Aural diversity:
Autistic people and sound

Bill Davies

Acoustics Research Centre, University of Salford, UK

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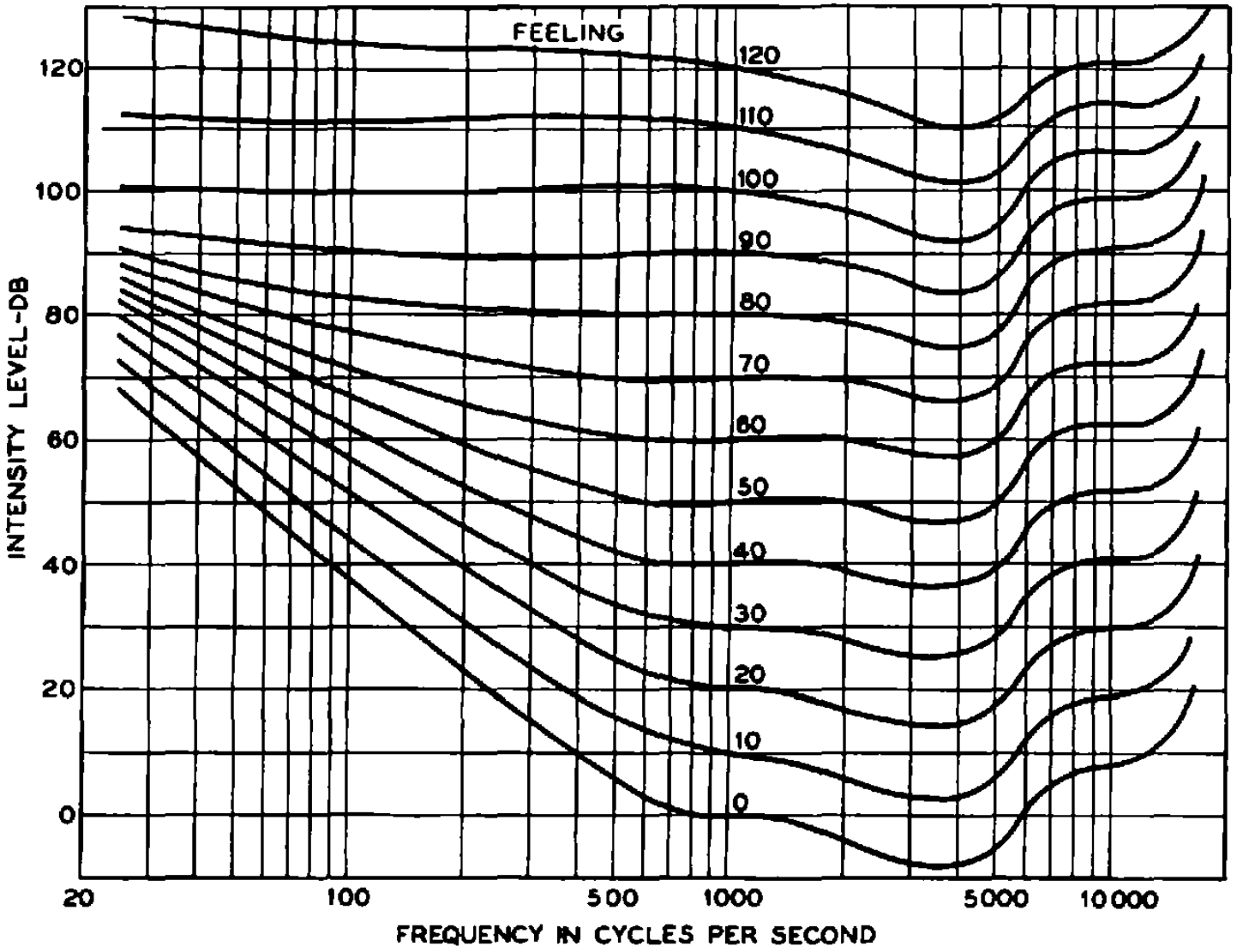
Outline

