Spatial processing in adults with hearing loss

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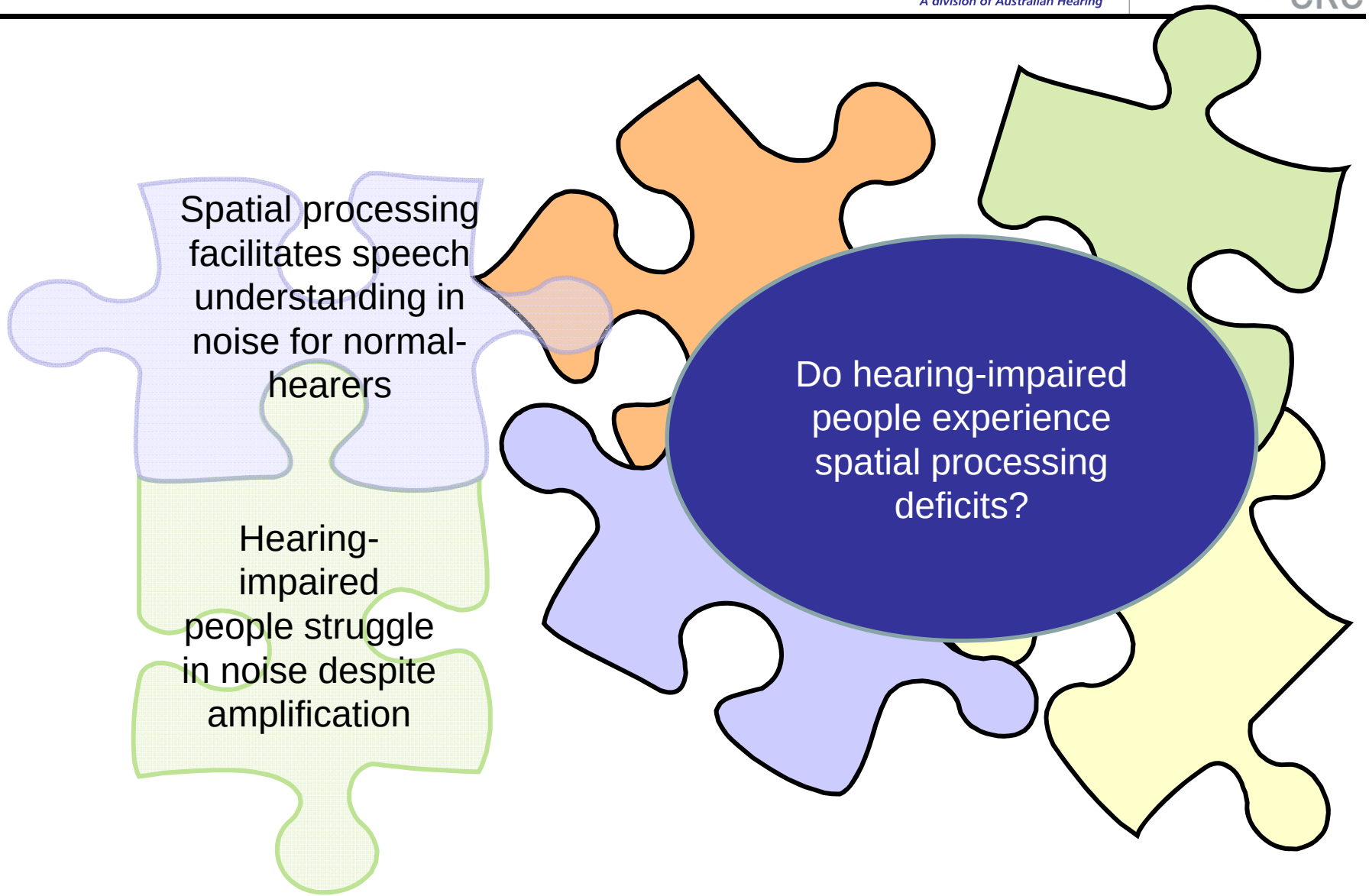
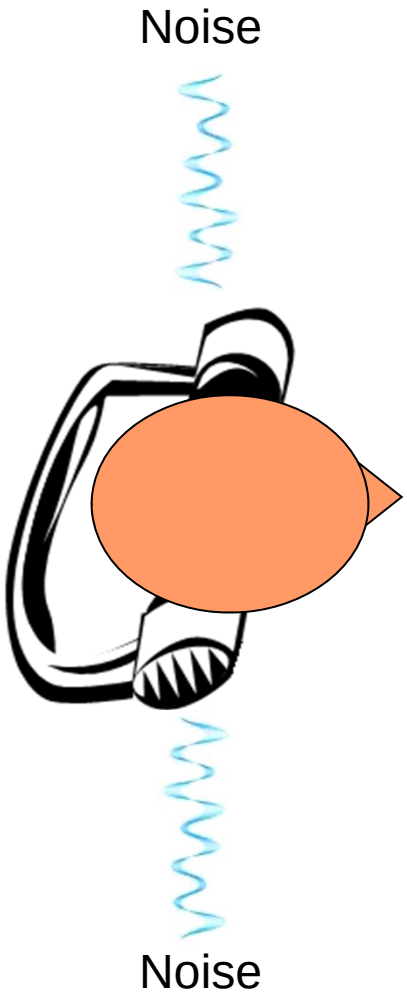
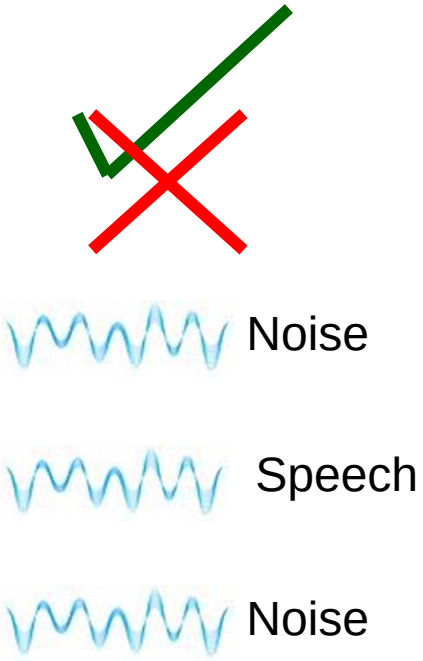

Spatial processing facilitates speech understanding in noise for normal-hearers
Hearing-impaired people struggle in noise despite amplification
Do hearing-impaired people experience spatial processing deficits?

What is Spatial Processing?

- Spatial Processing is the ability to selectively attend to sounds arriving from one direction while suppressing sounds arriving from other directions.
- It can be assessed by measuring speech understanding in spatially-separated and co-located noise.

What is SPD?



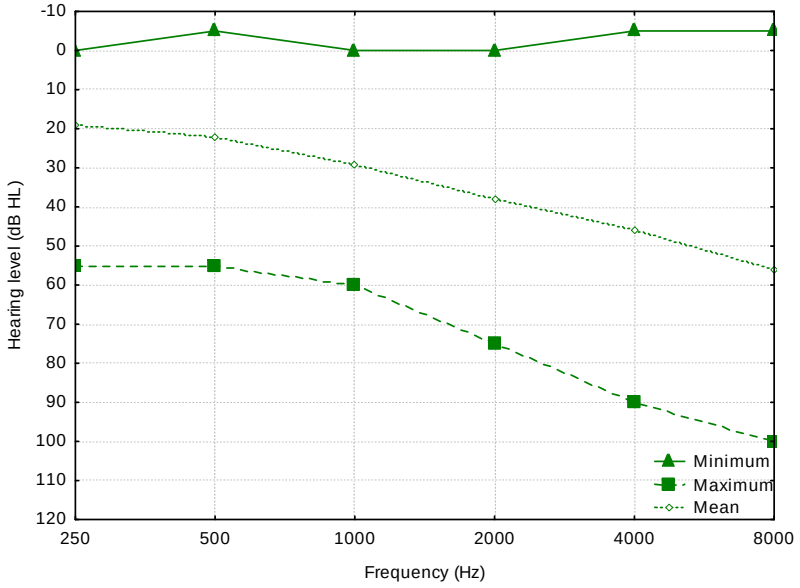


Study 1 - Aims

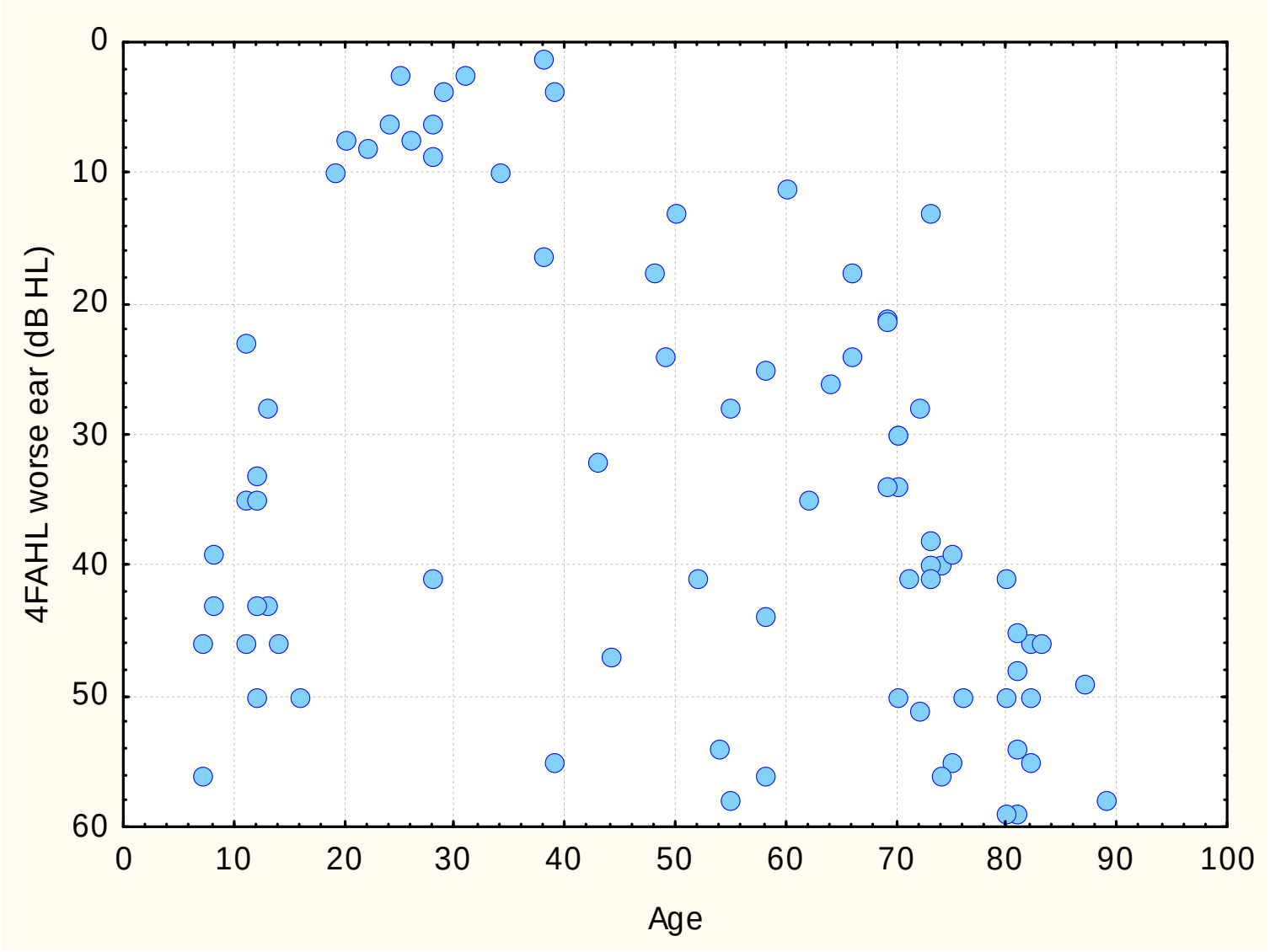
- To investigate the effect of hearing impairment and aging on spatial processing ability.
- To examine the relationship between spatial processing and self-report measures of difficulty.

