# Exploiting the Ganong effect to probe for phonetic uncertainty resulting from hearing loss


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## INTRODUCTION

When the speech signal is degraded, listeners need to guess certain phonemes and words they missed in the conversation.

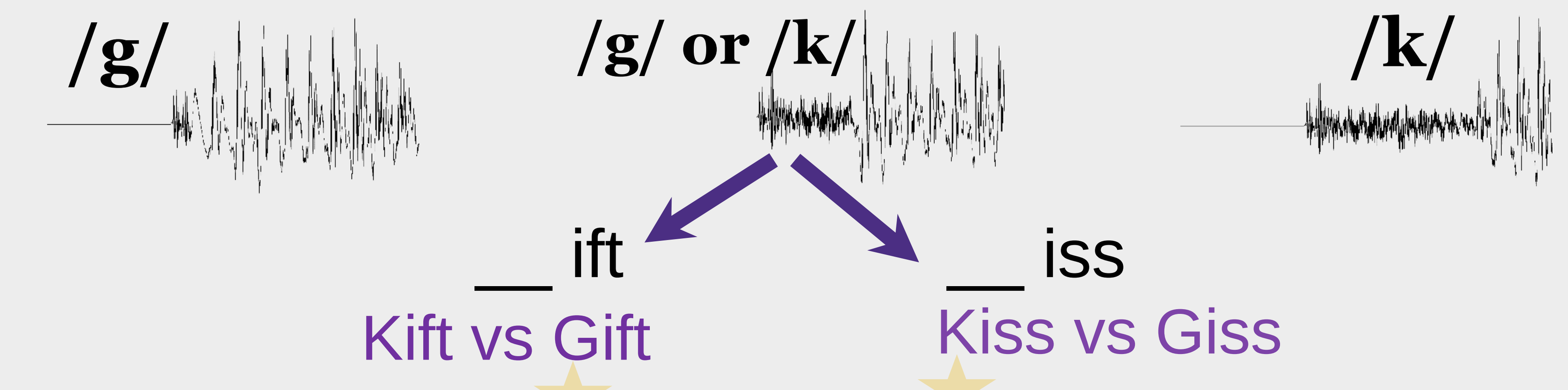
**The speech signal becomes compromised when a person has hearing loss or uses a cochlear implant.**

In this study we are studying the tendency to resolve phonetic ambiguities using experience (lexical bias) rather than your ears (the signal)

### The Ganong Effect

The Ganong effect is the tendency to perceive an ambiguous speech sound as a phoneme that would complete a real word, rather than completing a nonsense/fake word. [1]

### An example of this:




A sound that could be heard as either /g/ or /k/ tends to be perceived as /g/ when followed by “ift” and as /k/ when followed by “iss”, presumably because those sound sequences produce real words

### This shows

Because the acoustic signals are the same across contexts, the effect reflects top-down influence rather than pure reliance on the signal.

### This is influenced by...

- **Ambiguity of speech [1, 2]**
- Frequency of word in spoken language [3]
- Semantic Context [4]
- Phonotactic probability [5]
- Lexical context [6]
- Stimulus blocking [7]

### How can we use this?

- When speech sounds are ambiguous, we rely more heavily on our lexical knowledge
- This situation is probably very common for people with hearing loss
- **Hypothesis:** Degrading speech stimuli as if listening with a hearing loss or cochlear implant, should render the speech more ambiguous, thus yielding an increased reliance on top-down processing, seen as an increased “Ganong effect”.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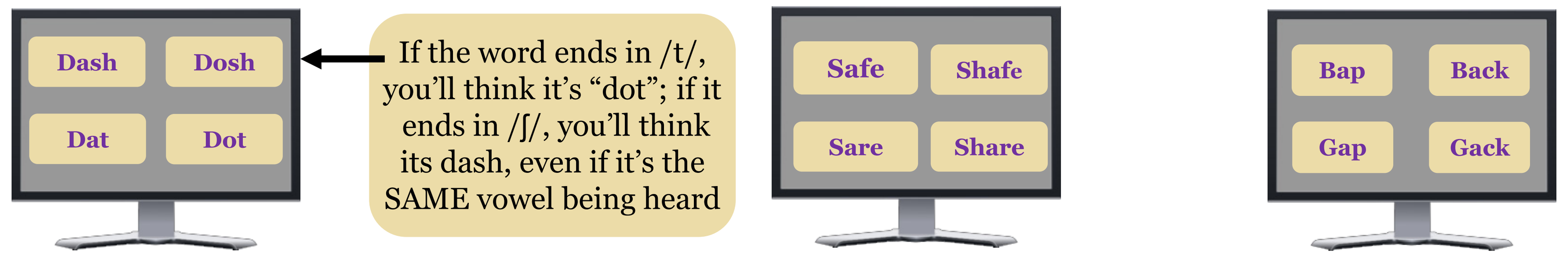
## METHODS

