Utilizing phonological cues during spoken word recognition in children with cochlear implants

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Introduction

The present study investigates how children with or without a hearing loss utilize phonological information during real-time spoken word processing. Specifically, we test the idea that children with hearing loss require more time to process spoken language than their normal hearing peers.

Children use phonological cues in spoken word recognition

- Children integrate prior knowledge of lexical items, such as **phonological cues**, with incoming speech input in order to facilitate spoken word recognition. [1,2]
- The efficient integration of perception and prior knowledge matures with age and is predictive of language and cognitive abilities later in life. [3,4]
- Children are able to use phonological cues in real time, as a word unfolds **(Figure 1)**

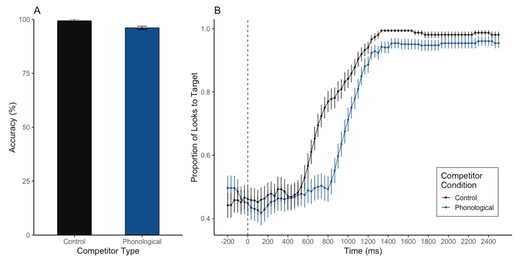

Figure 1 (left). Normal hearing children (N=4) were presented with two images corresponding to words with the same initial syllable (e.g., pencil, penny) and asked to select the spoken word. (A) Accuracy (mean ± SE) on 2-AFC. (B) Proportion of looks to the target image. Dashed line indicates the onset of the target word. Data collection is ongoing.

Cochlear implant users typically have slower word recognition

- Static measures of language proficiency, such as standardized vocabulary scores and speech perception in sound-controlled environments, indicate successful outcomes for cochlear implant (CI) users.
- Children with CIs are typically slower at responding to spoken language input than their age-matched peers and this persists through adulthood. [5,6]

Research Question: How does the presence of phonological competition impact spoken word recognition and how is this different when the listener has a hearing loss?

Methods

Participants: 25 children total; all children were monolingual English speakers. A subset of children completed both the task in both ISI conditions across two experiment visits. Data collection is ongoing.

Cochlear implant (CI) users: N=12 bilateral CI users (age range: 3.8 to 12.6 years old, mean: 8.3). Age of first implantation ranges from 1 to 4.25 years old (mean: 2.33).

Normal hearing (NH): N=13 children with no prior history of speech and language services (age range: 4.1 to 11 years old, mean: 7.3).

Procedure
Children completed a three-alternative forced choice task, where they heard a word and selected the corresponding image **(Figure 2).** Behavioral responses (3-AFC Accuracy) and eye gaze were quantified.

Competitor Conditions
In the 3-AFC task, the target image is presented with two other images:

Phonological

Target	Phonological Competitor	Unrelated Distractor
		

Control

Target	Unrelated Distractor	Unrelated Distractor
		

The phonological competitor shares the same initial CV sound as the target word.

Inter-stimulus interval (ISI) Length
The time between the presentation of the target word and when the images appear for the 3-AFC varies by two conditions (**Figure 2, Panel 2**): **Long (500 ms)** or **Short (300 ms)**.

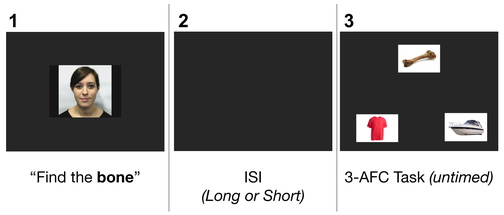

Figure 2 (left).
1. Children are presented with a still face and hear the carrier phrase and target word
2. The still face disappears for a **long** or **short** inter-stimulus interval (ISI).
3. Three images appear and children select the corresponding image.

CI users benefit from having more time to process spoken language

Fig.3: Children with CIs & NH perform similarly with a long ISI

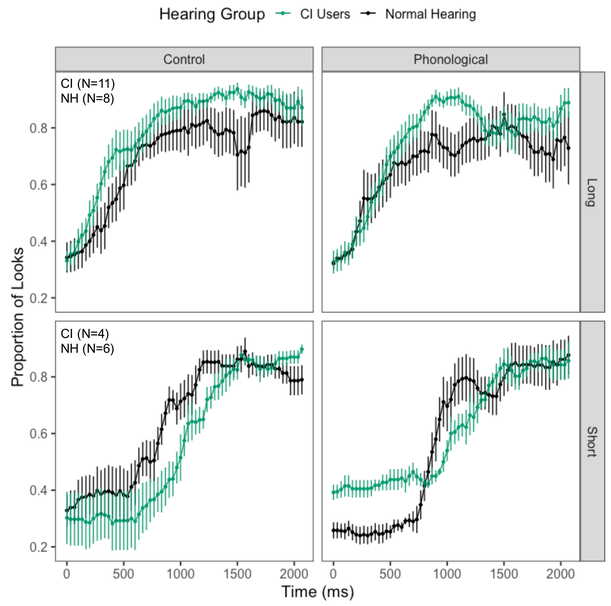

Fig. 4: Both hearing groups are slower to fixate on the target with a short ISI

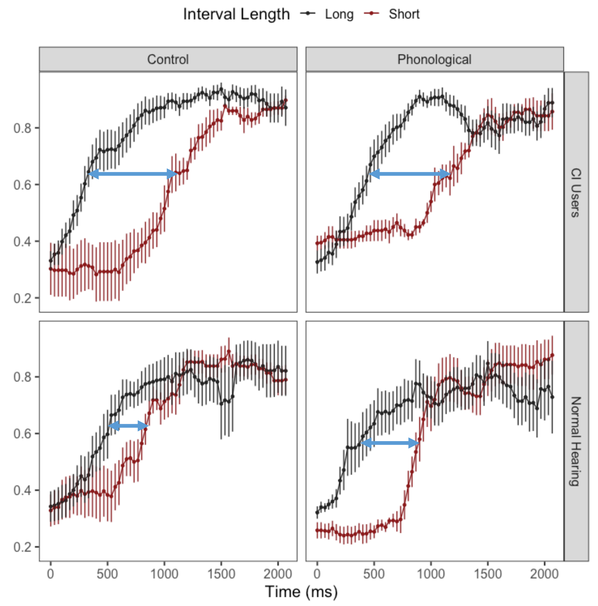

Figure 3 (left). Proportion of looks (mean ± SE) to the target image by **hearing group:** CI users (green) and NH (black).