1. The concept of normal hearing
2. Uses and abuses of dBA
3. Aural diversity
4. Autistic people and sound

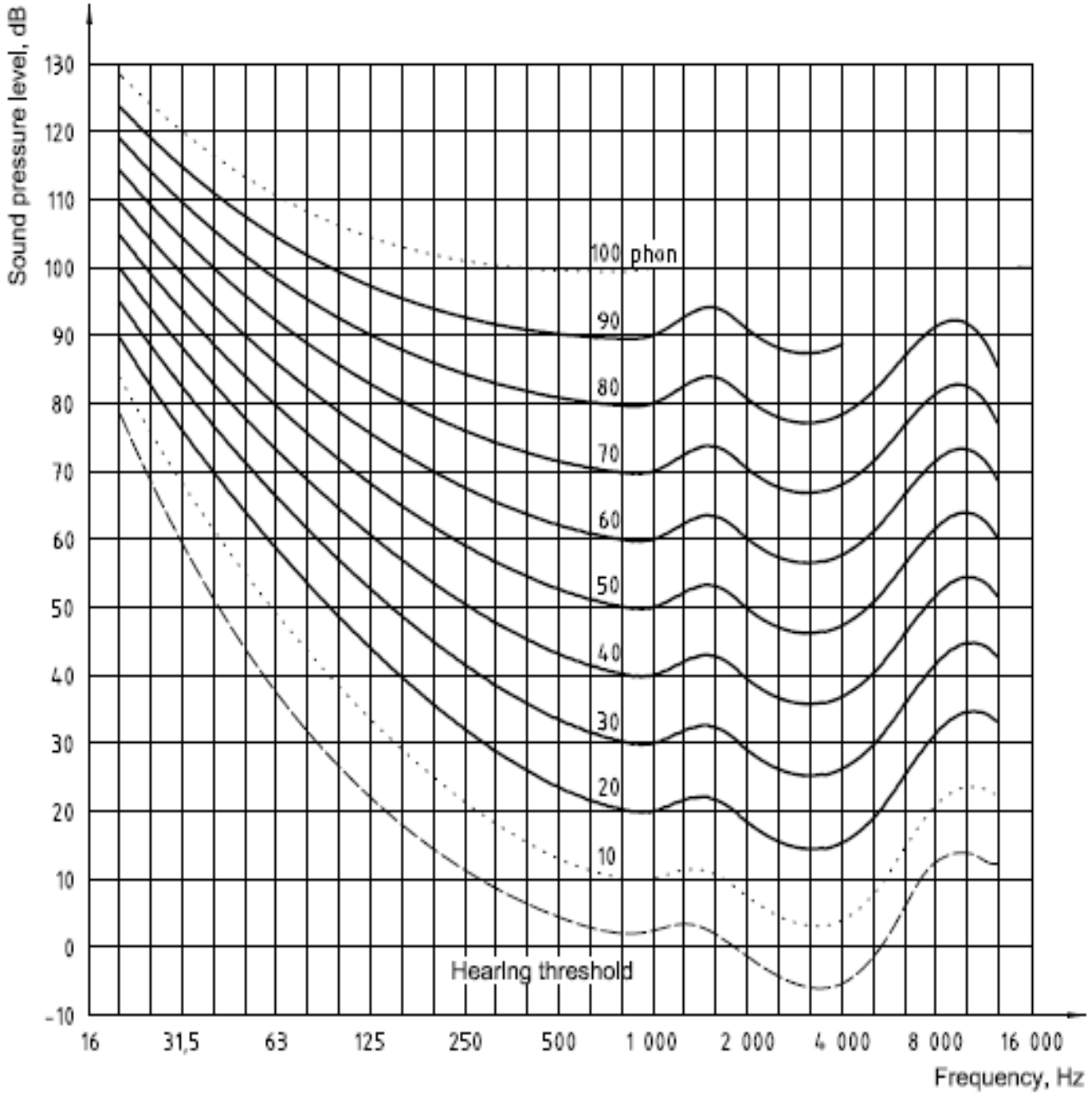
1. Normal hearing

- Starts with Fletcher & Munson
- Relating physical attributes of sound
  - Intensity
  - Frequency
- to perception of sound
  - Loudness
  - Pitch
- How does loudness vary with frequency?

Fletcher-Munson curves (1933)



Fletcher, H., & Munson, W. A. (1933). Loudness, Its Definition, Measurement and Calculation. The Journal of the Acoustical Society of America, 5(2), 82-108.


Sound pressure level, dB
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
100 phon
90
80
70
60
50
40
30
20
10
Hearing threshold
16
31,5
63
125
250
500
1 000
2 000
4 000
8 000
16 000
Frequency, Hz

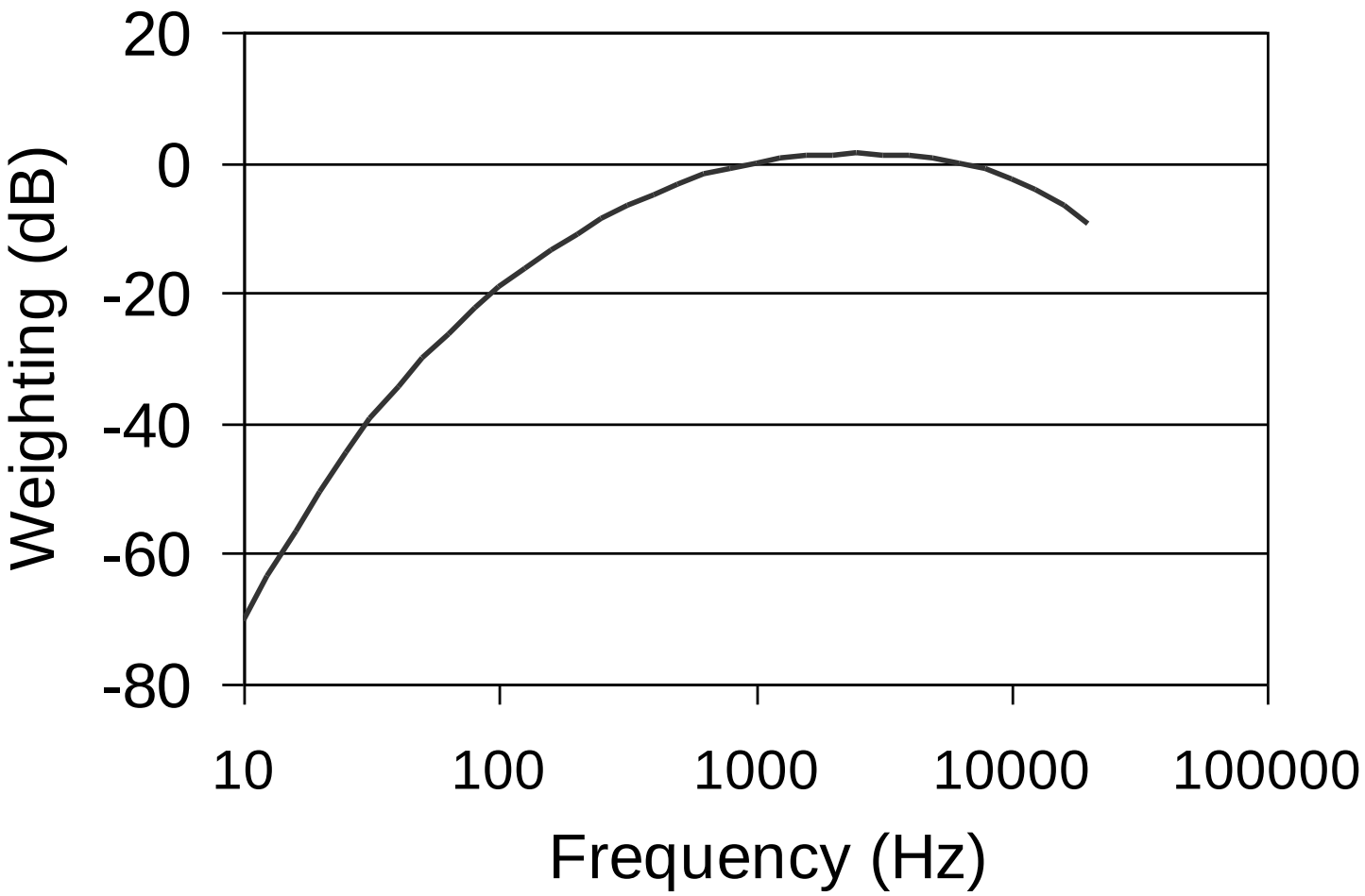
Normal hearing

- Modern loudness contours based on participants 18-25
- Normal hearing = threshold loudness response