**PARTICIPANTS**: 32 young listeners with normal hearing (ages 18 –34 y)
5 listeners with cochlear implants (ages 55-75 y)

**STIMULI: Three 7-step speech continua where spectral phonetic cues vary by speed:**

Slow: /æ/ vs /ɑ/  Medium: /s/ vs /ʃ/  Fast: /b/ vs /g/

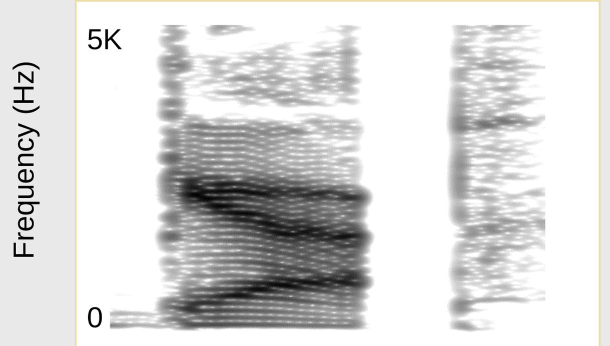



### Stimulus creation

- All stimuli were made using modified natural speech sounds
- For all stimuli, phonetic environments were kept consistent across stimulus sets using a cross-fading/ splicing
  - Formants for /æ/-/ɑ/ and /b/-/g/ modified using LPC decomposition in Praat (see Winn & Litovsky 2015)
  - /s/ - /ʃ/ continuum made from natural tokens of these fricatives combined with gradual attenuation
- Words were chosen from the HML database to control for familiarity and frequency in the English language
  - Stimulus contexts were controlled to avoid any bias other than lexical bias

### Simulating auditory distortion and hearing loss

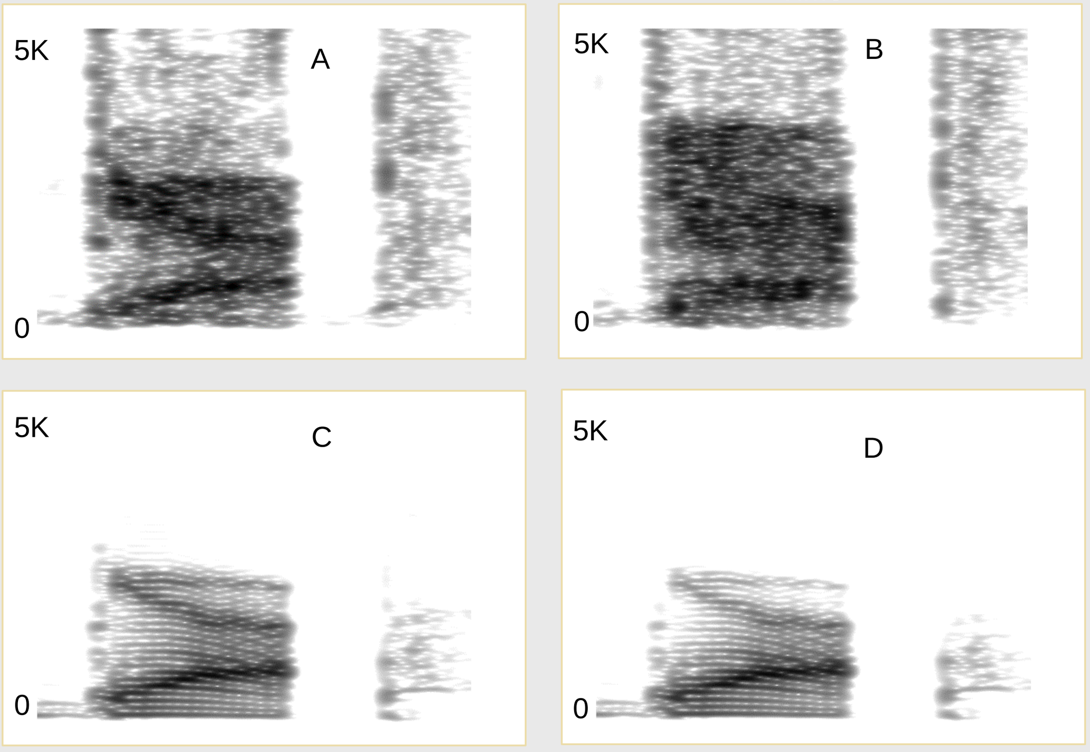
**Unprocessed (normal) speech** ‘Back’




