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AI-Enabled Hearing Aids: What Emerging Technologies Mean for Your Patients

Tammara Stender, Au.D.
GN Hearing
Director of Global Audiology – Chicago

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Learning Outcomes

1) After this course, participants will be able to discuss the difference between artificial intelligence and augmented intelligence.

2) After this course, participants will be able to identify how deep learning is currently used in ReSound hearing aids.

3) After this course, participants will be able to discuss different types of hearing aid signal processing including the use of AI that would benefit individual patients.

Limitations/Risks

- The applicability and accuracy of the course content may vary by the clinical, geographical, and cultural context; you should evaluate the course accordingly.
- As healthcare is rapidly evolving, new findings may change the validity of the information presented in this course. Providers should always consult the latest research and guidelines from professional associations.
- The interventions discussed in this course may be limited in generalizability, requiring practitioners to consider specific individual and population factors.
- The course may not cover all possible risk factors, diagnostic methods, or treatment options, and complex cases may require additional considerations.
- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

What do you think of when you hear the term “AI”?

Artificial Intelligence

Augmented Intelligence

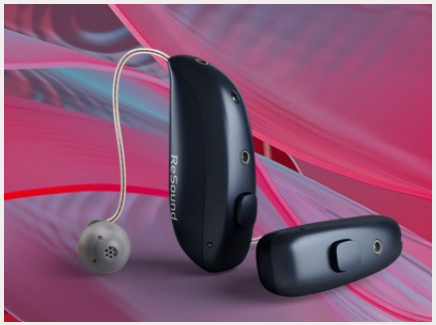
What is it?

Using technology to enhance our abilities, rather than replacing them

Examples:

- Provide drivers with more multisensory feedback
- Be alerted to invisible black ice on the road
- See the cyclist dressed in black on a dark road with no lights on
- Preventing drivers falling asleep as the car can ensure that you are fit to drive

Intelligence Augmented



The human brain is arguably the most powerful computational engine known.

Artificial Intelligence

The ability of machines to do tasks that historically only humans could do, such as reasoning, problem solving and decision making.

Machine Learning

The ability of machines to automatically learn without being explicitly programmed.

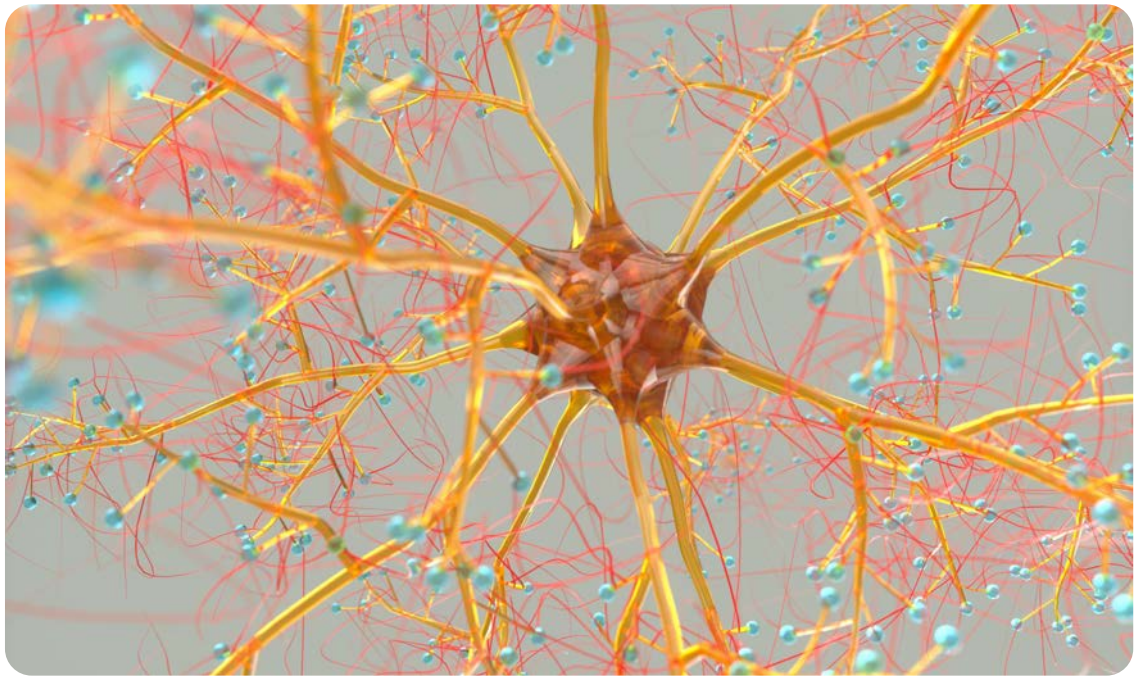
Deep learning

Algorithms with brain-like logical structure (called neural networks) capable of making decisions after being trained with vast amounts of data

Intelligence Augmented

Help, not replace the human

What is a Data-Driven Deep Neural Network?

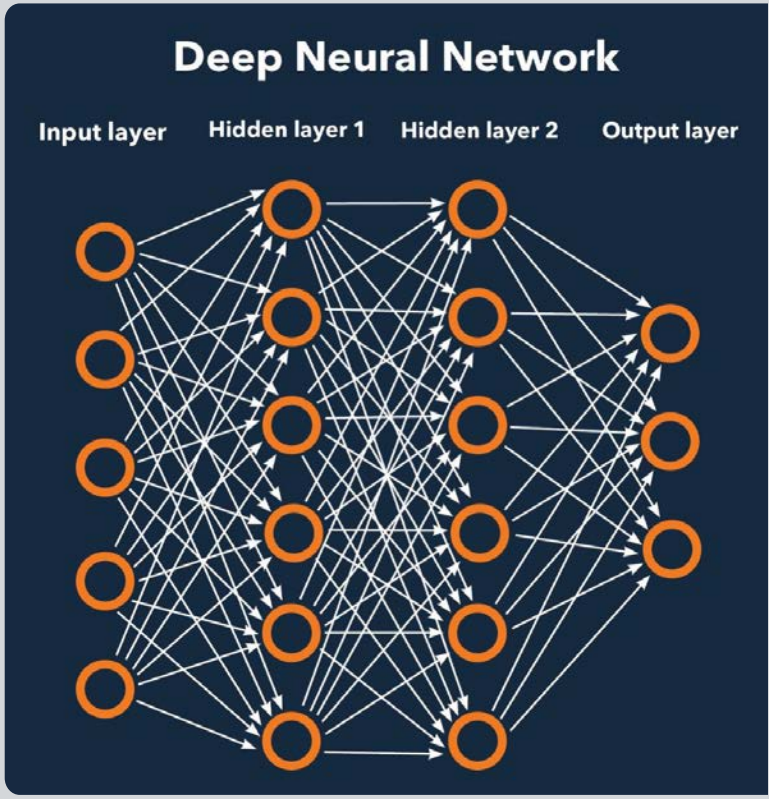


Deep Neural Networks

The “muscle” behind deep learning – a layered structure connected “nodes” or “neurons”. Each layer processes data step-by-step to recognize complex patterns

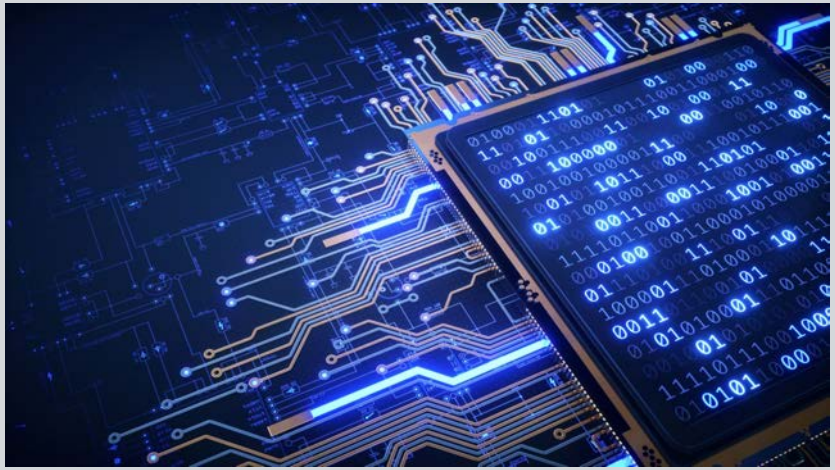
What is a Deep Neural Network?

