The Use of Binaural Beamforming to Reduce Listening Effort

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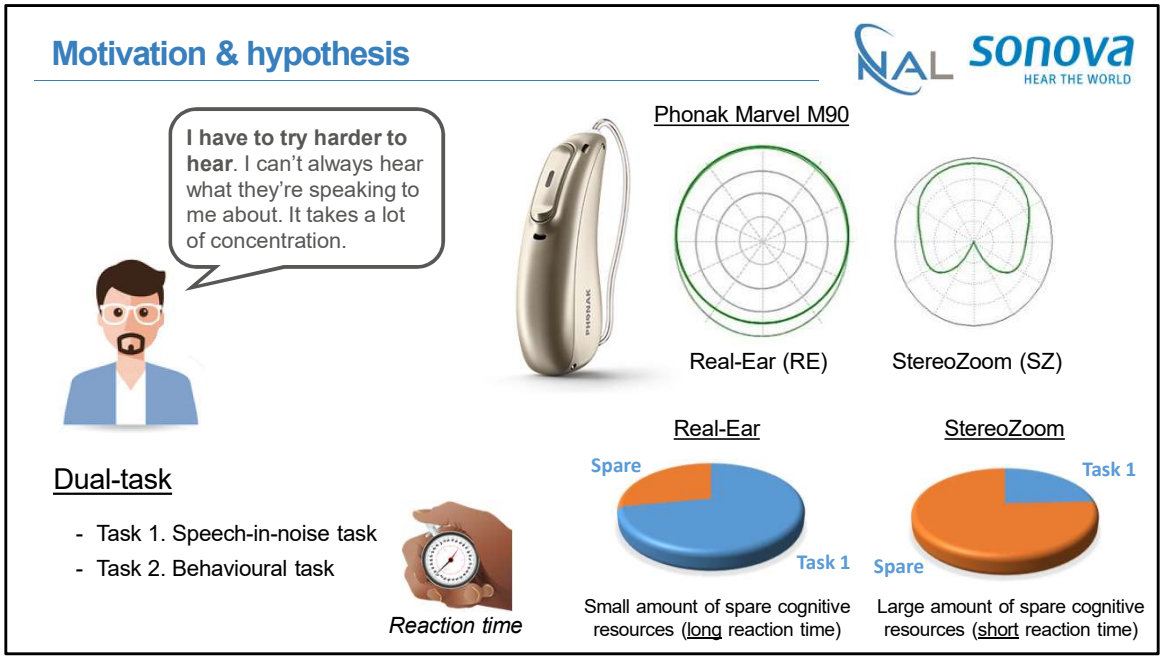
- Thank you Samira/Gabriella [moderators of the session].
- **Today I will present a study we have conducted** at the National Acoustic Laboratories in collaboration with Phonak from the Sonova group where we have evaluated whether an advanced mode of Phonak hearing aids based on a binaural beamforming is effective in reducing listening effort.



- **It is very common** that people with hearing loss often complain of the large amount of effort or concentration they need to dedicate to follow a conversation with their peers, particularly in noisy environments.

- For example, one participant reported "I have to try harder…"

- This study aimed to investigate if the additional directionality provided by a binaural beamformer reduced listening effort.