**Apart from normal speech, there were two kinds of stimulus degradations at two difficulty levels:**

**Vocoded speech**
to approximate spectral distortion in cochlear implants
(A) 24 channels & (B) 8 channels

**Low-pass filtered speech**
mimicking high-frequency hearing loss.
(C) mild-moderate (Sloping 15 dB per octave starting from 1 kHz),
(D) moderate-severe (25 dB/octave)

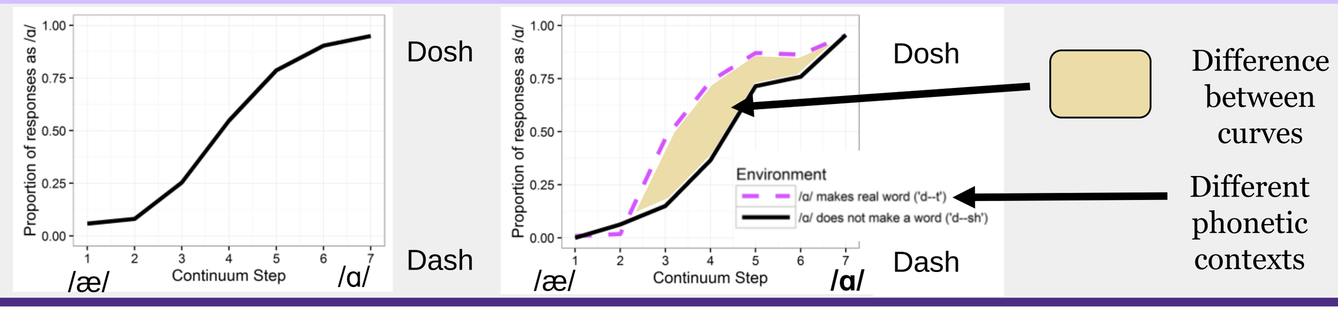




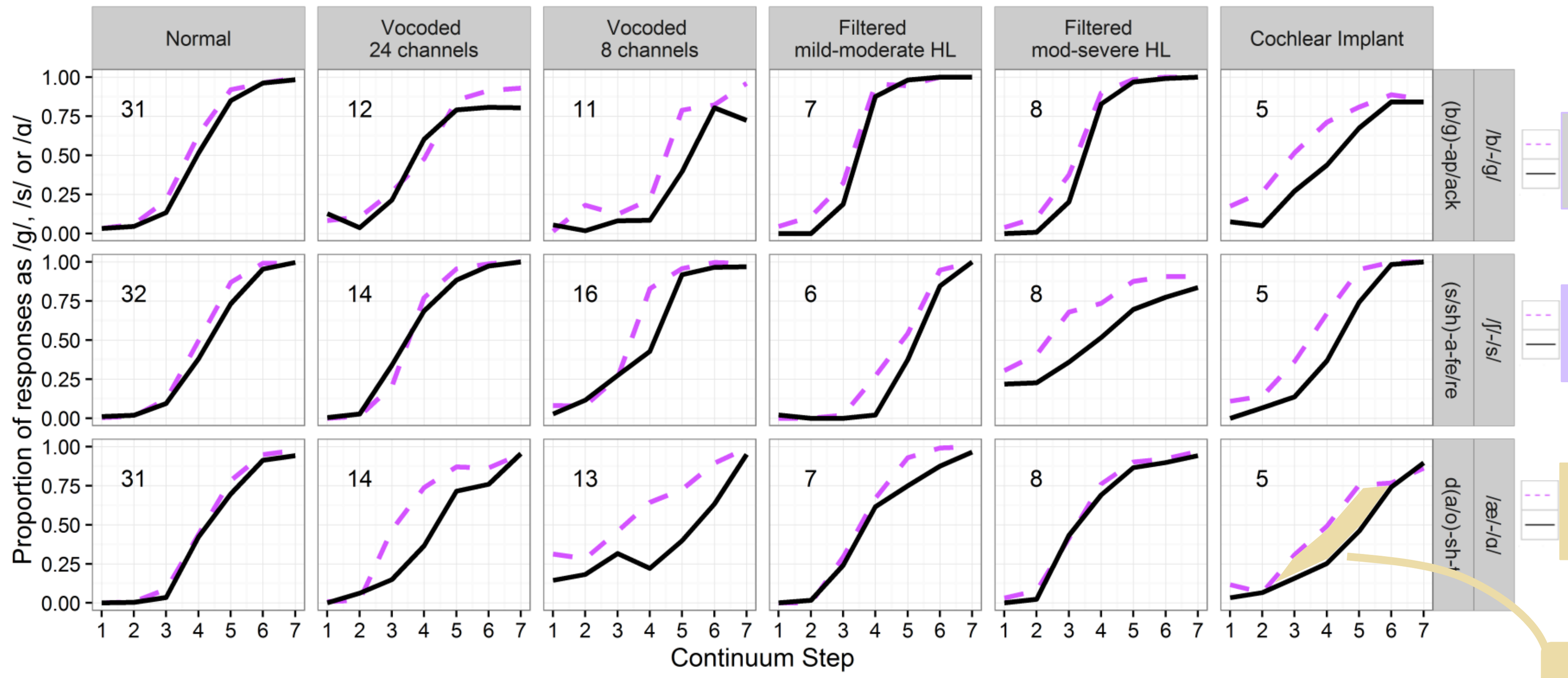
[1] Ganong W (1980) Phonetic Categorization in Auditory Word perception. *J Exper Psych: Hum Perc Perf*
[2] Burton M. (1995) Lexical Effects on Phonetic Categorization: The Role of Stimulus Naturalness and Stimulus Quality. *J Exper Psych: Hum Perc Perf*
[3] Morton J. (1979). Word recognition IN Morton J. & Marshall J.C. (Eds.). *Psycholinguistics 2: Structure and processes*
[4] Borsky S., Tuller B., & Shapiro L.P. (1998) The effects of semantic and acoustic information on phoneme categorization. *JASA*
[5] McClelland J.L., Mirman D., Holt L.L. (2006) Are there interactive processes in speech perception? *Trends in Cognitive Sci*
[6] Magnuson J, McMurray B, Tanenhaus M, & Aslin R. (2003) Lexical effects on compensation for articulation: a tale of two systems? *Cognitive Science*
[7] Pitt M.A. & Samuel A.G. (1993) An empirical and meta-analytic evaluation of the phoneme identification task. *J Exper Psych: Hum Perc Perf*


