Sound Scene and Spatial Speech Classification in Hearing Aids

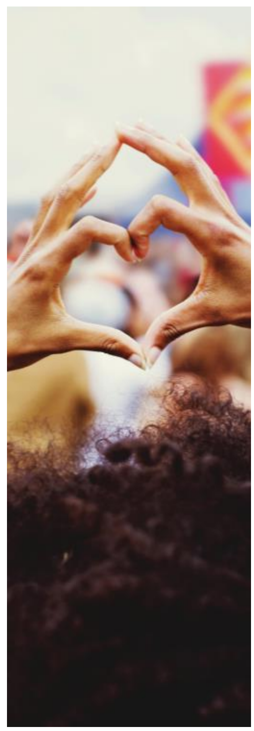
Donald Hayes, Ph.D.

Director, Clinical Research

unitron Love the experience

A Sonova brand

Do you ever think about what a modern hearing aid really is?



It is a system of interrelated parts working together in support of a philosophy

Two parts you may not think much about

Benchmarking results on two of the components

- Classification
  - Studies which highlight how it works and why it is important
- Spatial Detection
  - Studies that evaluate the benefits of spatial detection algorithms
  - What you can do when you know the direction of speech

unitron

Do you ever consider how automatic hearing aids classify acoustic environments?

We do!

Environmental Classification in Hearing Aids

Philosophy: The developers' choice of "detectors" and the decision rules weighted by design philosophy

Consequences: Engaging, disengaging, and parameter value selection for signal processing features

Importance: The best possible signal processing is only as good as the accuracy of the classifier and quality of the signal processing decisions driven by the classifier results.

Why is this clinically relevant?

It comes back to "Log It All"

The Global Listening Environment Study (GLES) took advantage of the Log It All feature to acoustically map the listening environments experienced by hearing aid wearers in 10 countries.

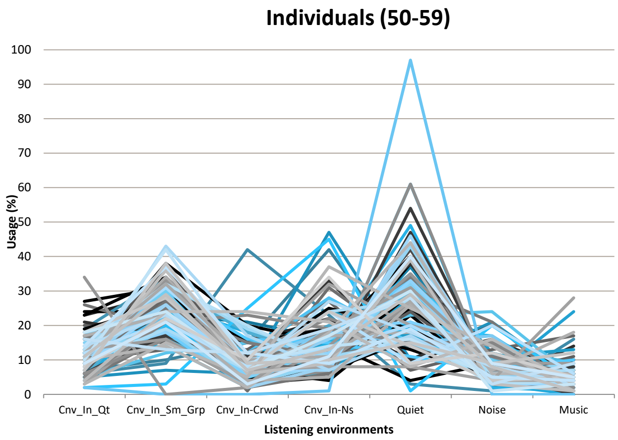
Global Listening Environment Study, Unitron. 2016

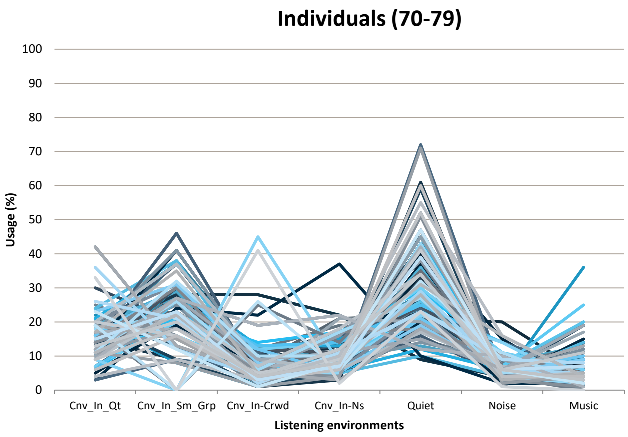
Clinics from ten countries participated

Country	Records
Australia	134
Canada	87
France	78
Germany	87
Netherlands	141
New Zealand	140
Slovenia	58
South Africa	55
Spain	67
USA	208
Total	1055

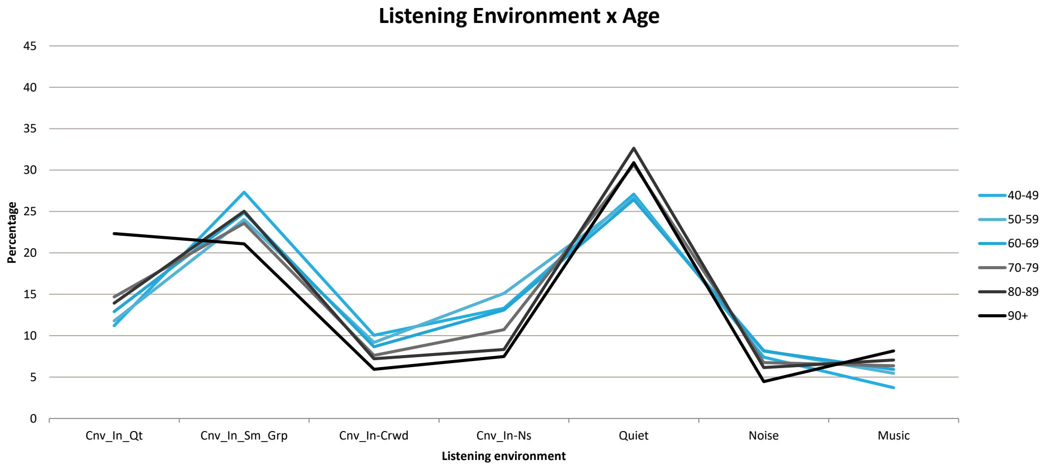
Global Listening Environment Study, Unitron. 2016

Greater variability within groups of people of the same age than there is across ages





Age is not a strong predictor of the time people spend in conversations



What we saw in the GLES

Average classifier results will be extremely similar for any large group of people regardless of:

- Age
- Country
- Gender
- Population density (rural, small town, big city)
- Hearing aid experience

unitron

Why is that?

