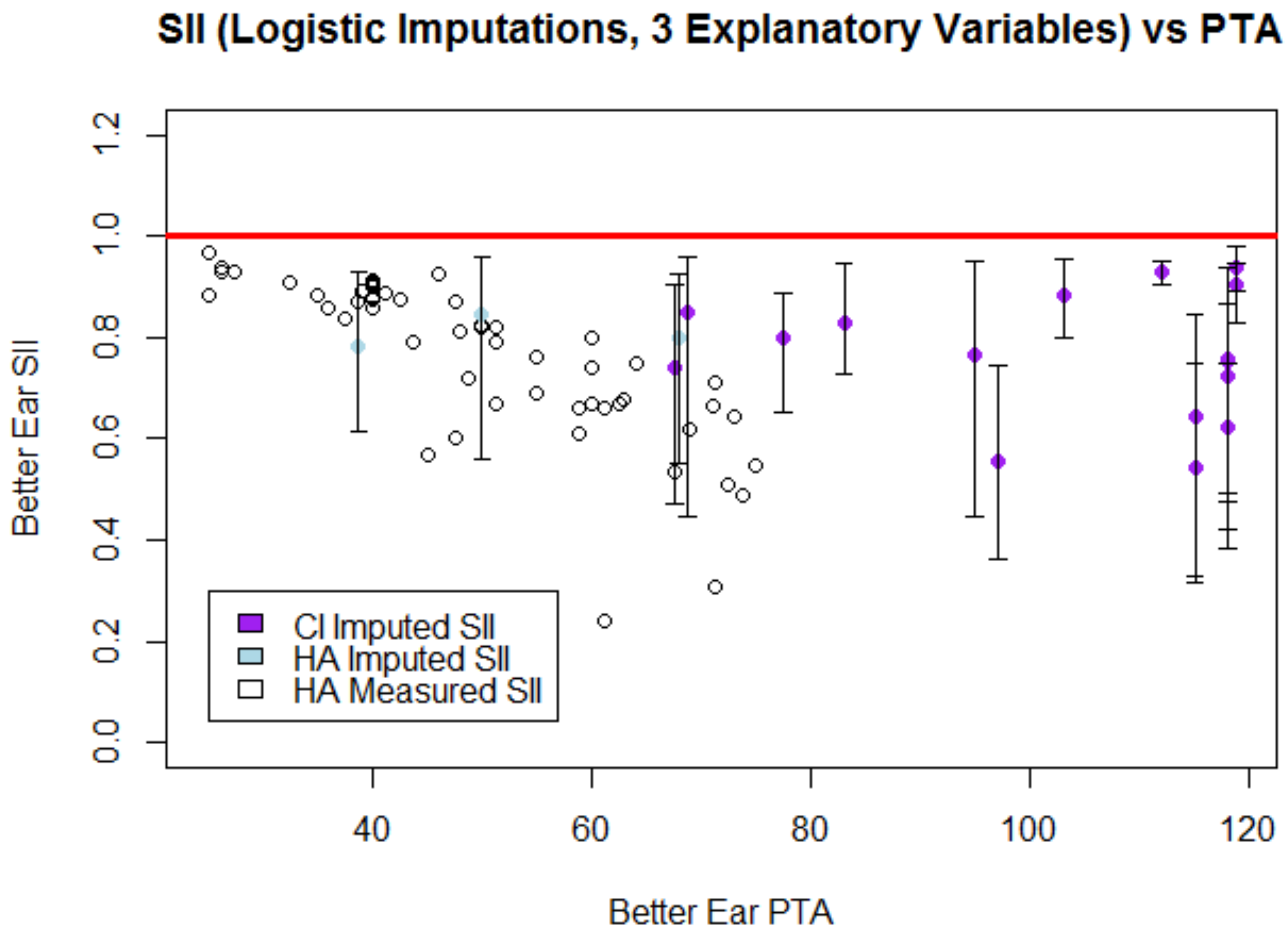
- Same relationship between SII and explanatory variables for children with HA and CI