2. A-weighting and dBA

- Sound level in dB doesn’t match loudness well
- A-weighting filter developed to simulate human loudness response

A-Weighting curve



- dBA used for:
  - Loudness
  - Hearing damage risk
  - Annoyance
  - Other health impacts
  - Assessment
  - Control
  - Regulation
  - Design
  - …

Dominant model in acoustics

- Normal hearing
  - Usually assumed to be total non-clinical population
  - Tacit assumption that it includes most individuals
  - Assumed in virtually all design (etc)
    - All outdoor environments
    - All buildings and rooms
    - All products that make noise
    - All audio devices
    - Almost all music, education, performance
- Impaired hearing
  - Hardly ever designed for
  - Hearing aids about the only exception

Awkward question

- Does A-Weighting work for everyone?

Angus Carlyle & Matthew Hawkins (2009), *You are Ear*

3. Aural Diversity

- John Drever (2018)
- Binary normal/impaired not a good fit
- Hearing differences are very widespread
- “Everybody hears differently”

UNIVERSITY OF LEICESTER

AURAL DIVERSITY

Andrew Hugill, 2022

Version 1.6

HEARING DIFFERENCES

"Disabilities", "disorders", "impairments", "loss" etc. affect 1 in 6 people and are typically classified on an audiometric scale from profound deafness to mild hearing loss. But differences are more prevalent than that. Less than 17% of people in Europe meet the international standard for "normal" hearing. Deaf (big D) = primarily communicates through sign language. deaf (small d) = does not sign. Hearing may be through interpretation. Hearing loss may be present from birth or acquired, in one or both ears, but n.b: not all forms of hearing difference involve loss.

SENSORINEURAL
Inner ear or nerve problems. c. 90% of all hearing loss.

- **Genetic** Inherited but not necessarily present from birth. Caused by mutation of dominant, recessive or mitochondrial genes.
- **Congenital** Present from birth. May be hereditary or caused by drugs, viruses or syndromes.
- **Acoustic Shock** Caused by unexpected loud sounds.
- **Auditory Neuropathy** Ear detects sound but has trouble passing it to the brain.
- **Disease** Viral, bacterial, fungal infections, diabetes, meningitis, tumour, inflammatory, Ménière's etc.
- **Ototoxic** Caused by drugs. Includes cochleotoxicity and vestibulotoxicity (one or two-sided).
- **Other Causes** e.g. stroke, head trauma, perinatal conditions, hypothyroidism, cancers etc.
- **Noise-induced** Caused by one brief intense sound or continuous exposure to loud sounds.

MIXED SENSORINEURAL & CONDUCTIVE
Genetic, age-related, noise-related, drugs, disease, trauma, ear wax, infections auditory system, etc.

CONDUCTIVE
Problems sending sound waves through the ear.

- **Blockages** Caused by wax, fluid, narrrow canal, abnormal bone growth, tumours, cholesteatoma, etc.
- **Barotrauma** Unequal air pressure between external and middle ear.
- **Inner ear** Enlarged Vestibular Aqueduct; Labyrinthine Fistula; Superior Canal Dehiscence.
- **Inflammations** Caused by viral, bacterial, fungal infections, allergies, otitis, Eustachian tube dysfunction, etc.

AUDITORY SYSTEM
Neurological differences that affect hearing

- **Tinnitus** Perception of sound when no sound is present. May be subjective, objective or pulsatile. Often involves clicking, buzzing, hissing or roaring sounds.
- **Recruitment** Reduced tolerance of loudness.
- **Amusia** Inability to perceive or produce musical sounds. Congenital or acquired (a.k.a. "tone deaf").
- **Palinacusis** Sounds repeat after inaudibility.
- **Diplacusis** Perception of pitch differences between the two ears.
- **Hyperacusis** Increased sensitivity to sound.
- **Hallucinations** Musical (hearing music when none is present); hearing voices etc.
- **Phonophobia** Fear of specific sounds.
- **Misophonia** Negative emotional reactions to certain trigger sounds.
- **Auditory Processing Disorder** "Normal" hearing, but sound cannot be processed by the brain.
- **Neurodivergence** Autistic people often have heightened sound perception and an ability to focus on detail.

UNIVERSAL VARIATIONS

- **Temporary** e.g. wax, viral, bacterial or fungal infections, common cold, tiredness etc.
- **Natural** e.g pinna shapes unique to every individual.
- **Non-cochlear** e.g. touch, vibration, textual, visual.
- **Historical** e.g. past differences in hearing, evidenced by hearing aids.
- **Ethnic** e.g. prevalence of hearing loss varies across ethnic groups.
- **Geographical** e.g. regional patterns of hearing loss.
- **Cultural** e.g. d/Deaf culture.
- **Economic** e.g. disparities as a determinant of hearing health
- **Environmental** e.g. noise exposure, lifestyle issues, etc.