Is it because:

1. On average everybody experiences roughly the same distribution of acoustic environments in their daily lives?
2. Our classifier sees the same distribution regardless of a person's daily life?

Individual results would indicate it is the first one. But we must also rule out the second one.

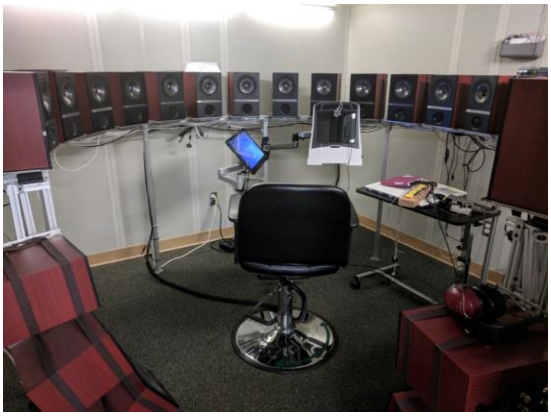
We do that through a **Benchmarking** study

unitron

Benchmarking Studies - USF

Multiyear project with the University of South Florida

- Principle Investigators
  - David Eddins, Ph.D.
  - Erol Ozmeral, Ph.D.
- Together with Sonova they have studied
  - Classifier Performance
  - Azimuth Detection Behavior
  - Take home comparison to leading competitor



Classifier performance

First we designed the sound parkour to simulate real world listening

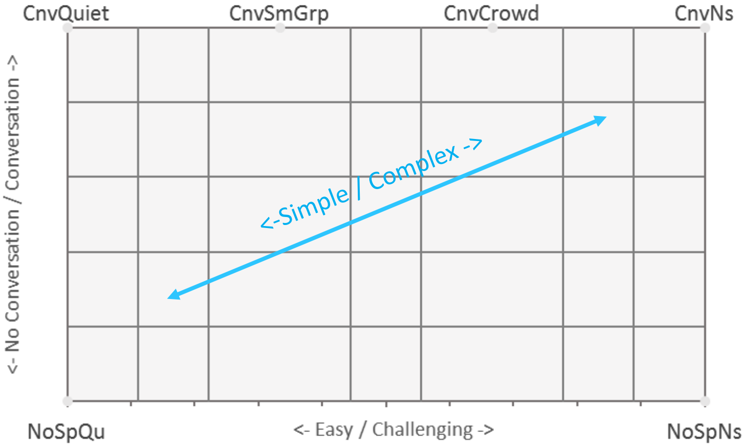
Then we had 16 normal hearing listeners "classify" each sound file

Finally we had our hearing aids "classify" the same sound files

The sound parkour

(a walk through the acoustic park)