- Explanatory variables are independent

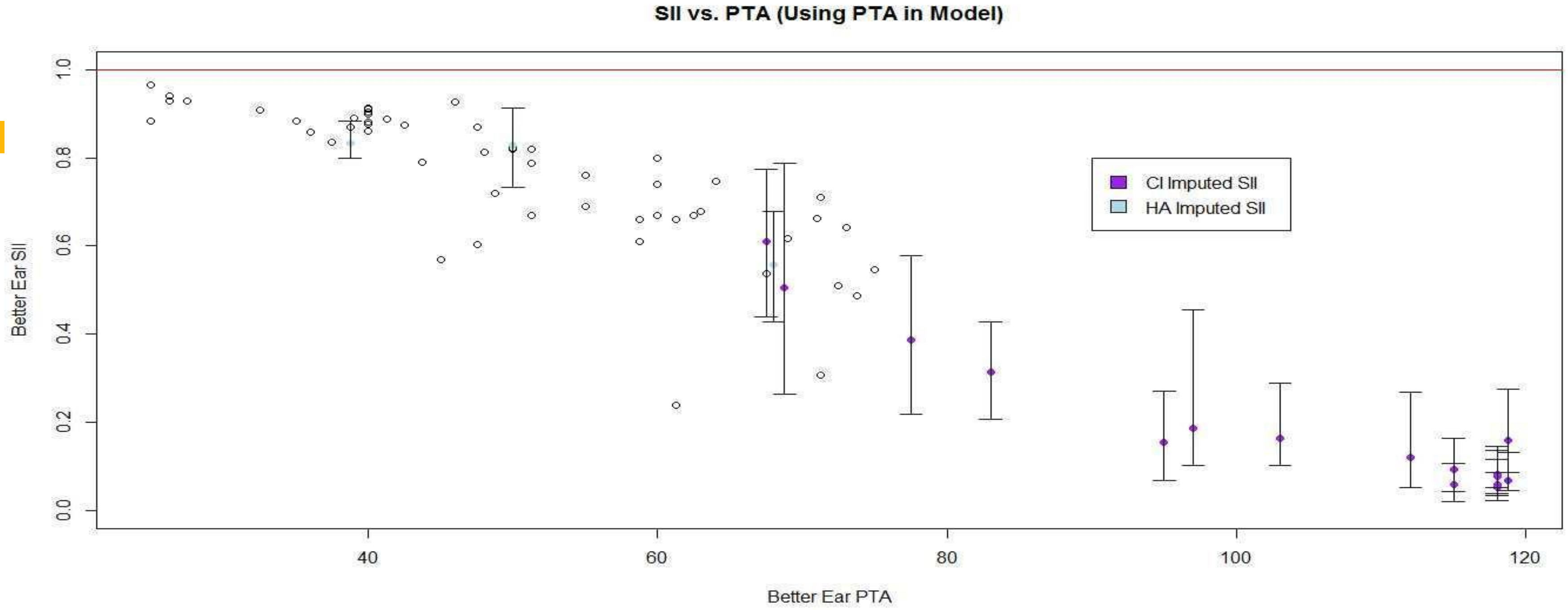


This model produces impossible results, or "Pregnant Fathers!"