TECHNOLOGY

- **Hearing Aids** Amplification devices. Behind-the-ear (BTE), In-the-ear (ITE), In-the-canal (ITC), Right-In-the-Ear (RITE) and others use acoustic waves. Bone-Conduction HA use mechanical waves to carry the signal to the cochlea. Contralateral Routing of Signals (CROS) aids transmit auditory information from one ear to the other.
- **Cochlear Implants** Surgically implanted neuroprostheses which bypass acoustic hearing by direct electromagnetic wave stimulation of the auditory nerve.
- **Machine Listening** a.k.a. Computer Audition, a branch of AI and computer science.
- **Other Devices** e.g. hearables, smart earbuds, assistive listening, apps, etc.

ANIMAL HEARING
Humans hear 20Hz-20kHz whereas bats hear 9 kHz-120 kHz and mice hear 1 kHz to 70–90 kHz. Pigeons hear infrasound (down to 0.5Hz). Dolphins, rats, horses, cats, dogs, elephants, owls, moths and many other species have specially adapted hearing which far exceeds human capabilities.

ACOUSTICS ENGINEERING
Includes many fields that affect aural diversity.

Trained Ears
Auditory (re-)training, and professional ear training for e.g. musicians, linguists, doctors, engineers.

"NORMAL" HEARING
defined by the International Standards Organisation as: "otologically normal persons in the age range from 18 years to 25 years inclusive" (ISO 226:2003) i.e. around 17% of the population.

Foetal hearing A foetus's hearing is fully formed and functional from the last trimester of pregnancy.

→ **Infant hearing** It typically takes six months for babies' hearing to develop to the point that they can fully hear and understand a range of sounds.

→ **Teens/young adults** The normal hearing frequency range of a healthy young person is about 20 to 20,000Hz. A 'normal' audible range for loudness is 0-180dB SPL. Anything over 85dB SPL risks damaging hearing.

→ **Adults to old age** Hearing deteriorates throughout life at varying rates from person to person. Male hearing typically declines at twice the rate of female hearing. Age related hearing loss (or presbycusis) may also be worsened by external factors such as environmental and medical conditions. High frequencies are lost first, and this usually becomes noticeable at c. 40 years, when our hearing range starts to dip below 14kHz. We may have difficulty understanding speech and distinguishing sounds in crowded noisy places. We may need to raise volume levels, ask people to repeat themselves, or experience tinnitus.

Aural diversity

- Lots of implications for:
  - Design of buildings, environments
  - Design of products
  - Music
  - Audio
  - Regulation and assessment of noise

4. Autistic people and sound

- Several types of hearing/processing difference:
- Sensitivity to sound
- Picking sounds out of background
- Perfect pitch
- Structure and scale
- Auditory capacity

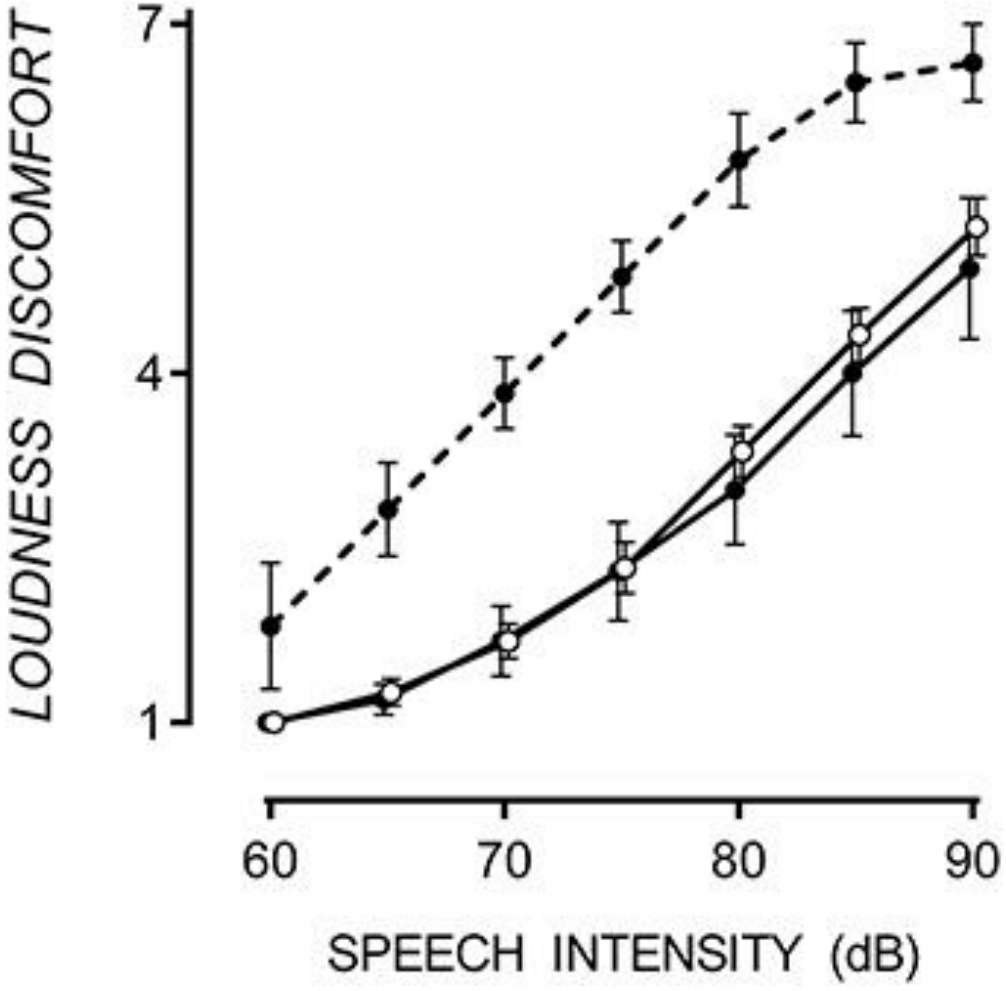
Autism and hyperacusis

“I can't stand those hand dryers and it amazes me whenever I see people nonchalantly using them like the sound is nothing. It's very painful for me. I won't go in restrooms that have them unless it's absolutely necessary and if someone uses the dryer while I'm in there, I plug my ears. I don't care if I look like an idiot.”