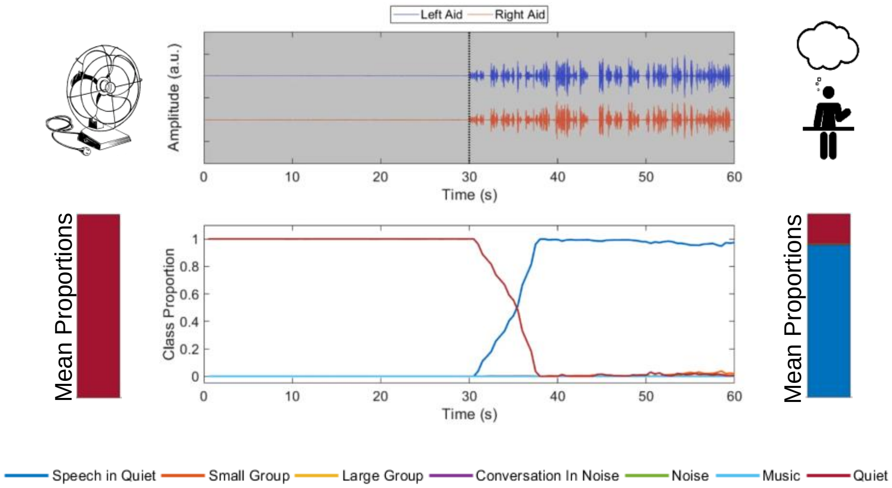
Defining a listening environment



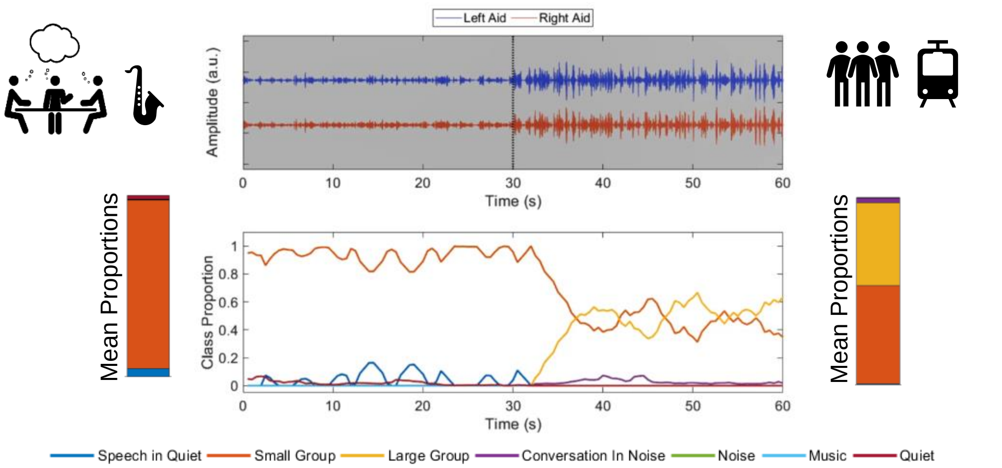
Condition	Short ID	Talkers	Background Noise	Talker Distribution°	Noise Distribution°	SNR	Overall Level
Quiet Listening	Q-Fan	0					
Quiet Conversation	Q-1T	1					
	Q-3T	3					

Condition	Short ID	Talkers	Background Noise	Talker Distribution°	Noise Distribution°	SNR	Overall Level
Quiet Listening	Q-Fan	0	Fan noise	N/A	0°, 90°, 180°, 270°	N/A	40 dB
Quiet Conversation	Q-1T	1	N/A	0°	N/A	N/A	55 dB
	Q-3T	3	N/A	0°, 300°, 60°	N/A	N/A	55 dB
Quiet Conversation with Music	Q-1T-M	1	Music	0°	90°	-3	55 dB
	Q-3T-M	3	Music	0°, 300°, 60°	90°	-3	55 dB
Small Group Conversation with noise	C-Tube1	[illegible]	Subway	270°, 0°, 90°	0°, 90°, 180°, 270°	+15	70 dB
	C-Tube2	3	Subway	270°, 0°, 90°	0°, 90°, 180°, 270°	+10	70 dB
	C-Tra1	2	Traffic	270°, 90°	0°, 90°, 180°, 270°	0	70 dB
	C-Tra2	2	Traffic	270°, 90°	0°, 90°, 180°, 270°	-10	70 dB
	C-Car1	3	Car	270°, 0°, 90°	0°, 90°, 180°, 270°	-10	70 dB
	C-Car2	3	Car	270°, 0°, 90°	0°, 90°, 180°, 270°	-15	80 dB
	C-Food	3	Food court	300°, 0°, 60°	0°, 90°, 180°, 270°	0	70 dB
Small Group Conversation with Noise/Music	C-Traf1-M1	3	Traffic, Music	300°, 0°, 60°	0°, 90°, 180°, 270°, 90°	0, -5	70 dB
	C-Traf2-M1	3	Traffic, Music	300°, 0°, 60°	0°, 90°, 180°, 270°, 90°	-5, -5	70 dB
	C-Traf2-M2	3	Traffic, Music	300°, 0°, 60°	0°, 90°, 180°, 270°, 90°	-5, +5	70 dB
	C-Traf2-M3	3	Traffic, Music	300°, 0°, 60°	0°, 90°, 180°, 270°, 90°	-10, +15	75 dB
Large Group Conversation	LG1	1	6T-Babble	0°	315°, 45°, 135°	+5	65 dB
	LG2	1	8T-Babble	0°	315°, 45°, 135°, 225°	0	70 dB
	LG3	1	10T-Babble	0°	315°, 45°, 135°, 225°, 180°	-5	75 dB
Large Group Conversation with Music	LG1-M1	1	6T-Babble, Music	0°	315°, 45°, 135°, 90°	+5, -10	65 dB
	LG2-M1	1	8T-Babble, Music	0°	315°, 45°, 135°, 225°, 90°	0, -10	70 dB
	LG3-M1	1	10T-Babble, Music	0°	315°, 45°, 135°, 225°, 180°, 90°	-5, -10	75 dB
	LG2-M2	1	8T-Babble, Music	0°	315°, 45°, 135°, 225°, 90°	0, 0	70 dB
	LG3-M2	1	10T-Babble, Music	0°	315°, 45°, 135°, 225°, 180°, 90°	-10, 0	75 dB
Television Viewing	TV	0	TV (CSI S01E01)	N/A	0°	N/A	70 dB