Method

- Participants: 80 participants aged between 7 & 89 years
  - English as a first language
  - Normal middle ear function on day of testing
  - No history of learning or attention disorders
  - Up to a moderate-severe sensorineural hearing loss



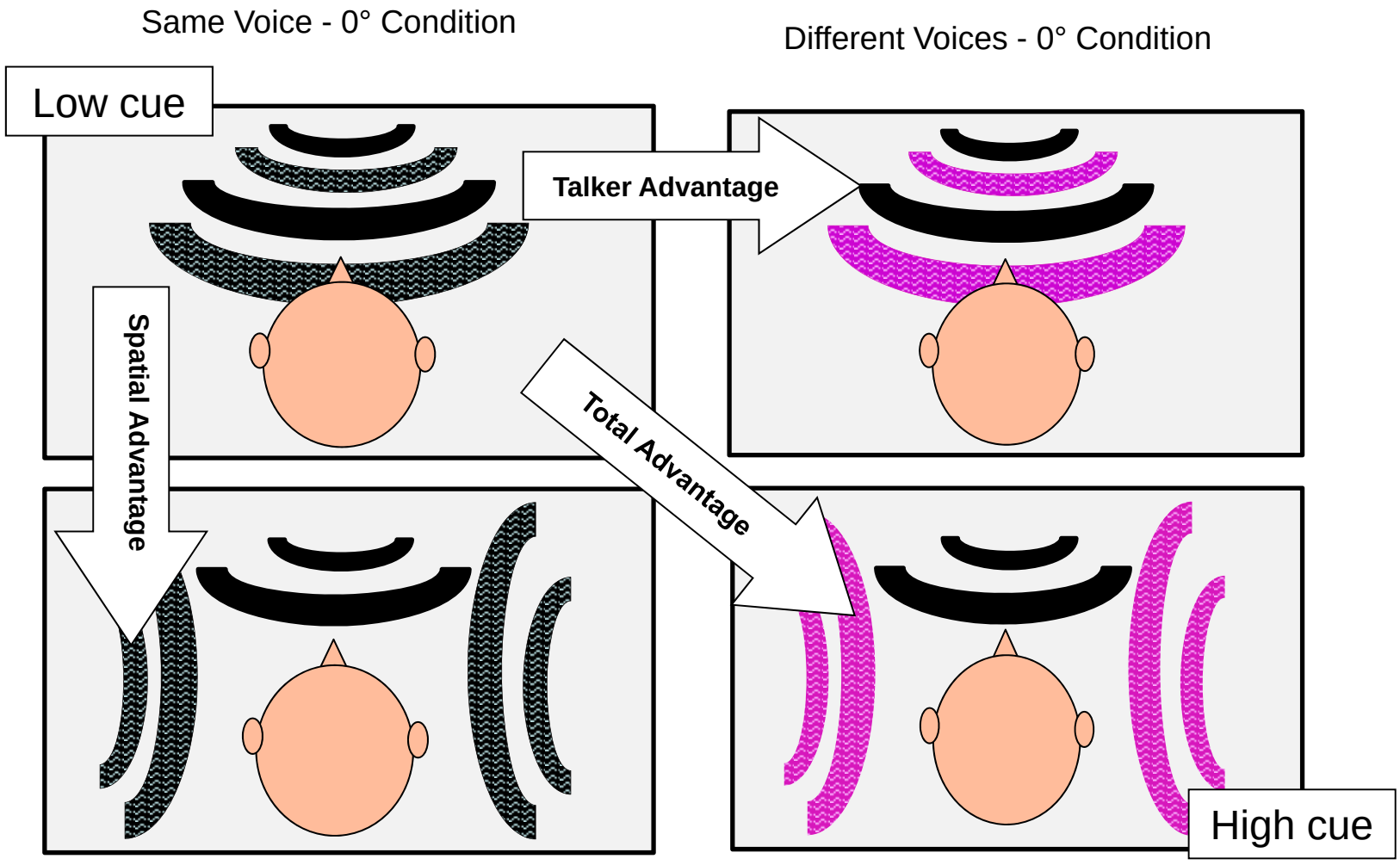
Age and hearing loss



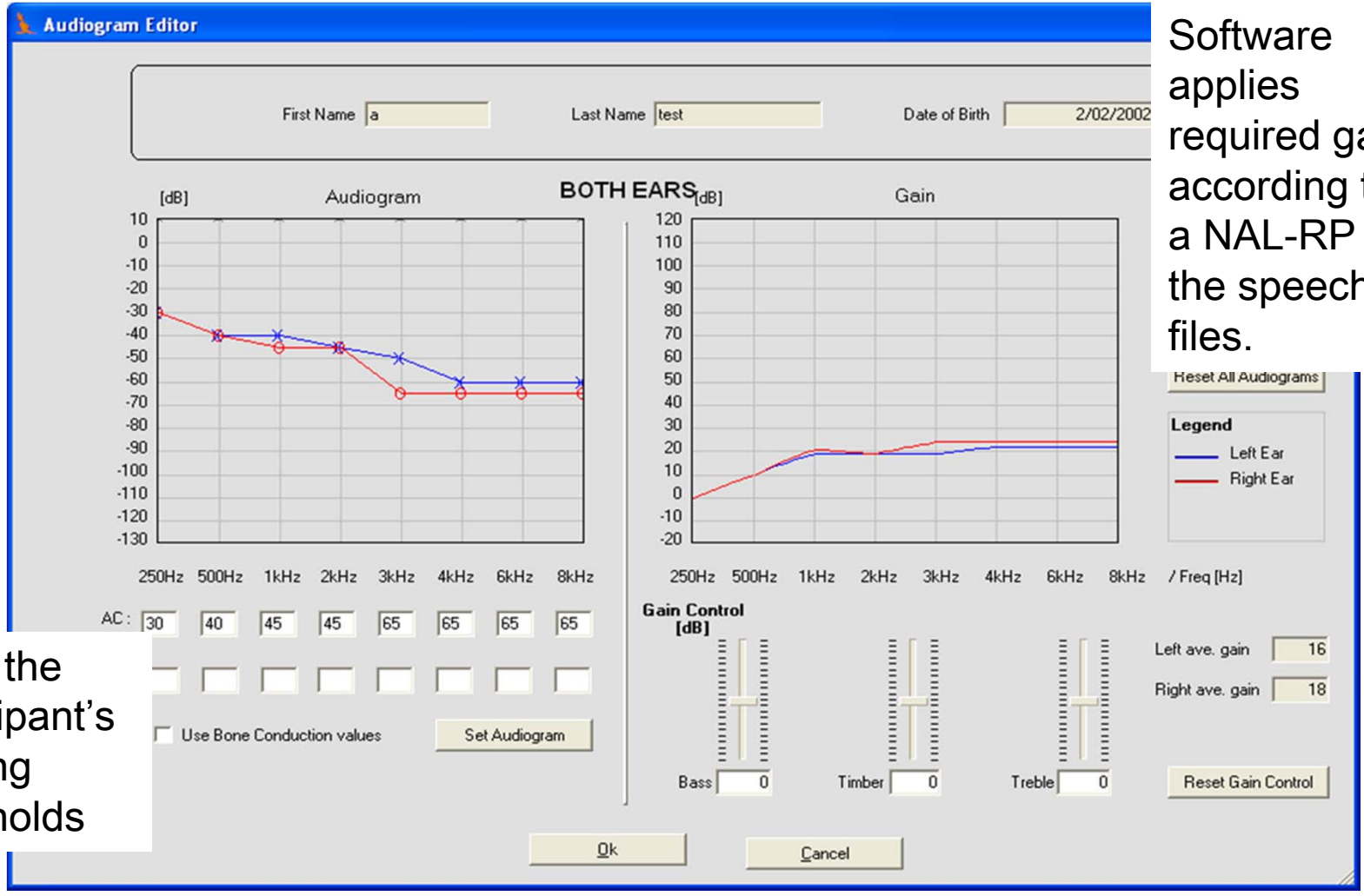
Method

- The Listening in Spatialized Noise - Sentences Test (LiSN-S)
  - Adaptive speech in noise test using spatialized stimuli. (Target adaptive, distractors at 55 dB SPL)
  - Assesses how well normal-hearing people use spatial cues and pitch cues to understand speech in noise
  - Includes amplification

Four LiSN-S Conditions



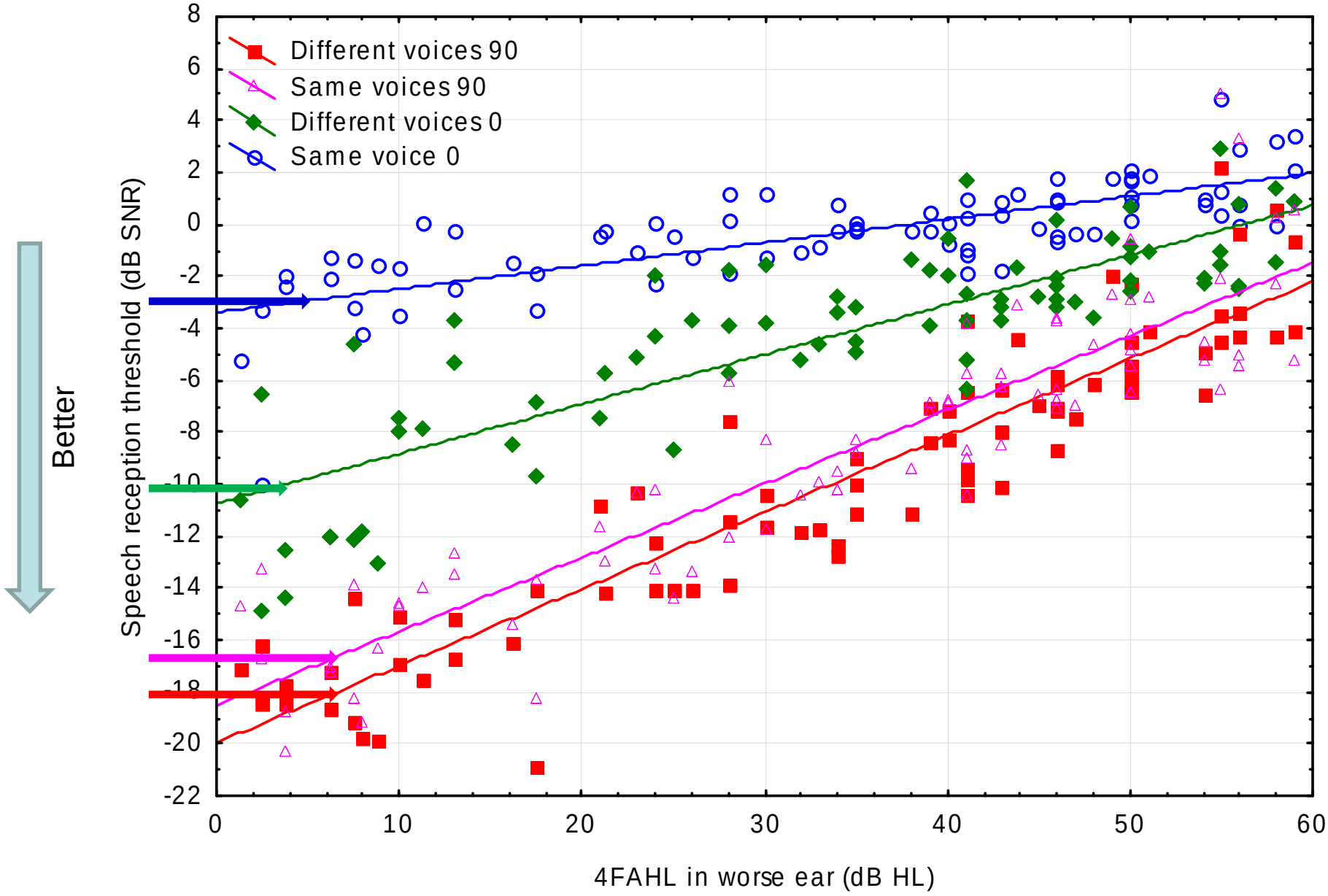
Adaptation of LiSN-S for hearing-impaired



Software applies required gain according to a NAL-RP to the speech files.

Enter the participant's hearing thresholds

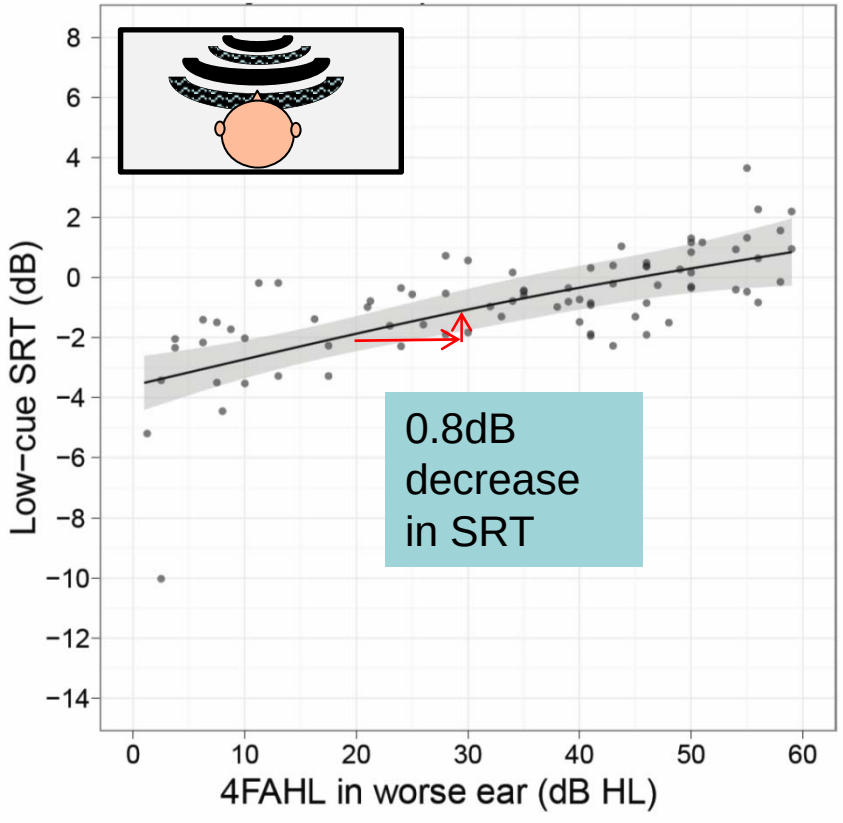
Changes in LiSN-S scores with hearing loss