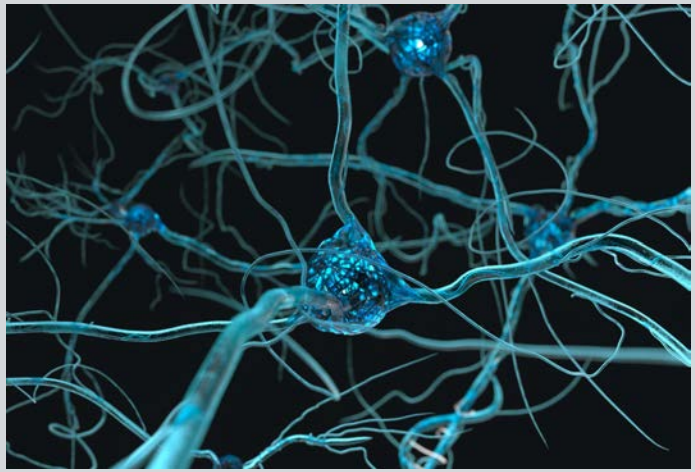
- Conceptualized by Geoffrey Hinton in the 1980s
- Type of artificial neural network – to mimic the human brain
- Built up of at least 4 layers
  - Input layer –
  - At least 2 hidden layers – learning happens
  - Output layer



What is a Deep Neural Network?

- Trained on enormous datasets of real-world sound
  - Photos, audio, speech, noise, etc.
  - Recognize patterns, like distinguishing a voice vs clinking dishes





What is a Deep Neural Network?

A **Learning Algorithm** Designed to Mimic the Process of Human Thought

Take an image
– what the computer sees is pixels that are given a number representing the color intensity

A small change to the picture gives a new set of values.
Thus, we must **train the computer with many samples to accurately classify the image, without over- or under-generalizing the outcome**.

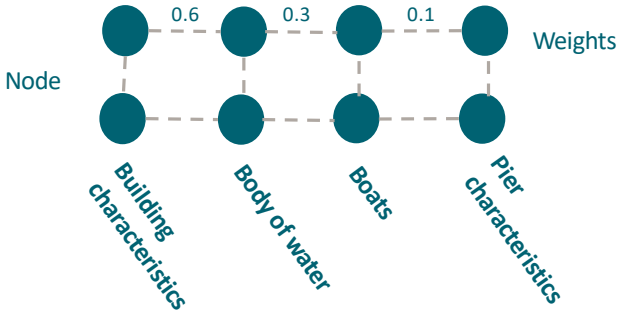
How does a Deep Neural Network work?

INPUT

Hidden layers

Statistical calculations and analysis

Investigate input in detail



OUTPUT

Chicago Skyline

Weights are optimized until prediction is correct

Desired Result

How does a Deep Neural Network work?

Desired Result

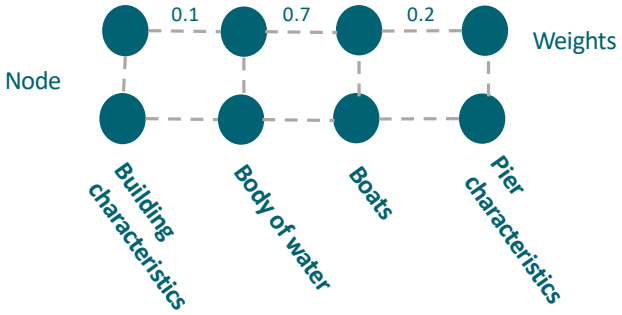
How does a Deep Neural Network work?

INPUT

Hidden layers

Statistical calculations and analysis

Investigate input in detail



OUTPUT

Sydney, Australia

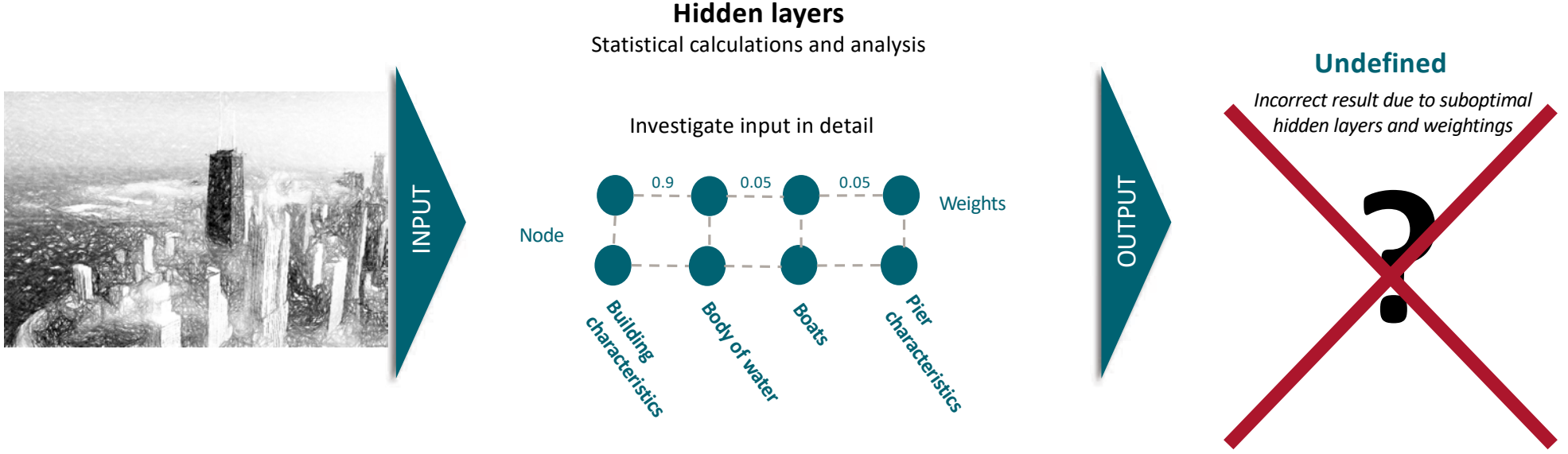
Incorrect result due to suboptimal hidden layers and weightings

Error due to Overgeneralization

Similar Characteristics, but *Incorrect!*

Some Similar Characteristics, but Still *Incorrect!*

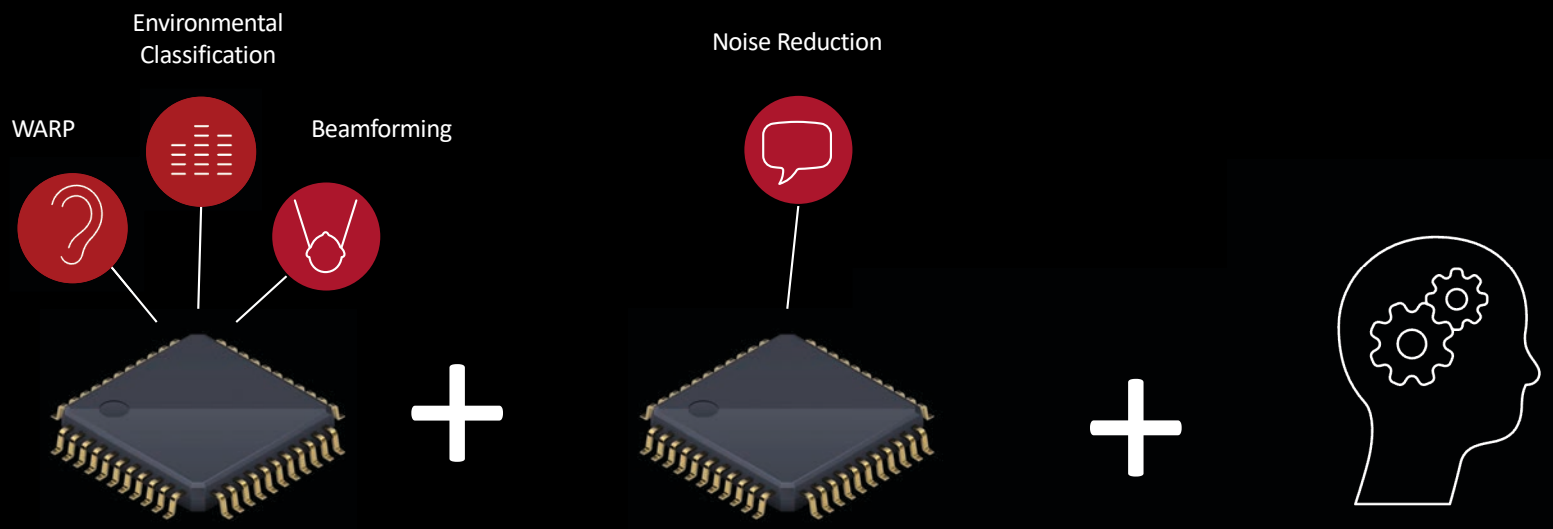
How does a Deep Neural Network work?



Error due to Undergeneralization

No Result Found.