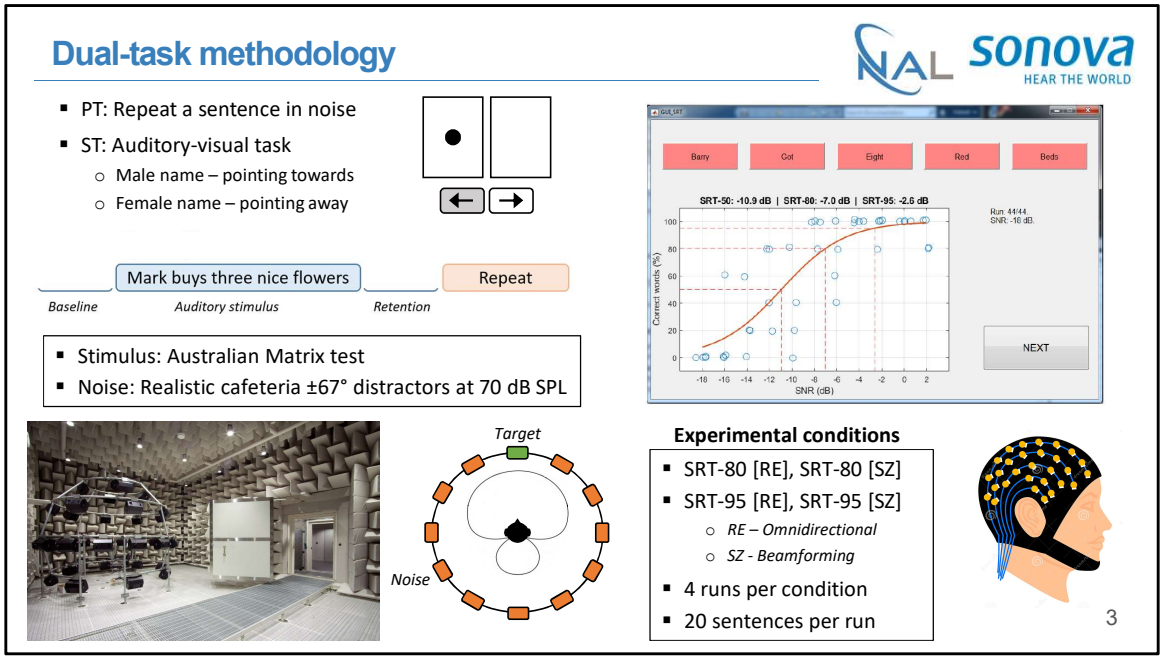
- For this, we used the Phonak Marvel M90 hearing aids in which the microphones were programmed in two modes:
    1) Real-Ear is a basic mode that presents a quasi-omnidirectional function that simulates the pinna effect
    2) StereoZoom is an advanced mode based on a binaural beamformer that presents a very strong directionality

- The methodological approach we took to measure listening effort was based on a dual task.

- In dual tasks, participants are instructed to conduct two tasks simultaneously:
    - a primary task usually consists on repeating back a sentence presented in noise, and
    - a secondary task is usually a behavioural task where performance can be measured, for example via their reaction time

- The hypothesis of the study was that understanding a sentence in noise in the RE mode would require a large amount of cognitive resources, leaving less cognitive resources available to conduct the secondary task, which would lead to longer reaction times in that task.

- However, the acoustic advantage provided by the stronger directionality in StereoZoom would reduce the cognitive resources required to understand the sentence in noise, which would lead to shorter reaction times due to the extra spare cognitive capacity.



- In the Primary task of the dual task that we developed to measure listening effort, participants had to repeat back a sentence from the Australian version of the Matrix test presented in realistic cafeteria background noise. The sentences from the Matrix test have the same structure: *name + verb + number + adjective + noun*; and there are ten words per category that can be combined to make a large number of meaningful sentences.

- The Secondary task was an auditory-visual task where participants could see two rectangles in front of them. At the start of the sentence, a large black circle appeared randomly in one of the rectangles, and participants were instructed to press the arrow pointing towards the circle if the name was a male name, or the arrow pointing away the circle in case of a female name.

- This experiment was administered in the anechoic chamber of the Australian Hearing Hub in Sydney.

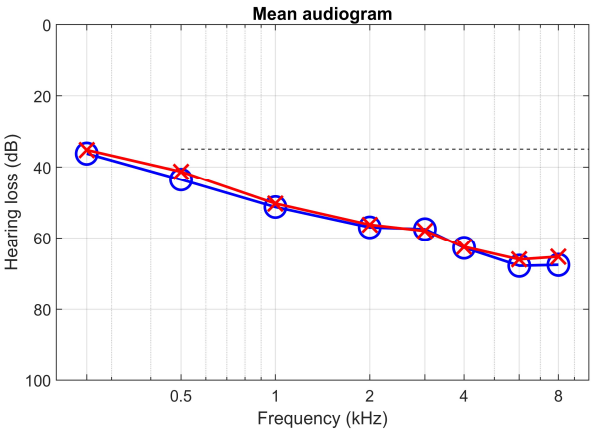
- We estimated the SNR corresponding to 80% and 95% intelligibility for each participant – we called these SNRs SRT-80 and SRT-95; and we tested our participants in those SNRs, both in RE and SZ conditions, obtaining 80 measures

per condition in each participant.

- In addition, we also used self-reported measures of listening effort, and took neurophysiological measures via a 64-channels EEG setup.

