A general-purpose pipeline to interface the Tympan hardware with an external computer

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2 Decreased sound tolerance

“The feeling is so intense it feels like pain, I know it’s not pain but it reminds me, it’s very very similar to physical pain” (from Landon et al., 2016).

→ Hearing protectors are often used to alleviate sound-induced distress (Neave-DiToro et al., 2021; Jastreboff & Jastreboff, 2014).
Over-attenuation

Conventional hearing protectors attenuate all sounds.

→ Can reduce engagement with surroundings (Pfeiffer et al., 2019a).

→ May worsen sensitivities over time (Formby et al., 2003; Jastreboff & Jastreboff, 2014).
4 Project objective

→ A hearable to manage decreased sound tolerance with attenuation only when necessary.

Motivation – Initial prototypes – Hackathon Submission
5 Project components

- Control of audio processing
- Voice activity detection
- Alarm sound detection
- Detection of distressing sounds
- Manual user controls

- Low-latency audio processing
- Acoustic transparency with adaptive feedback cancellation
- Masking noise
- Dynamic range limiting
- Frequency filtering

Motivation – Initial prototypes – Hackathon Submission
Audio processing latency requirements

Delay between original & actively transmitted signals

- Multiple perceptual effects
  - Two distinct audio signals (echo threshold)
  - Audiovisual asynchrony (lip sync error)
- These effects may differ for individuals with decreased sound tolerance
  - E.g. audiovisual temporal processing differs in children on the autism spectrum (Noel et al., 2017)
- Hearing aid latency: usually < 9-10 ms (Alexander, 2016)
Prototype #1: Mini-PC

Auditory research platform 3.1: device developed within CRITIAS

Motivation – Initial prototypes – Hackathon Submission
Prototype #1: Challenges

• Measured latency of passthru in Matlab:
  • Fixed sampling rate of 44.1 kHz
  • Varied block size, if GUI + recording
  • Minimum: 22 ms
    • Block size of 256, w/o GUI + recording
    • 57 ms in later measurement

→ PC not suitable for low-latency audio processing

Motivation – Initial prototypes – Hackathon Submission
Prototype #2: Tympan

Tympan Open-Source Hearing Aid Platform, Rev-D + CRITIAS earpieces

Motivation – Initial prototypes – Hackathon Submission
Prototype #2: Challenges

- CPU usage
  - Rev-D: 91% for 1-channel 8-band IIR WDRC with AFC, $fs = 24000$ & block size = 16
  - Rev-E: 97% for 2-channel 16-band FIR WDRC, $fs = 44117$ & block size = 16
- Need to adapt machine learning algorithms for embedded system
  → Tympan well-suited for real-time audio processing, but limited for automatic control of audio processing
Prototype #3: PC + Tympan

→ Pipeline to interface Tympan with an external PC
Prototype #3: Hackathon project

White noise player toggled with clap detection

Motivation – Initial prototypes – Hackathon Submission

~800 ms to toggle
Prototype #3: Challenges

Not a simple addition to Tympan library

- Tested on Python 3.8.10, Arduino 1.8.15 & Teensy 1.54
  - Needed to modify Teensy library
- Had to adapt code to new machine (Ubuntu → Windows)

Motivation – Initial prototypes – Hackathon Submission
Future possibilities

- Potential extensions of pipeline:
  - Wireless transmission
  - GUI to inform device usage
  - Software to record “in situ” research data

- Promise of open-source hardware & software for decreased sound tolerance research
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