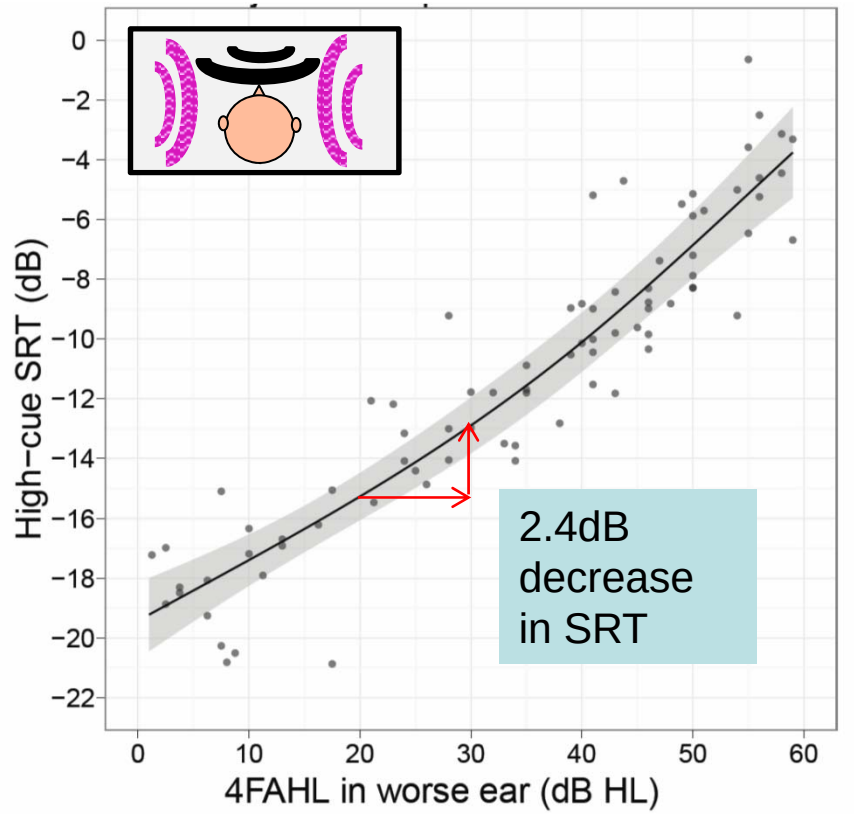
Results: Multiple regression

	p-value		r^2
	4FAHL (worse)	**Age**	
Low Cue SRT	<0.001 *	0.075	0.59
High Cue SRT	<0.001 *	0.001 *	0.89
Spatial Advantage	<0.001 *	0.104	0.76
Talker Advantage	<0.001 *	0.523	0.51
Total Advantage	<0.001 *	0.059	0.81

Results: The effect of hearing impairment

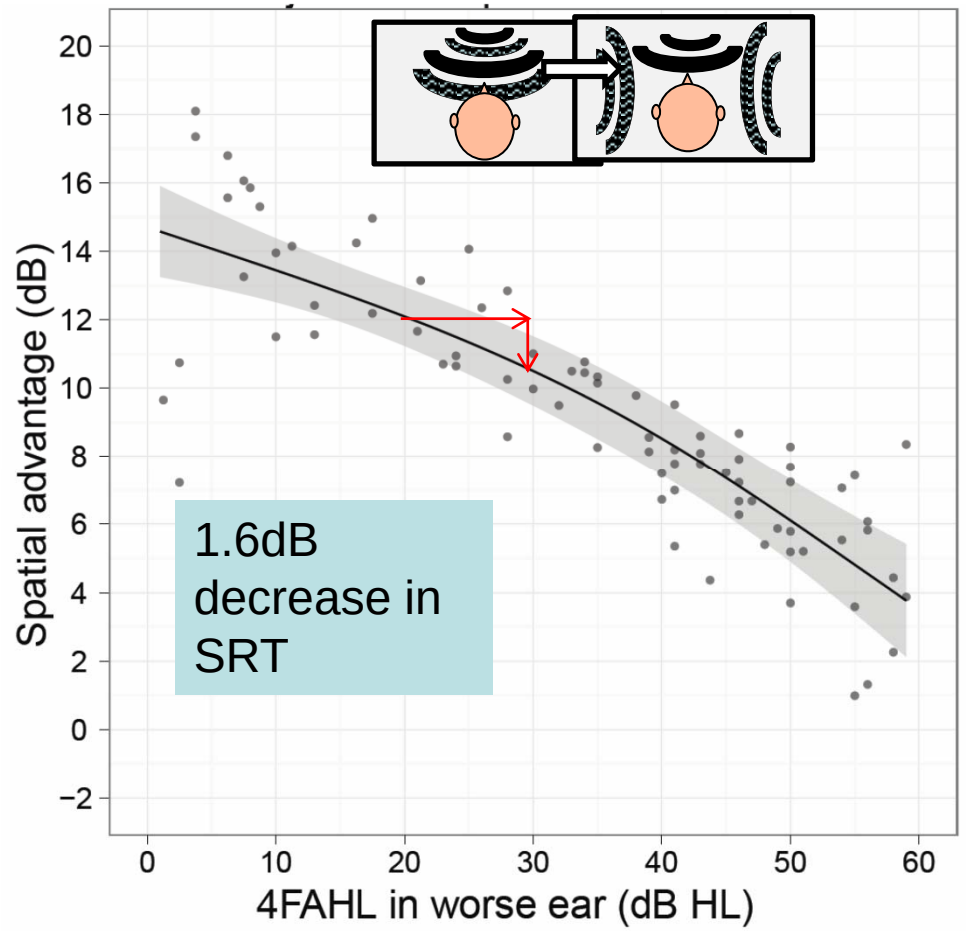


Low Cue SRT vs 4FAHL
p <0.001 *



High Cue SRT vs 4FAHL
p <0.001 *

Results: The effect of hearing impairment

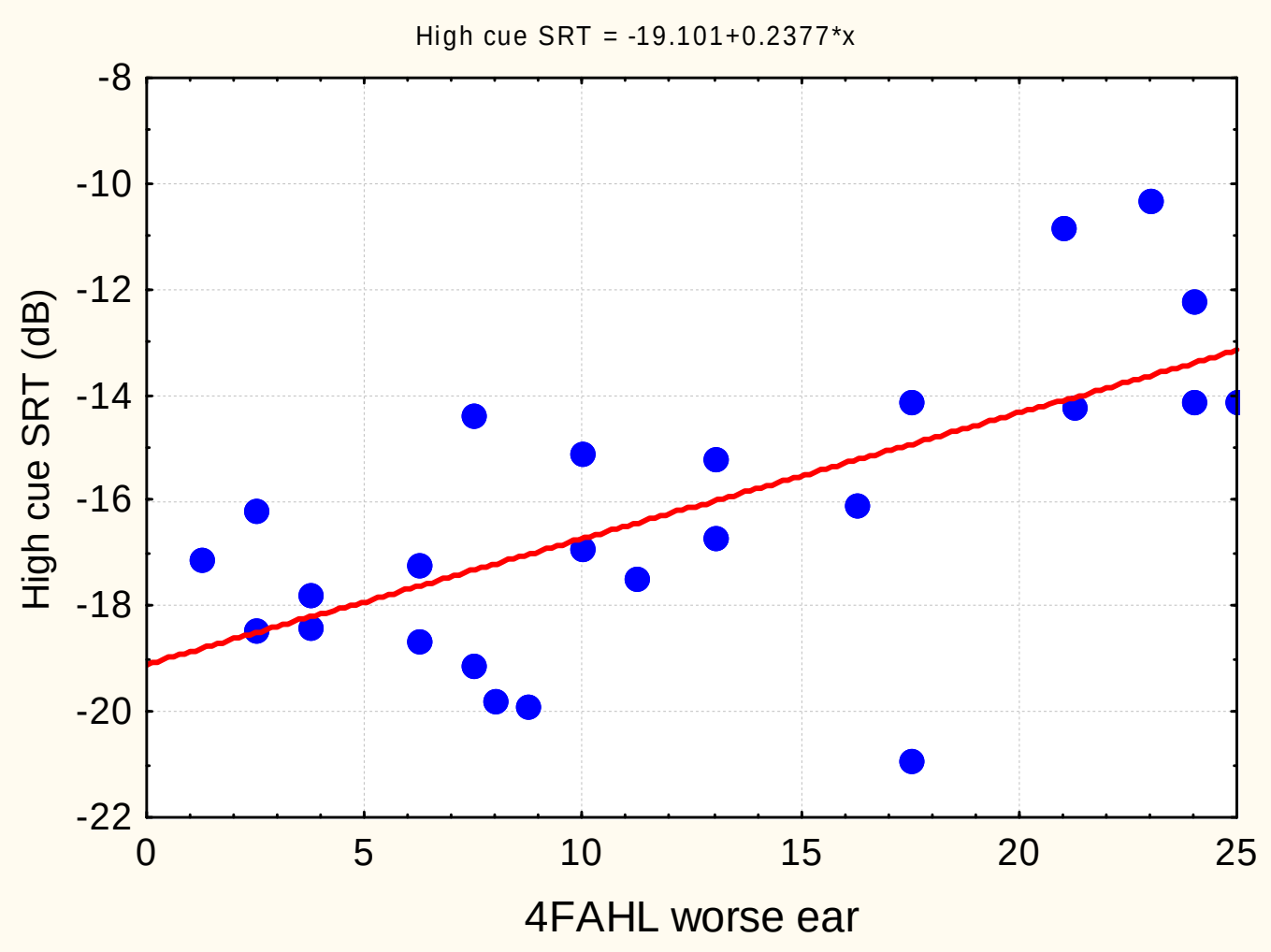


Spatial Advantage vs 4FAHL
p <0.001 *

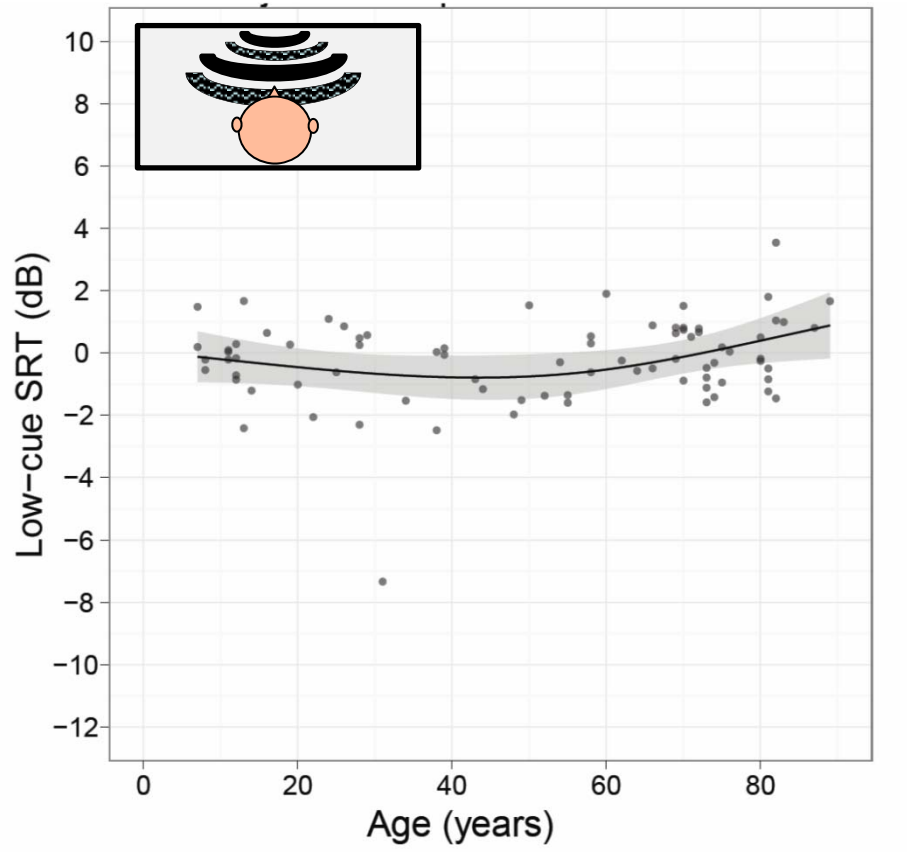
A Quick Summary

- Spatial processing ability declines as hearing loss increases.
- The non-spatially separated measures of the LiSN-S are less affected by hearing loss than the spatialized measures.