## RESULTS:

### Understanding the perceptual shift



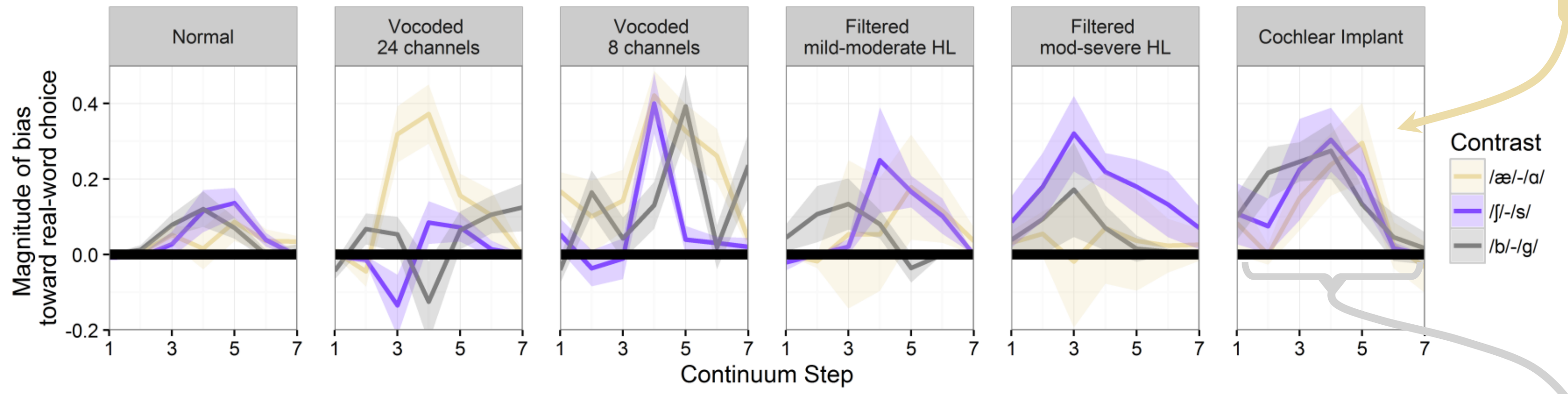

The space between dashed and solid lines reflects the influence of lexical bias.
If dashed line is higher than solid line, listener shows bias to hear phoneme as sound that makes a real word