Participants

- 20 participants (9 females)
- [26 - 81] years, mean = 65 years
- Native English speakers
- Experienced hearing aid users (>2 years)
- MoCA > 75%
- Bilateral downward-sloping hearing loss
  - >35 dB at 500 Hz and above
  - Symmetry differences <20 dB for 0.5-4 kHz



- Participant 0 for acoustic measures

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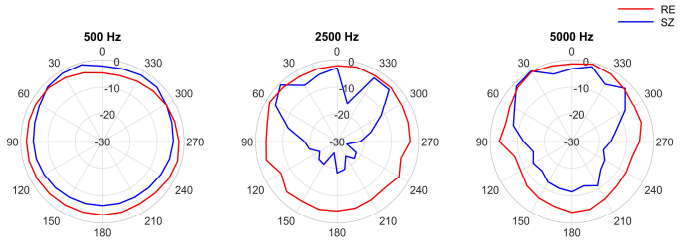
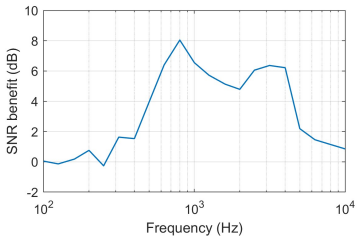
- 20 adults (9 females) with hearing loss participated in the study.
- (Go over the headings)
- In addition, we also recruited our participant 0 (KEMAR) for acoustic measures.

Acoustic measures

1. Directionality



2. SNR benefit



Articulation index-weighted directivity index
of SZ relative to RE = +5.6 dB

Articulation index SNR benefit
of SZ relative to RE = +4.8 dB

RE – Omnidirectional
SZ – Beamforming

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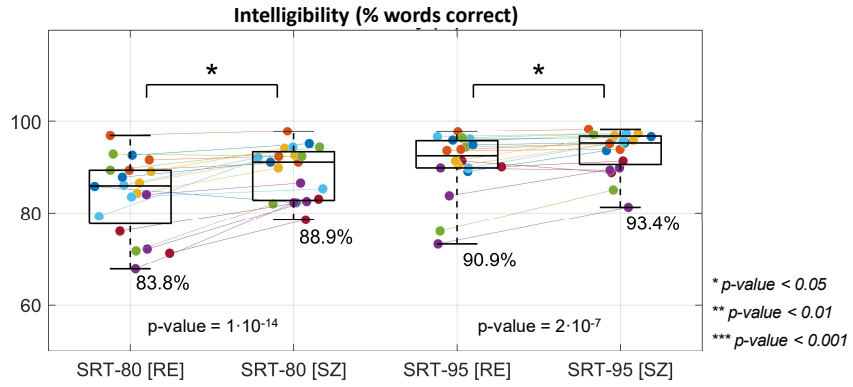
- As predicted, acoustic measures showed that StereoZoom (in blue in the polar plots) presented a much higher directionality than Real Ear.
- We estimated that there was a difference of 5.6 dB in the articulation index-weighted directivity index between SZ and RE – this is an interesting measure because this index weights the contributions at different frequencies according to their relevance in speech perception.
- Consistent with the previous result, the articulation-index SNR benefit was around 5 dB of SZ advantage against RE

