Data Logging & Sound Classification

in Hearing Aids and CIs

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Why is this important?

- data logging and sound classification are becoming more common and more sophisticated
- new generation of hearing devices and hearing care
- Changing the role of the audiologist & SLPs
- …and the patient

Support the user

- Automatically change sound processing settings
- Trainable Hearing Aids

Support the clinician

- programming and counselling
- Research

Topics

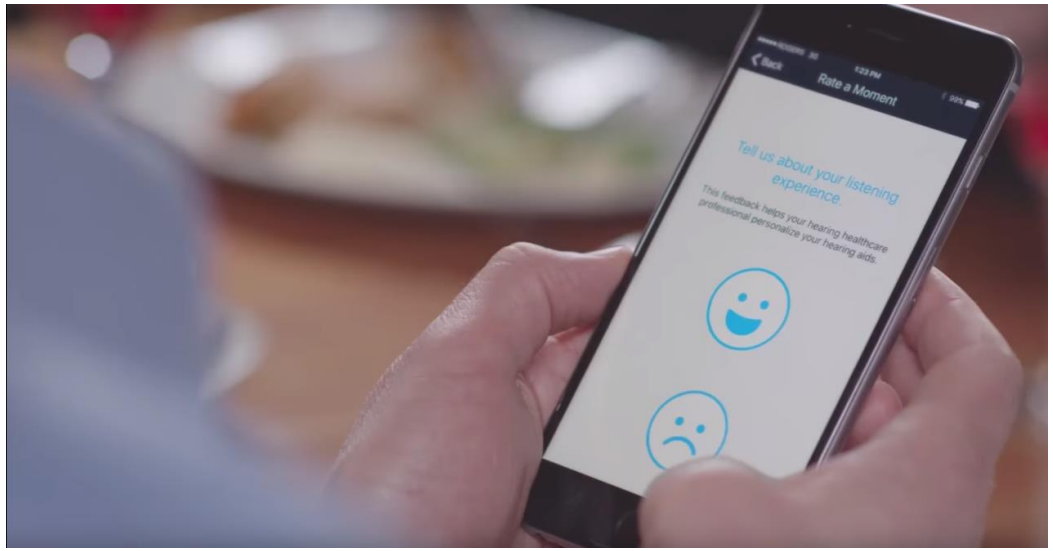
- What is in a data log?
- How does sound classification work?
- Applications for sound classfication and data logging:
  - Changing HA settings automatically
  - Fitting and counselling
  - Research

What's in a hearing aid data log?

- **User Input**
  - duration of use
  - program use
  - changes to volume/sensitivity, noise reduction, directional microphones…
  - accessory use
- **Device diagnostics**
  - errors, battery life, …
- **Sound environment**
  - sound intensity
  - acoustical scenes (sound classifier)

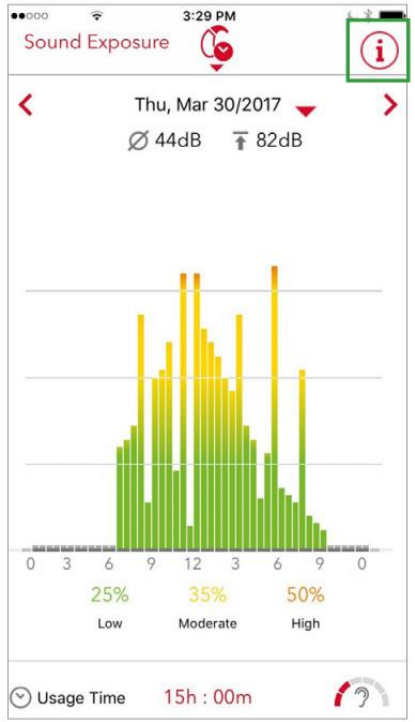
Long term logs
time between clinic visits

Short term (event) logs
situations in which user is not satisfied (+user feedback)



http://journals.lww.com/thehearingjournal/Fulltext/2007/10000/Data_logging__It_s_popular,_but_how_can_this.4.aspx
http://journals.lww.com/thehearingjournal/Fulltext/2007/10000/MANUFACTURERS_EXPLAIN_HOW_THEIR_DATA_LOGGING.5.aspx

Interfaces for Clinicians, Apps for Users



How does sound clasification work?

- Distinguish sound environments by their acoustic signature
- Typically: quiet, speech, speech in noise, noise, music, wind

Motivation: Adapt sound processing…

Table 10–1 Sensible Settings for Various Listening Situations

	Acoustic Directionality	Noise Reduction	WDRC	Feedback Cancellation
Speech	Yes, if speech is from the front	Not normally	Maximize intelligibility	Yes, if the amplification requires it
Music	Not normally, except in a reverberant room	No	Broadband amplification	No, if avoidable
Noise	Not normally	Yes, especially in case of loud noise	Depends on situation	No, if avoidable

Abbreviation: WDRC, wide dynamic range compression.

from: Schaub, Arthur, *Digital Hearing Aids*, p 110

How does sound clasification work?

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3 Steps:

Dissertation M. C. Büchler (2002) http://e-collection.library.ethz.ch/eserv/eth:24632/eth-24632-02.pdf
Dissertation Peter Nordqvist (2004) http://www.speech.kth.se/prod/publications/files/1742.pdf

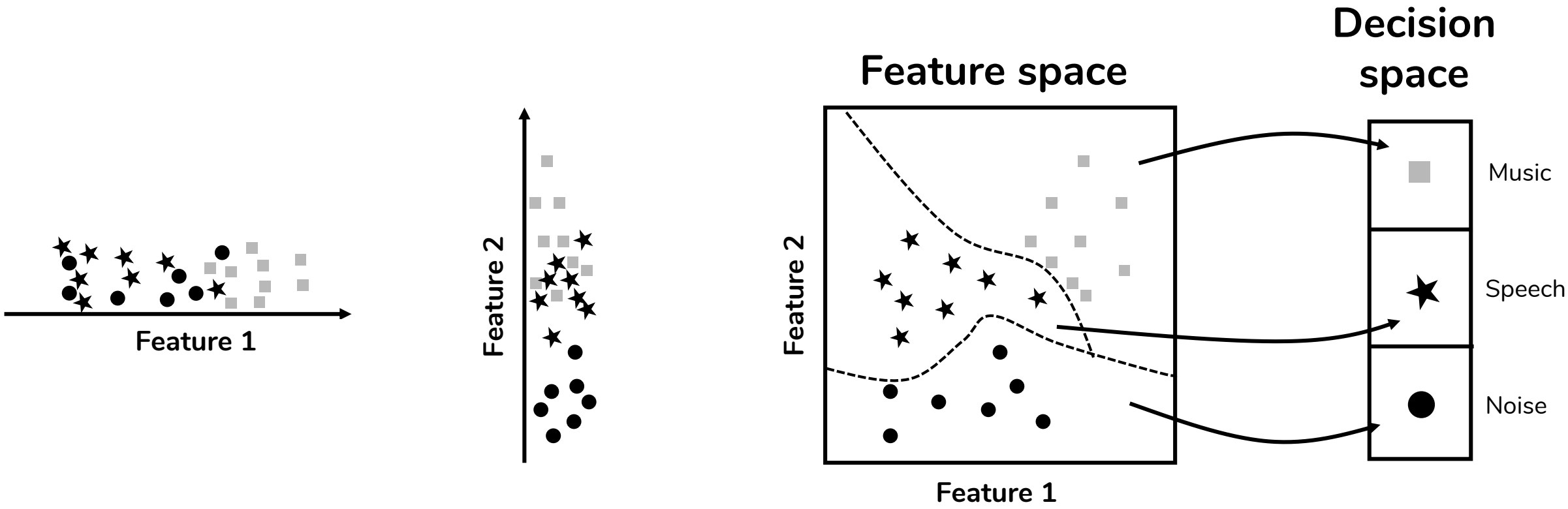
Step 1: Feature extraction

Extract features that help separate the sound classes, e.g.

