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The role of periodicity in speech-on-speech understanding in normal-hearing and hearing-impaired listeners

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In competing-talker scenarios, periodicity information can provide useful auditory cues for target-speech understanding. It is unclear what the importance of such cues is and to what extent hearing deficits limit their availability. This study explored how periodicity information in target and interfering speech contributes to speech intelligibility in young normal-hearing (NH) and older hearing-impaired (HI) listeners.

Background

When two competing talkers are present in the auditory scene, the periodicity information encoded in the speech signals provides useful auditory cues for speech understanding in NH listeners. For example, when the two competing voices differ in average fundamental-frequency (F_0) or F_0 dynamic range, the intelligibility of the target is improved[1,2].

These benefits are largely reduced in HI listeners, indicating that hearing loss limits the access to periodicity cues[1,3].

The aim of this study was to explore the role of periodicity of two competing speech signals on intelligibility, by selectively removing periodicity in target and/or interfering speech.

Research questions

- What is the contribution of target and masker periodicity to speech intelligibility in competing-talker scenarios?
- How does hearing loss affect the access to the relevant periodicity-related cues?

Hypothesis

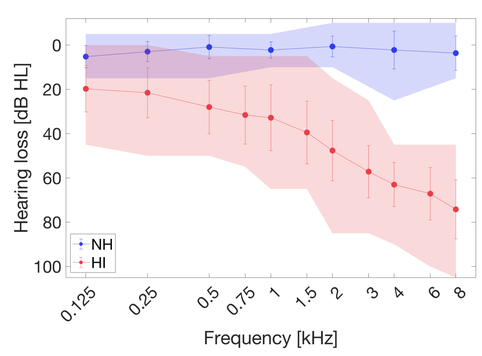
Both target and masker periodicity aid competing-speech segregation in the following ways:

- Target periodicity: essential for good speech intelligibility.
- Masker periodicity: beneficial in absence of target periodicity.
- Hearing loss (especially at low frequencies) reduces access to periodicity information in target and masker.

Methods

Test participants

- 12 young NH
- 30 older HI



Auditory and cognitive profiling

- Audiogram (PTA4)
- Audible Contrast Threshold (ACT™)[4]
- Reading span test[5]

Speech intelligibility test

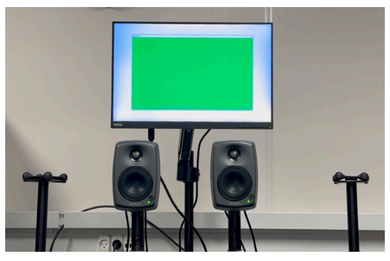
- Two-competing voices
- Target: Danish HINT[6] sentences (embedded in running speech)
- Masker: running speech or noise

Stimulus generation

- Selective removal of periodicity information from target and/or masking speech using TANDEM-STRAIGHT[7]
  - Natural speech (periodic) - NAT
  - Vocoded speech (non-periodic) – VOC[8]
- Additional masking condition: speech-modulated noise (ICRA-7[9]) - SMN
- Target-masker onset difference (2 s)

Procedure

- Two frontal loudspeakers (30 cm separation)
- Target position randomized
- Visual cue for marking HINT sentence in target
- Speech reception threshold (SRT) measurement
- Linear-gain amplification for HI listeners using hearing aids