Drever, J. (2013). Sanitary Soundscapes: the noise effects from ultra-rapid ’ecological’ hand dryers on vulnerable subgroups in publicly accessible toilets, AIA-DAGA 2013.

Habib M’henni (2022). Silent applause during Wikiconvention Francophone 2022, Wikimedia Commons https://commons.wikimedia.org/wiki/File:Applaudissements_%C3%A0_la_Wikiconvention_Francophone_2022.webm (Accessed 8 May 2023).

Autism and hyperacusis



- Loudness discomfort ratings for speech
  - Hypersensitive autistic participants (filled circle, dashed line)
  - Non-autistic (empty circles)
  - Non-hypersensitive autistic (filled circles, solid line)

Dunlop, W. A., Enticott, P. G., & Rajan, R. (2016). Speech discrimination difficulties in high-functioning autism spectrum disorder are likely independent of auditory hypersensitivity. *Frontiers in human neuroscience*, 10, 401.

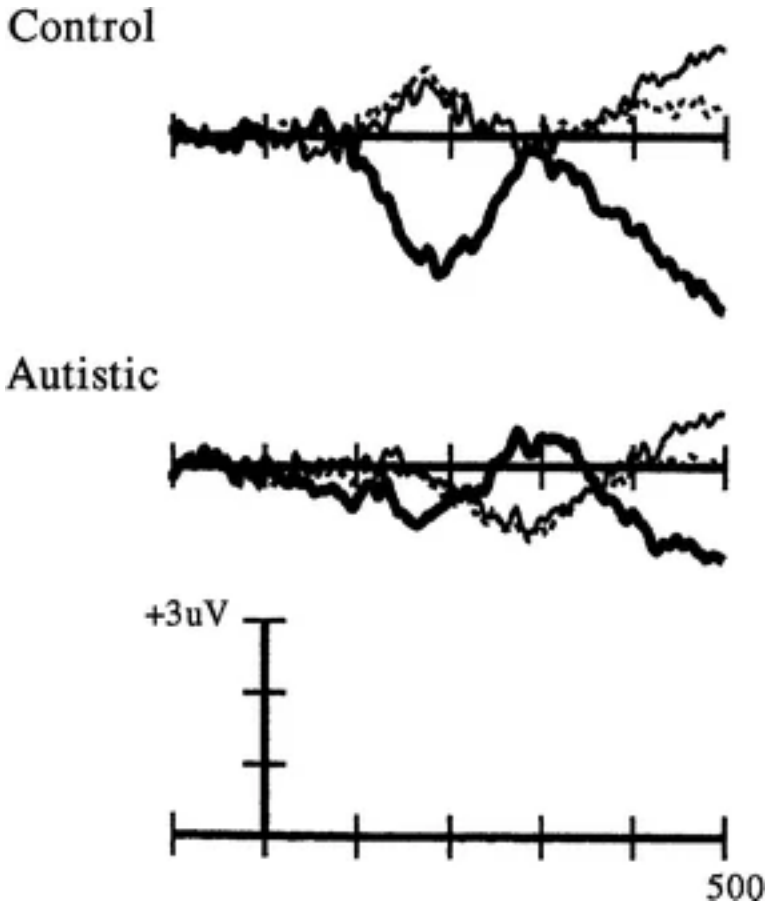
Autism and auditory processing

“I can't filter out background noise. So I can't hear the person speaking to me. I hear way too much”

“when there’s too much different sounds going on (when it is overwhelming, especially with people talking and/or machine sounds) it all blurs into one terrible wall of sound”

Chrith Abhayaratne on Twitter: *IVMSP P4 session at IEEE ICASSP 2019 is getting busy.* https://twitter.com/charithmetic/status/1128660780189196290