- Periodicity
- fundamental frequency
- Spectral gradient
- resonance frequencies
- Sound pressure level
- Modulation
- …

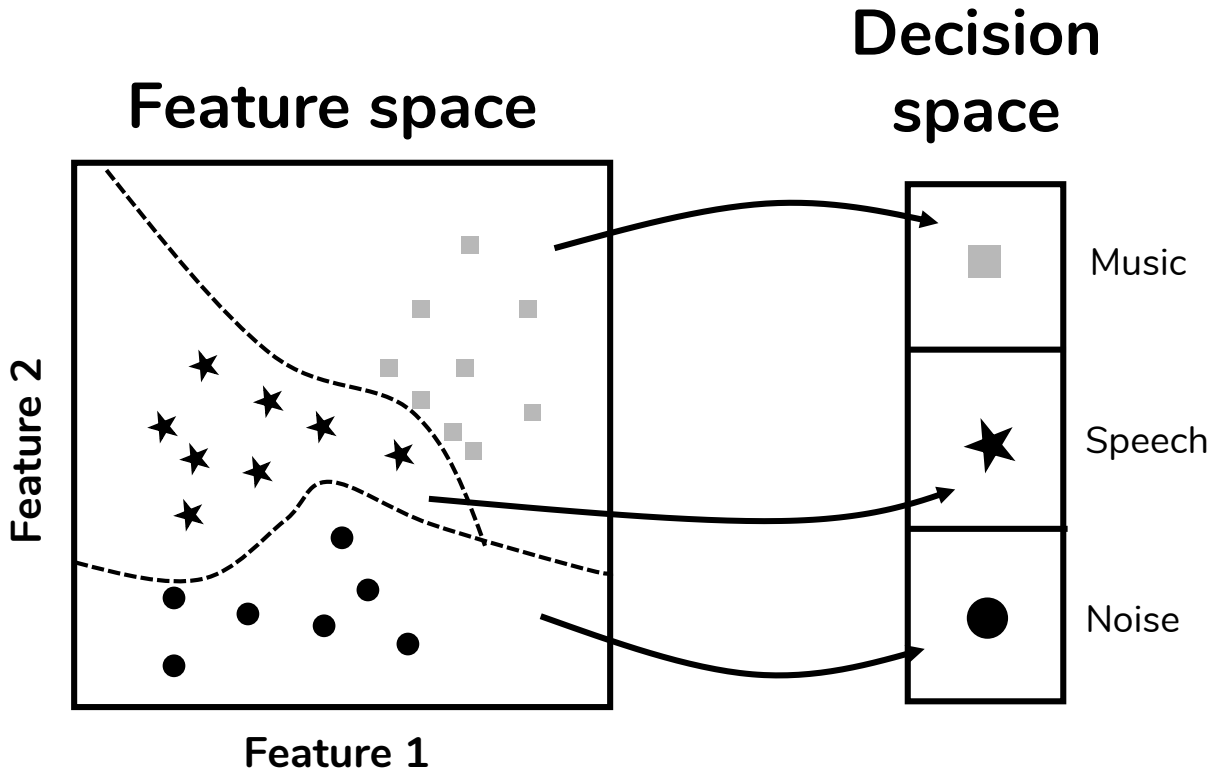
- Feature **selection** is an important part of developing a classifier

Step 2: Classification



Step 2: Classification

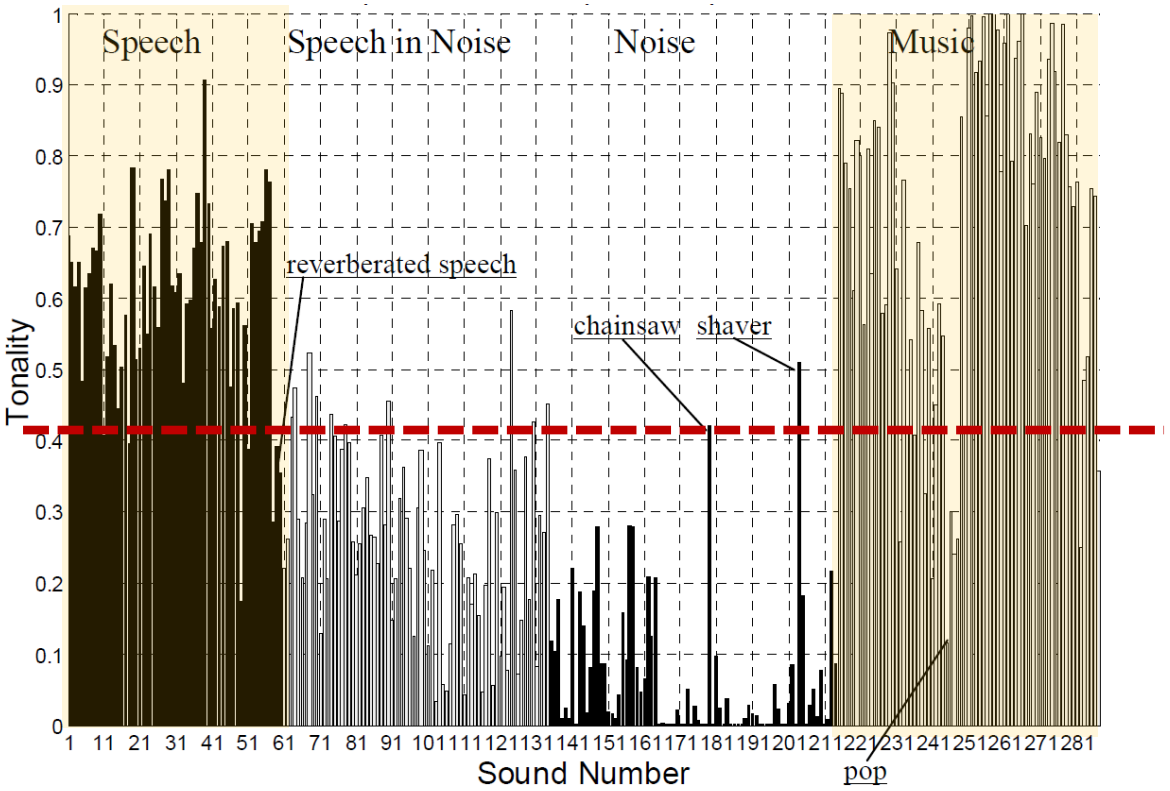
- Mapping from feature space to decision space
- Decision boundaries are the result of training a classifier