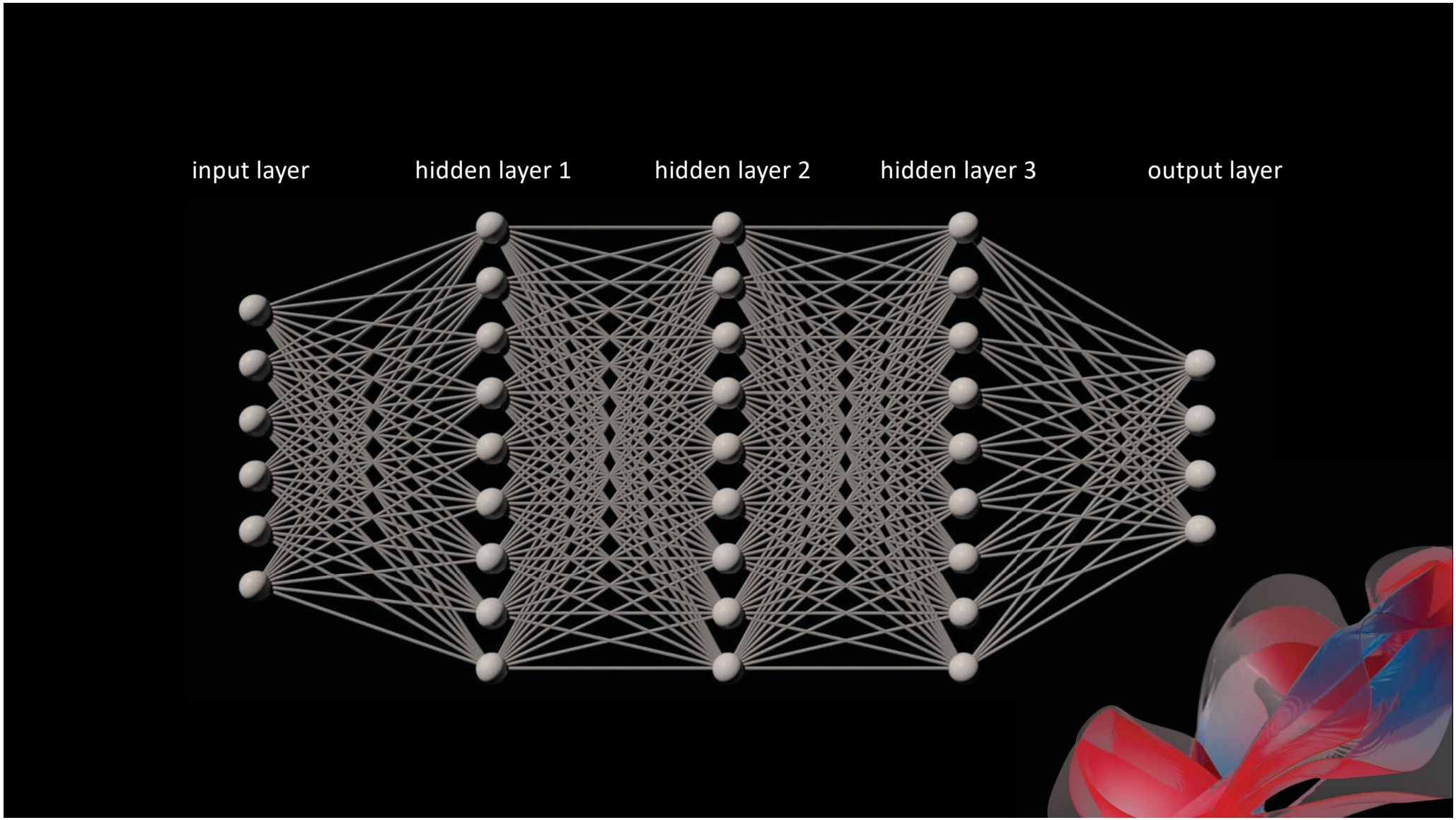
Intelligence Augmented



360 Chip
Co-processor

DNN Chip
Co-processor

Human brain
Core processor


input layer
hidden layer 1
hidden layer 2
hidden layer 3
output layer

What the network is trained on is important

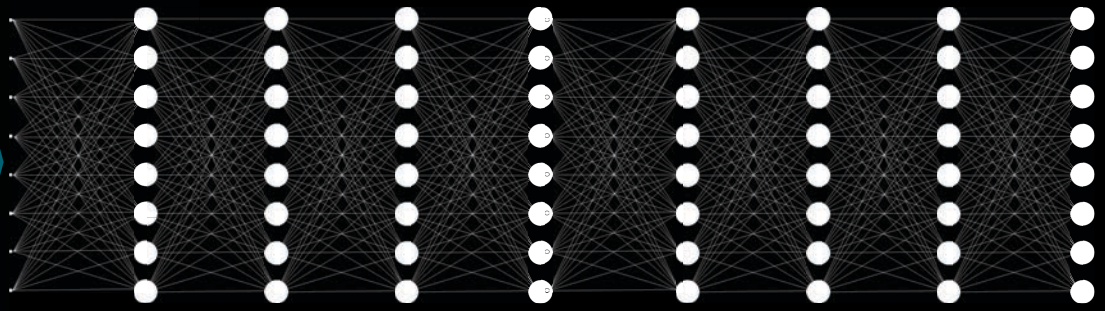
We used real life **speech in noise** sentences
where the **noise can be classified as noise by everyone**

Layers – each layer studies a different aspect of the input

Noise examples:

- Traffic Noise
- Airplane noise
- Multi-talker babble
- Cafeteria noise
- Cutlery on plates

INPUT



OUTPUT

The output of the DNN is compared to the speech in the sample and then the model resets the weights and iterates again.

Training the DNN

We've trained the DualChip on

13.5 million

speech sentences

We've worked across

3.9 million

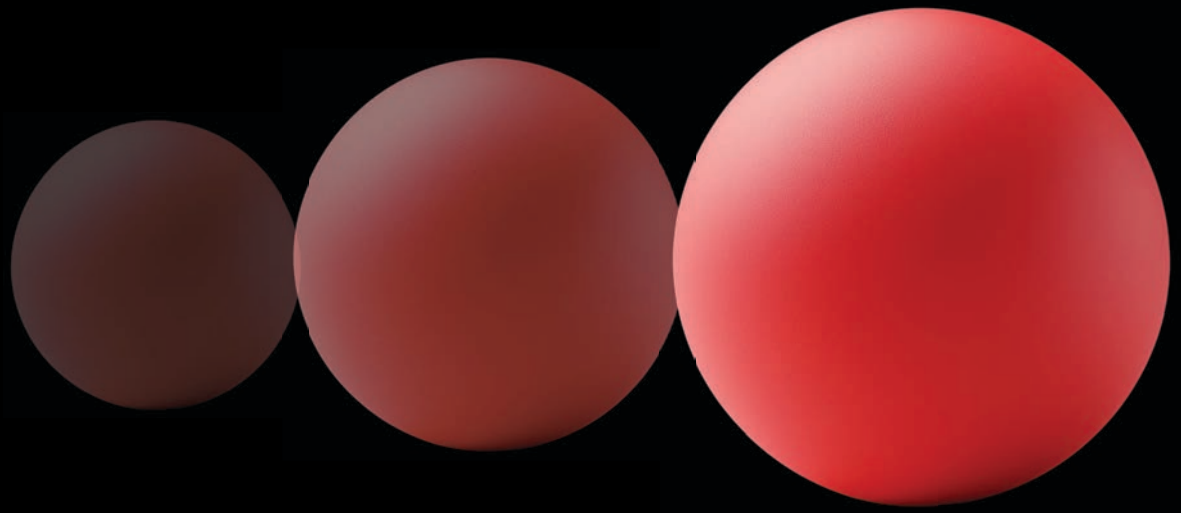
tuned sound parameters

So, the DualChip can do

4.9 trillion

operations per day

In which direction is the ball moving?