Auditory processing

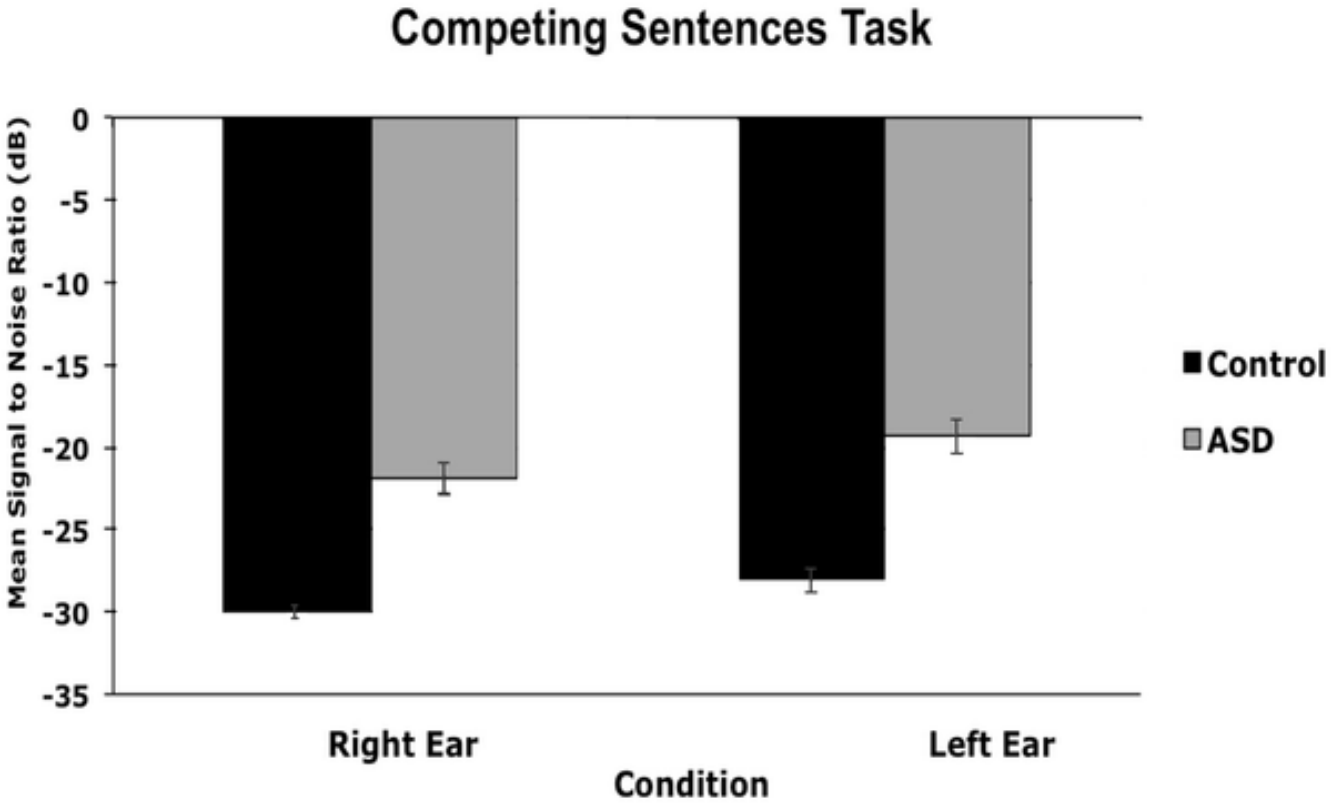


Dunn, M. A., Gomes, H., & Gravel, J. (2008). Mismatch negativity in children with autism and typical development. *Journal of autism and developmental disorders*, *38*, 52-71.

- Oddball experiments common
- Mismatch Negativity differences at different EEG sites
- Small effect size for both pitch and duration oddballs

Schwartz, S., Shinn-Cunningham, B., & Tager-Flusberg, H. (2018). Meta-analysis and systematic review of the literature characterizing auditory mismatch negativity in individuals with autism. *Neuroscience & Biobehavioral Reviews*, *87*, 106-117.

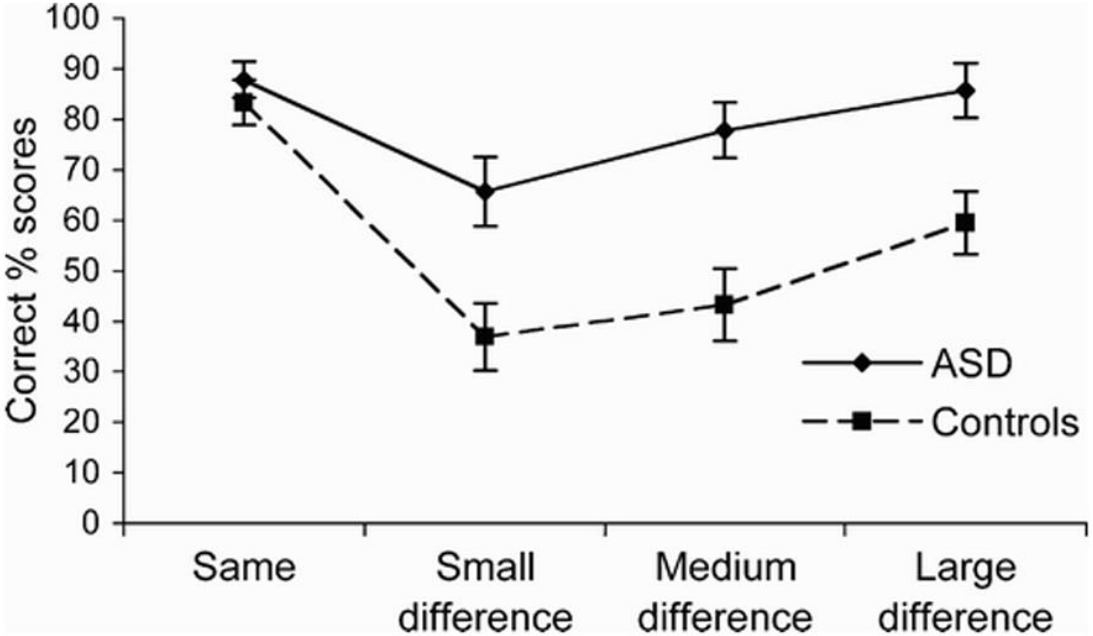
Autism and speech processing



- Detecting target speech with competing speech in other ear

DePape AMR, Hall GBC, Tillmann B, Trainor LJ (2012) Auditory Processing in High-Functioning Adolescents with Autism Spectrum Disorder. *PLOS ONE* 7(9): e44084.