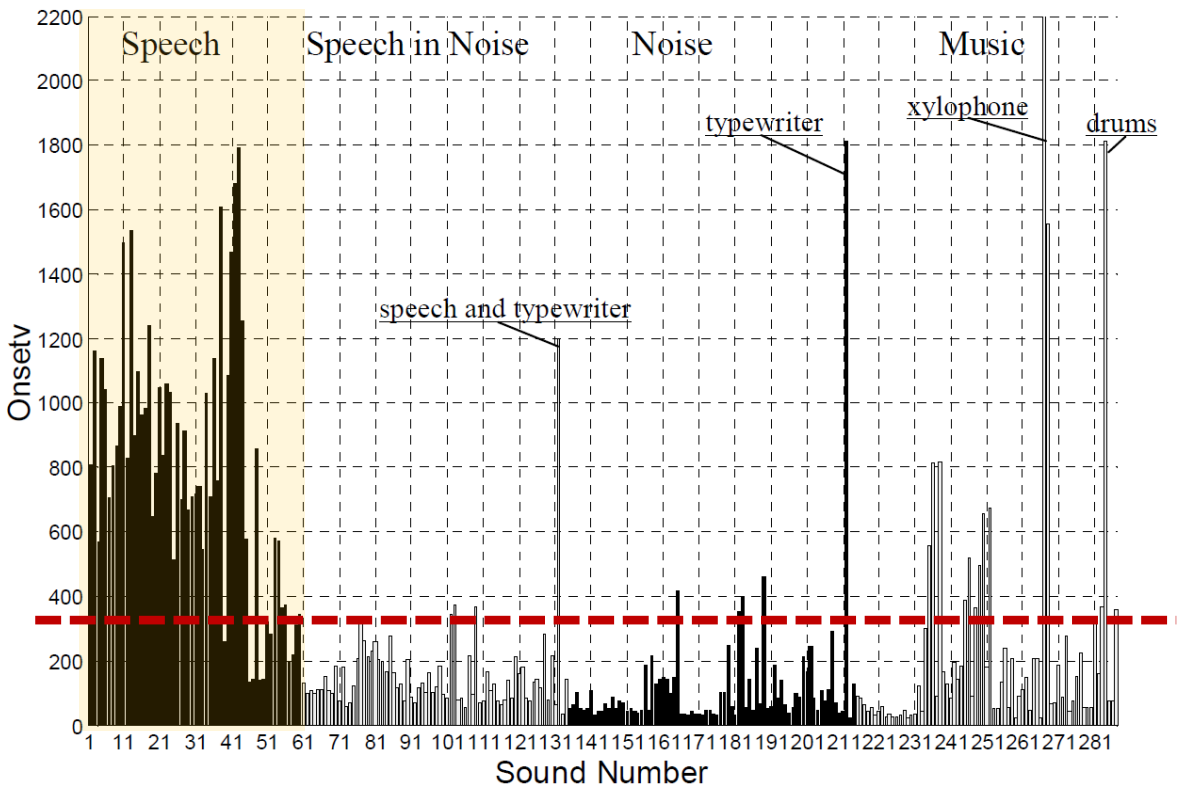
Feature Selection Example

Can Tonality and onset strength be used to identify speech and music?

Feature 1: Tonality

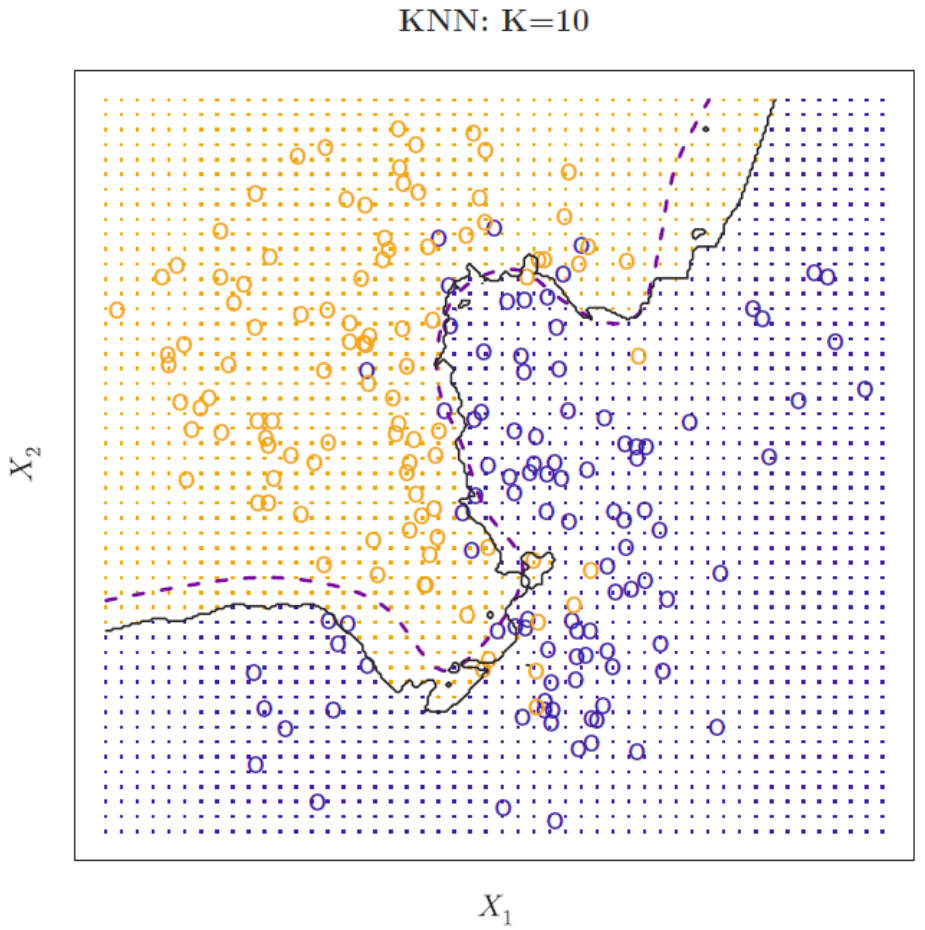


Feature 2: variance of onset strength



Step 2: Classification

- In reality we use dozens or hundreds of features
- the classification boundaries are **high-dimensional**
- …and usually **non-linear**
- This makes it difficult to
  - describe the boundaries
  - understand the classifier's decisions



from: James et al., Introduction to Statistical Learning, http://www-bcf.usc.edu/~gareth/ISL/