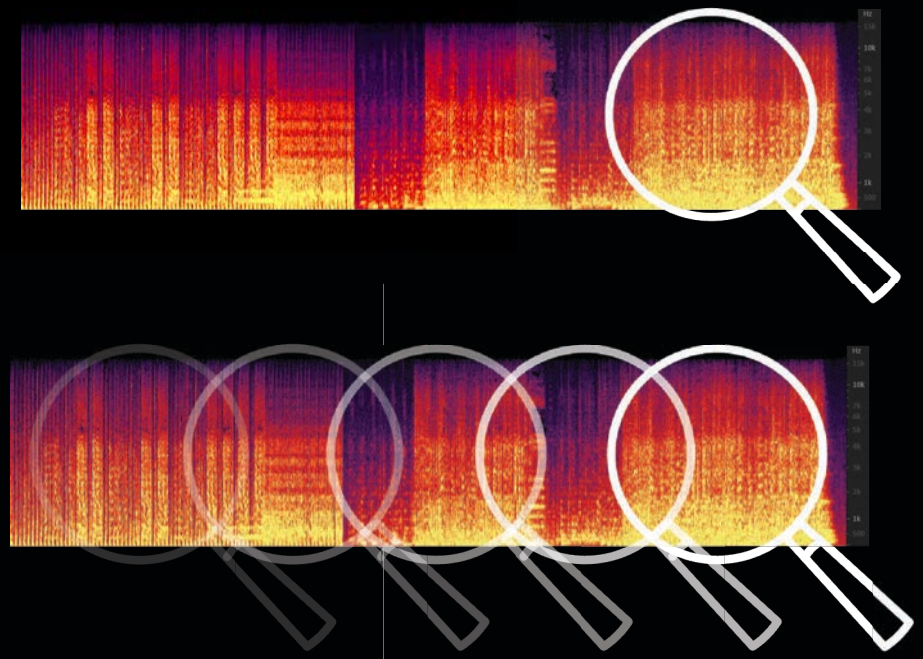
Recurrent neural network

Uses information from the past to make more accurate and faster predictions

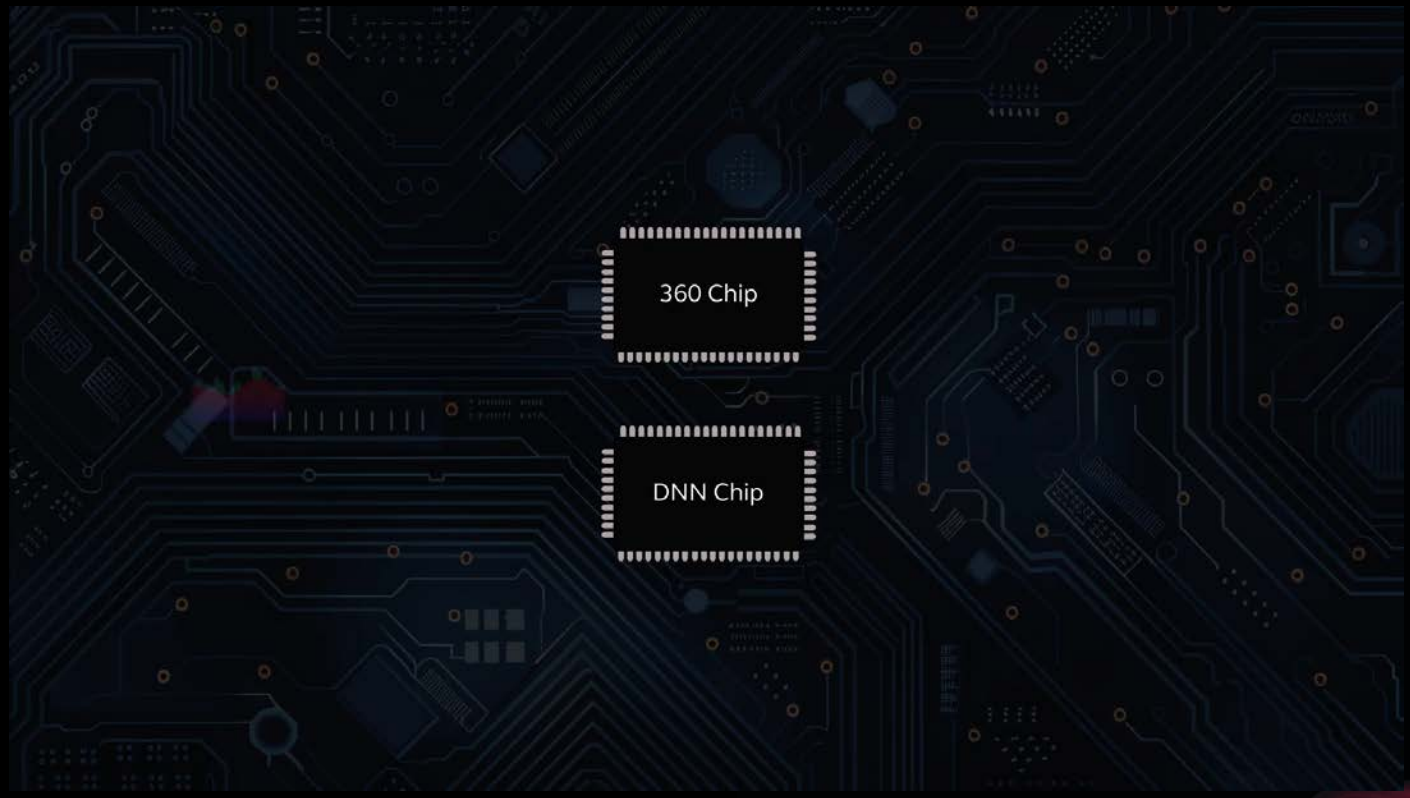
Faster predictions with longer battery life

More power intensive method

Better power conservation method



Putting It Together in a ReSound Hearing Aid

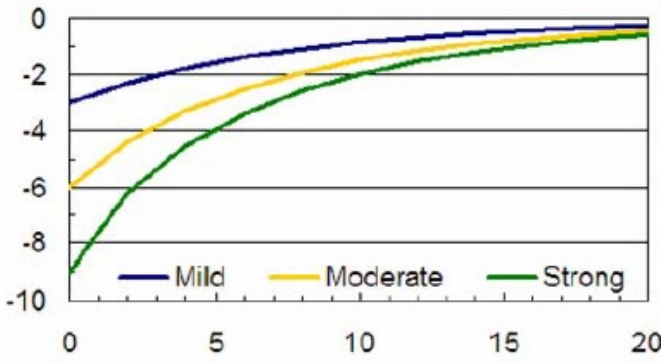


How Does DNN-based Noise Reduction Compare to Traditional Noise Reduction?

Signal model-based noise reduction

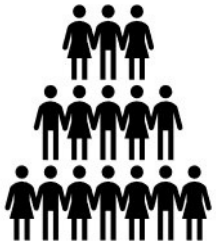
Estimate SNR per band

Look up how much to reduce gain per band depending on estimated SNR and setting



Sound Quality Preference Test

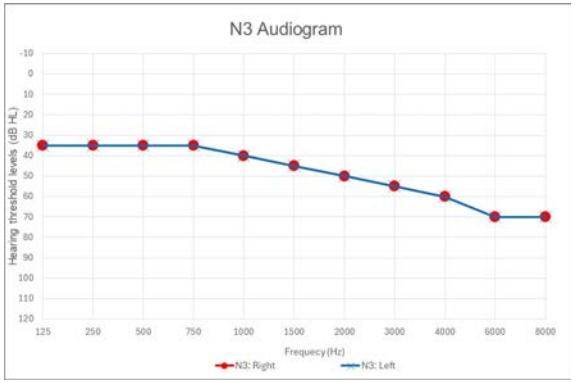
20 participants



7 females

13 males

Hearing aids and test conditions



Hearing aids fitted with 2 programs dedicated for hearing in noise. Identical programs with exception of the type of noise reduction:

- Legacy noise reduction
- Deep Neural Network noise reduction

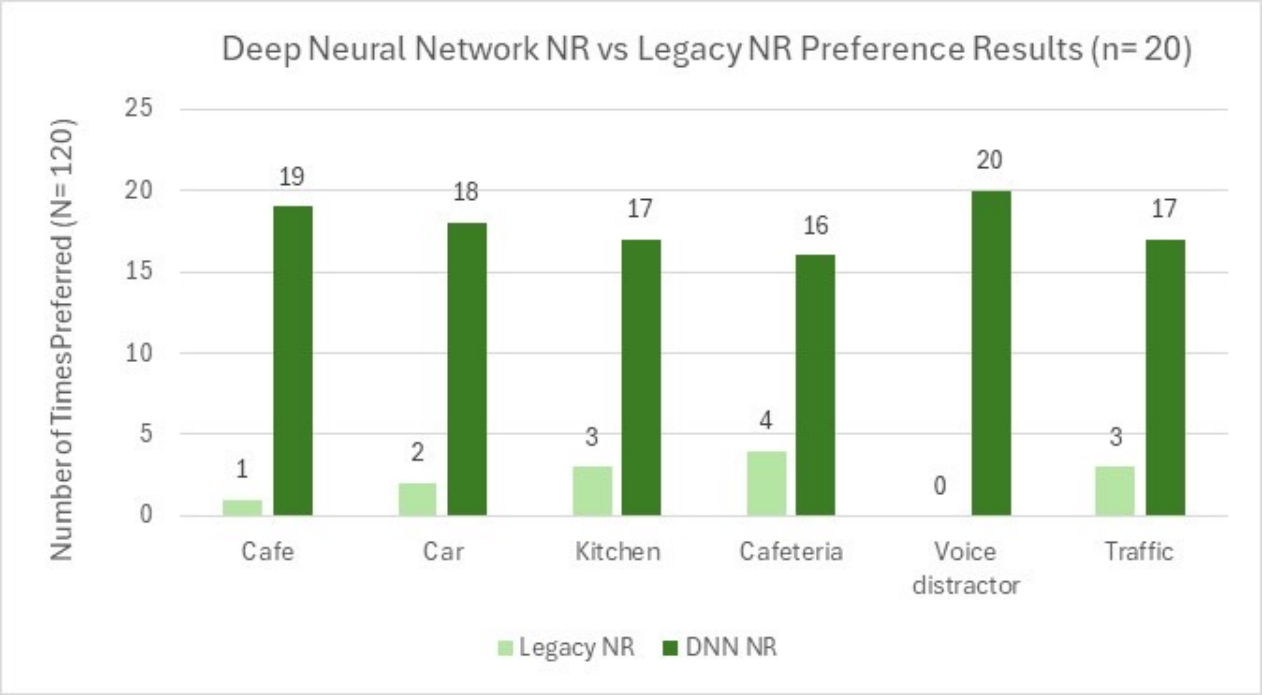
Sound Quality Preference Test

SenseLabOnline System

- Recordings through hearing aid programs with hearing aids on an acoustic manikin.
- Recordings were made in 6 sound scenes supplemented with Dantale II and HINT female and male speech:
  - Cafeteria
  - Traffic
  - Voice distractor
  - Cafe
  - Car
  - Kitchen

- Recordings were binaural recordings made at ecologically valid signal-to-noise ratios to simulate real-life conversations.