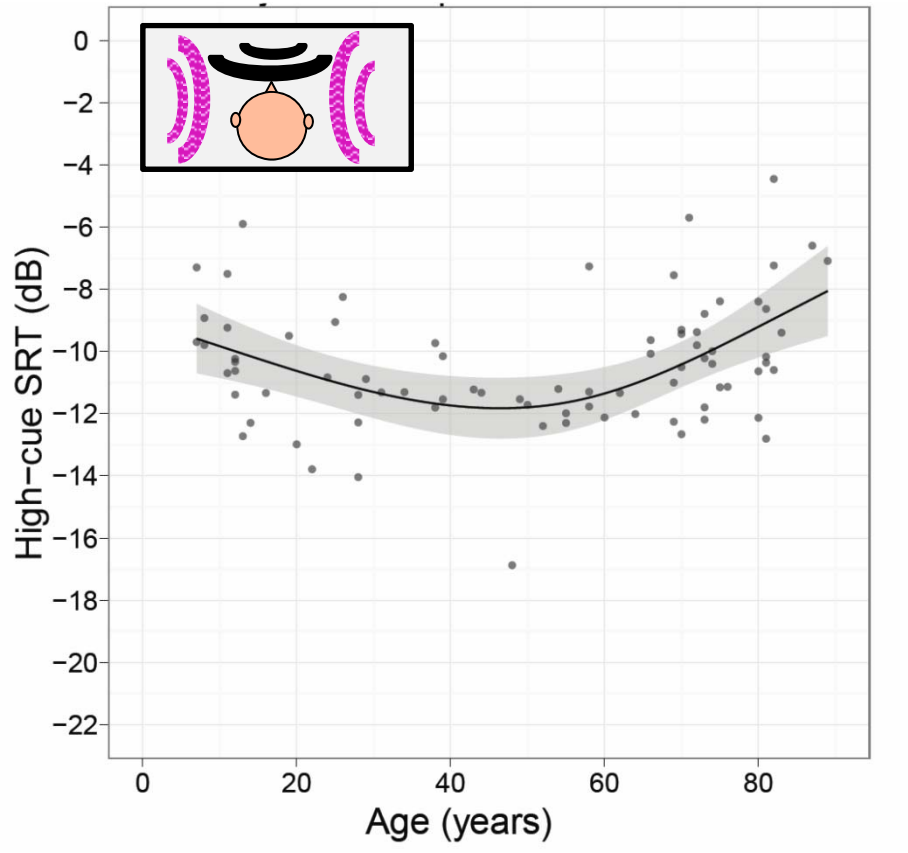
Effect of mild loss



Results: The effect of aging

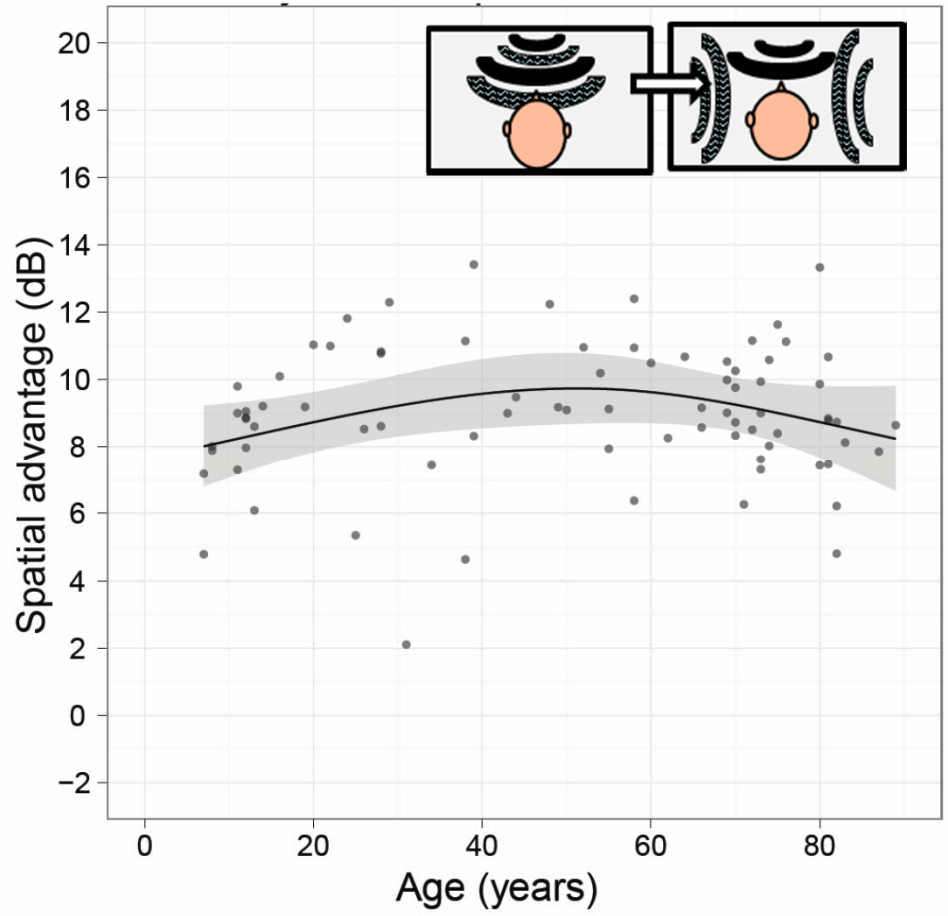


Low Cue SRT vs Age
p = 0.075



High Cue SRT vs Age
p = 0.001 *

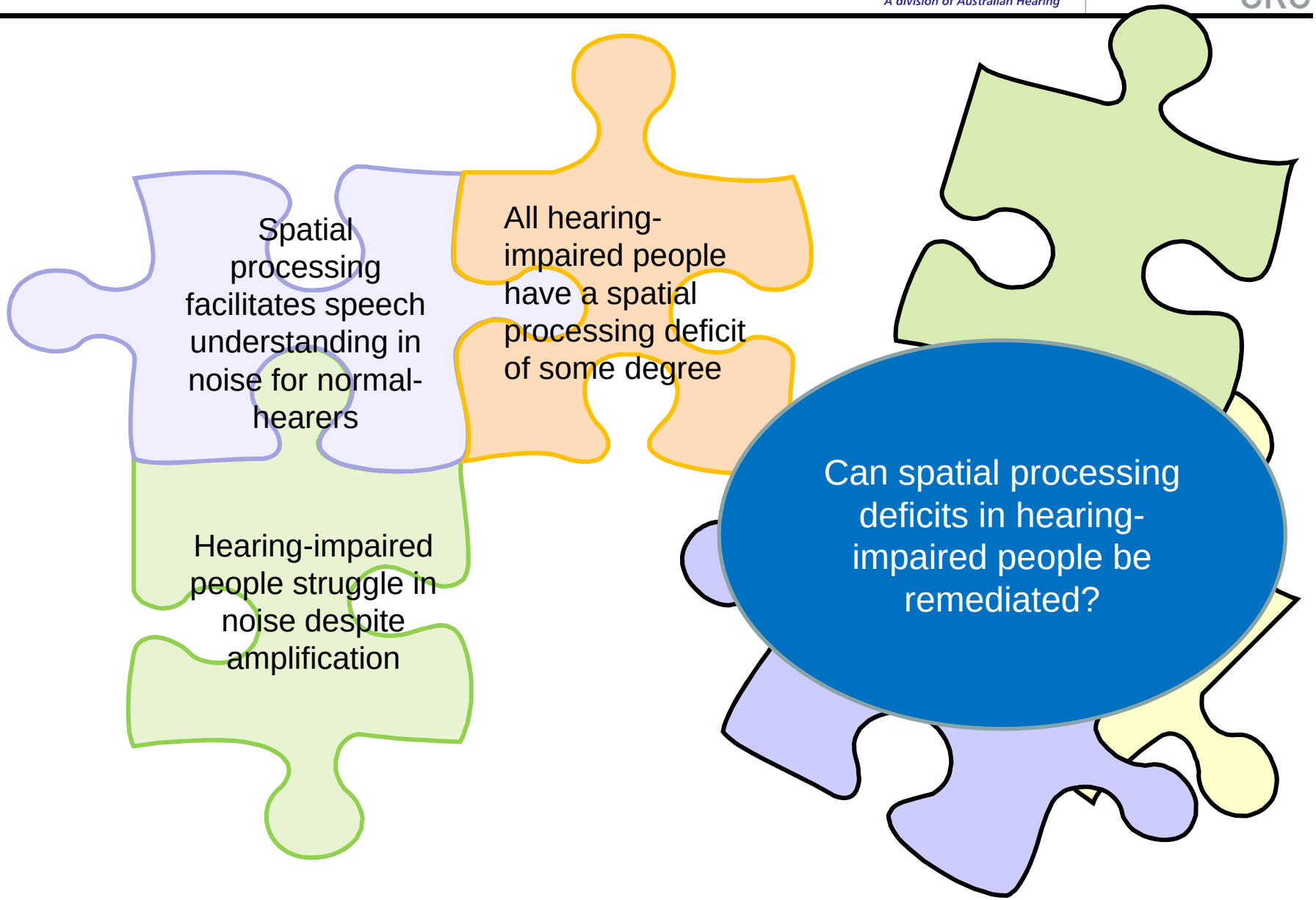
Results: The effect of aging



Spatial Advantage vs Age
p = 0.104

Study 1 - Conclusion

- **All hearing-impaired people will have a spatial processing disorder of some degree.**
- Spatial processing ability declines only mildly (insignificantly) with age.
- Use of non-spatialized speech in noise tests will underestimate difficulty.
- Even slight hearing loss results in loss of SRT in noise.


Spatial processing facilitates speech understanding in noise for normal-hearers
All hearing-impaired people have a spatial processing deficit of some degree
Hearing-impaired people struggle in noise despite amplification
Can spatial processing deficits in hearing-impaired people be remediated?

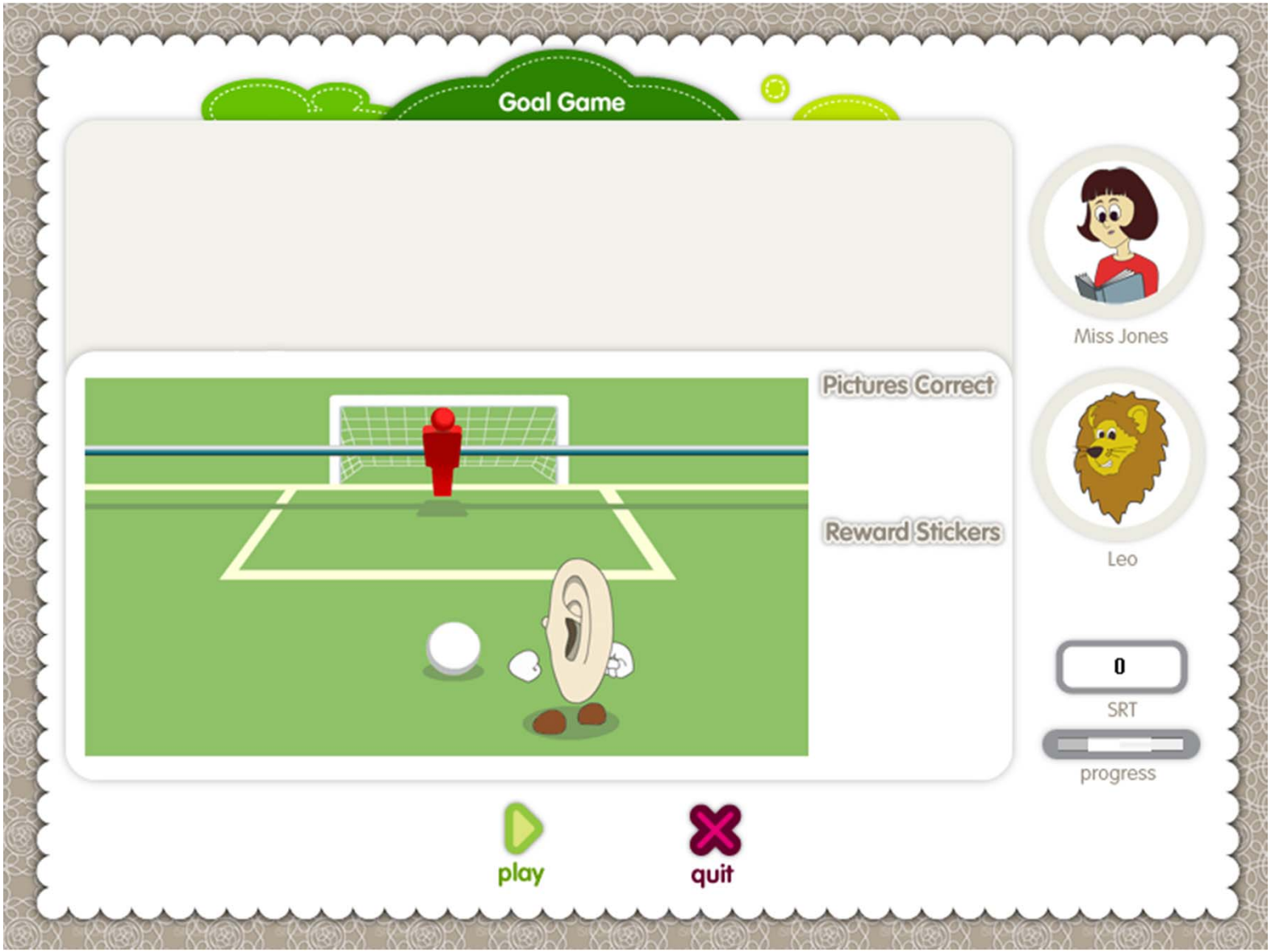
Study 2 - Aims

- Can spatial processing deficits in hearing-impaired people be remediated (with LiSN & Learn)?
- (LiSN & Learn already shown to be effective for children with spatial processing disorder and normal hearing thresholds)

What is LiSN & Learn?