Step 3: Post-Processing and Decision

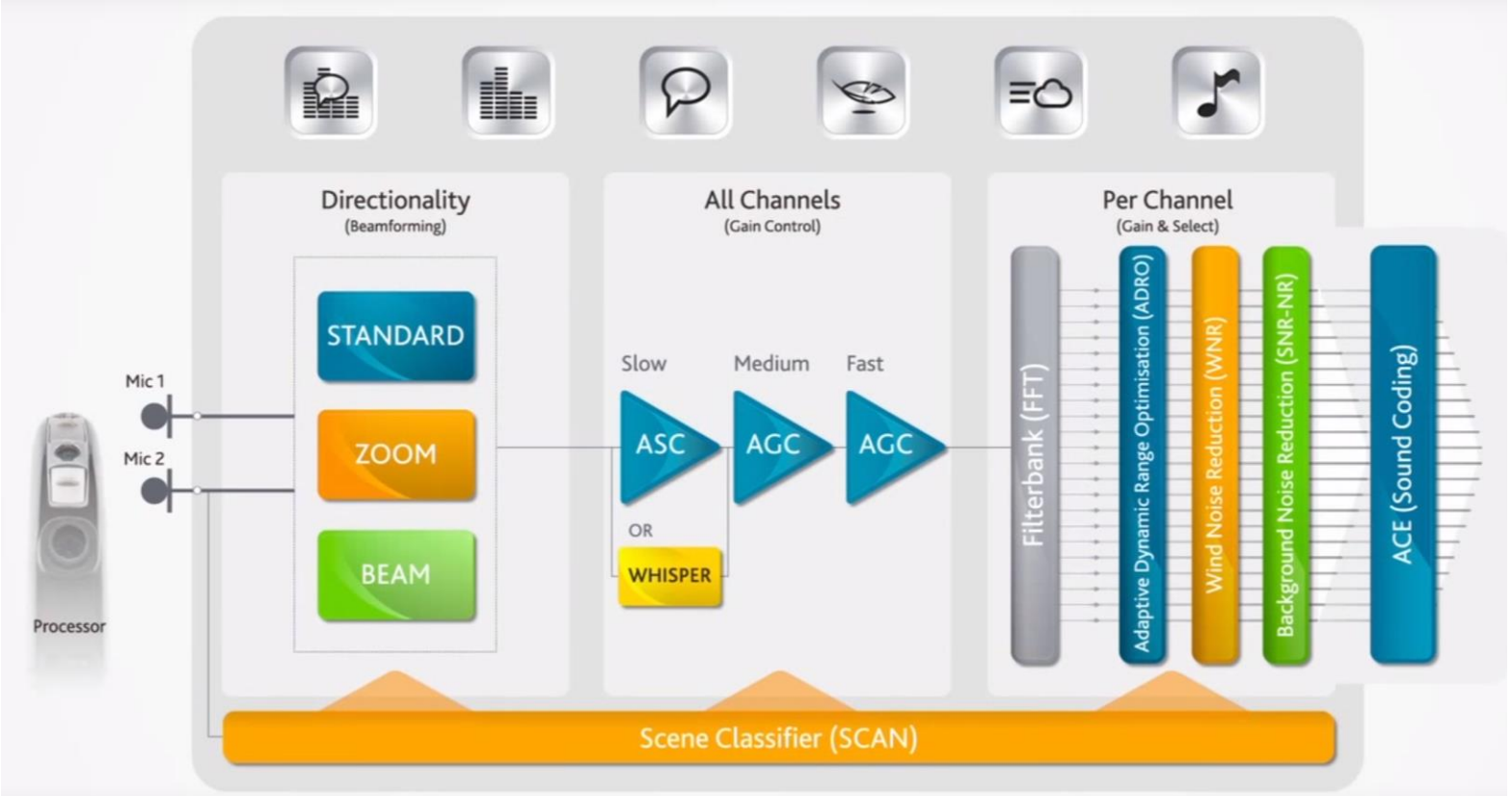
Before making decision…

- **Smoothing:** avoid jumps and misclassifications
- Consider additional factors? (motion sensors, geo location, learned user preferences…)

https://www.youtube.com/watch?v=uikJ1ko5mdQ

Change Sound Processing online

- Select settings that best fit the auditory environment
- For convenience / listening comfort



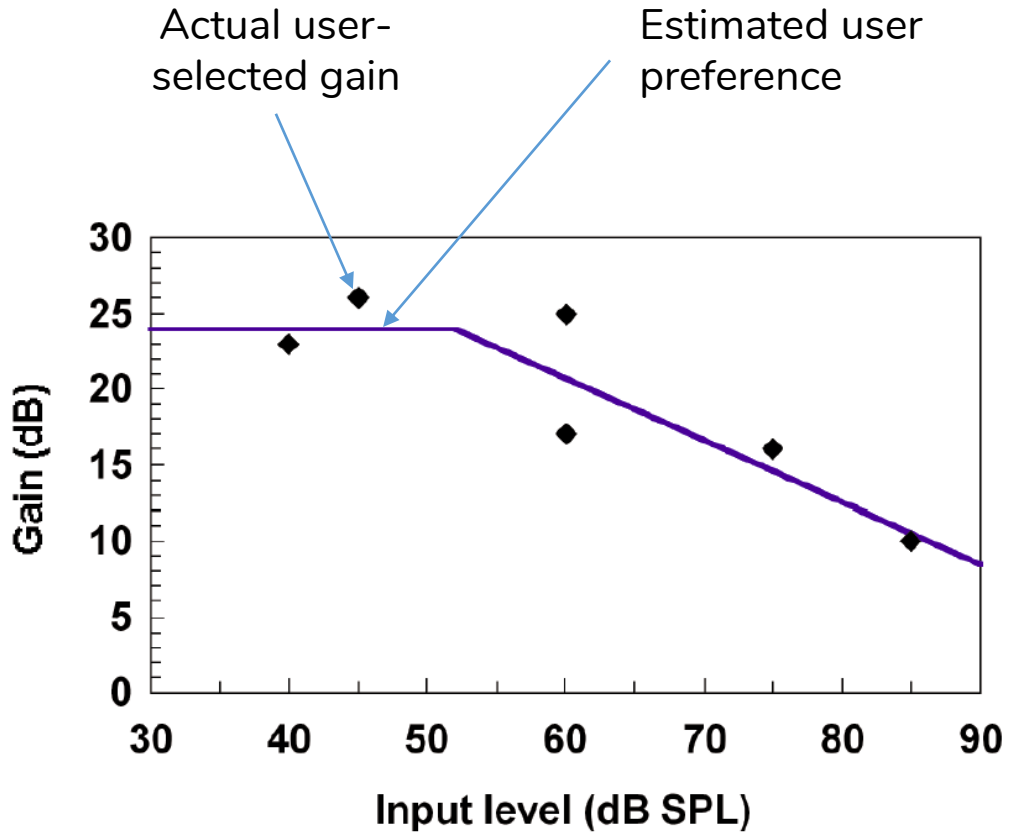
http://pronews.cochlearamericas.com/cochlear-tech-talk-smartsound-iq/

Trainable Hearing Aids

- Remember adjustments made by the user
- Remember environment at time of adjustment
- deduce user's preferred settings
- **make permanent changes to HA programming**

→ ownership, autonomy, fewer clinic visits

- Related: self-fitting, acclimatization managment



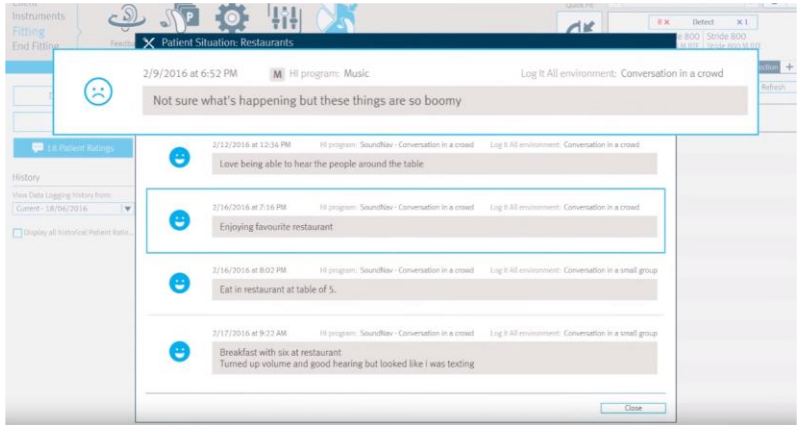
Dillon, H. et al. (2006) *The trainable hearing aid: What will it do for clients and clinicians?* The Hearing Journal

Fitting & Counselling with Data Logs

- **Understand user's lifestyle and listening needs**
  - Are settings optimal? (e.g. user keeps increasing volume)
  - Would assistive devices be useful?
- **Detecting Problems**
  - Are programs/features used as intended?
  - Does the user understand what the programs are for?
  - Are both HA used?
  - Is the use time much higher or lower than reported?
  - Long-term changes in gain? (deteriorating hearing? faulty HA?)
- **Automatic recommendations**
- **Troubleshoot complaints**

Fitting & Counselling with Data Logs

Short-term logging for fine-tuning and troubleshooting



https://www.youtube.com/watch?v=sk3gXC84ELk

Fitting & Counselling with Data Logs

- Emphasize patient's active role
- Data logs as conversation starter
- Feedback / Motivation for patient
- Integration into Telemedicine / mHealth

- (But be careful not to patronize user!)