Pitch



- ~5% have absolute pitch
- Enhanced relative pitch
- … even with speech

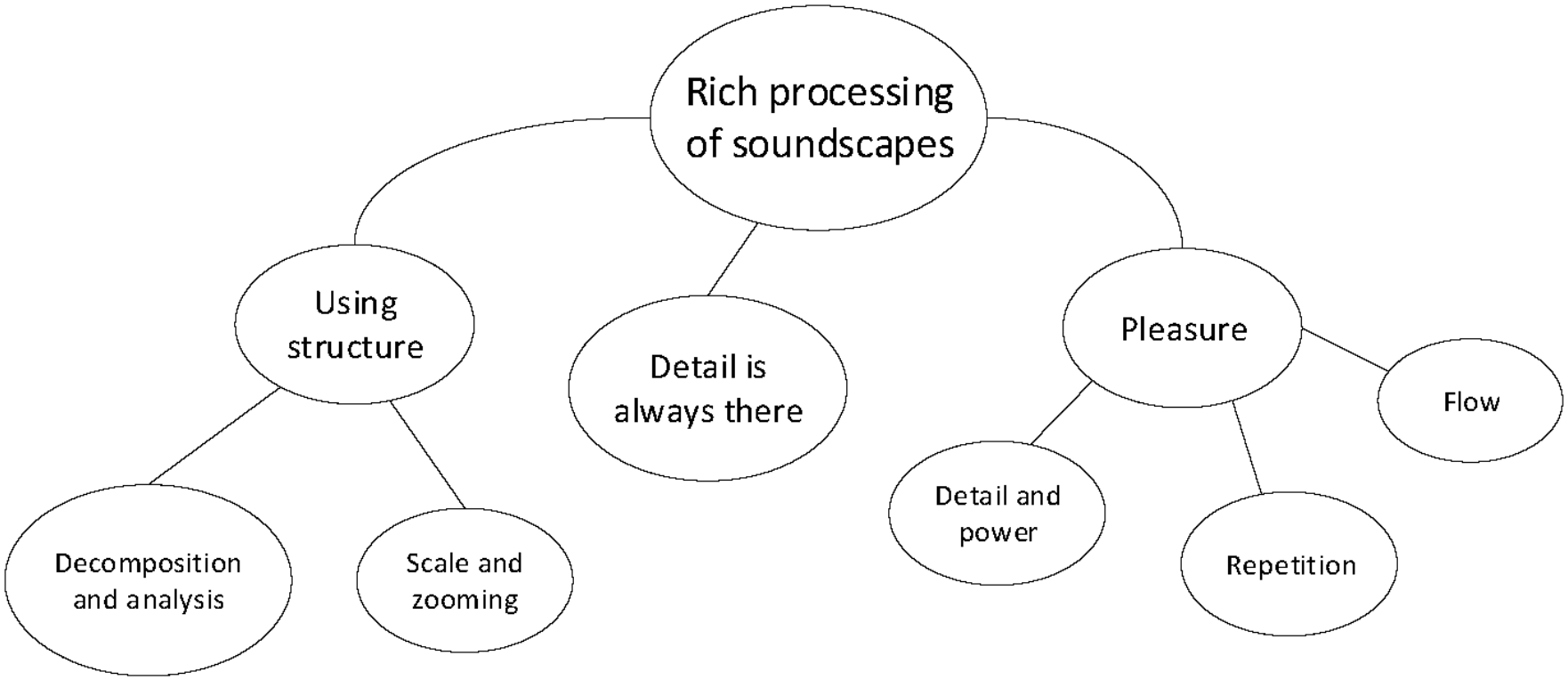
Heaton, P., Hudry, K., Ludlow, A., & Hill, E. (2008). Superior discrimination of speech pitch and its relationship to verbal ability in autism spectrum disorders. *Cognitive neuropsychology*, *25*(6), 771-782.

Structure & scale

“When I listen to music I can "zoom in" on different parts of it. I can find the structure of different parts and split it up.”

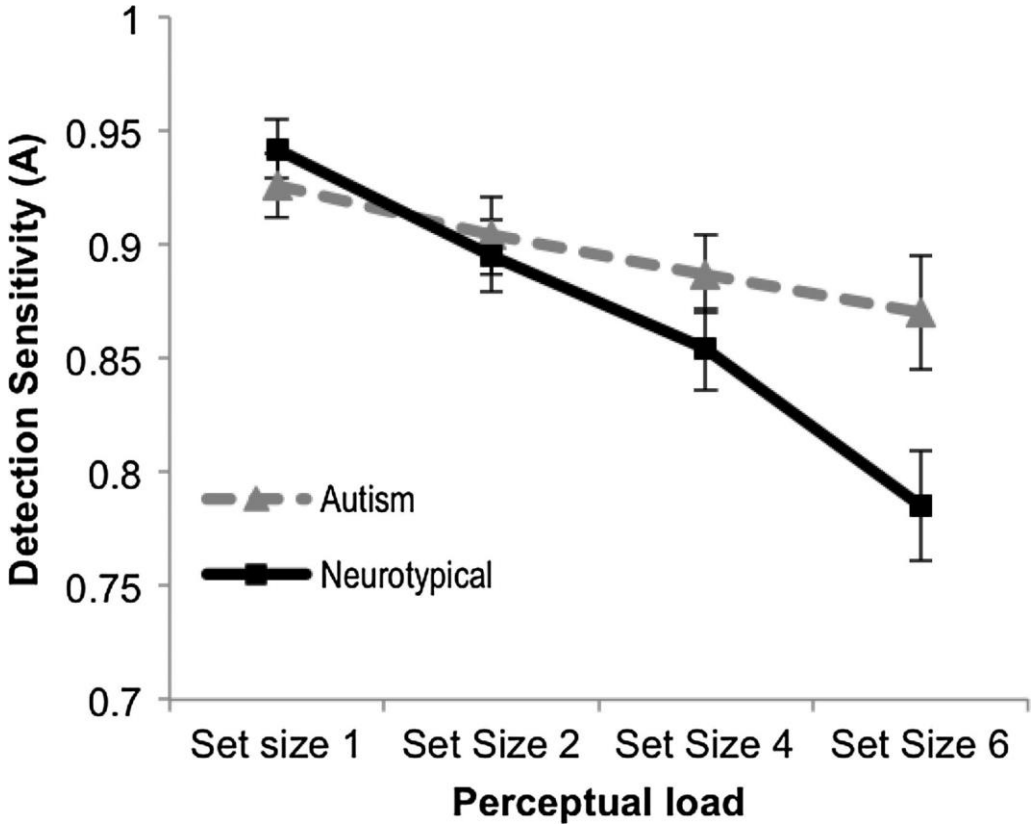
“I do that too! I guess it's one of our superpower. For me it's a positive trait. For all the artist friends I met, it's a positive trait to have someone that can somehow "really" listen and understand their creations.”

Autistic soundscape: Thematic map



Davies, W. J. (2022). Autistic Listening. In J. L. Drever & A. Hugill (Eds.), *Aural Diversity (pp. 90-100). Abingdon: Routledge.*

Auditory capacity



- Detecting target sound against 0-5 competing sounds
- Better performance -> higher auditory capacity?

Remington, A., & Fairnie, J. (2017). A sound advantage: Increased auditory capacity in autism. *Cognition*, *166*, 459-465.