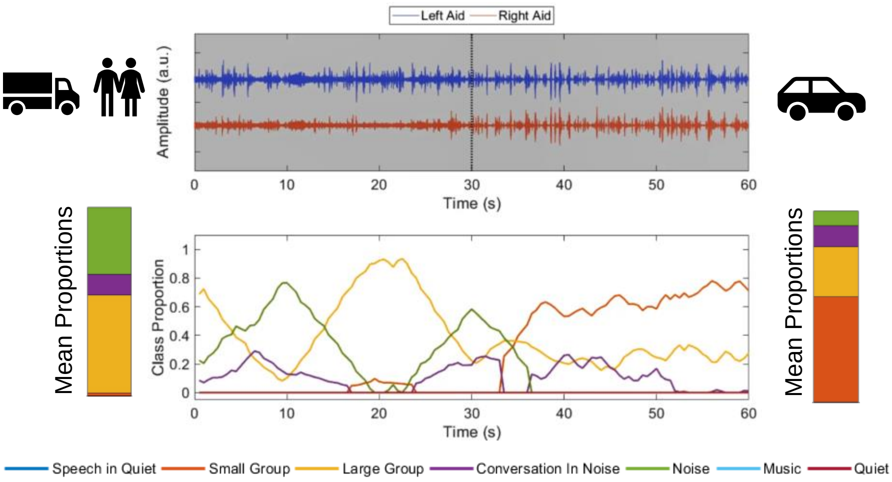
Transition Case 1
Quiet (Q-Fan) → Speech in Quiet (Q-1T)



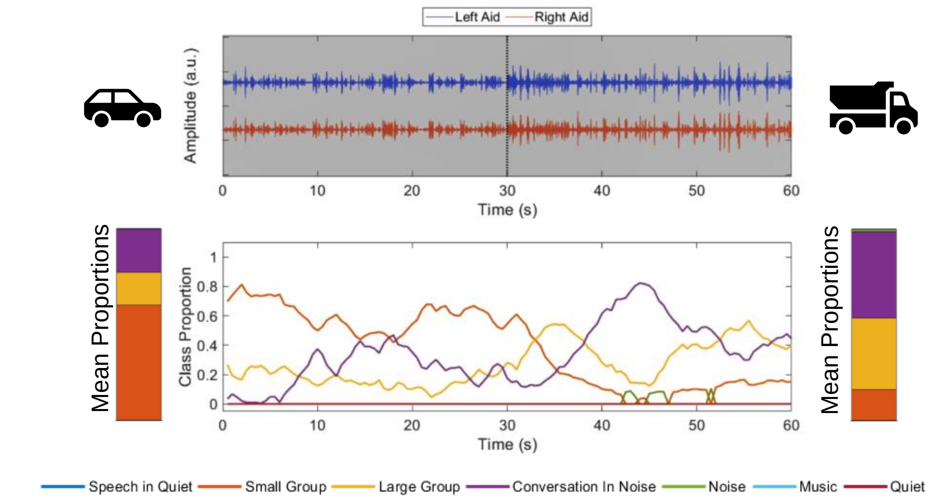
Transition Case 3
Small Group with Music (Q-3T-M) → Small Group in Subway (3T-Tube)



Transition Case 4
Two Talkers in Traffic (2T-Traf) → Three Talkers in Car (3T-Car)



Transition Case 5
3 Talkers in Car-Avg (3T-Car-A) → Three Talkers in Car-Loud (3T-Car-L)



That is Classification under the microscope

Classifier Benchmarking

You can benchmark against either:

- A gold standard
- Similar devices

Gold Standard = 16 normal hearing listeners

Similar devices = 4 top competitor’s Premium hearing aids

unitron.

Classifier performance

First we designed the sound parkour to simulate real world listening

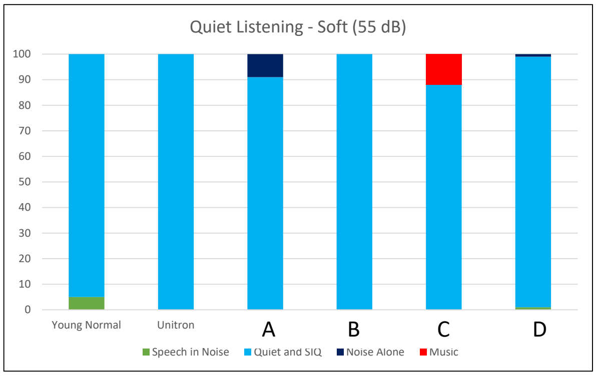
Then we had 16 normal hearing listeners “classify” each sound file

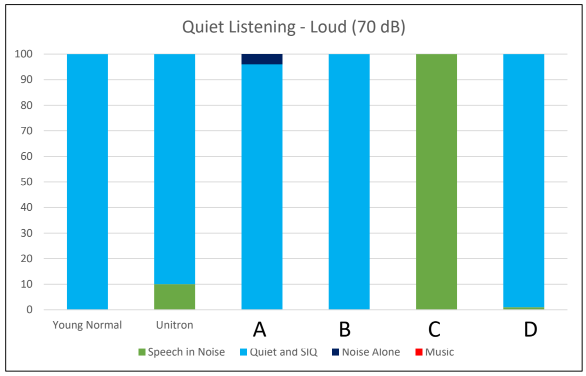
Finally we had our hearing aids “classify” the same sound files

unitron.