- Computer based auditory training software
- Originally designed for children
- Five games presented over headphones
- Target sentences at 0º azimuth; competing stories at ±90º azimuth.
- Weighted up-down adaptive procedure used to adjust the signal level of the target
- SRT calculated over 40 sentences

LISN & Learn Game



Target at 0˚:

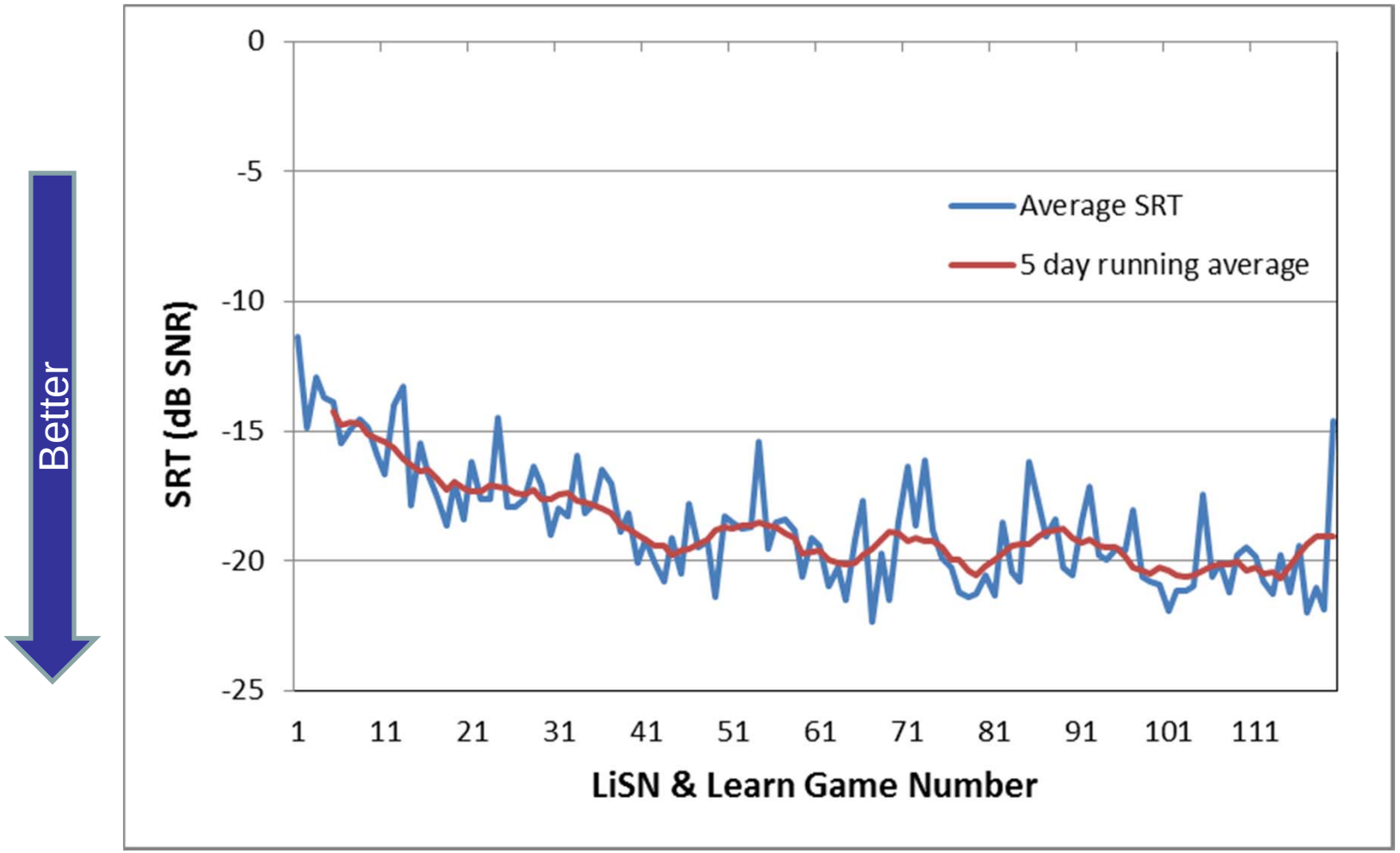
Distracters at + and -90˚:

Target: The horse kicked six wet <u>shoes</u>

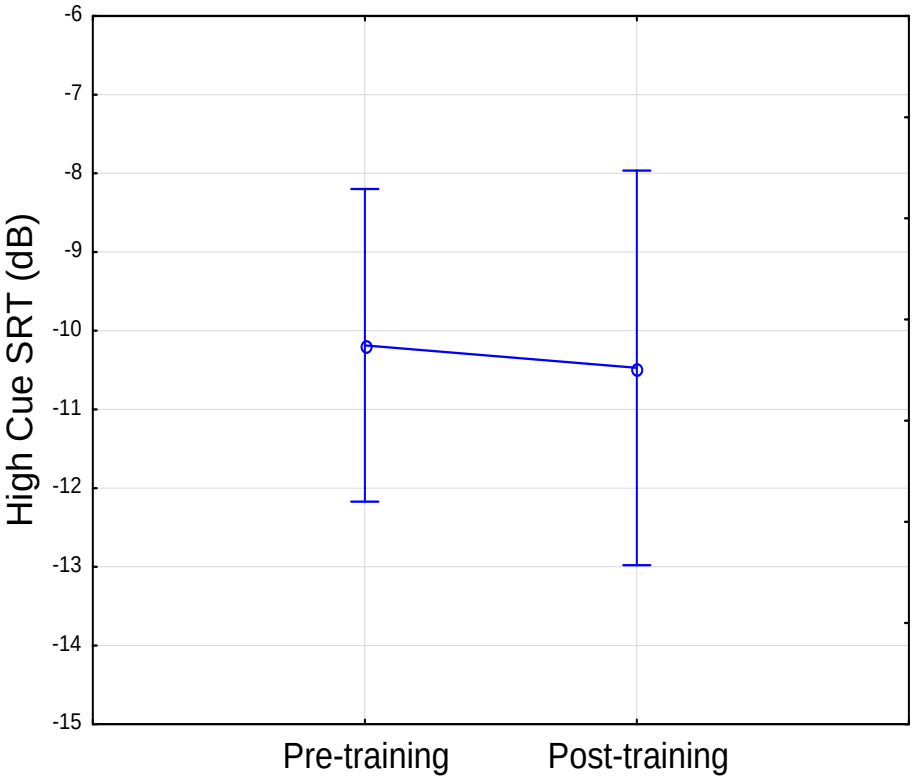
Method

- 10 participants (5 children & 5 older adults) with symmetrical sensorineural hearing loss
- Assessed pre- and post-training on LiSN-S, questionnaire of listening difficulty & BKBs in noise
- LiSN & Learn speech files shaped with NAL-RP gain for each participant.
- Train with LiSN & Learn 15 min/day, 5 days/week, 12 weeks.

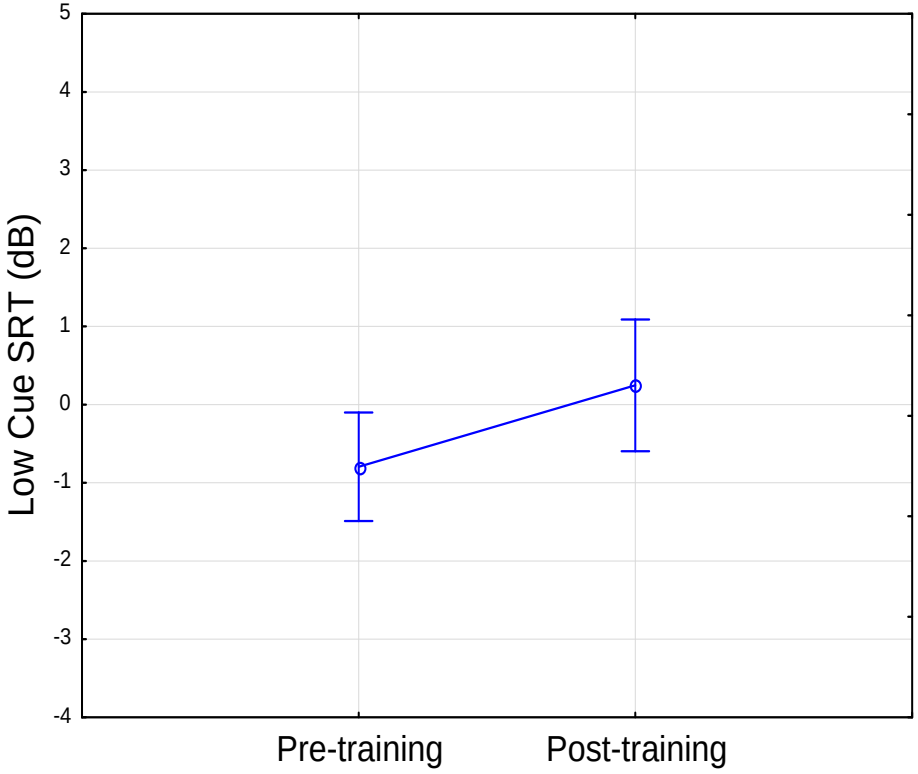
Preliminary Results: LiSN & Learn (n = 6)



Preliminary Results: LiSN-S (n = 6)