Many research gaps

- Positive experiences
- Translational research – e.g., room acoustic design
- Participatory design (e.g., what do autistic people think?)
- Differences in auditory attention (informational masking?)
- Modulating factors (signal, context, listener, etc.)
- Large cohorts

Amit Patel/Simon Atkinson, *Undertone* at the Fifth Aural Diversity workshop 21 Jan 2023.

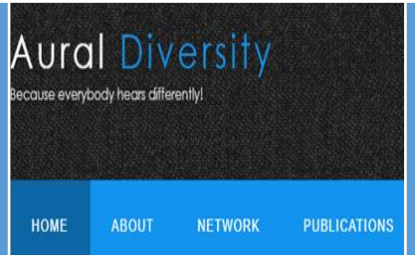
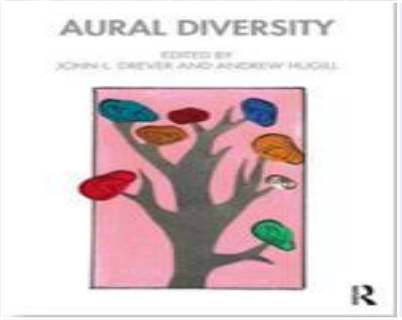
The Leverhulme Aural Diversity Doctoral Research Hub

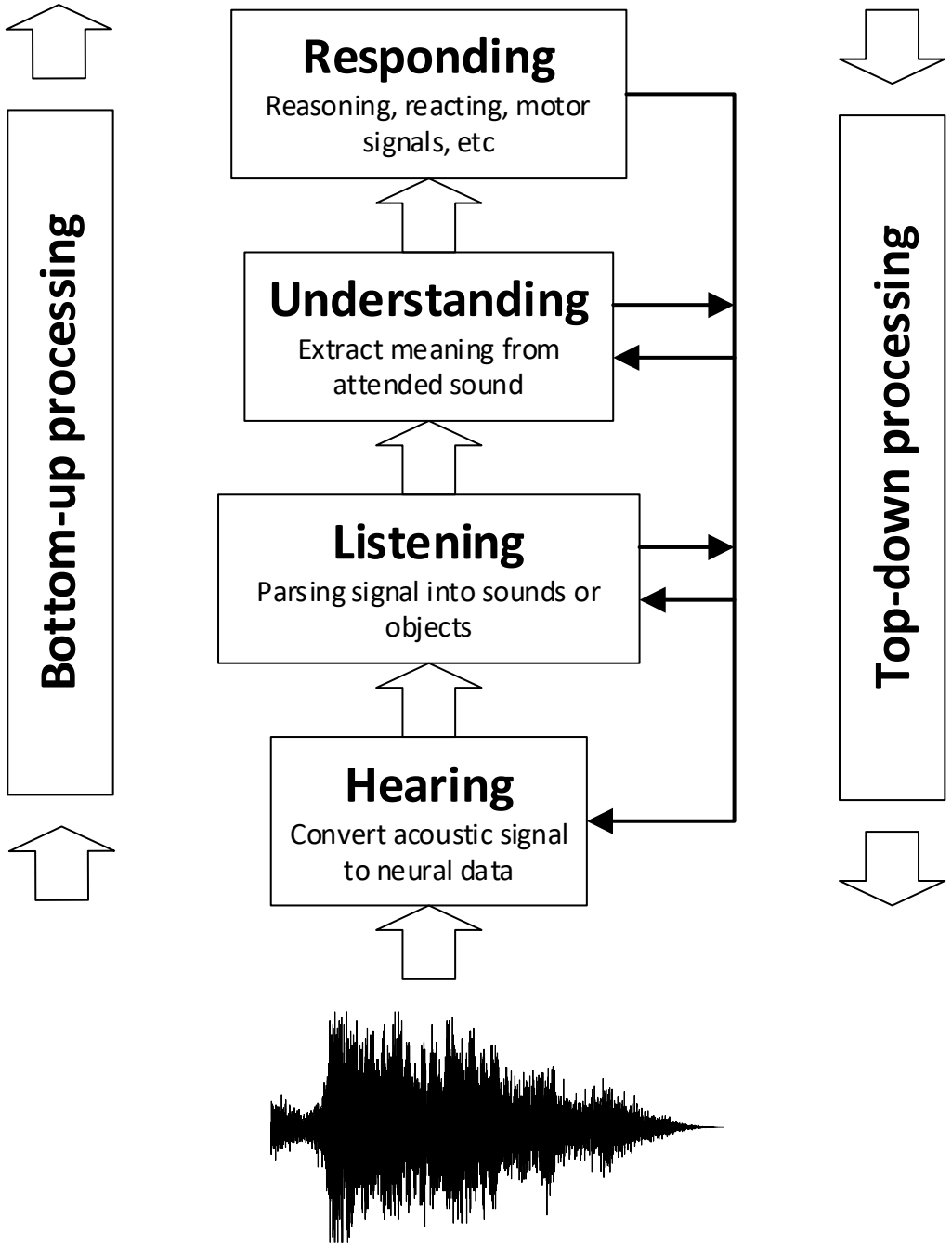
- 21 PhD places total
- Approx 6 this year
- Salford & Goldsmiths joint hub
- (6 = 4 Salford + 2 Goldsmiths)

Conclusions

- Multiple differences in autistic listening
- Loudness, pitch, object parsing, speech in noise, attention, capacity, detail
- May not be apparent in behaviour
- More research needed!

Further info

Aural diversity network		https://auraldiversity.org/index.html
Aural diversity PhD funding		https://www.salford.ac.uk/school-of-science-engineering-and-environment/laura-the-leverhulme-trust-aural-diversity-doctoral-research-hub
Aural diversity book		https://www.routledge.com/Aural-Diversity/Drever-Hugill/p/book/9781032024998
Bill Davies		https://www.salford.ac.uk/our-staff/bill-davies



After Davies, W. J. (2022). Autistic Listening. In J. L. Drever & A. Hugill (Eds.), *Aural Diversity. Abingdon: Routledge.*