LEAPing on with Language

http://www.cochlear.com/wps/wcm/connect/au/home/support/rehabilitation-resources/leaping-on-with-language

How can I encourage conversations?

The more conversations you have and the longer your shared conversations are, the more opportunities your child has to learn.

Use these techniques to encourage your child to join in with a conversation, but if they don't choose to, you can continue the conversation without pressuring them. They will gradually hear different ways of responding and in time conversations will grow.

TECHNIQUES TO GENERATE AND EXTEND CONVERSATIONS

Remember the balance in conversations –
At first the adult will be supporting the conversations.
Gradually there will be a more equal exchange.

Always accept your child's attempts at conversation –
Never correct when trying to support longer conversations.
Remember your mind reading and try and respond to them.

Prompt your child to take their turn –
If you have made a comment or a sister has answered the same question, prompt your child to take their turn.

Ask the same question to different family members –
Let your child hear others' responses and then they can have a try.
Set up scenarios where each child takes their turn.

Give your child a choice –
Suggest two or three items to choose from.
E.g. When practising the weekly spellings
'Shall we use a pen or a pencil?' (pause for around 5 seconds, if no response)
'Here, I've found a pencil.' **Ask yourself questions (rhetorical questions)**
E.g. I wonder what we should have for dinner tonight?
E.g. What shall we do if it rains today?

Ask Wh- questions

The Ear Foundation

something to do

ACTIVITY: Joke of the Week

One member of the family chooses a joke for that week. It's written down on a card and placed on the kitchen table. When you are sitting down together someone can tell the joke. Another person can tell the same joke, can anyone remember last week's joke?

Examples:

Puns on words:

What do cats eat for breakfast?

I don't know, what do cats eat for breakfast?

***Mice** Krispies*

What do frogs eat for breakfast?

*Cocoa **Hops***

NOTE: More jokes available in the Resources Section item# 2G.

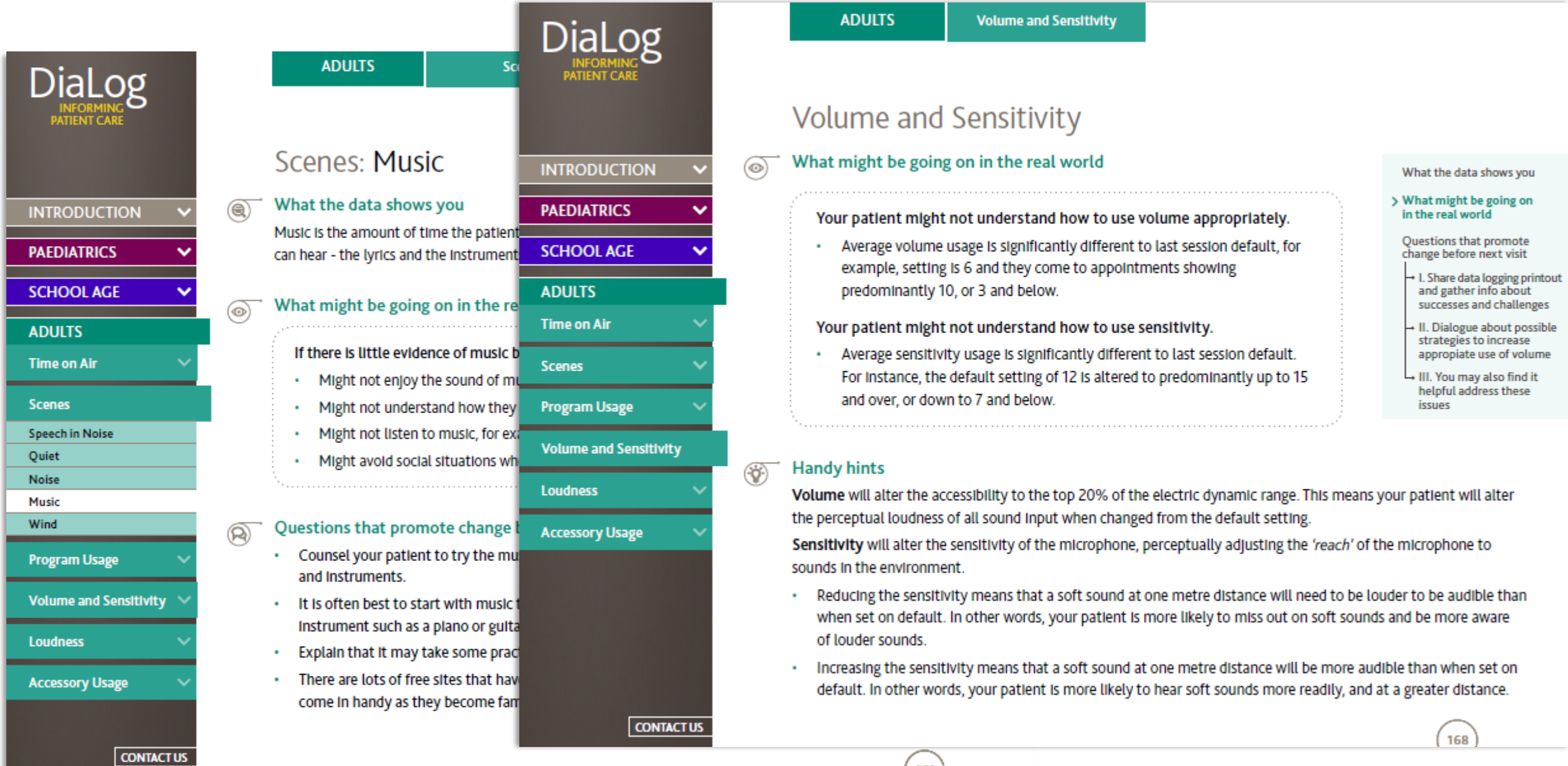
When words don't mean what they say!

Listen to what you say – a lot of it does not actually mean what it says.

Once your child has established conversational skills, it is important to move them on in their use of detailed and descriptive language. There is an increasing link between what they say and what they read. Some phrases will be learned by you using them, others will be learned by your child reading them. It is important you check that your child understands these words and can use them in context over and over again.

Cochlear DiaLog

http://www.cochlear.com/wps/wcm/connect/uk/for-professionals/rehabilitation-resources/dialog



Data Logging in Research

People with hearing loss…

- learn and participate in various environments
- are vulnerable to deficient auditory environments

Data logging as a method for **naturalistic observations**

→ understand risk factors and challenges in everyday life
→ optimize support and rehabilitation

Language development with Hearing Impairment

Early auditory deprivation, effects remain after amplification / implantation

Continued limited access to language environment due to technical problems, non-compliance, signal quality

- problem learning from overheard speech, classrooms (-7 to +5 dB SNR) (Crandell & Smaldino, 2000)
- increasing mainstream education of children with CI: Flanders 65%, US 71% (DeRaeve & Lichtert, 2012; Geers & Brenner, 2003)
- listening effort, fatigue, frustration… (Bess & Hornsby, 2014)

Hearing loss shapes interactions

- Amount, responsiveness of parental speech affected by HL (Ambrose et al., 2014; VanDam et al., 2012)
- Influence of parent's self-efficacy beliefs (Desjardin & Eisenberg, 2007)