Intelligibility



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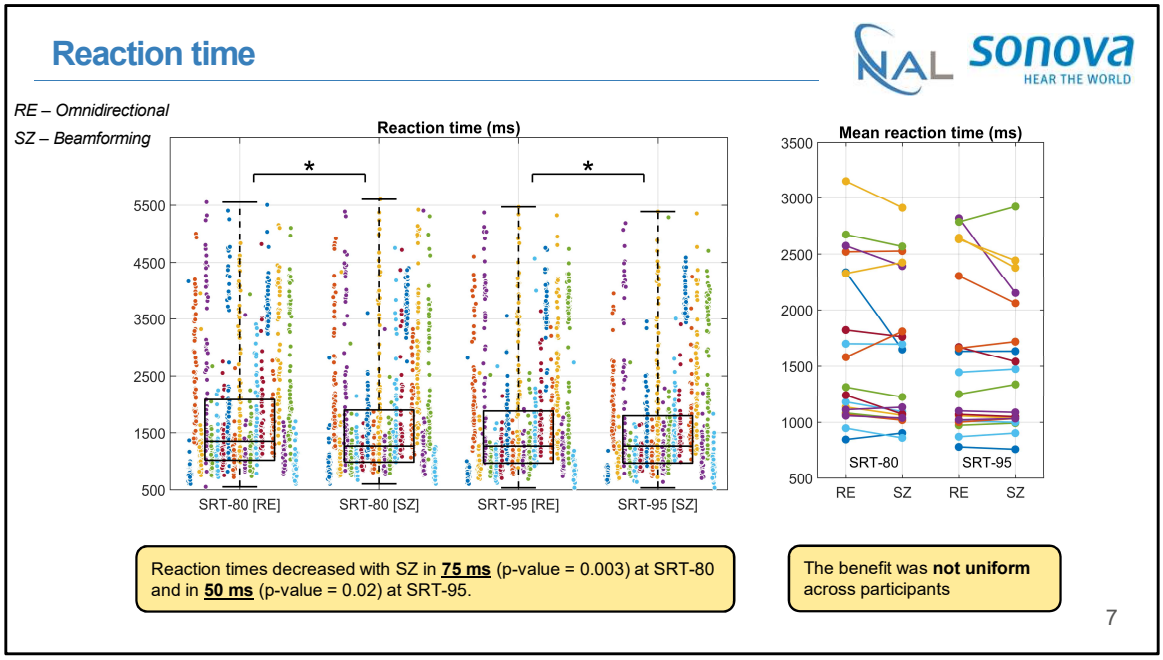
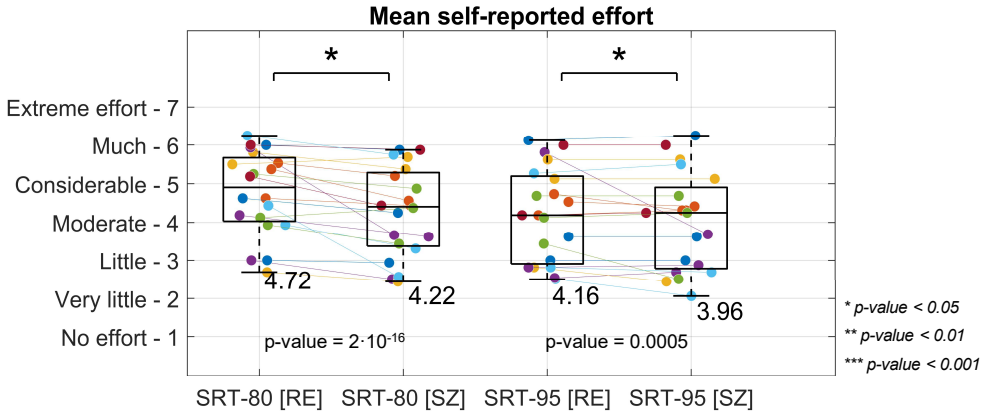
- Compared to RE, **intelligibility** improved with SZ in the two SRTs.
- At SRT-80, intelligibility advanced from 83.8% to 88.9%, and this difference was statistically significant (with a p-value = $1 \cdot 10^{-14}$)
- At SRT-95, intelligibility improved from 90.9% to 93.4% (p-value = $2 \cdot 10^{-7}$) at SRT-95.
- Overall, the SNR improvement of SZ relative to RE was +1.2 dB in the two SRTs.



- The figure on the left shows the raw data of the reaction time per participant in each of the test conditions – each colour is a different participant; and the right figure shows the mean data per participant.
- These two figures show a large variability in the reaction time across participants.
- The figure on the right also shows that reaction times with SZ were not always shorter in all participants.
- However, the statistical analysis showed that, on average, SZ reduced reaction times in 75 ms at SRT-80 and in 50 ms at SRT-95 – a result that is consistent with our prediction.

Self-reported measures



RE – Omnidirectional
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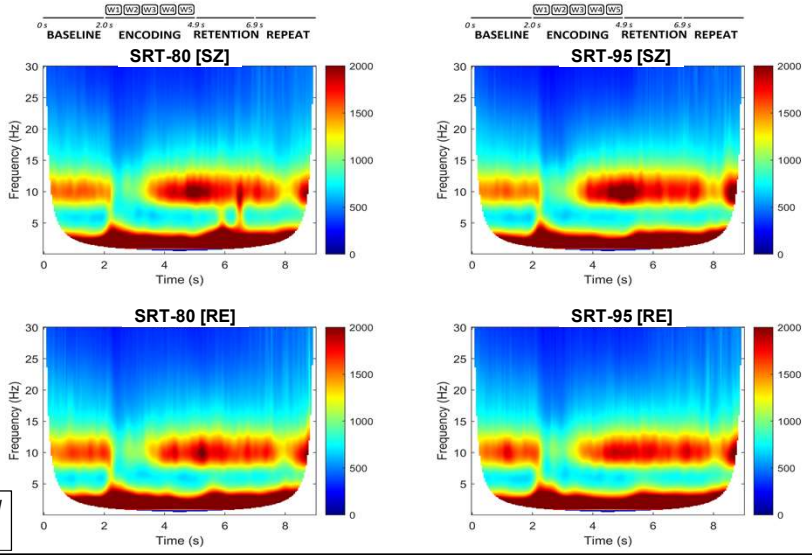
- When participants were asked to rate their self-perceived effort in a 7-point scale, results showed that their self-perceived effort decreased with SZ in the two evaluated SRTs.
- Importantly, participants were blind with regards the hearing mode.
- Self-perceived effort decreased with SZ from 4.72 to 4.22 at SRT-80 and from 4.16 to 3.96 at SRT-95.

