Age-related changes in the use of linguistic cues for speech intelligibility in adverse listening conditions

Antje Heinrich
Department of Linguistics, University of Cambridge, UK

Changes in Speech Perception with Age

Two common results for speech perception in background noise:
1) Speech perception decreases for older adults (OA) due to increase in age-related hearing loss (HL)
- shown for single words and sentences without contextual information (e.g., Helfer & Wilber, 1990)

2) Speech perception remains robust or even increases for OA due to increased linguistic knowledge
- shown for connected speech and sentences with rich contextual information (e.g., Pichora-Fuller, Schneider & Daneman, 1995)

Overarching Questions (3-year project):

1) Can the positive effect of age on linguistic knowledge be extended to linguistic cues other than contextual information (see Pichora-Fuller et al.)?
2) How do opposing age-related changes in hearing (decrease) and linguistic knowledge (increase) interact?
3) Does this interaction lead to the emergence of compensatory mechanisms? How can these mechanisms be characterised?

Long-domain resonance effect

- Present in all spoken speech (not only connected, high-context sentences)
- Also known as phonetic or co-articulation cues
- Have been suggested to contribute to robustness of speech intelligibility in noise, aging, and hearing loss
- Example of phonetic cue: resonance effects due to /r/ compared with /l/ phonemes:

Sadie hoped to see the *miller* today.
Sadie hoped to see the *mirror* today.

- The presence of /r/ in *mirror* systematically decreases third (F3) and forth (F4) formant frequencies in preceding syllables.
- The effect is strongest in the syllable immediately preceding the target word, but is acoustically present in unstressed syllables up to 600 ms prior to target word (West, 1999; Heid & Hawkins, 2000; Coleman, 2003)
- The following figure explains the effect:

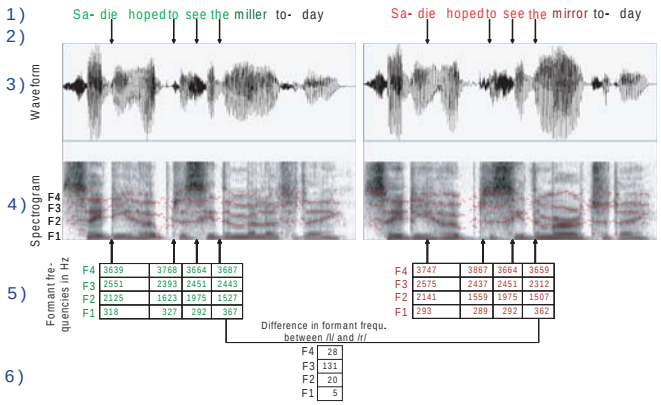


Figure 1:
1) Recordings of "Sadie hoped to see the miller today" and "Sadie hoped to see the mirror today"
2) Unstressed syllables before target word miller/mirror (for which formant frequencies will be measured)
3) Amplitude waveform
4) Spectrogram (energy per frequency in Hz)
5) Formant frequencies of first 4 formants (F1-F4) of the four unstressed syllables preceding the target word
6) Difference in formant frequency of "the" preceding /miller/ and /mirror/

Research Methodology

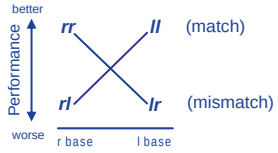
- Recordings of natural sentences by native British English (RP) speaker
- 52 sentences were cross-spliced (=cut&paste) to contain either matching sentence base and target word (both from /l/ or /r/ sentence), or mismatched base and target:

	/l/ target word	/r/ target word
/l/ sentence	Sadie hoped to see the miller today **MATCHED CONDITION /ll/**	Sadie hoped to see the mirror today **MISMATCHED CONDITION /lr/**
/r/ sentence	Sadie hoped to see the miller today **MISMATCHED CONDITION /rl/**	Sadie hoped to see the mirror today **MATCHED CONDITION /rr/**

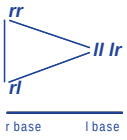
- Presented in +2 dB SNR cafeteria noise
- 41 native English speakers were tested
- Age range: 18-35 years of age
- Task: listen to sentence in noise and write down what you heard
- Scored for correct target words

Predictions

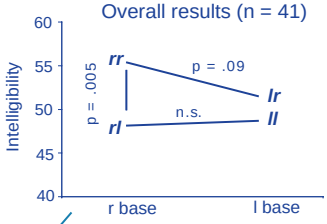
1. If /r/ and /l/ are salient
match always better than mismatch



2. If only /r/ is salient
match /rr/ best; mismatch /rl/worst;
both /l/ base conditions "neutral"



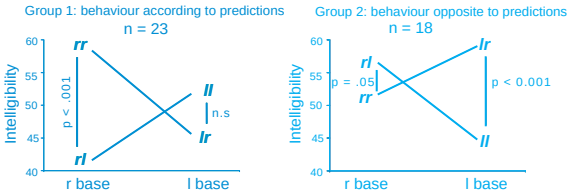
Results



The overall results corresponded best to prediction 2: only /r/ resonances were salient, whereas /l/ resonances were not predictive of the upcoming word and therefore were not misleading when the resonance was followed by a mismatched target word.

However, not all listeners followed this answer pattern. Rather, the responses seem to fall into two categories:

At closer inspection, listeners fell into two groups



Listeners followed one of two listening strategies: They were either very sensitive to matching acoustic patterns (/rr/ in Group 1), or disregarded the predictive value of the resonance information (/rl/, /lr/, and possibly /rr/ in Group 2).

Research Questions of Current Study

1) Can listeners in general take advantage of resonance cues in naturally spoken speech?

- Prelimenary evidence suggests: listeners use long-domain /r/-resonances to improve intelligibility:
  - in synthetic speech (Hawkins & Slater, 1994; Tunley, 1999)
  - in naturally spoken low-context carrier sentences with the crucial syllable replaced by noise (West, 1999)

2) Can older adults (OA) take advantage of this cue?

- Most resonance information is in 2-3 kHz frequency range
- Most OA show *some* hearing loss between 2-3 kHz
- Do OA rely more (due to increased linguistic knowledge) or less (due to HL) on this cue?

Conclusions and next steps

- Speech resonances affect intelligibility of natural speech in adverse listening conditions
- Listeners seem to follow one of two listening styles (see results, groups 1&2)
- Listeners can not be easily swayed to change their style of listening (follow-up experiment, not presented here)
- Next step: test older adults with varying degrees of hearing loss
  Can they use the same cues?
  Do they also show one of two listening styles?
  How does age and hearing loss interact with the results?

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