↓ communicative experience

↓ analyzable language model

Personal and Professional Life with HA/CI

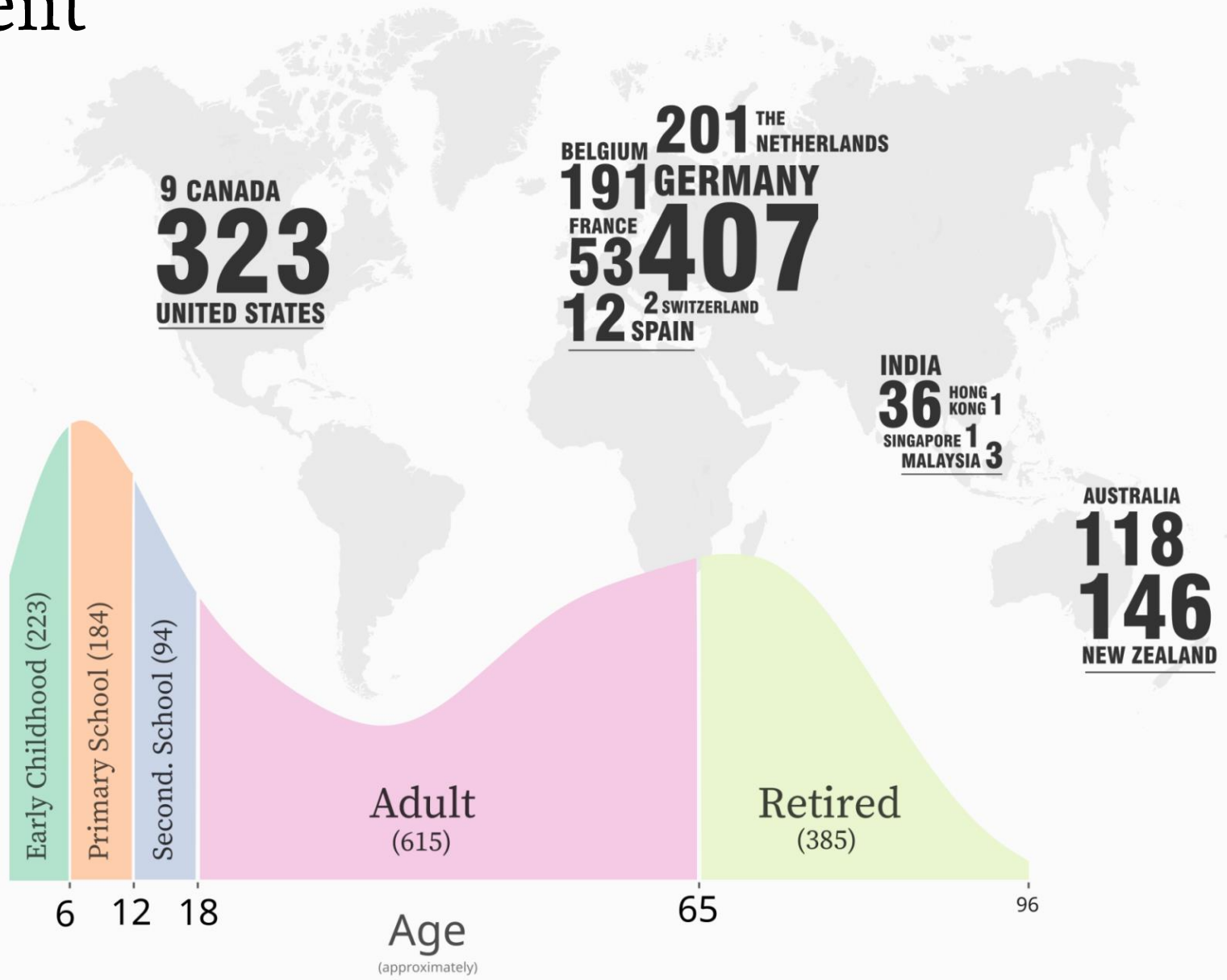
- insufficient hearing aid performance causes **frustration** and **non-use**
- Frequent complaints: noise and multitalker conversations