Hearing aids versus human classification

Basic classification

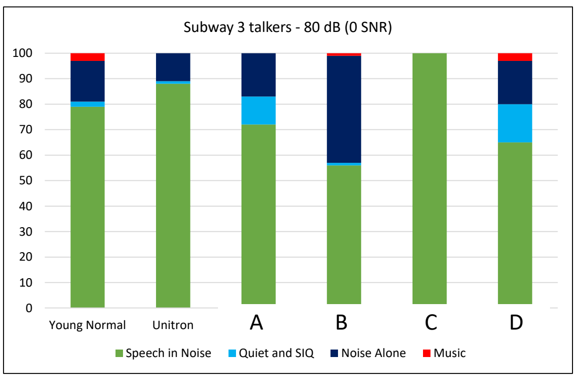


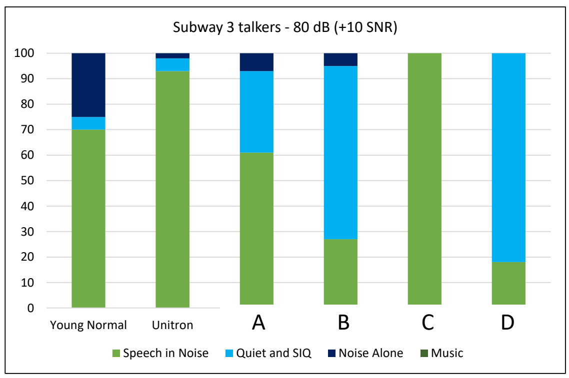


Soft Speech

Loud Speech

Complex classification





Difficult SNR

Favorable SNR

What does the benchmarking tell us?

Comparisons to normal listeners and competitors show:

1. In simple acoustic environments all manufacturers do a pretty good job of classification
2. The differences in philosophy appear when the environment becomes more complex
    a) Some are sensitive to overall level
    b) Some to SNR
    c) Some lock in on speech
3. Log It All results are valid because our classification correlates well with normal listeners, even in complex (blended) environments.

unitron

Now let us look at some real world data

Ecological Study

Ecological momentary assessment (EMA) involves repeated sampling of subjects' current behaviors and experiences in real time, in subjects' natural environments.

EMA aims to minimize recall bias, maximize ecological validity, and allow study of microprocesses that influence behavior in real-world contexts.

Shiffman S[1], Stone AA, Hufford MR. Annu Rev Clin Psychol. 2008;4:1-32.

Ecological Study

1. EMA = Ecological Momentary Assessment

2. Joint effort between: Unitron/UWO under the ORF/MITACs
   - Unitron - Leonard Cornelisse
   - NCA - Susan Scollie, Danielle Glista
   - UWO Geography – Jason Gilliland, Tayyab Shah

3. They generated way more data than we have time for today

Environmental Classification in Hearing Aids

Method of evaluation:

- EMA study with UWO
- NCA/Geography Dept.
- 6 Intrepid grad students took to the streets of London over 54 hours in 1 sec intervals.

- Wearing only:
  - Laptop
  - HA's
  - NOAHLink
  - GPS
  - LENA
  - Cell Phones with Ratings

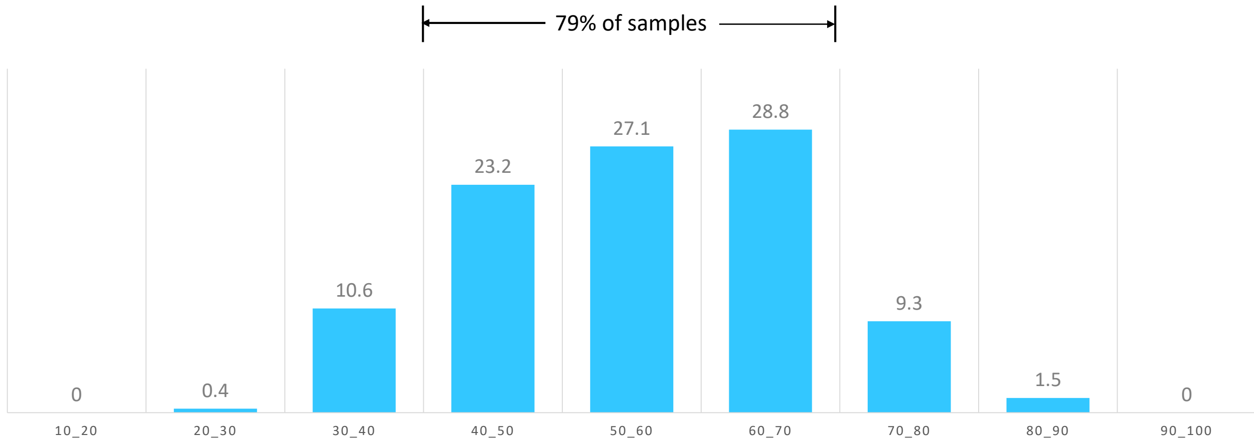
In other words:

Some basic measurements

1. Average over all level in the real world (55 hours of it anyway)
2. Average Signal to Noise Ratio
3. Left and right ear differences