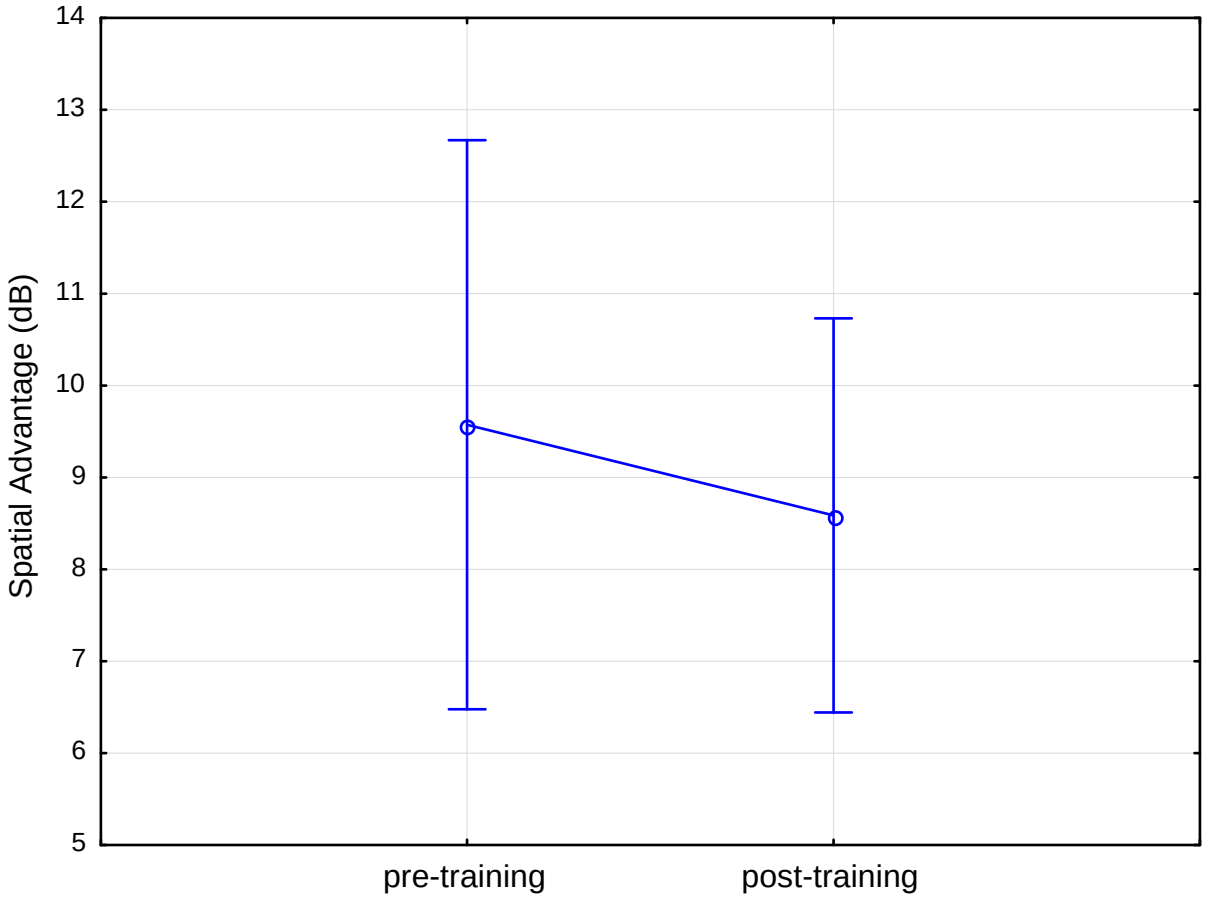


p = 0.83

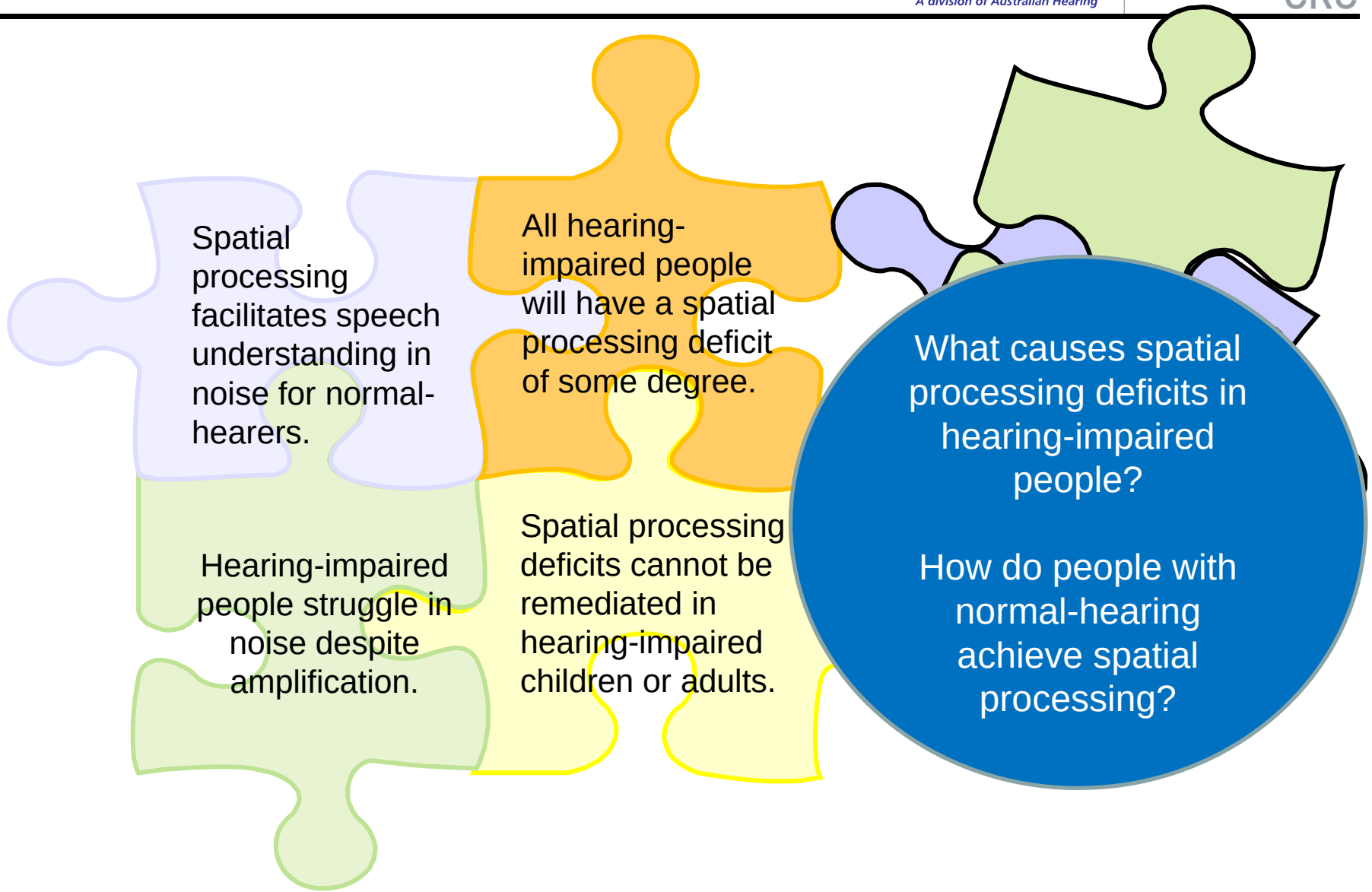


p = 0.10

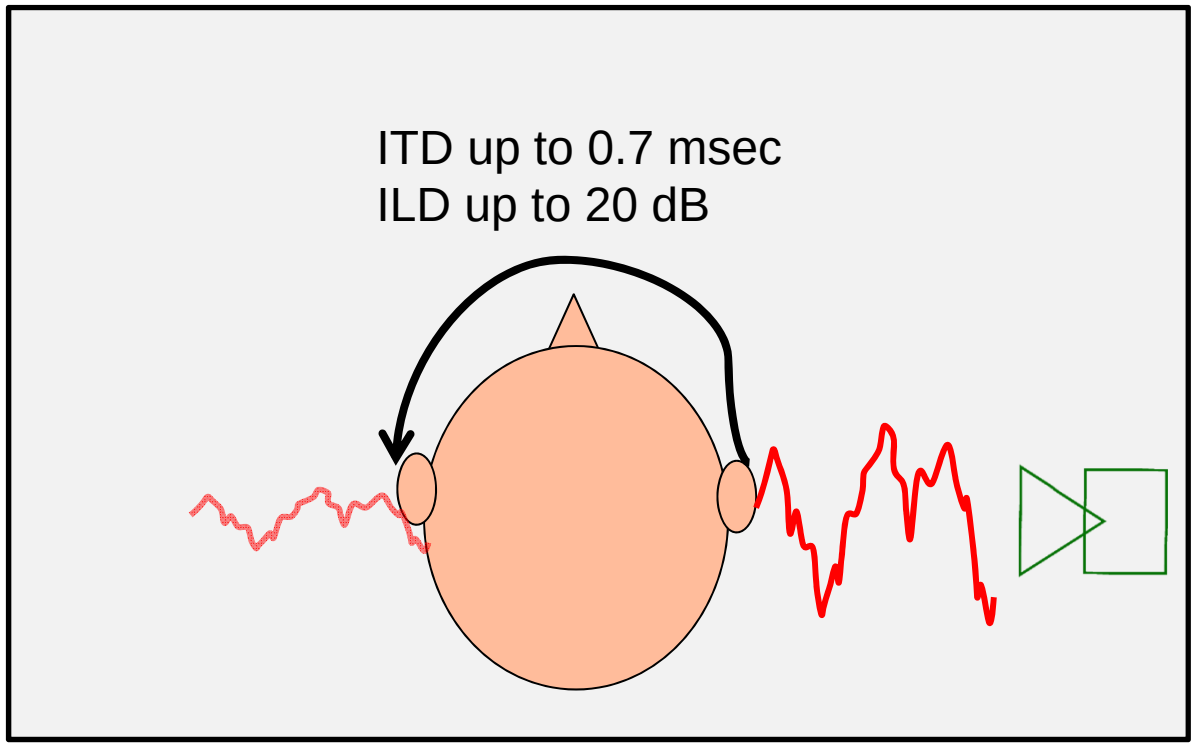
Preliminary Results: LiSN-S (n = 6)



p = 0.51


Spatial processing facilitates speech understanding in noise for normal-hearers.
All hearing-impaired people will have a spatial processing deficit of some degree.
Hearing-impaired people struggle in noise despite amplification.
Spatial processing deficits cannot be remediated in hearing-impaired children or adults.
What causes spatial processing deficits in hearing-impaired people?
How do people with normal-hearing achieve spatial processing?

Interaural cues



- Interaural Time Differences (ITDs) dominant for low frequency sounds.
- Interaural Level Differences (ILDs) dominant for high frequency sounds.

Previous Research

- Theories about use of ITDs and ILDs largely generalised from localization research.
- ITDs dominant for localising speech
- Very little evidence to show a link between speech understanding in spatially separated noise and localization.

Study 3 - Aim

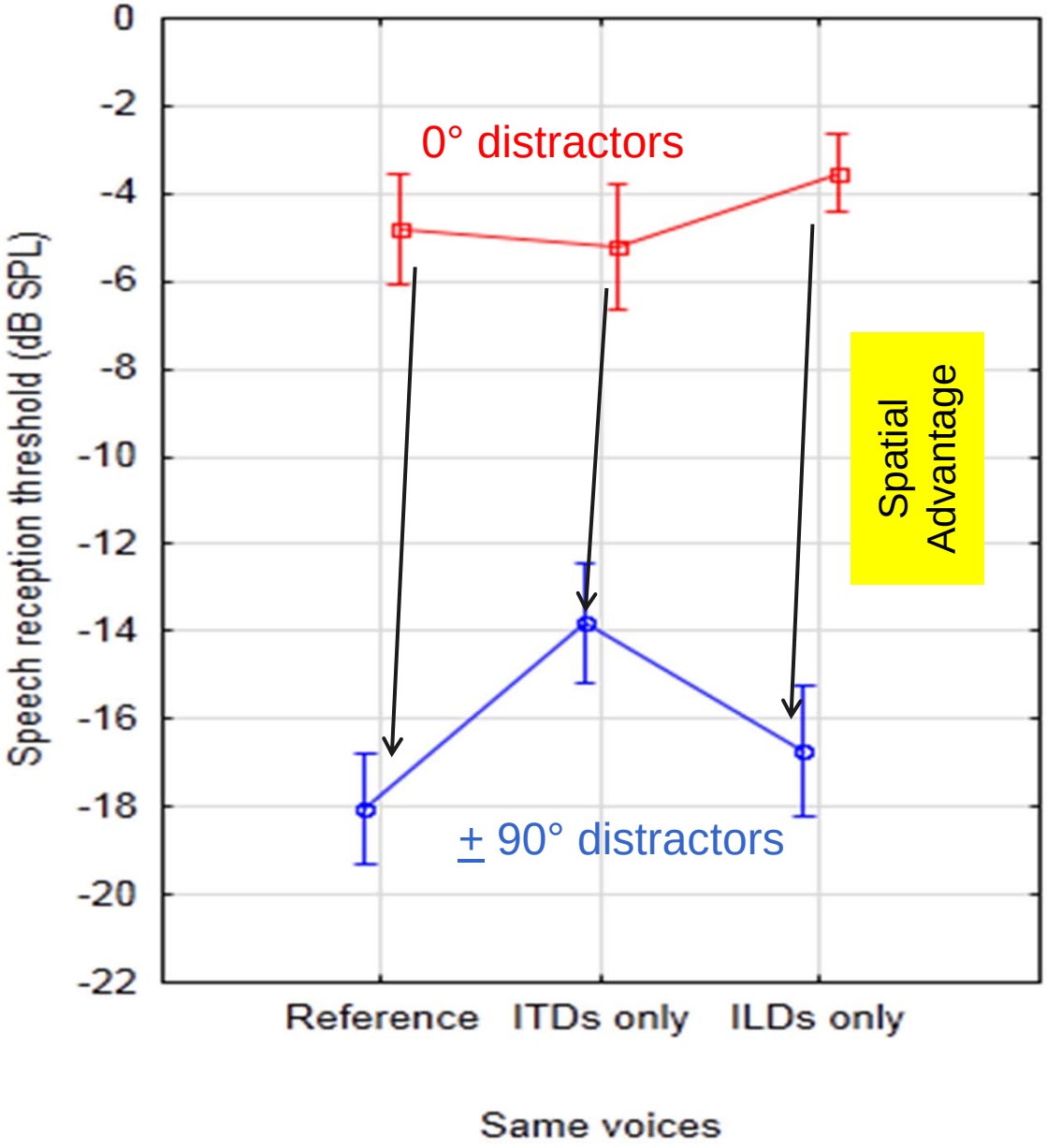
- To investigate the relative importance of ITDs and ILDs to spatial processing.
  - Using Listening in Spatialized Noise – Sentences test (LISN-S) paradigm
  - Special version with altered cues

Method

- 12 normal-hearing participants aged 24 – 53 years

	ITD cues	ILD cues
Reference	✓	✓
ITD only	✓	✗
ILD only	✗	✓

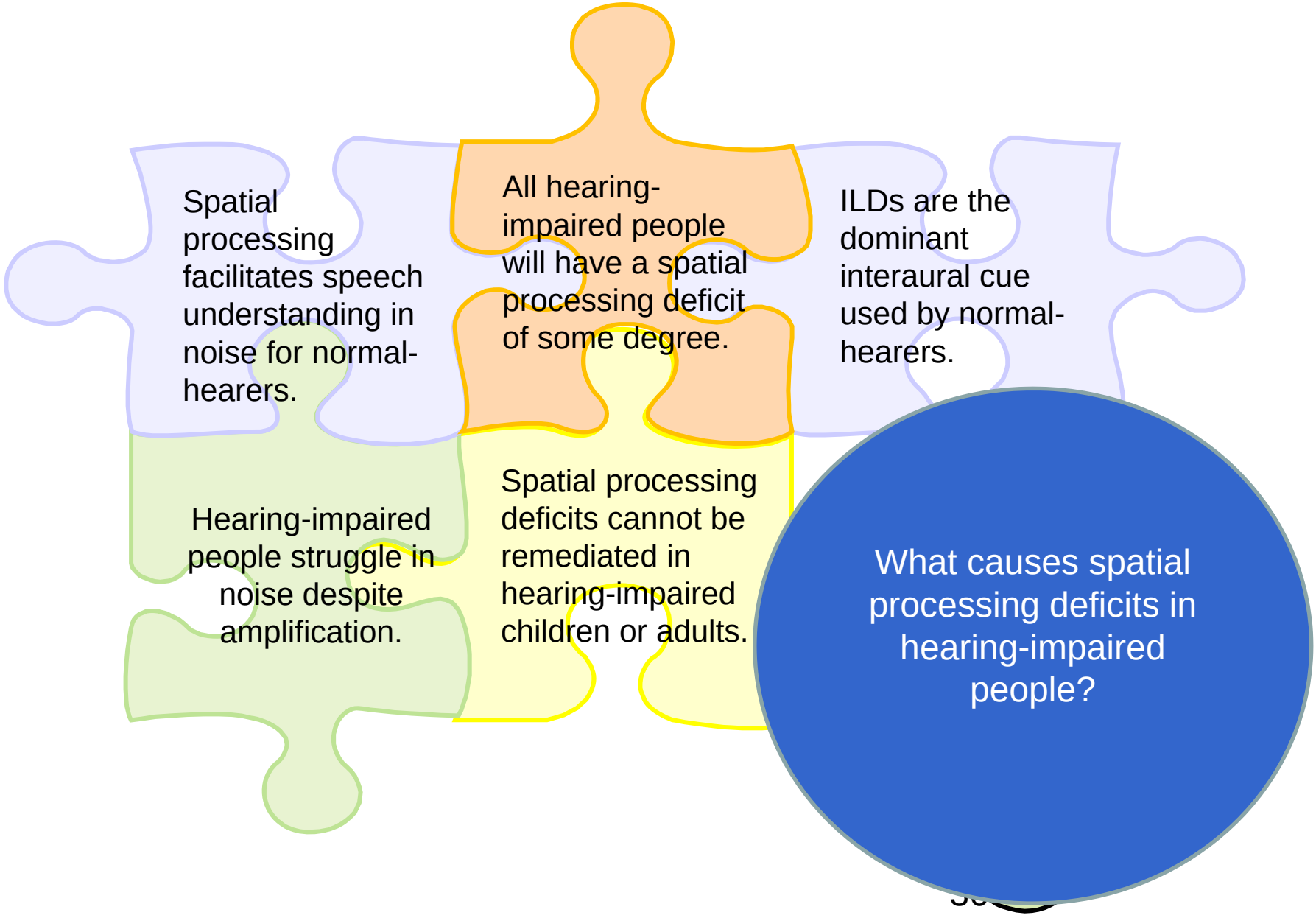
Results



- No sig. difference between spatial advantage in ILD only and reference condition ($p = 0.938$).
- Spatial advantage is significantly reduced in ITD only condition ($p < 0.001$).