Busch, Vanpoucke, van Wieringen (2017). JSLHR

Auditory Environment Across the Lifespan of CI Users

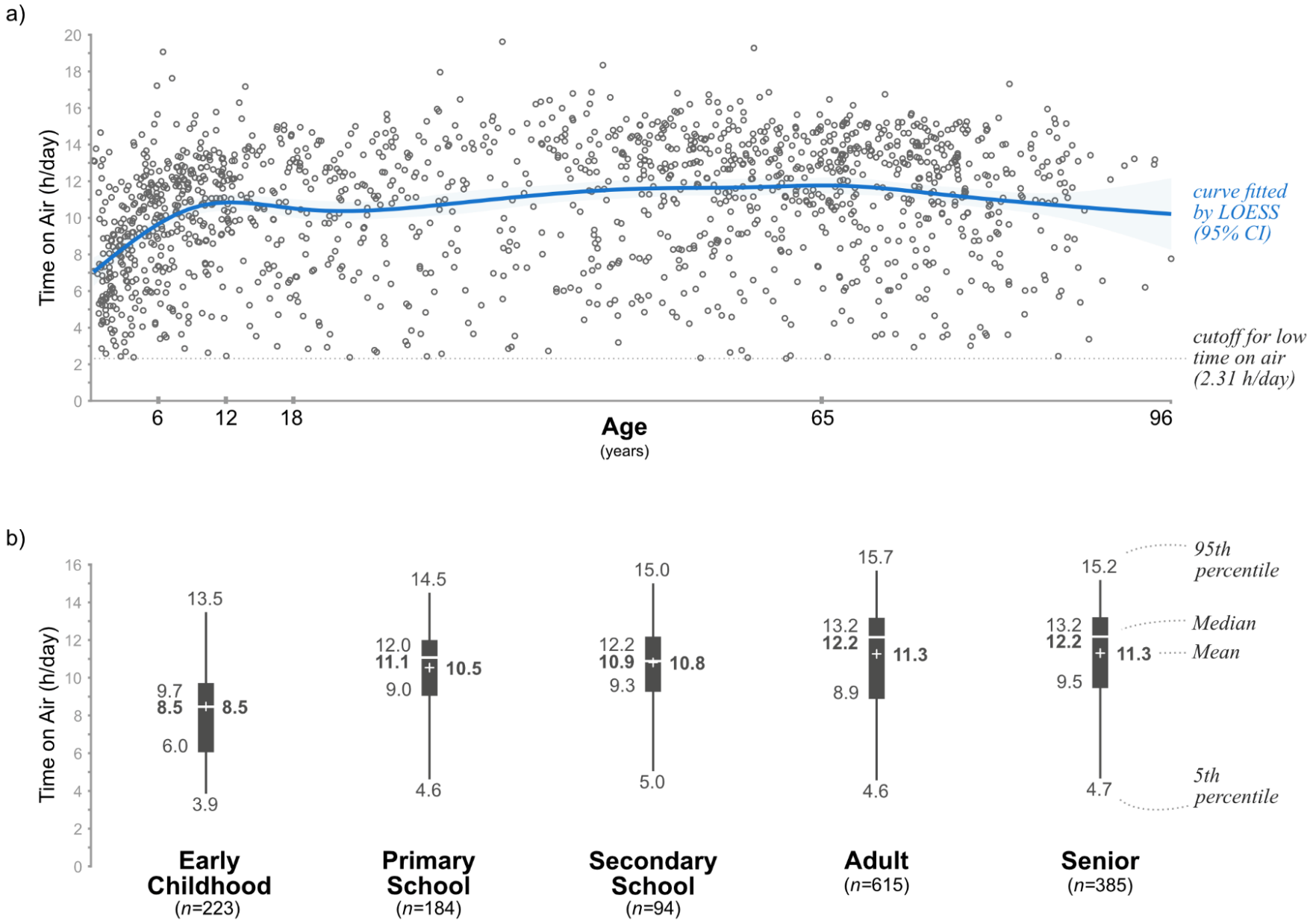
Insights from Data Logging

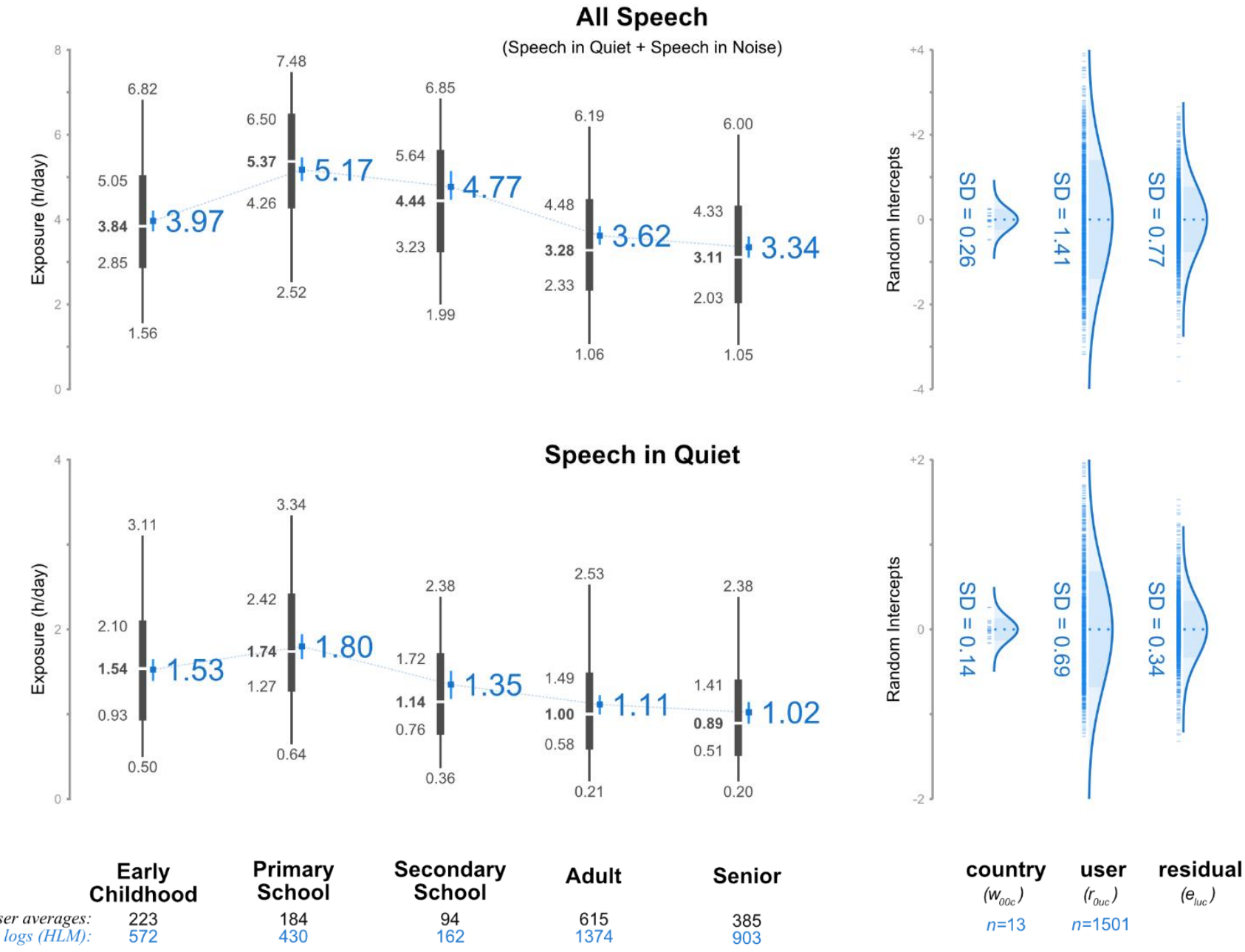
Cochlear's data log database:
3400 logs from 1500 users,
2.4 mio hours CI use



Download the paper here:
http://jslhr.pubs.asha.org/article.aspx?articleid=2621837
(open access)

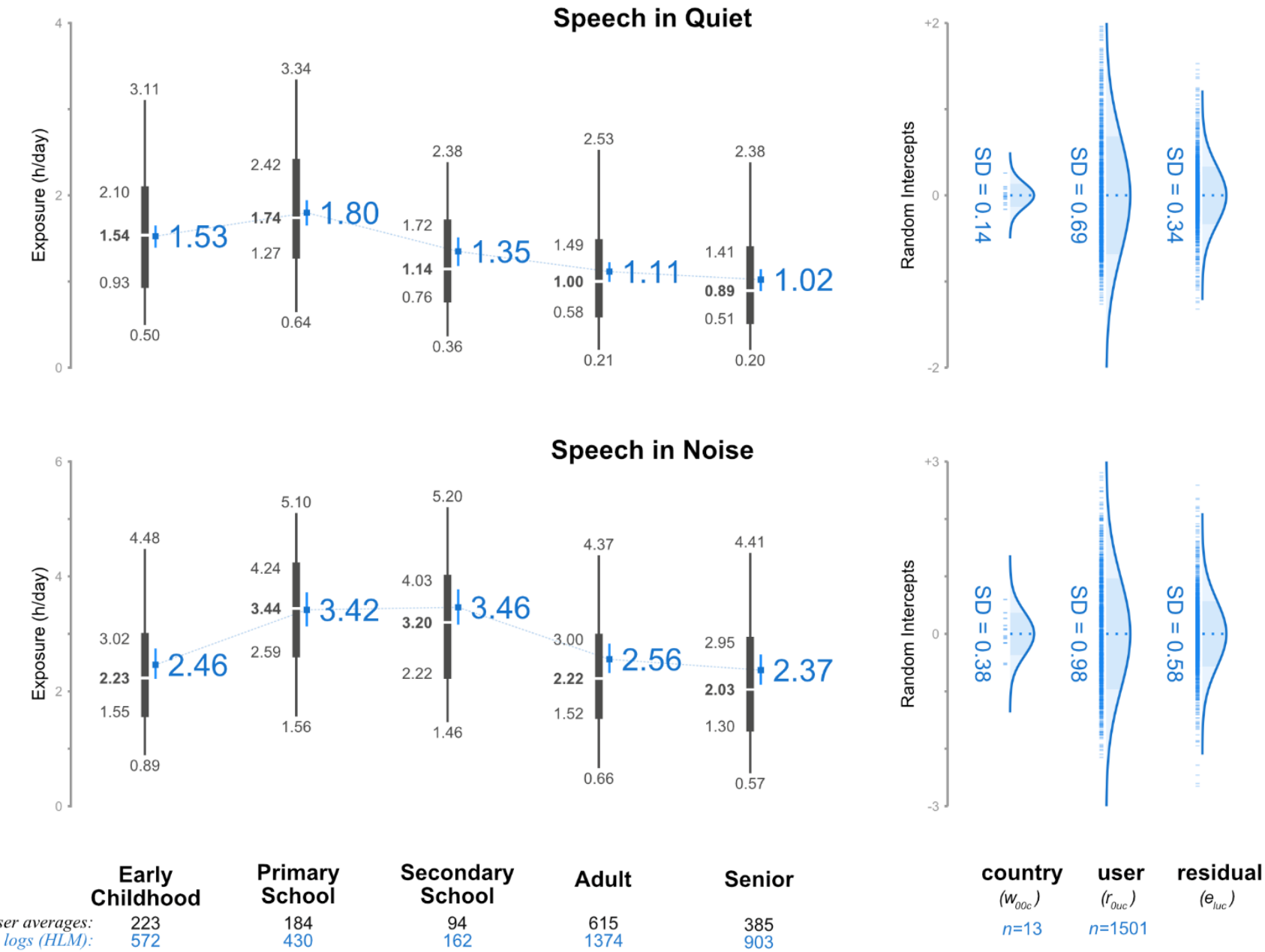
Device Use (Time on Air)