In case you ever wondered

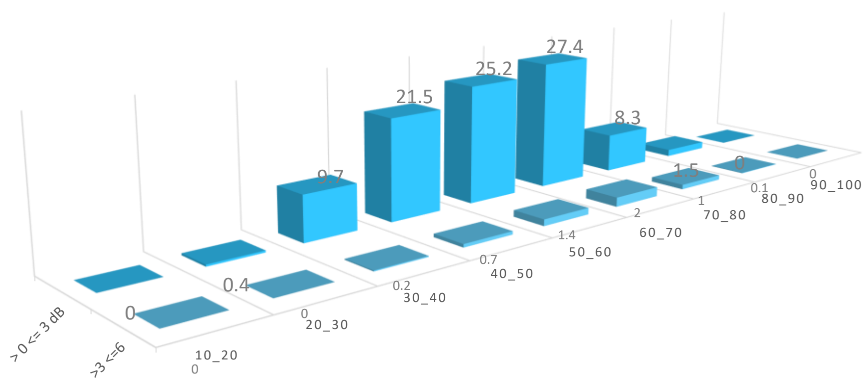
Distribution of overall levels experienced



1 second samples over 55 hours

SIGNAL LEVEL X RANGE (DB)

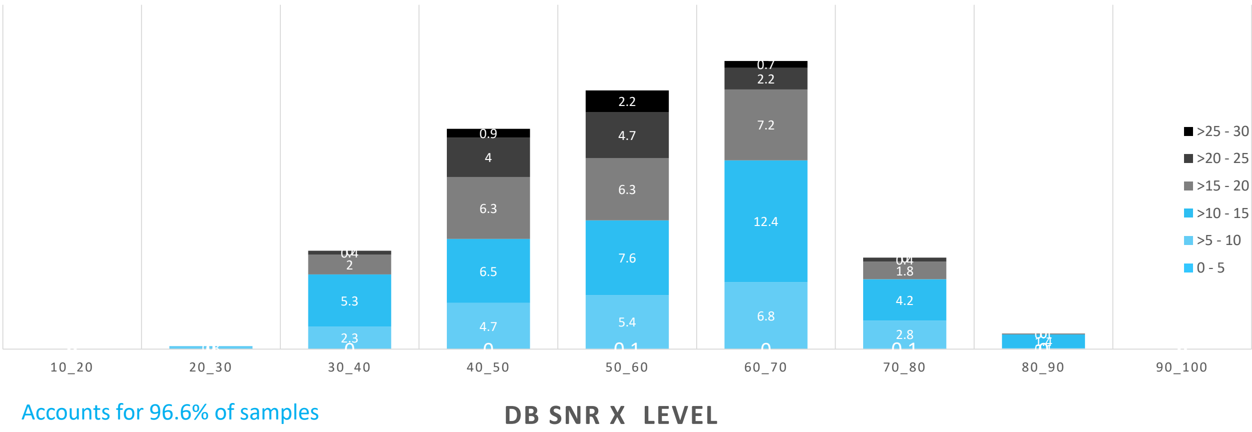
Average ear “level” difference



94% <= 3 dB Difference

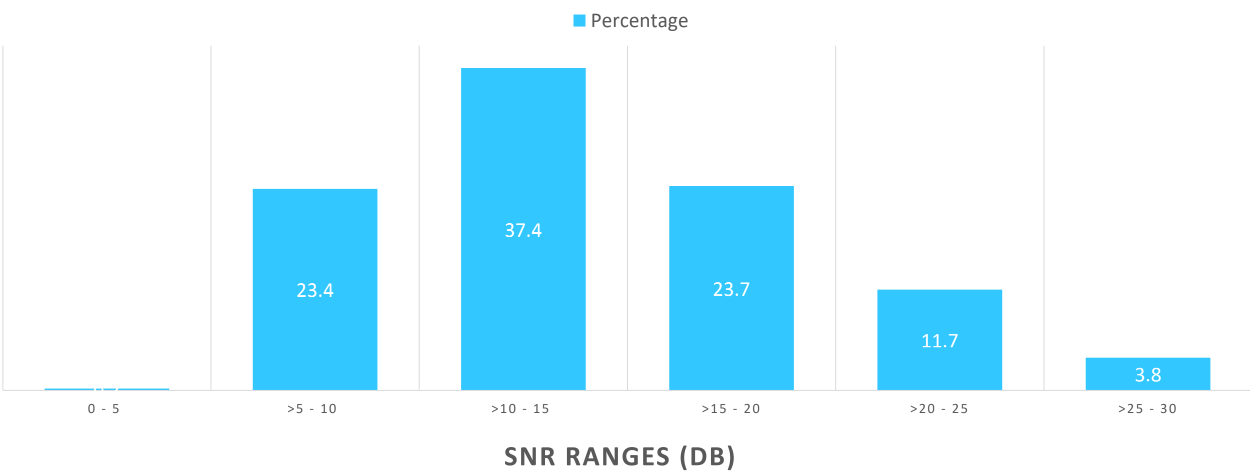
SIGNAL LEVEL X DIFFERENCE (DB)