Conclusion

- Interaural Level Differences are the dominant cue used in this spatial processing task.
- Interaural Time Differences alone do result in some spatial release from masking.
- The benefits from ITD and ILD not additive.
- Suggests that hearing-impaired people are unable to take advantage of ILD cues.


Spatial processing facilitates speech understanding in noise for normal-hearers.
All hearing-impaired people will have a spatial processing deficit of some degree.
ILDs are the dominant interaural cue used by normal-hearers.
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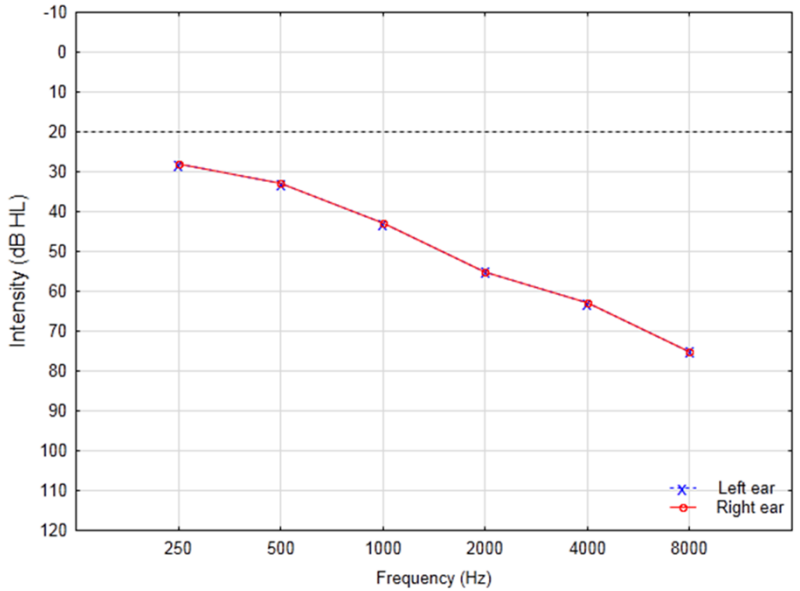
Spatial processing deficits cannot be remediated in hearing-impaired children or adults.
What causes spatial processing deficits in hearing-impaired people?

Study 4 – Aims and background

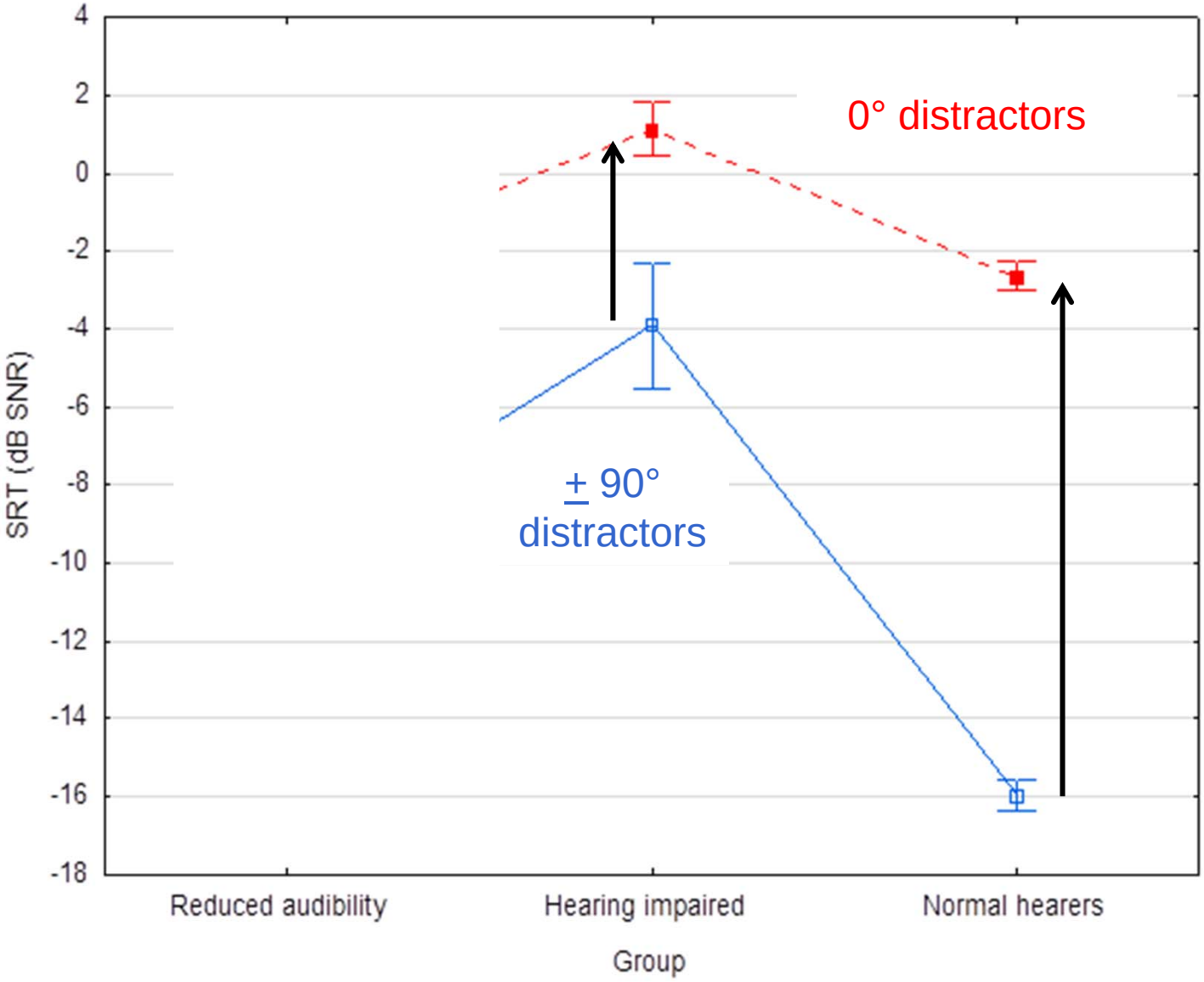
- ILD use may be impaired if hearing thresholds limit audibility of speech.
- Study 1 provided amplification to improve audibility but did not match audibility to normal-hearers.
- Does reduced audibility cause of spatial processing deficits in hearing-impaired people.

Method

- 12 normal hearing adults (25 – 47 years)
- Frequency specific filtering (attenuation) applied to LiSN-S to match audibility experienced by average hearing-impaired listener in Study 1.
- Results compared normative data for normal-hearers and subset of 16 hearing-impaired participants



Results

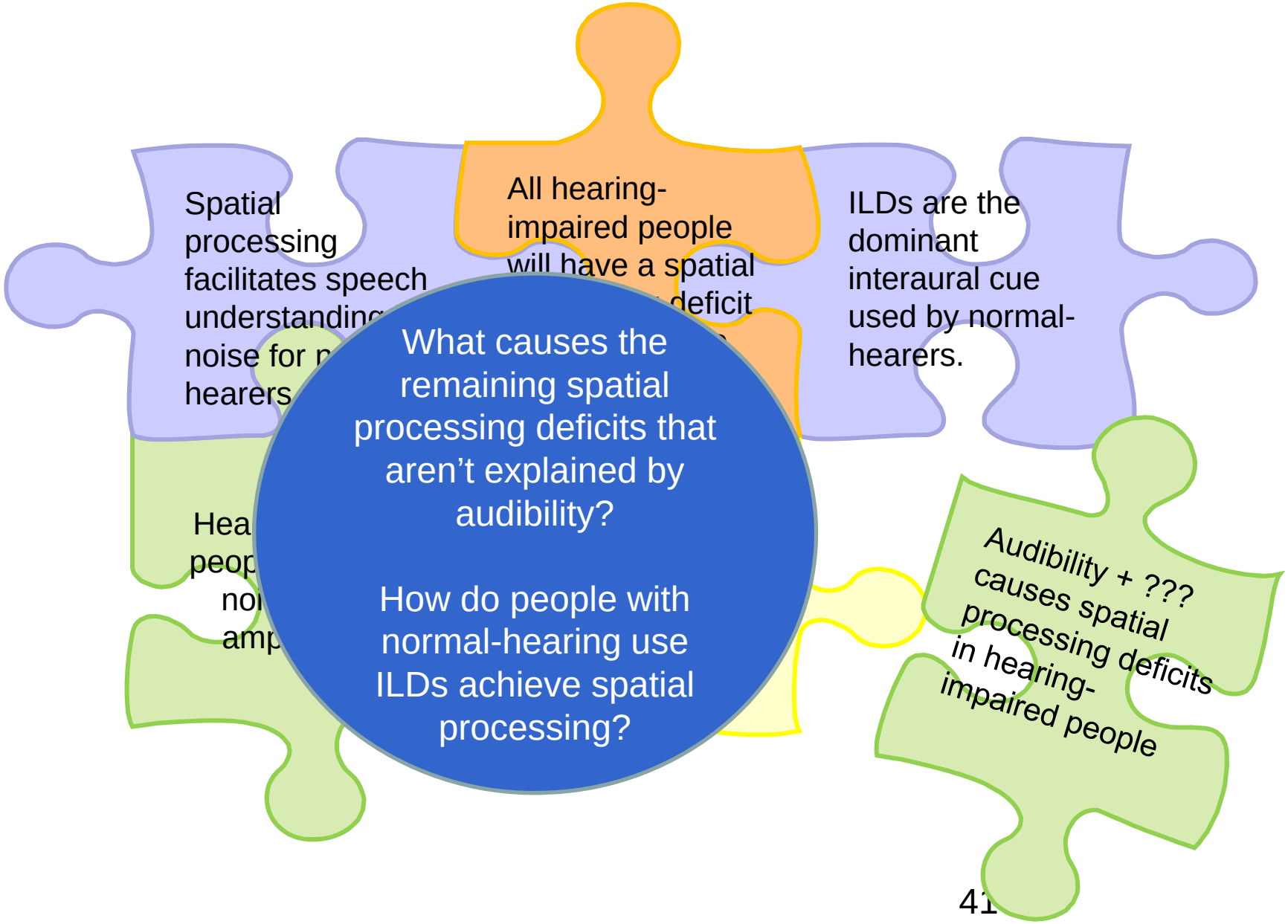


Reduced audibility different from:

- Normal hearers
- Hearing impaired

Conclusions

- Reduced audibility explains a large portion of the observed spatial processing deficits.
- Approximately 2 dB of spatial advantage remains unexplained.


Spatial processing facilitates speech understanding
noise for n
hearers
All hearing-impaired people will have a spatial
deficit
ILDs are the dominant interaural cue used by normal-hearers.
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What causes the remaining spatial processing deficits that aren't explained by audibility?
How do people with normal-hearing use ILDs achieve spatial processing?
Audibility + ??? causes spatial processing deficits in hearing-impaired people

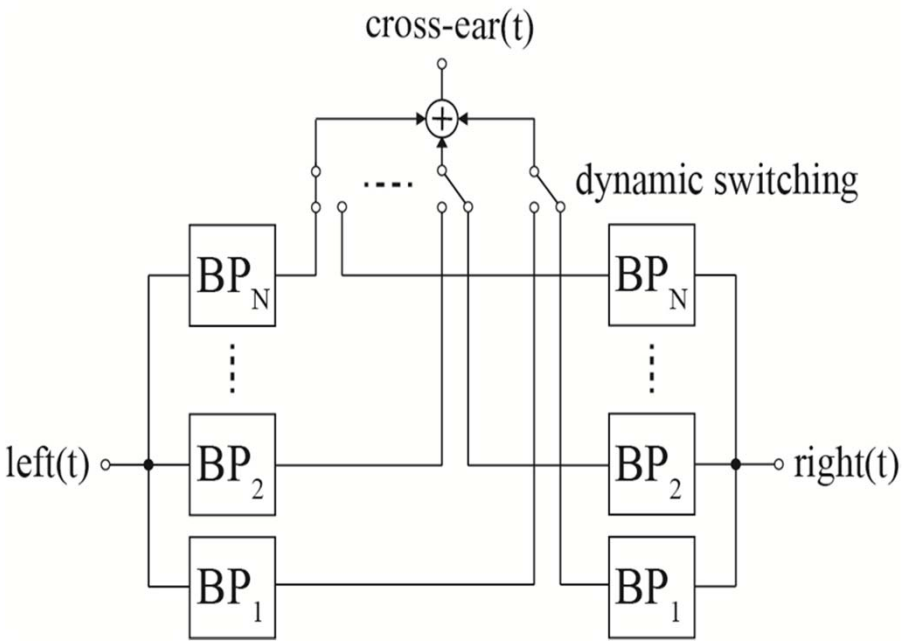
Study 5 - Aims

- One way that ILDs may be used to achieve spatial processing is through cross-ear dip listening.
- Is cross-ear dip listening used by normal-hearers?
- Do widened auditory bands could reduce hearing-impaired people's spatial processing ability.