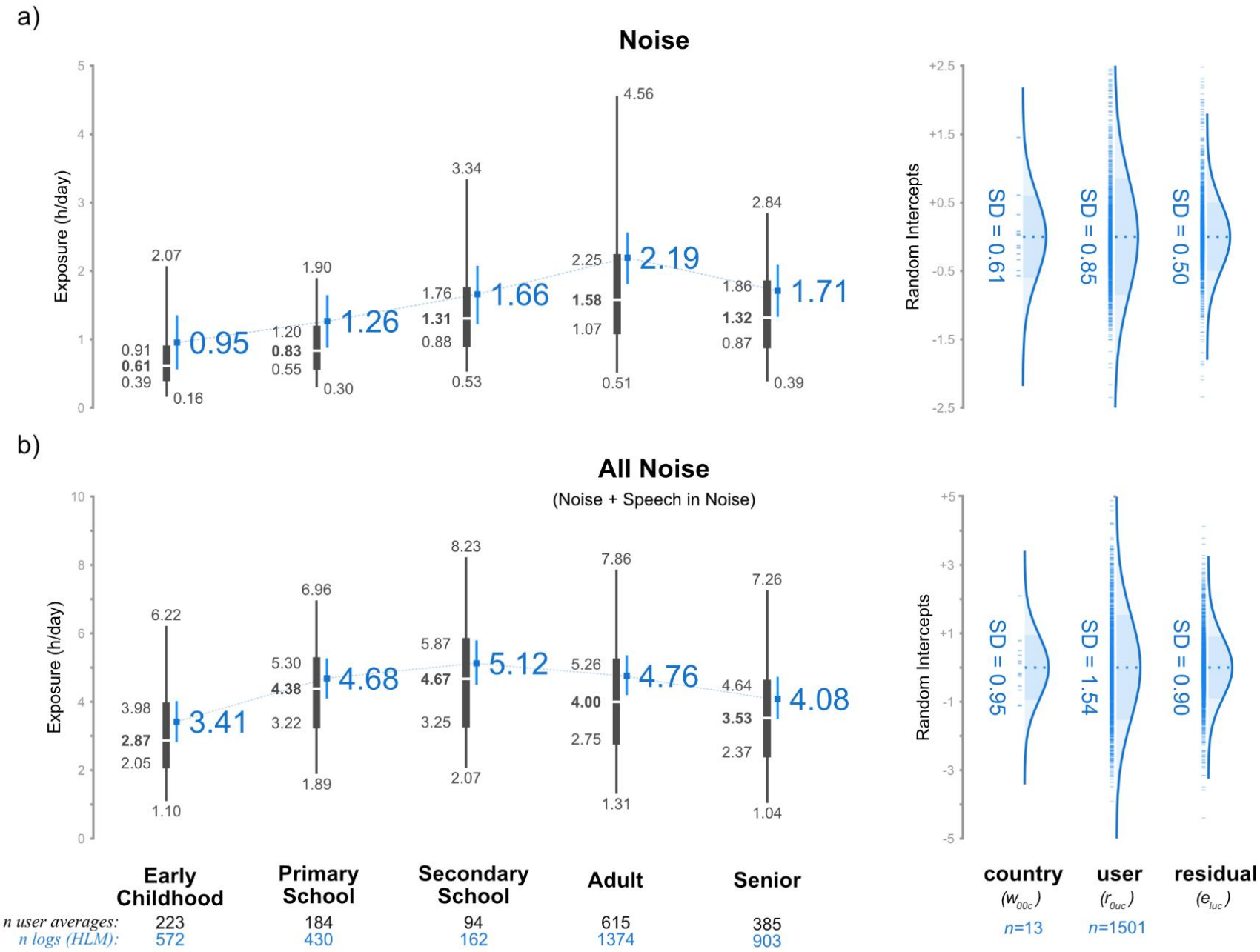




	Early Childhood	Primary School	Secondary School	Adult	Senior
n user averages:	223	184	94	615	385
n logs (HLM):	572	430	162	1374	903

country (w_{00c})	user (r_{0uc})	residual (e_{luc})
n=13	*n*=1501	


Speech in Quiet
Exposure (h/day)
4
2
0
3.11
2.10
1.54
0.93
0.50
1.53
3.34
2.42
1.74
1.27
0.64
1.80
2.38
1.72
1.14
0.76
0.36
1.35
2.53
1.49
1.00
0.58
0.21
1.11
2.38
1.41
0.89
0.51
0.20
1.02
Random Intercepts
+2
0
-2
SD = 0.14
SD = 0.69
SD = 0.34
Speech in Noise
Exposure (h/day)
6
4
2
0
4.48
3.02
2.23
1.55
0.89
2.46
5.10
4.24
3.44
2.59
1.56
3.42
5.20
4.03
3.20
2.22
1.46
3.46
4.37
3.00
2.22
1.52
0.66
2.56
4.41
2.95
2.03
1.30
0.57
2.37
Random Intercepts
+3
0
-3
SD = 0.38
SD = 0.98
SD = 0.58
Early Childhood
Primary School
Secondary School
Adult
Senior
n user averages: 223 184 94 615 385
n logs (HLM): 572 430 162 1374 903
country (w_{00c}) n=13
user (r_{0uc}) n=1501
residual (e_{luc})


a)
Noise
Exposure (h/day)
2.07
0.91
0.61
0.39
0.16
0.95
1.90
1.20
0.83
0.55
0.30
1.26
3.34
1.76
1.31
0.88
0.53
1.66
4.56
2.25
1.58
1.07
0.51
2.19
2.84
1.86
1.32
0.87
0.39
1.71
Random Intercepts
SD = 0.61
SD = 0.85
SD = 0.50
b)
All Noise
(Noise + Speech in Noise)
Exposure (h/day)
6.22
3.98
2.87
2.05
1.10
3.41
6.96
5.30
4.38
3.22
1.89
4.68
8.23
5.87
4.67
3.25
2.07
5.12
7.86
5.26
4.00
2.75
1.31
4.76
7.26
4.64
3.53
2.37
1.04
4.08
Random Intercepts
SD = 0.95
SD = 1.54
SD = 0.90
Early Childhood
Primary School
Secondary School
Adult
Senior
n user averages: 223 184 94 615 385
n logs (HLM): 572 430 162 1374 903
country (w_{00c}) n=13
user (r_{0uc}) n=1501
residual (e_{luc})

Main conclusion

Significant differences in environments between and within age groups.

Open Question: Are the differences meaningful?

Can they explain variability in outcomes, identify risk cases?
→ optimize environment, optimize rehabilitation

Next Study:

Predict **language development** from past **auditory environment**

Download the paper here (open access):
http://jslhr.pubs.asha.org/article.aspx?articleid=2621837

Review of Topics

- Contents of data logs
- The 3 steps of sound classification
- Applications for sound classfication and data logging:
  - Changing HA settings online and trainable haring aids
  - Fitting and counselling with data logs
  - Research: The auditory environment of CI users