Results

Overall findings

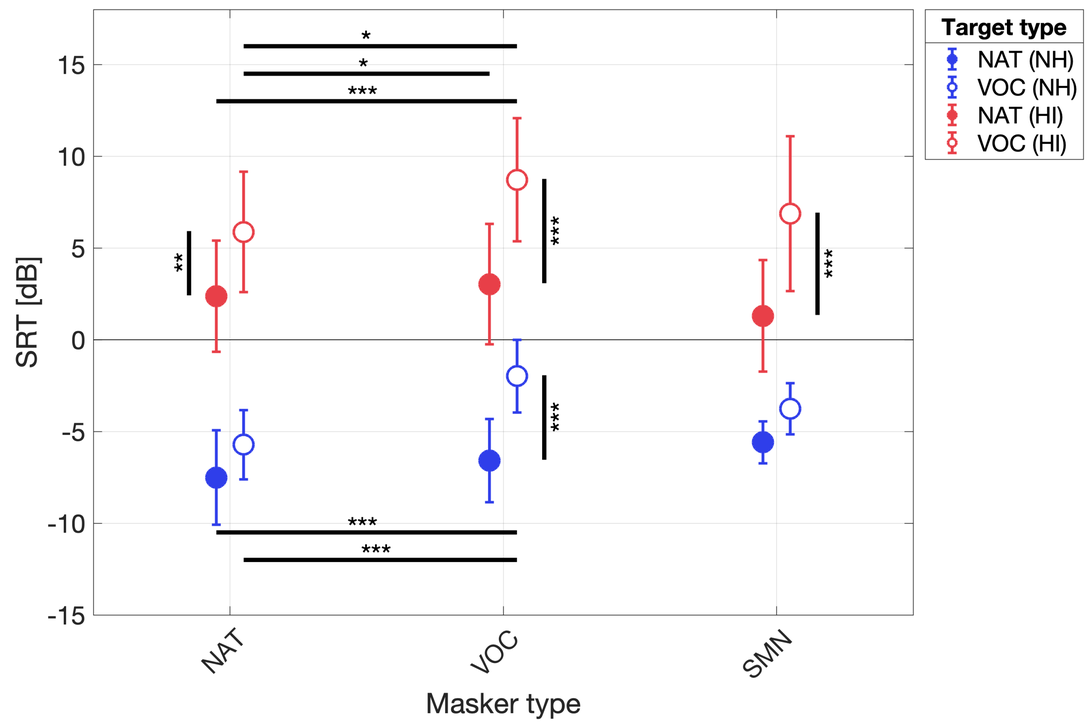
- On average, higher SRTs and wider variability for HI listeners compared to NH listeners in all conditions (~10 dB SRT elevation due to hearing loss).
- For HI listeners: NAT-NAT speech intelligibility performance correlated with
  - PTA4 (ρ=0.7, $p<10^{-3}$)
  - ACT (ρ=0.5, $p<0.05$)

Effect of selective removal of periodicity (re. NAT-NAT)

- Removal of target periodicity (VOC-NAT) is detrimental for HI but not for NH.
- Removal of masker periodicity (NAT-VOC) does not affect intelligibility for NH and HI.
- Removal of periodicity from both signals (VOC-VOC) is detrimental for NH and HI.

Effect of SMN masker (NAT-VOC vs NAT-SMN)

- Speech intelligibility changes are not significant.
- NH: SMN masker decreases intelligibility.
- HI: SMN masker increases intelligibility.



Discussion

Overall, the results indicate that in two competing-talker scenarios with very limited spatial cues

- Both NH and HI listeners rely on periodicity cues for segregating the speech signals.
- NH exhibit excellent speech segregation abilities even in absence of periodicity cues.
- Compared to NH, HI persons show substantial difficulties in speech segregation even if provided with linear gain amplification.

The role of target/masker periodicity

- NH listeners: the presence of periodicity in at least one of the competing speech signals is sufficient for good speech intelligibility. In particular, NH can utilize masker periodicity for speech segregation even in absence of target periodicity (VOC-NAT).
- In contrast to NH listeners, HI listeners have poorer access to masker periodicity and rely mostly on target periodicity.

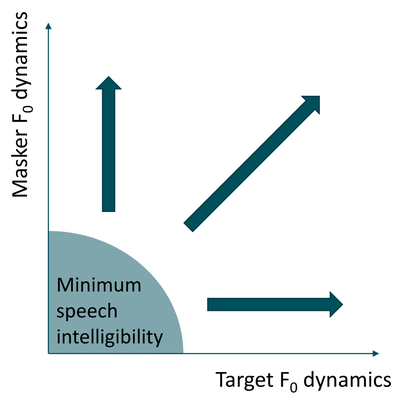
The role of masker intelligibility

- Presence of linguistic content in the masker is beneficial for NH listeners but reduces segregation abilities in HI listeners. However, this trend in the data is not supported by statistical significance.

Future work

Can enhanced periodicity cues improve speech intelligibility for HI listeners?

- Enhanced F_0 dynamics have been shown to provide better intelligibility in competing-talker scenarios for NH listeners[10].
- We will soon test the possibility of increasing the salience of periodicity cues for HI listeners by manipulating fundamental-frequency (F_0) dynamics.



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