

# **The Role of F0 in Lexical Segmentation by Listeners with Cochlear Implants and in Simulations**

Julie M. Liss, Stephanie Spitzer, Tony Spahr,  
Michael Dorman, Kaitlin Lansford

*Arizona State University, Department of  
Speech and Hearing Science, Tempe, AZ,*

# Background

- There are significant benefits of complementing the electric hearing provided by a cochlear implant (CI) with residual low-frequency acoustic hearing (Dorman et al., 2008).
- The benefit of low-frequency hearing (<250 Hz) may be due to improved representation of fundamental frequency (F0), which is poorly represented in electrical hearing (Spahr & Dorman, 2004).

- How might this low frequency information serve to improve speech perception?
- We hypothesized that one benefit might be linked to the use of F0 variation as a cue for syllabic stress for the purpose of lexical segmentation.
- F0 variation has been shown to be a robust cue for marking word onsets when speech is degraded (Spitzer et al., 2007)
- Normal hearing listeners make use of F0 variation to segment the continuous speech into its component words.

- It is possible to evaluate this function of F0 variation by reducing the cue (F0 flattening) and examining the lexical boundary error patterns that emerge.
- If listeners use the cue, we would expect that flattening would result in
  - Reduced intelligibility
  - Traceable to difficulties in segmenting the connected speech into words
  - With a greater number of “nonpredicted” error types

# Participants

- Listeners with cochlear implants
  - 6 Electric-Acoustic Stimulation (**EAS**): possessed residual low-frequency hearing in the non-implanted ear.
  - 6 Traditional Electric-Only (**E**):
- Normal-hearing listeners (**NH**)
  - 10 NH adults

# Speech Stimuli

- 80 phrases
  - (3-5 words, alternating Strong and Weak syllables) spoken by one male speaker.
- Half of the phrases were modified by replacing the F0 contour across each phrase with the mean F0 using ASL (KayPentax, 2004).

# Electric-Only Condition

- CI Listeners –
  - presented via loudspeaker to the implanted ear
  - foam earplug in the non-implanted ear of EAS
- Normal-Hearing Listeners –
  - Phrases processed through a 15-channel vocoder (Litvak et al, 2007)
  - Simulated electric signals presented at a comfortable level to the left ear via headphones.

# Electric-Acoustic Condition

- EAS Listeners
  - Phrases presented to both ears.
- NH Listeners
  - vocoded phrases presented to the left ear
  - lowpass filtered phrases presented to right ear
    - cutoff frequency of 500 Hz (6th order butterworth)

# Summary of Listeners and Conditions

	<b>Electric Only Condition</b>	<b>Electric &amp; Acoustic Condition</b>
<b>Normal F0</b>	E=6 EAS = 6 NH = 10	E=0 EAS = 6 NH = 10
<b>Flattened F0</b>	E=6 EAS = 6 NH = 10	E=0 EAS = 6 NH = 10