Explanatory Variables: Word Attack, Passage Score, Mother's Education



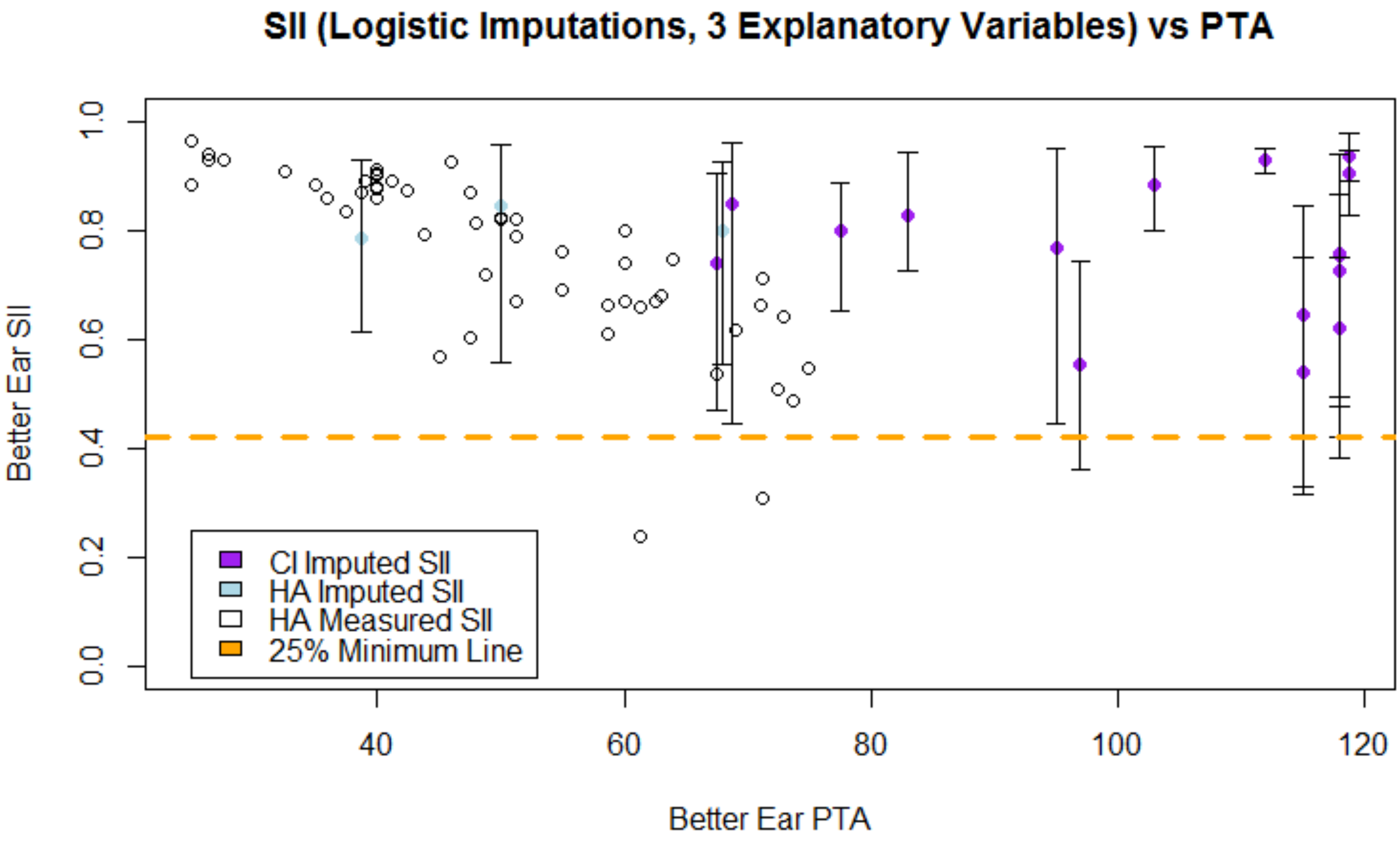
- Imputes SII using logistic transformation
- Creates upper bound of 1.0
- Transforms SII back to normal range after imputation
- No pregnant fathers



- Imputed SII values are strongly influenced by PTA
- Conceptually this does not make sense
- Violates “variables missing at random”- significant difference between CI and HA
- Conclusion: remove PTA from the model

Our Final Imputation Model

- Impute Logistic SII (Response Variable)
- Explanatory variables: Word Attack, Passage Score, Mother’s Education