Sound Quality Preference Test Results



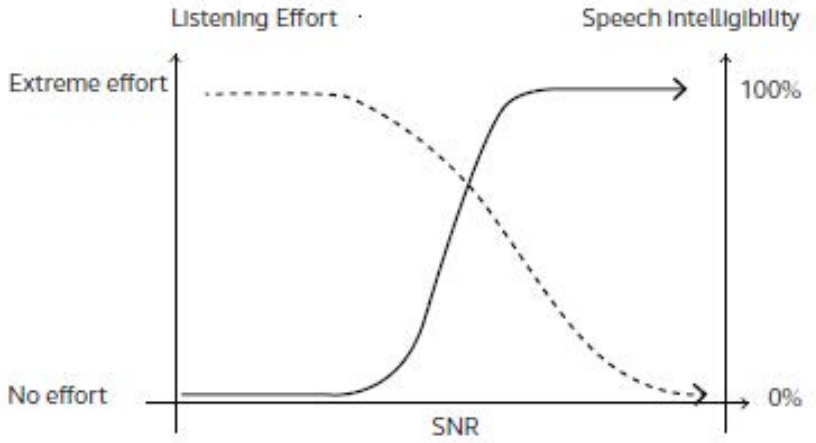
There is a significant preference for Deep Neural Network noise reduction over legacy signal model-based noise reduction

Deep Neural Network Noise Reduction

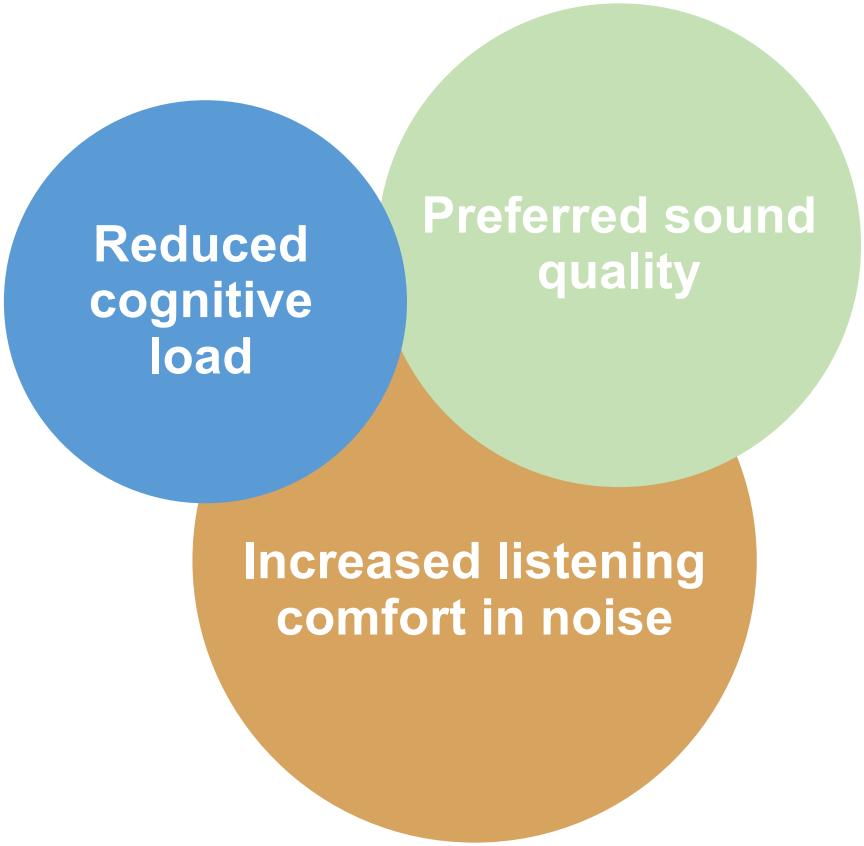
- It makes sense to combine Data-Driven Deep Neural Network noise reduction with other features focused on improving hearing in noisy environments.
  - Directionality
  - Dedicated hearing aid program for hearing in noise

Expected benefits and trade-offs

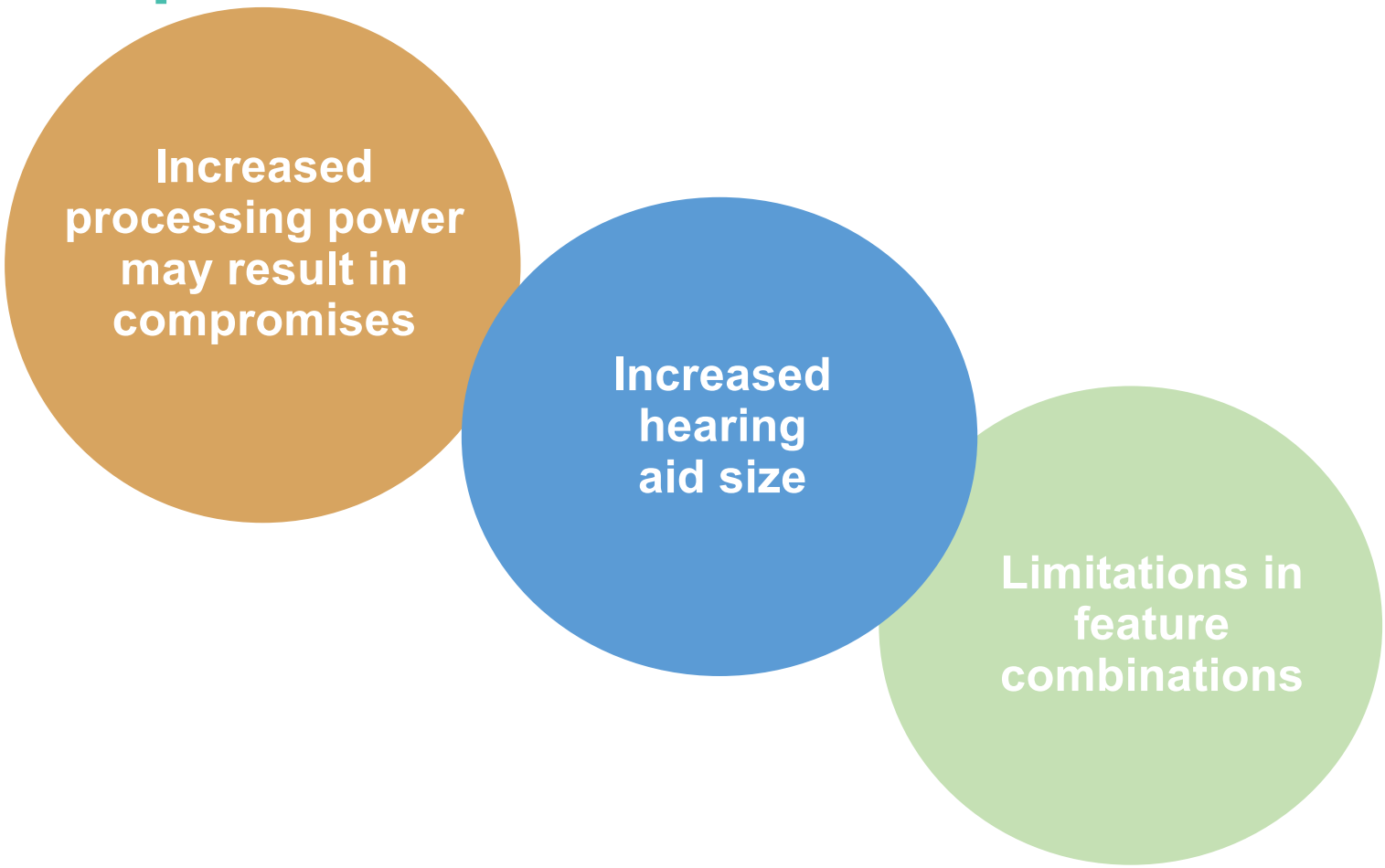
- Directionality provides improvement in SNR and speech recognition
- DNN can potentially enhance listening effort benefit even when speech intelligibility is maxed out



Expected Benefits and Trade-offs



Expected Benefits and Trade-offs



Summary

- Data-driven Deep Neural Network can be thought of as a machine's artificial brain.
- This DNN noise reduction has been trained on meaningful sound samples commonly found in the real world (quality over quantity).
- The DNN will attenuate any sound source that is not speech because it has been trained to recognize speech, so no matter the background (stationary or non-stationary), it will be attenuated.
- Patient benefits: Increased listening comfort, improved sound quality, and reduced cognitive load.
- Data-driven DNN noise reduction is typically combined with directionality in dedicated hearing aid programs focused on hearing in noise.