# Analysis

Transcripts scored independently by two trained judges

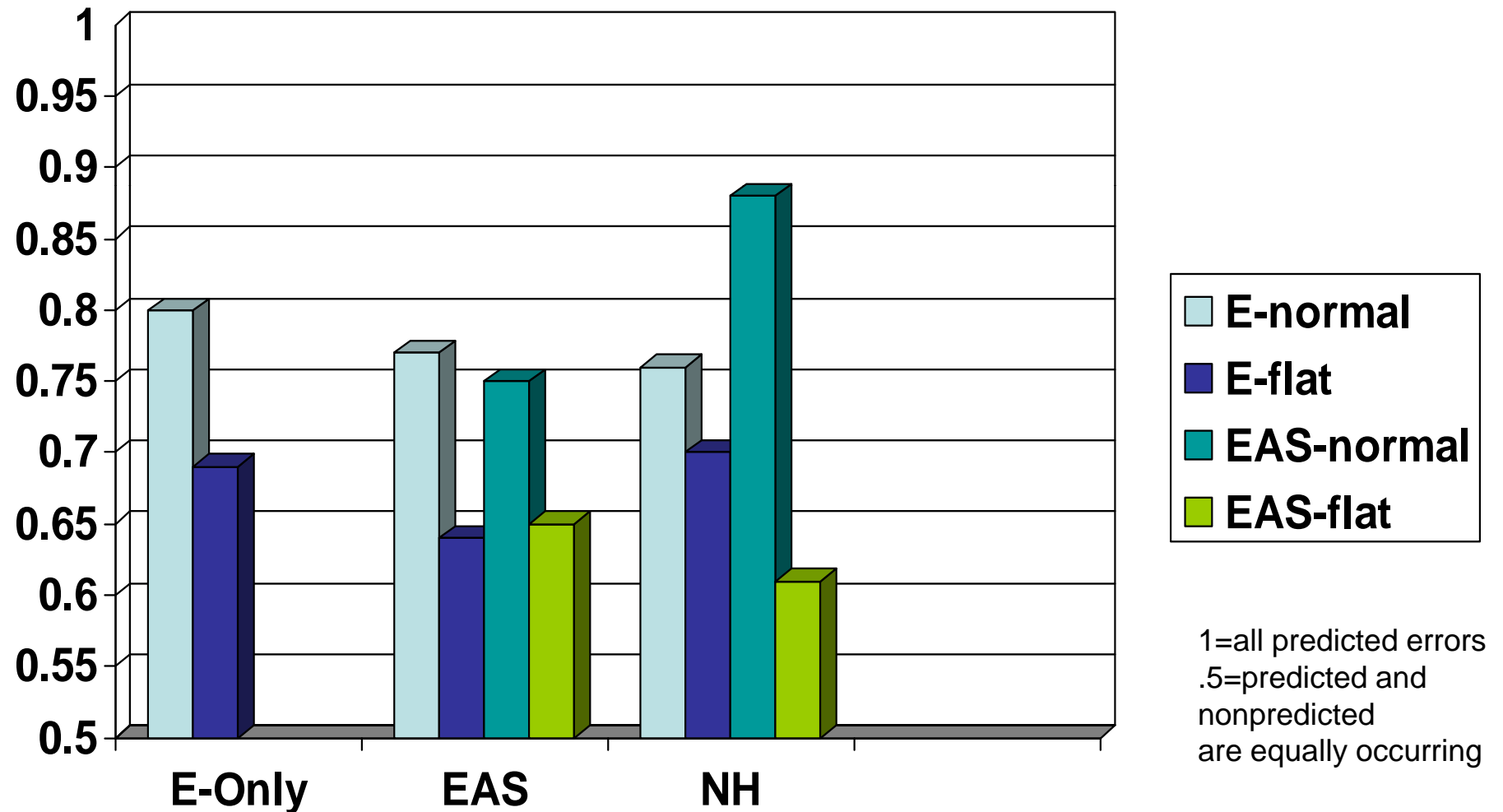
- % words-correct intelligibility
- the number and type of lexical boundary errors
  - Insertion (I) or deletion (D) errors
  - Either before strong (S) or weak (W) syllables
  - Predicted errors (Cutler & Carter, 1987):
    - Insertion before a strong syllable (IS)
    - Deletion before a weak syllable (DW)