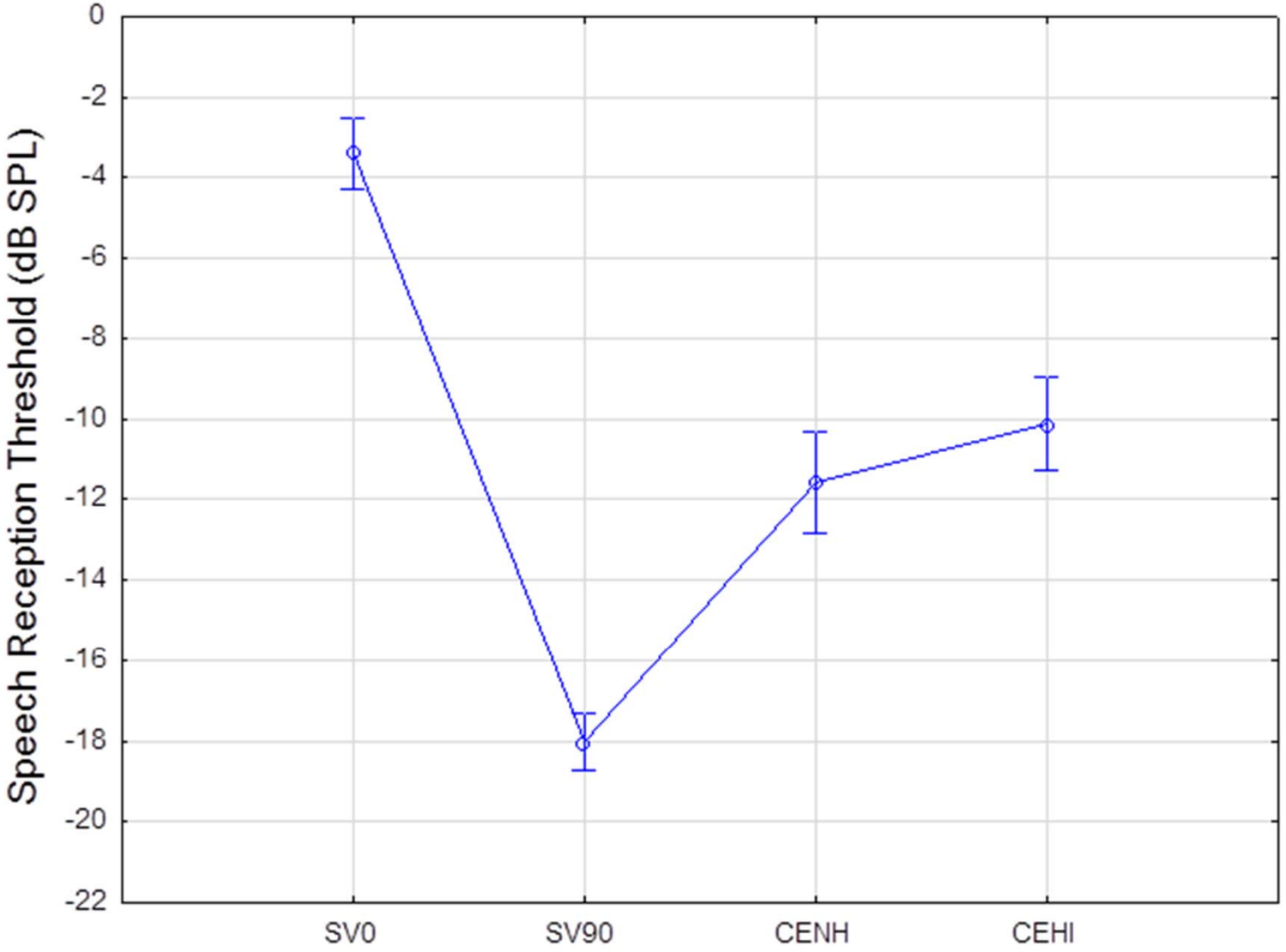
Method

- Tested Cross-ear normal hearing (CENH) and Cross-ear hearing impaired (CEHI)

- CEHI used widened auditory bands.
- 22 normal-hearing adults (18 – 29 years)



Results


Speech Reception Threshold (dB SPL)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
SV0
SV90
CENH
CEHI

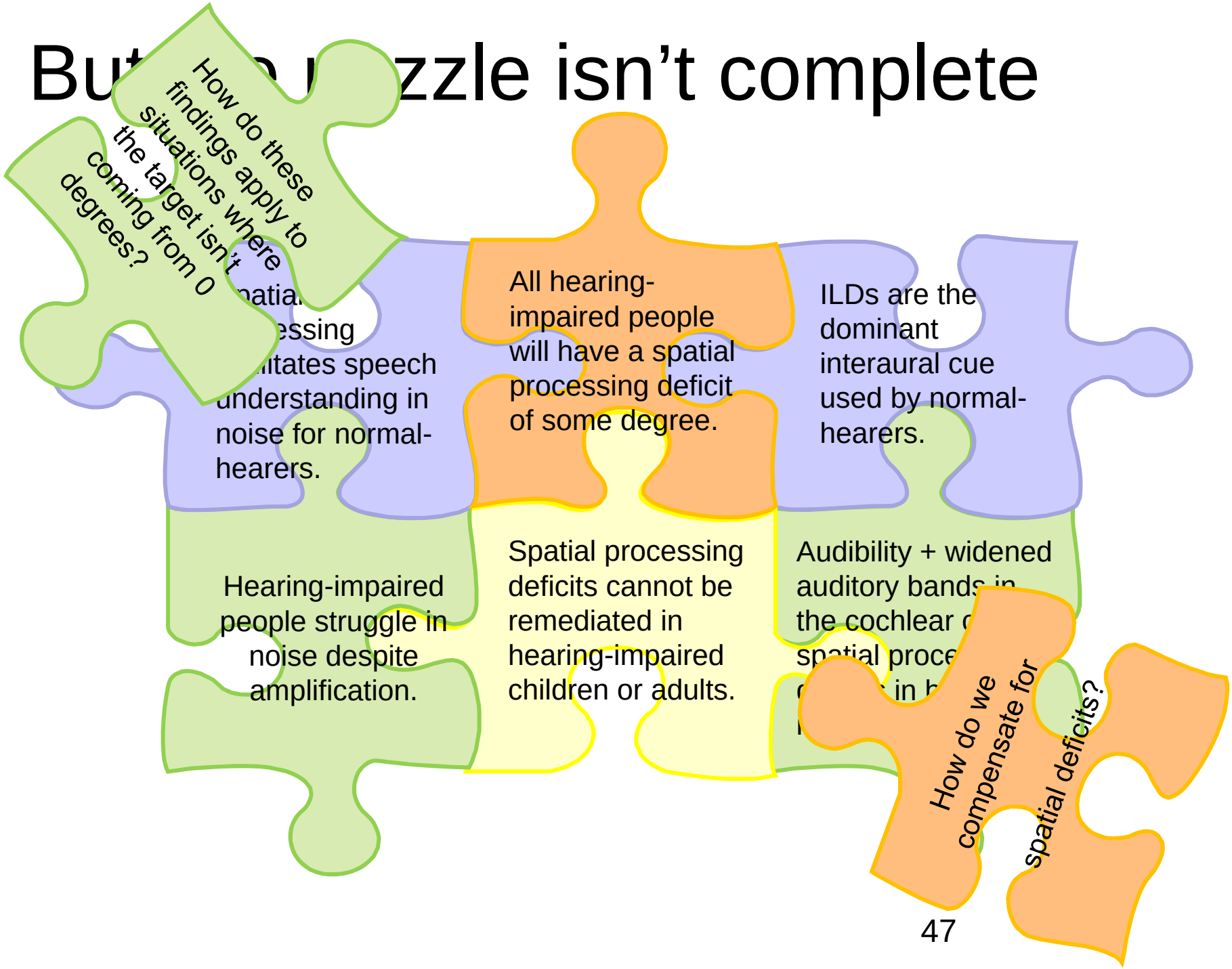
Study 5 - Conclusions

- Cross-ear dip listening explains some, but not all, of the benefit gained from spatial processing.
- Widened auditory bands may explain the spatial processing deficits not attributable to audibility.

Overall Interpretation

- Normal hearers use level differences between the ears → combine bands across ears that have the better SNR
- Normal hearers supplement this with spatial cues available from either ITDs or ILDs
- Hearing impaired people lose lower level information in the gaps, even with (linear) amplification
- Widened auditory bands further limits spatial processing ability

But the puzzle isn't complete



So what for the clinician?

- Hearing impaired people ***will*** need better SNR than normal hearers
- Deficit in SNR ***will*** be underestimated if speech and noise are co-located.
- Deficit in SNR ***cannot*** be trained
- Deficit in SNR can ***easily*** be measured using LiSN-S
- Implications for directional microphones, wireless remote hearing aids are clear

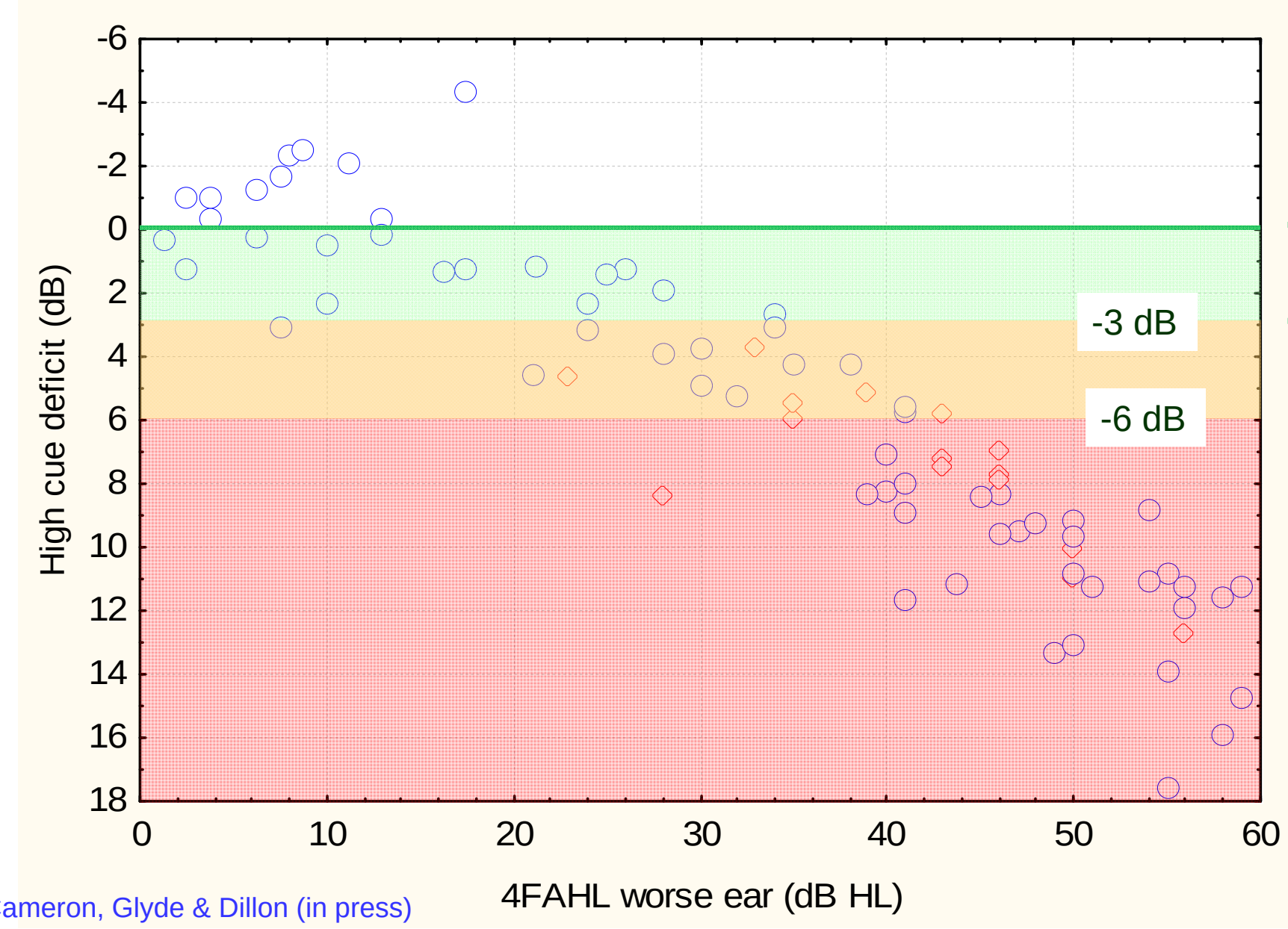
Clinical Implications

High-cue condition:

If the deficit re normal hearing is:

- < 3 dB …….. Should do well with hearing aids, even in noisy places.
- 3 to 6 dB …… Should do well with directional hearing aids, even in noisy places, provided the target or the dominant noise is close.
- > 6 dB ……. Will often need more than any hearing aid can offer to enable effective communication in noise places – remote microphone hearing aids.

SNR deficit



Cameron, Glyde & Dillon (in press)

National Acoustic Laboratories
A division of Australian Hearing

THE HEARING CRC

The University Of Queensland
AUSTRALIA

Thanks for listening

Acknowledgements

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