Intelligence Augmented

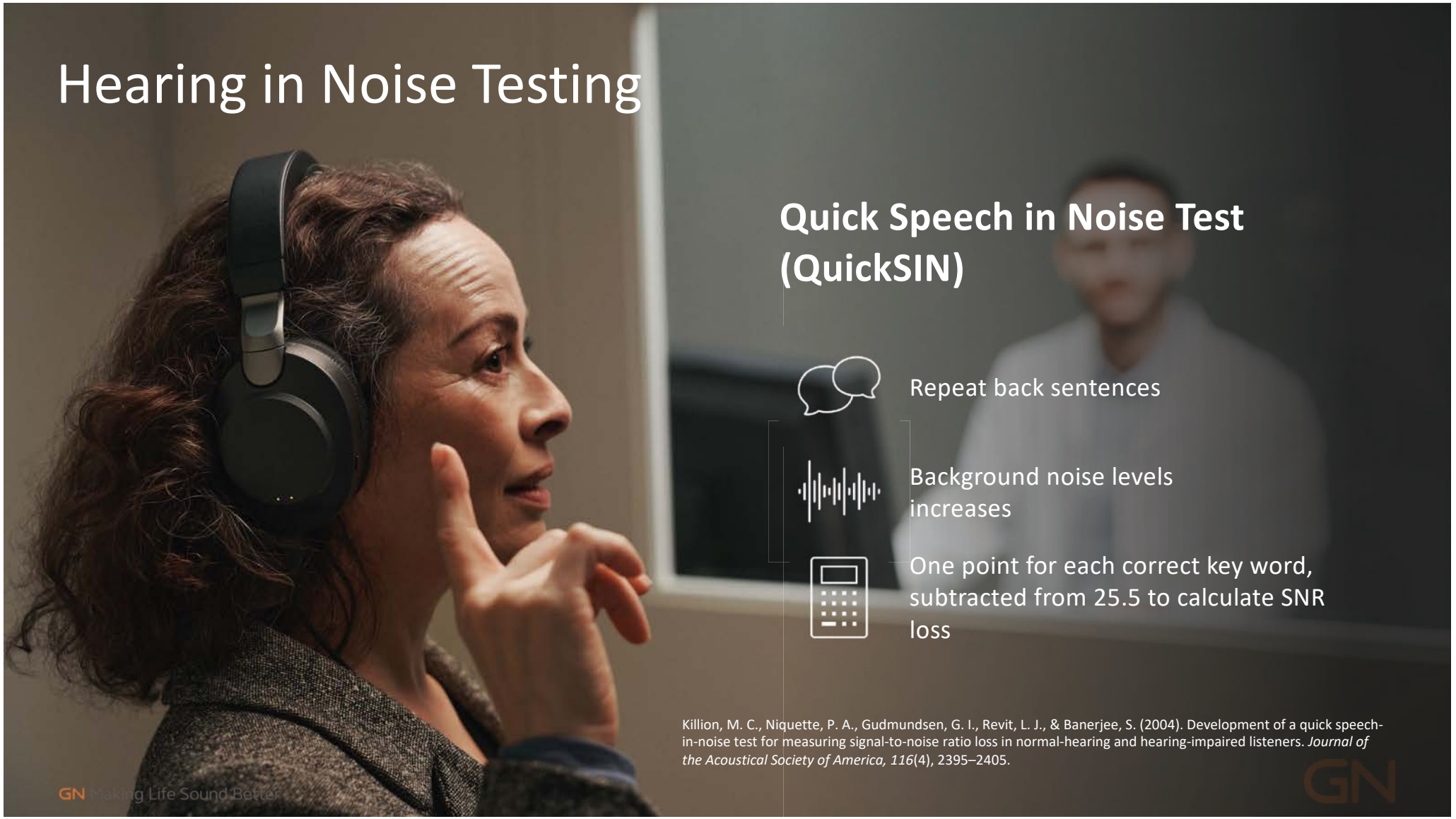
- **Intelligence Augmented** is a small but important, distinction from the term AI.
  'Augment' suggests that the machine is designed to **assist the human in solving the problem**,
  while 'artificial' implies a more machine-centered solution for the human, where there is less control and autonomy.

- **Goal is to augment the hearing aid user's decisions** by being careful to not take out all the noise but to use our system to decrease known noise and spotlight speech in front.

- The combination of the four-microphone beamformer and the DNN-based noise reduction creates **powerful help in noisy situations**.

Is there a clinical way to measure how much help a person will need in noisy situations?

Hearing in Noise Testing



Quick Speech in Noise Test (QuickSIN)

- Repeat back sentences
- Background noise levels increases
- One point for each correct key word, subtracted from 25.5 to calculate SNR loss

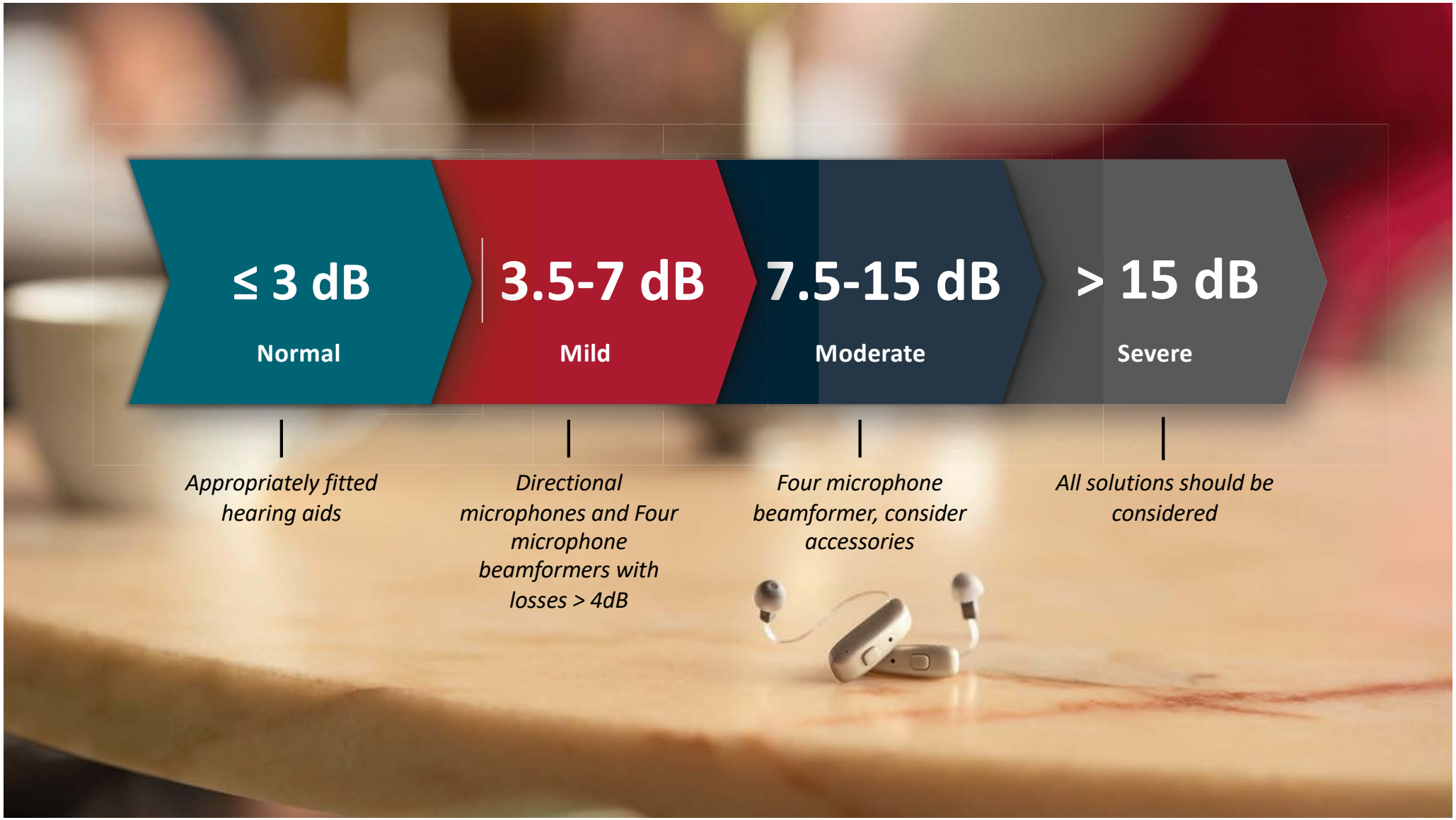
Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S. (2004). Development of a quick speech-in-noise test for measuring signal-to-noise ratio loss in normal-hearing and hearing-impaired listeners. *Journal of the Acoustical Society of America, 116*(4), 2395–2405.