**In all plots, the spacing between curves indicates lexical bias effect**

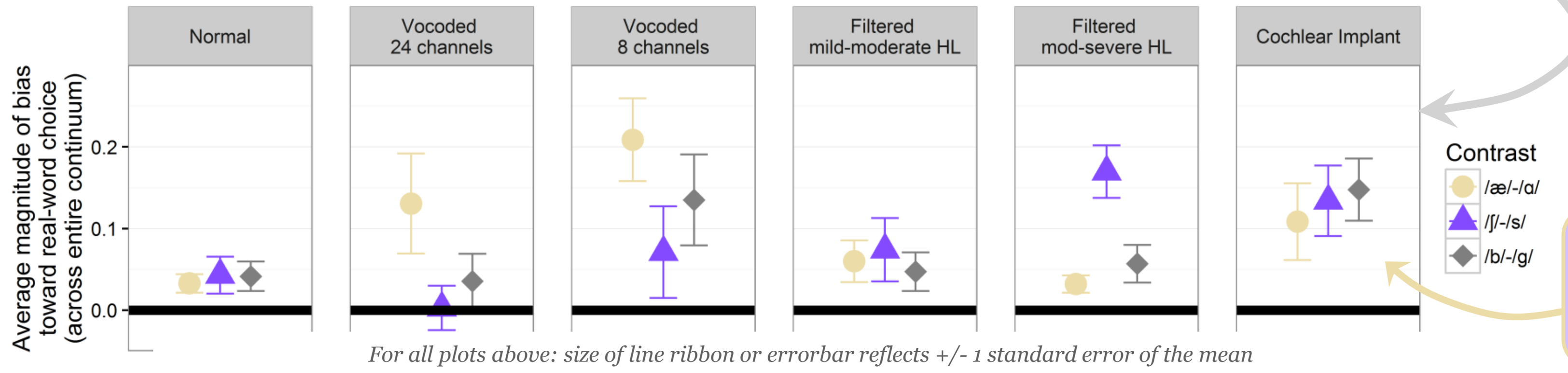
**The difference between curves generally becomes greater as the ambiguity of the speech stimuli increases**

**direct difference between curves**




**The difference between curves is greatest for the center of the continuum when the stimuli are the most ambiguous**

Average bias across the *entire* continuum

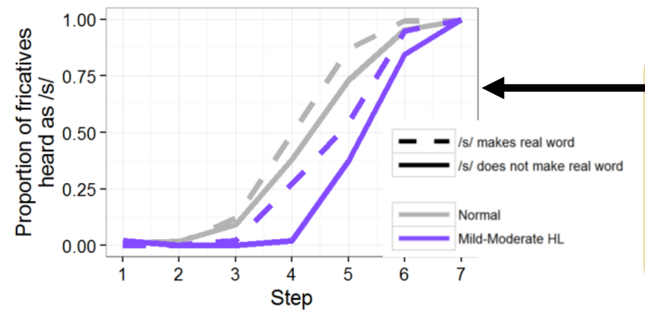



*For all plots above: size of line ribbon or errorbar reflects +/- 1 standard error of the mean*

**More severe degradations elicit greater lexical bias**

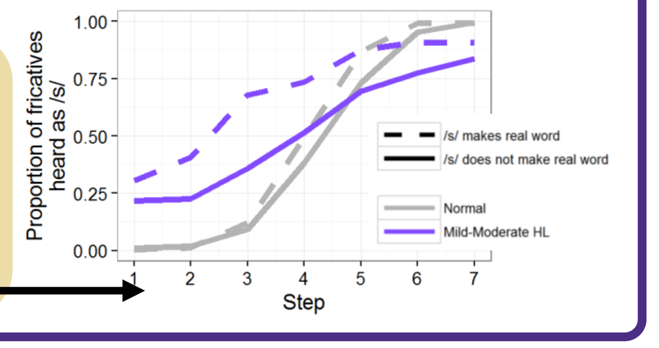
**People with cochlear implants show increased lexical bias with faster phonetic contrasts**

### Extra details of response shift and slope




The simulated *mild-moderate* hearing loss removes some high-frequency energy, making /s/ sound like /ʃ/ (mild shift to the right)

The *moderate-severe* hearing loss removes *so much* high frequency information that listeners seem to no longer judge spectral shape in the same way; they perceive /s/ more often (centered function) are less reliable (shallower slope), and rely on lexical knowledge (Ganong effect)




## CONCLUSIONS

- Phonetic perception is informed by lexicon knowledge (the same sound is perceived differently depending on lexical status)
- Listeners tend to rely more heavily on lexical knowledge when the auditory signal is spectrally degraded or band-limited
- People with cochlear implants potentially show greater dependence on lexical knowledge when acoustic cues are faster