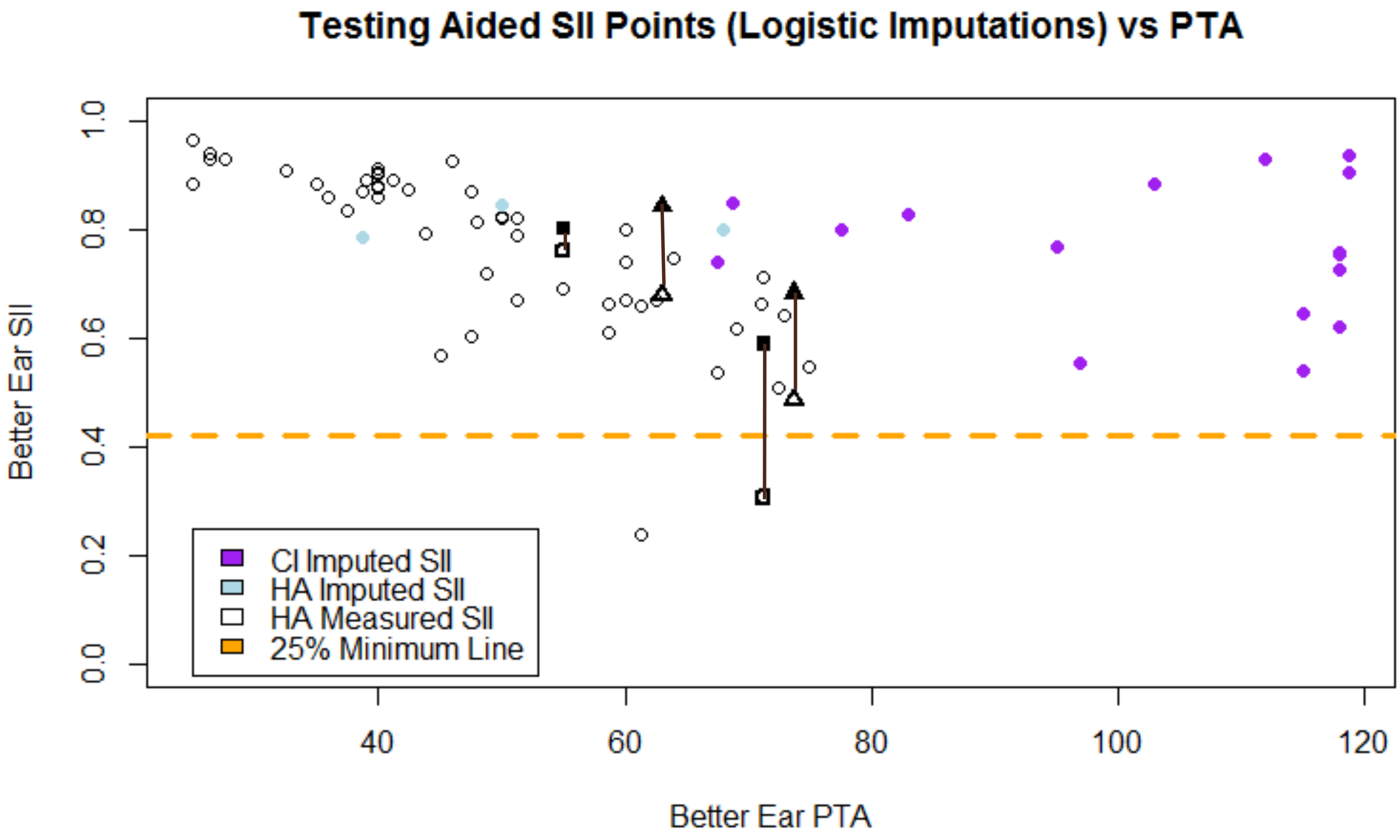

SII (Logistic Imputations, 3 Explanatory Variables) vs PTA
Better Ear SII
0.0
0.2
0.4
0.6
0.8
1.0
40
60
80
100
120
Better Ear PTA
CI Imputed SII
HA Imputed SII
HA Measured SII
25% Minimum Line

Regression with Completed Data

- After completing data set, the following multiple regression can be used to predict SII:

$$Predicted\ Cl\ SII = -2.21 - 0.016(Word - Attack) + 0.049(Passage) + 0.053(Mom'sEd3) + 0.011(Mom'sEd4) + 0.117(Mom'sEd5)$$