Example recording from QuickSIN test

		Score the # Correct
+25	1. To have is better than to wait and hope.	5
+20	2. The screen before the fire kept in the sparks.	5
+15	3. Thick glasses helped him read the print.	4
+10	4. The chair looked strong but had no bottom.	4
+5	5. They told wild tales to frighten him.	2
0	6. A force equal to that would move the earth.	0
		Total 20

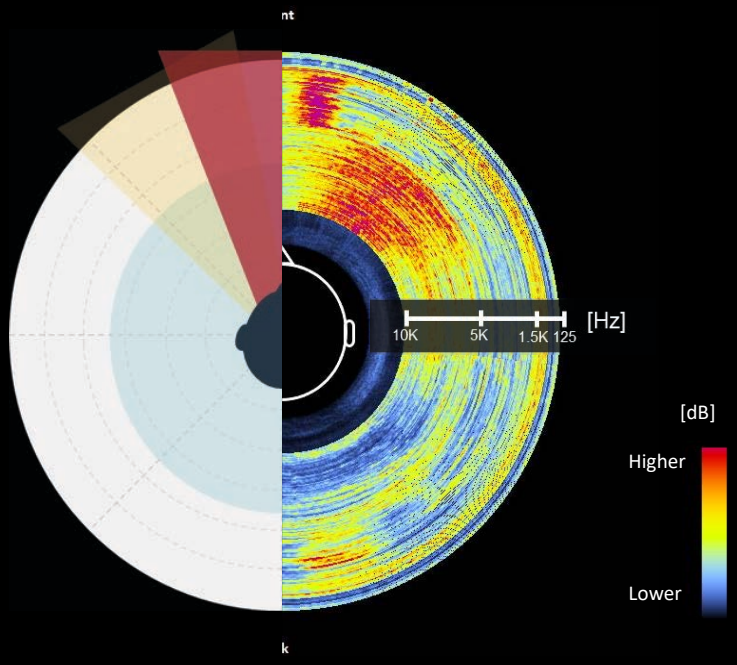
25.5 – Total # Correct = SNR Loss

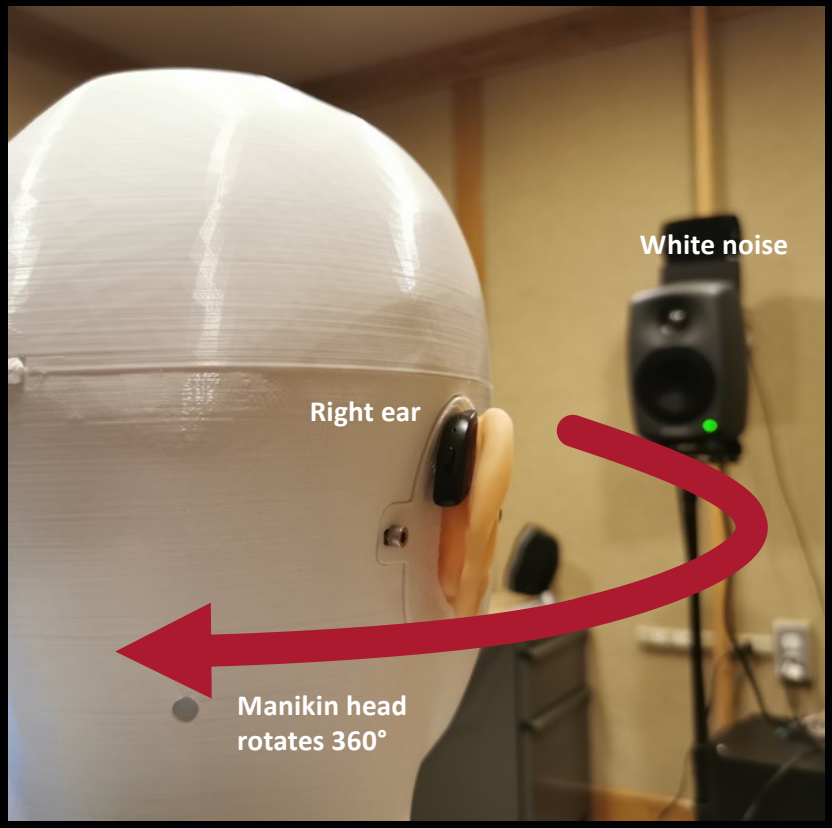
25.5 – 20 = **5.5 dB**


≤ 3 dB
Normal
3.5-7 dB
Mild
7.5-15 dB
Moderate
> 15 dB
Severe
Appropriately fitted hearing aids
Directional microphones and Four microphone beamformers with losses > 4dB
Four microphone beamformer, consider accessories
All solutions should be considered

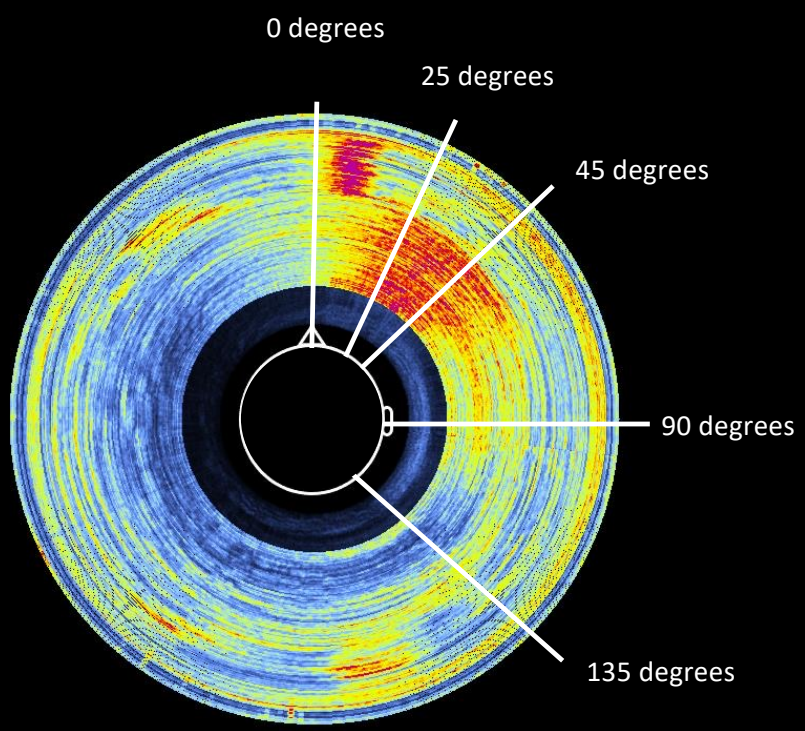

Directional Microphones
Does it matter which you choose?
2 microphones
4 microphone beamformers

Measuring a Directional Beamformer



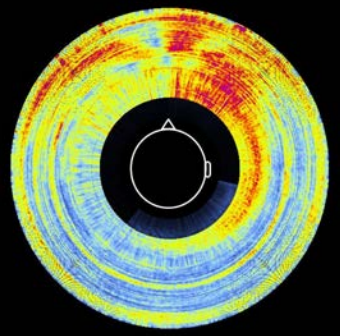


Two vs Four Microphone Directionality

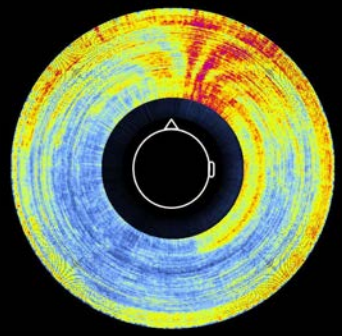


ReSound

Four Microphone

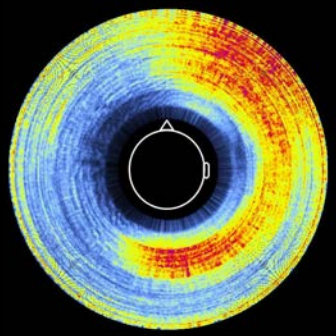


Brand A

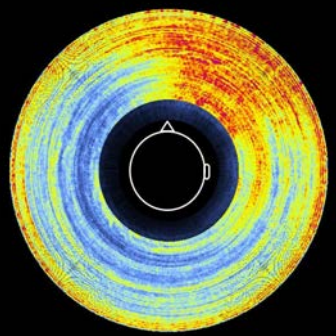


Brand B

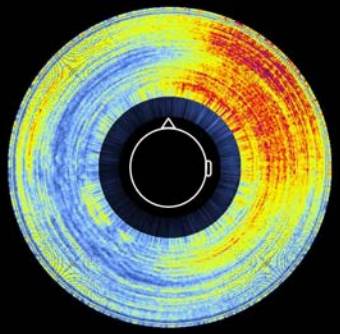
Two Microphone



Brand C



Brand D



Brand E

Directional Microphones

The narrower the beam, the higher the SNR benefit.