Figure 4 (right). Proportion of looks (mean ± SE) to the target image by **ISI length:** long (black) and short (red).

Time (y-axis) is in relation to the first frame that the images appear (**Figure 2, Panel 3**).

Phonological competition is stronger in a short ISI

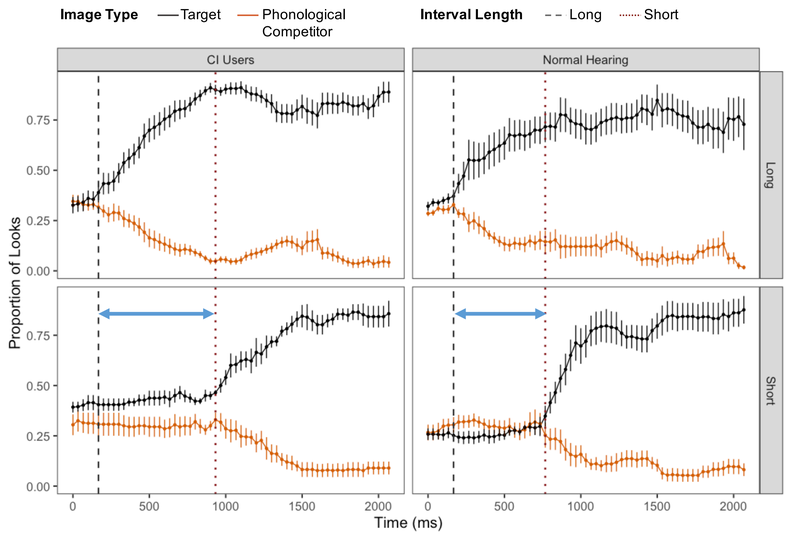

Figure 5. Proportion of looks (mean ± SE) to the target image (black) and phonological competitor (orange) by hearing group and ISI length. The vertical lines indicate the approximate time at which looks to the target image and phonological competitor separate in the long (black, dashed) and short (red, dotted) ISI conditions. Time (y-axis) is in relation to the first frame that the images appear.

Summary

Preliminary results suggest that:

- Phonological competition is stronger in the short ISI compared to the long ISI length for both the CI and NH groups.
- A longer ISI may give children with CIs enough time obtain real-time speech recognition performance similar to that of the NH group.

Children achieve high word recognition accuracy across competitor conditions

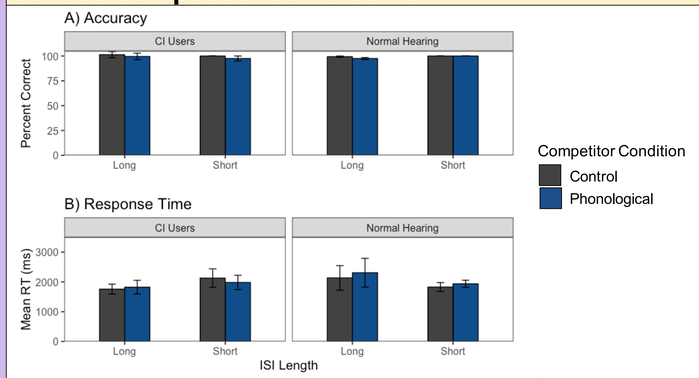

Figure 6. Behavioral data for 3-AFC task. (A) Accuracy (mean ± SE) and (B) Response time (mean ± SE) by hearing group and ISI length. Both groups perform perform at ceiling on the 3-AFC task, regardless of ISI length. There are no differences in performance between the two competitor conditions.

Acknowledgments

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References

[1] Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive psychology*, *10*(1), 29-63.
[2] Mahr, T., McMillan, B. T. M., Saffran, J. R., Ellis Weismer, S., & Edwards, J. (2015). Anticipatory coarticulation facilitates word recognition in toddlers. *Cognition*, *142*, 345–350. PMCID: PMC4500663
[3] Law, F., Mahr, T., Schneeberg, A., & Edwards, J. (2017). Vocabulary size and auditory word recognition in preschool children. *Applied psycholinguistics*, *38*(1), 89-125. PMCID: PMC5400288
[4] Weisleder, A., & Fernald, A. (2013). Talking to Children Matters: Early Language Experience Strengthens Processing and Builds Vocabulary. *Psychological Science*, *24*(11), 2143–2152. PMCID: PMC5510534
[5] Grieco-Calub, T. M., Saffran, J. R., & Litovsky, R. Y. (2009). Spoken word recognition in toddlers who use cochlear implants. *Journal of Speech, Language, and Hearing Research*, *52*(6), 1390-1400. PMCID: PMC2873612
[6] McMurray, B., Farris-Trimble, A., & Rigler, H. (2017). Waiting for lexical access: Cochlear implants or severely degraded input lead listeners to process speech less incrementally. *Cognition*, *169*(August), 147–164. PMCID: PMC5612912