Neurophysiological measures



RE – Omnidirectional
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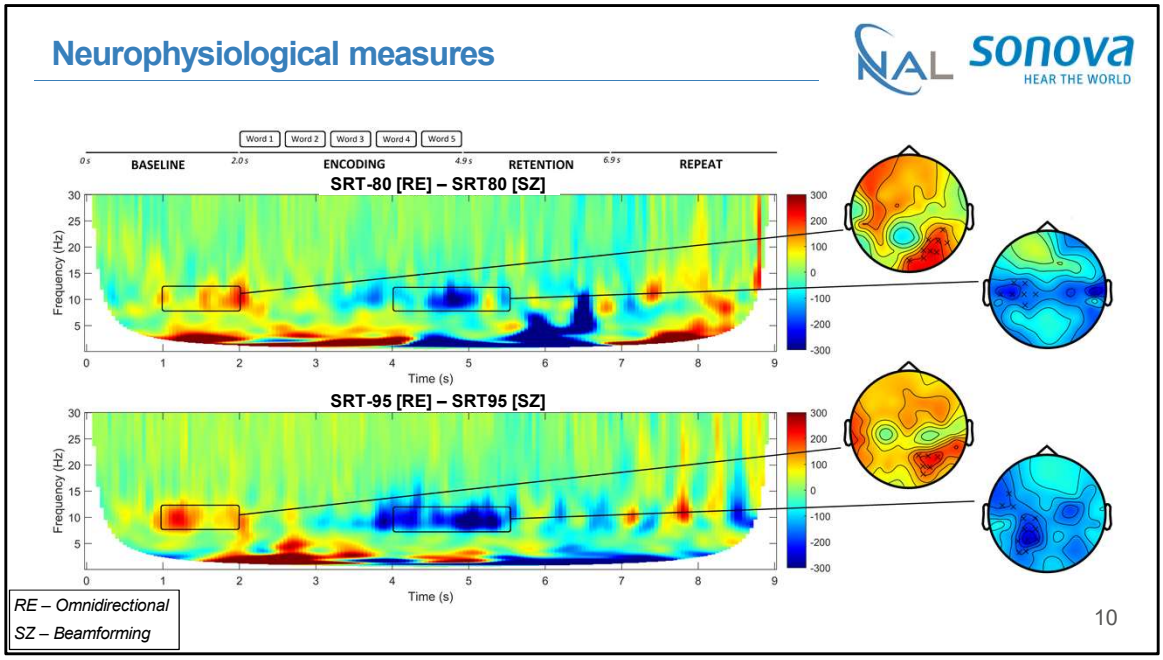
- These figures show the grand-average spectrograms across participants and electrodes in the four experimental conditions.
- They show a consistent brain activity pattern in the energy in the alpha frequency band, i.e. between 8 and 12 Hz.
- In order to evaluate brain activity differences between RE and SZ, a statistical analysis was conducted on the DIFFERENCE between the two modes in each SRT condition.



- This is shown in these two plots, that show the brain activity differences between RE and SZ in SRT-80 at the top, and in SRT-95 in the bottom plot.

- The statistical analysis showed two important differences between RE and SZ.

1. increased pre-stimulus alpha in the RE condition in the right parietal section of the brain, and
2. increased alpha in the encoding and retention part in SZ in the left temporal side of the brain.

- These differences were consistent in the two SRT conditions (which increases the reliability of the findings); and are consistent with the two fundamental roles of alpha-band oscillations: inhibition and information processing.

Take-home message & Acknowledgements

- The higher directionality of SZ provides an AI-SNR benefit of +4.8 dB, which led to an **increase in intelligibility** in the two evaluated SRTs.
- Behavioural, neurophysiological and self-reported measures demonstrate that SZ **reduces listening effort** relative to RE in a realistic cafeteria scenario.
- The effect size of the SZ benefit may **assist clinicians** in providing evidence-based recommendations to their clients, and adequately manage their expectations.

Sponsors

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- To take home… (read take-home messages)
- To conclude, I would like to acknowledge the contribution of the rest of the research team and thank the sponsors of this research: the Sonova holding group and the Australian Government through the Department of Health.
- Thank you for your attention. I am happy to take any question.