Distribution of SNRs x Level



Accounts for 96.6% of samples

Distribution of SNRs x percentage of time

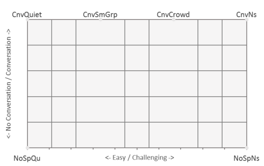


What we learned about the classifier

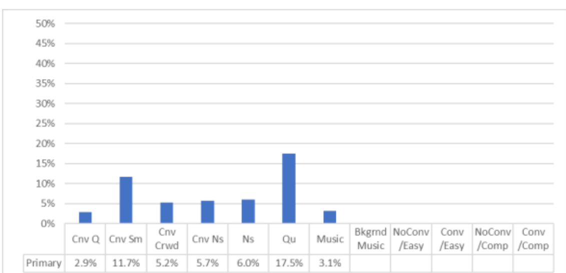
1. Some useful but not surprising information

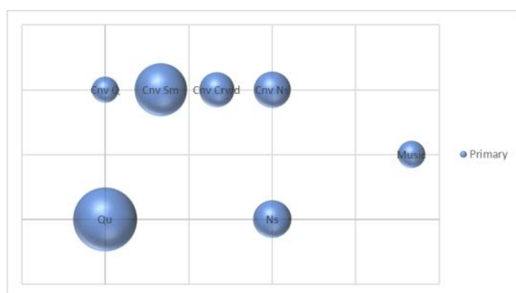
2. Some further information to consider for the future

Log-It-All: Primary Classes (52%)

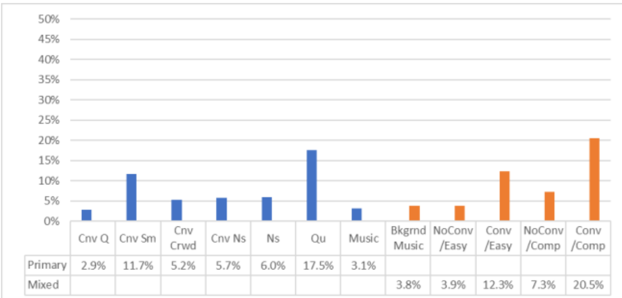


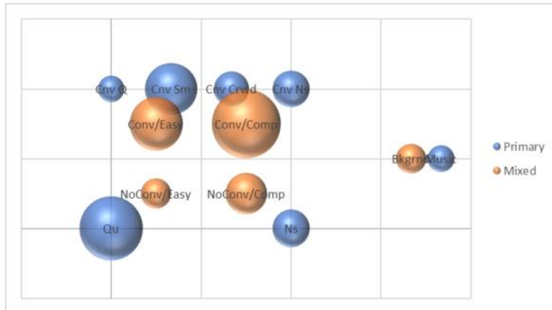
Percentage of time class proportion exceeded 75%





Log-It-All: Primary (52%) & Mixed Classes (48%)





What does the EMA study tell us?

These results are based on one day (9 hours) of recordings from each of 6 people

1. Our participants were in acoustic environments that were clearly defined as primary classes based on *our* system about half the time.
2. The rest of the time the acoustic environments were complex enough to be classified as mixed (blended) classes.
3. Those proportions will vary depending on the philosophy and priorities set by each manufacturer.

unitron.

How about Spatial Detection?

Two parts you may not think much about

Benchmarking results on two of the components

- ✓ Classifier
  - ✓ Studies which highlight how it works and why it is important

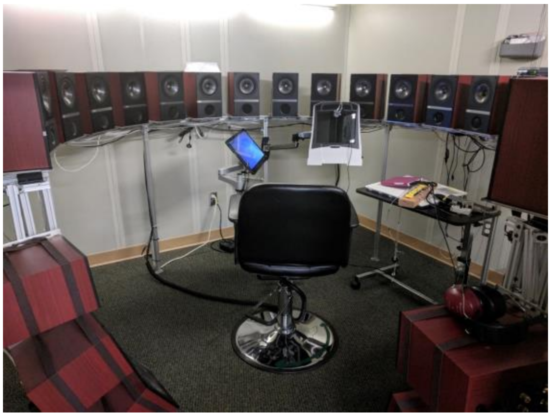
- Spatial Detection
  - Studies that evaluate the benefits of spatial detection algorithms
  - What you can do when you know the direction of speech

unitron

Benchmarking Studies - USF

Multiyear project with the University of South Florida

- Principle Investigators
  - David Eddins, Ph.D.
  - Erol Ozmeral, Ph.D.
- Together with Sonova they have studied
  - Classifier Performance
  - Azimuth Detection Behavior
  - Take home comparison to leading competitor



unitron.

Azimuth detection in two parts (n=19)

Locating the direction of speech

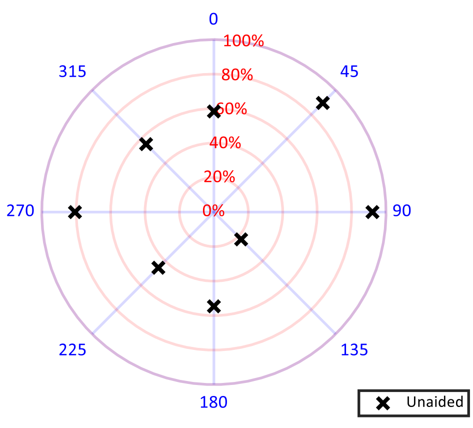
- Presented short snips of speech and asked the listener to indicate its direction
  - Speech came from one of 8 directions
  - One snip every 4 seconds for 16 seconds