Multiple R-squared: 0.3279


Testing Aided SII Points (Logistic Imputations) vs PTA
Better Ear SII
Better Ear PTA
0.0
0.2
0.4
0.6
0.8
1.0
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80
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CI Imputed SII
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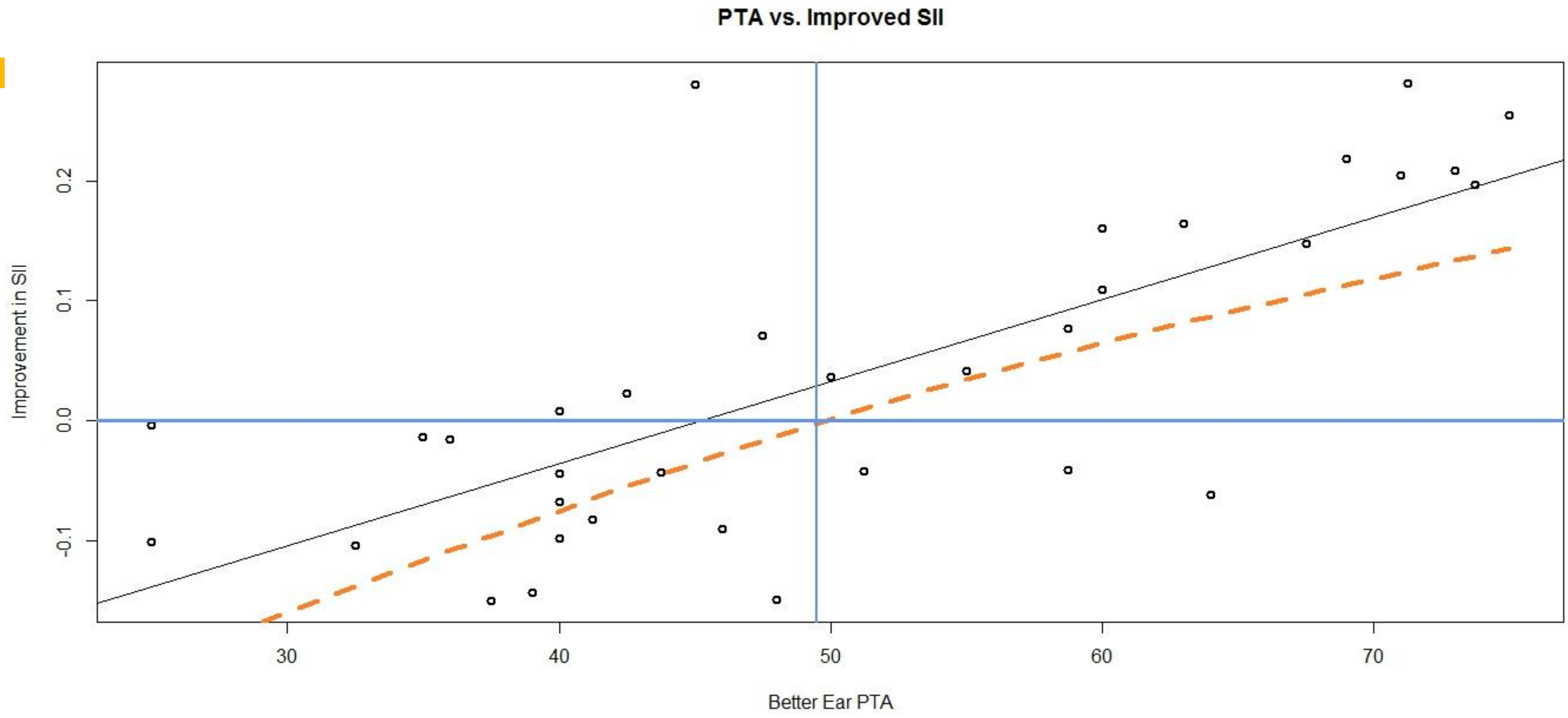
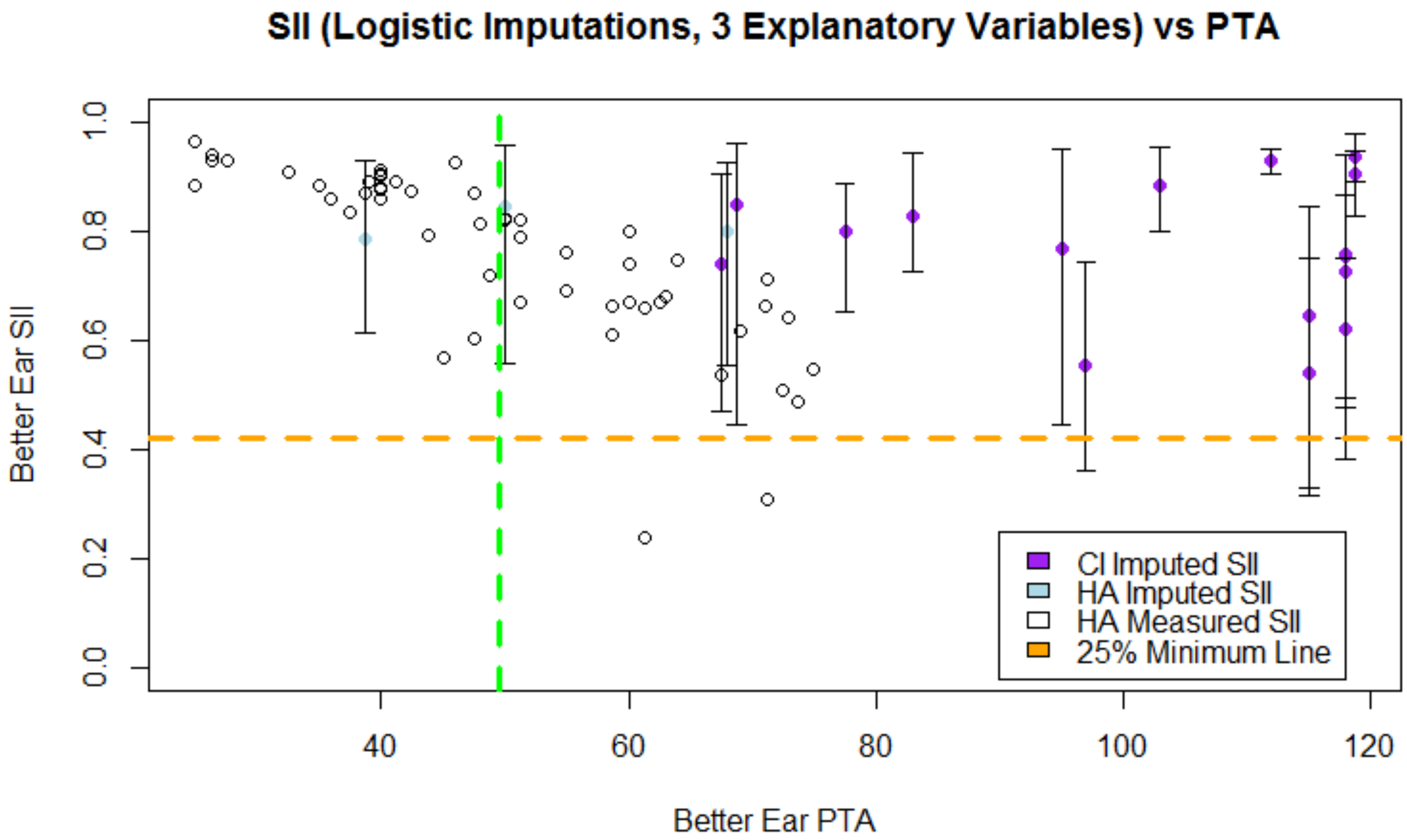

PTA vs. Improved SII
Improvement in SII
0.2
0.1
0.0
-0.1
30
40
50
60
70
Better Ear PTA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Conclusion

- New Criteria:
  - Any child with aided SII < 0.42
  - Any child with PTA > 49.5 dB
- Future research topics:
  - Determine if the newly-developed less-invasive Hybrid 10 Implants could further improve SII in children with severe hearing loss
  - Studying how generalizable our model is to different age groups

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Questions?