# Intelligibility (% Words Correct)

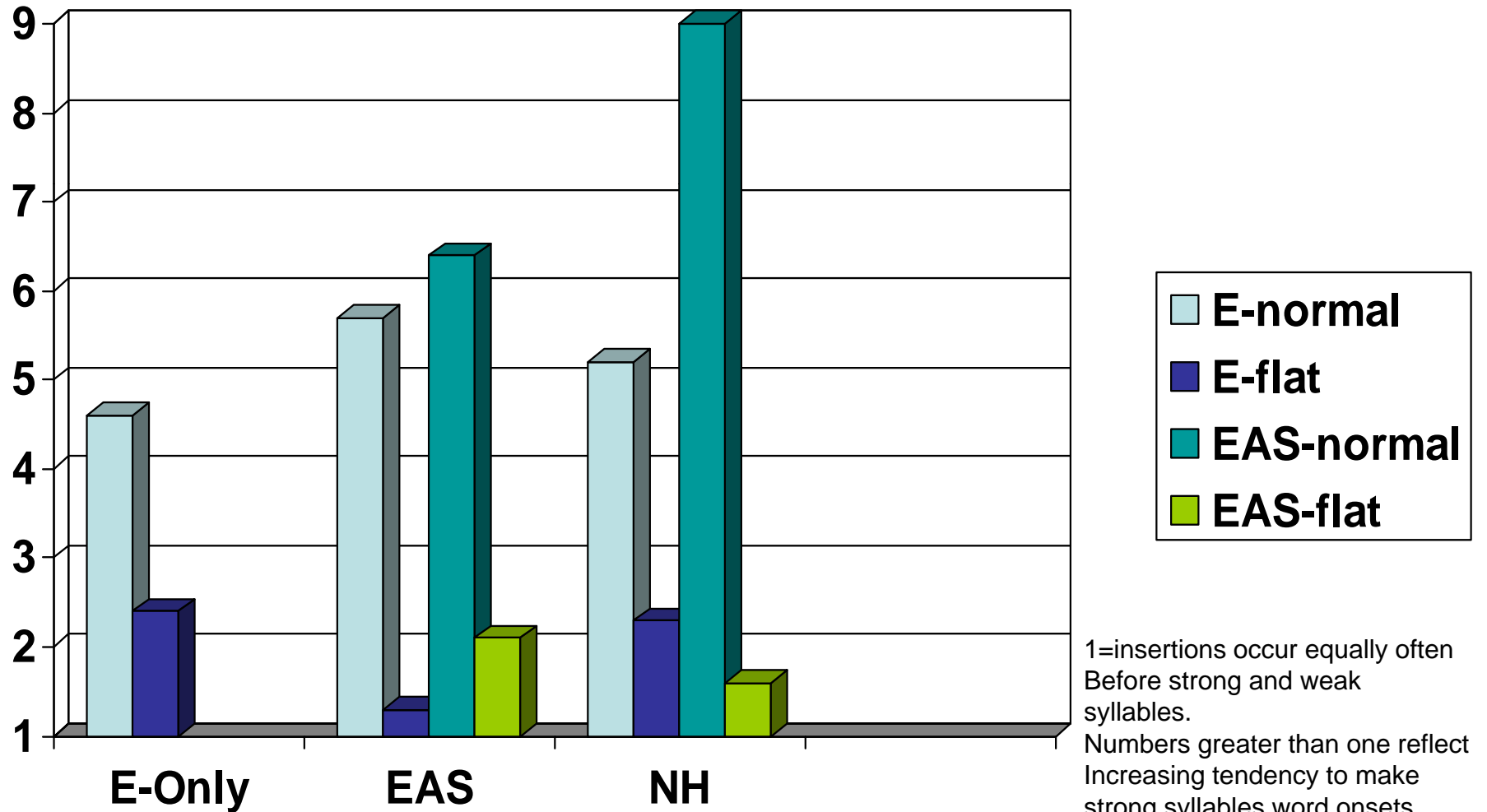
Intelligibility	Electric only		Electric & Acoustic	
	Normal F0	Flat F0	Normal F0	Flat F0
Electric only [N=6]	34.4	24.7*		
EAS [N = 6]	41.3	31.6*	56.3	49.7*
NH Listeners [N=10]	43.3	40.5	68.1	48.2*

\*p<.01

# Predicted Lexical Boundary Errors (IS+DW/total)



# Predicted Lexical Boundary Insertion Errors (IS/IS+IW)



# Summary

- **INTELLIGIBILITY**
  - Flattening of F0 as per the present method significantly decreased phrase intelligibility for all listener groups and conditions except for NH-electric only
  - The effect for traditional CI listeners was not expected.

- **LEXICAL SEGMENTATION**

- All groups relied on metrical stress for segmentation with more predicted than nonpredicted errors.
- However, reduction of the F0 cue to stress resulted in more non-predicted errors
  - Inserting a boundary before a weak syllable
  - Deleting a boundary before a strong syllable
- The presence of the F0 cue resulted in a preponderance of insertion errors before strong syllables (IS), suggesting a heavy reliance on this segmentation strategy.

# Conclusion

This study provides preliminary evidence that CI listeners use syllabic stress to make lexical segmentation decisions, much in the same way that normal hearing listeners do. Reduction in F0 as a cue to stress has a detrimental effect on the listeners' ability to apply this segmentation strategy.

This type of analysis provides insight to WHY intelligibility is reduced, and provides a tangible entry-point for processor improvement.

Work supported by NIH-NIDCD  
grants awarded to M. Dorman and J.  
Liss