- Speech perception from different directions
- CNIT
  - Adaptive Speech in Noise test
  - Asked to repeat numbers from different directions and at different SNR's

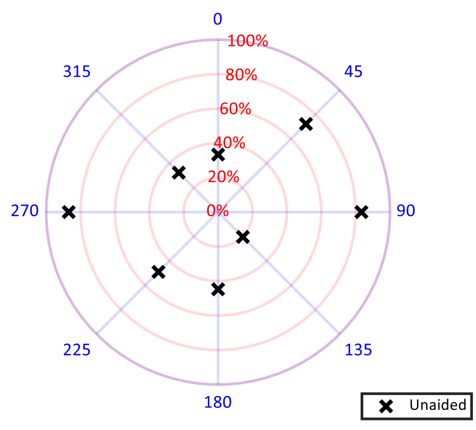
unitron.

Locating the direction of speech

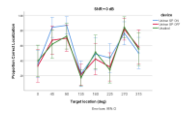
0 dB SNR

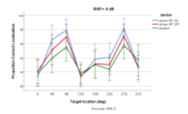


-6 dB SNR



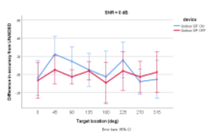
Effect of amplification and directional enhancements on localization

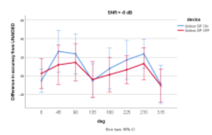




Main effects of device (p = 0.05), snr (p < .001), and location (p < .001). No significant interactions.

Benefit relative to Unaided condition





Effect of device and location reaching significance (p = 0.07, p = 0.08, respectively). No other main effects or interactions.

Azimuth detection in two parts (n=19)

Locating the direction of speech

- Presented short snips of speech and asked the listener to indicate its direction
  - Speech came from one of 8 directions
  - One snip every 4 seconds for 16 seconds

Speech perception from different directions

- CNIT
  - Adaptive Speech in Noise test
  - Asked to repeat numbers from different directions and at different SNR's

unitron

CNIT

Noise is presented from four speakers: 0°, 90, 180° & 270° azimuth simultaneously

Running speech is presented from one of three directions (0°, 90° or 180°) at a time.

The hearing aids detect the direction of the speech

This focuses aids in the desired direction before the numbers test begins

Speech and noise levels are at a fixed at a +6 dB SNR

The listener is asked to ignore the words repeat a 3 integer sequence presented from the same azimuth as the speech.

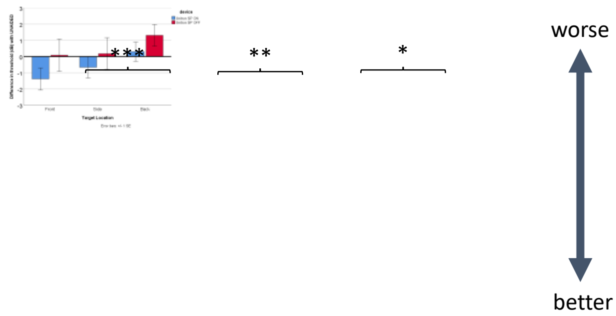
The level of the integers is varied adaptively when the listener gets them right or wrong.

unitron

Benefit of amplification and directional enhancements on speech ID in noise

- In each case, directional enhancements were shown to have an advantage relative to when they were off.

- Benefit, however, relative to unaided was only significant (p = 0.05) at the Front.



(n=19)

***p<.001; **p<.01; *p=0.07

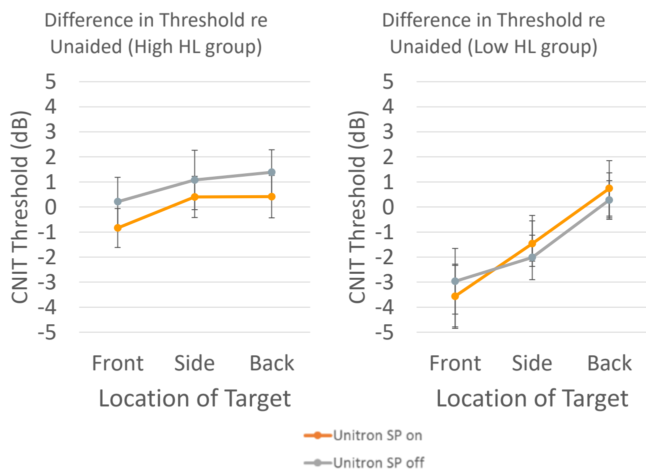
Unaided hearing thresholds seem to matter

Listeners arbitrarily split in half by pure-tone average PTA (500, 1000, 2000 Hz) threshold.

- High HL (n = 15; PTA >=35 dB HL)
- Low HL (n = 15; PTA <35 dB HL)

High HL group received very little aided benefit (left panel).

Low HL group received large aided benefit at the Front and Side, and little benefit at the Back.



What does this say about azimuth detection?

1. People with hearing loss frequently have degraded localization abilities and adding hearing aids rarely improves that.
2. The largest benefits we found for localization were from the sides and people did better with more signal processing than unaided.
3. Regarding speech perception we saw significant benefits from more processing (Speech Pro on/off) from all three directions.
4. From the front there was a significant benefit of more processing over the unaided condition.

unitron.