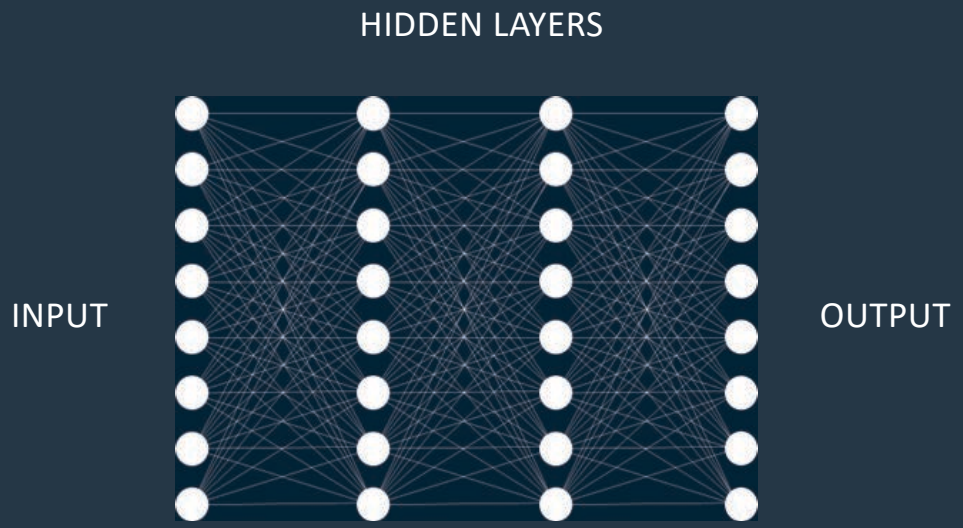
2 microphones: **3-4 dB SNR improvement**

4 microphone beamformers: up to **9 dB SNR improvement**

Deep Neural Networks

Preliminary research:

~ 1 dB of SNR improvement
Less listening effort



Let’s Look at a Few Case Studies!


Peter
Restaurant Consultant
• Severe high frequency hearing loss
• Prefers to experience restaurants during peak hours, but struggles to hear his clients in noise
• Considering early retirement due to significant fatigue
• QuickSIN results: 9 dB SNR loss

Greta

Retired Social Worker

- Severe flat hearing loss and 18 years of hearing aid experience
- Lives with her family and acts as caretaker for her 2 young grandchildren
- She’s always had issues hearing in noise, but recently noticed that she’s also struggling more in 1:1 interactions
- QuickSIN results: 16 dB SNR loss

- Severe high frequency hearing loss and no previous hearing aid experience
- Tries to stay physically and socially active
- Loves traveling but has a hard time understanding tour guides and navigating public transportation.
- QuickSIN results: 4 dB SNR loss

Let’s Chat With Each Other!

What Kind of Technology Would You Consider for Each Patient?

Consider…

What type of directionality: 4-mic, or 2-mic?

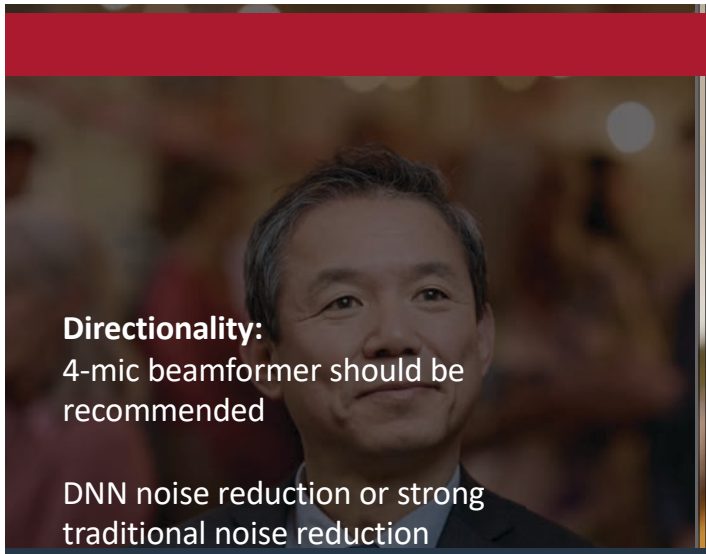
How strong should the DNN-based or traditional noise reduction be?

What other settings would you consider?

What level of technology would suit the user’s needs (e.g., top, mid, low price point)

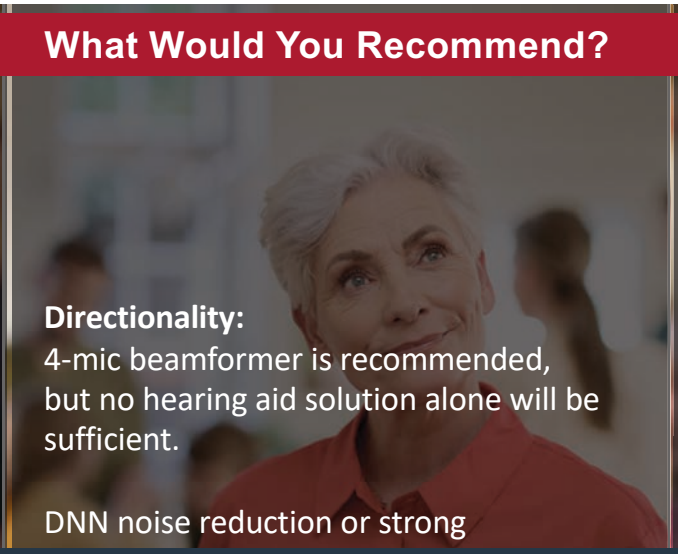
What about streaming and wireless accessories?

What Would You Recommend?



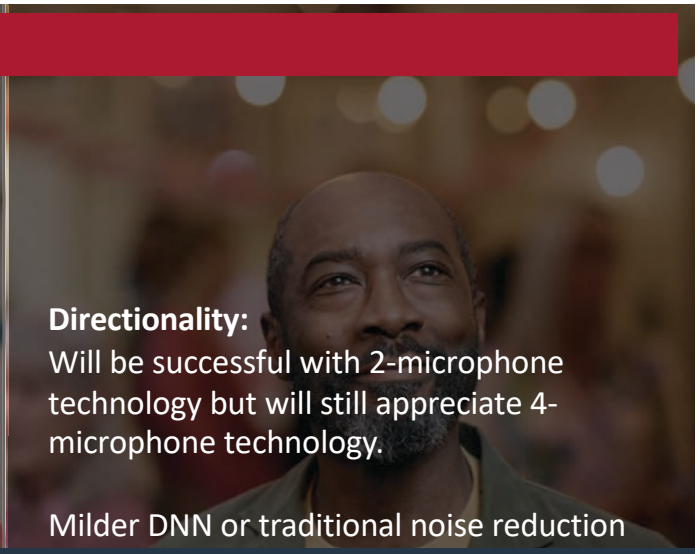
Directionality:
4-mic beamformer should be recommended

DNN noise reduction or strong traditional noise reduction



Directionality:
4-mic beamformer is recommended, but no hearing aid solution alone will be sufficient.

DNN noise reduction or strong



Directionality:
Will be successful with 2-microphone technology but will still appreciate 4-microphone technology.

Milder DNN or traditional noise reduction

What type of directionality: 4-mic, or 2-mic?
How strong should the DNN-based or traditional noise reduction be?
What other settings would you consider?
What level of technology would suit the user's needs (e.g., top, mid, low price point)
What about streaming and wireless accessories?

Peter	Greta	Sam
Restaurant Consultant Significant listening fatigue 9 dB SNR loss	Retired Social Worker Caretaker to 2 young children Struggling in all situations 16 dB SNR loss	Retired Pilot Active Traveler 4 dB SNR loss

Intelligence Augmented Philosophy

Intelligence Augmented Philosophy

Help from the machine

To **empower** the **human**

npower the **machine**

To help
huma

The Future Is Here – Let's Use It To Help Real People

Thank You!

References

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