Report on the TIDAL Network Plus Feasibility Project: Towards improved communication of music via hearing aids and consumer devices exploiting wearable sensors

The performance of hearing aids for music is often poor, yet music is a vital part of being human, bringing people together and improving health and wellbeing in many ways.

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What we set out to discover

The project aimed to explore whether wearable sensors could improve the processing of music by hearing aids and headphones for individuals with hearing loss. This exploration is crucial because, while hearing aids are primarily designed to enhance speech comprehension, they often fall short in optimising music listening experiences. As music plays a significant role in human culture, health, and well-being, the project sought to address this gap by determining how physiological feedback from wearable sensors could be used to adapt music processing to individual listener needs. This pilot study was intended to lay the groundwork for a larger research initiative that would extend the use of sensor technology to various listening contexts, such as live performances and personal music experiences.

Background and research context

Hearing loss affects one in six people in the UK, and this number is expected to increase as the population ages, potentially impacting one billion individuals worldwide by 2050. Despite the prevalence of hearing loss, only 40% of those who could benefit from hearing aids actually use them, primarily due to perceived inadequacies in performance, particularly in music reproduction. Music is integral to human well-being, providing both direct pleasure and social connections that help combat loneliness and improve quality of life. Current hearing aid technology predominantly focuses on speech, neglecting the nuanced requirements of music listening. Previous projects, such as the EPSRC Cadenza project, which this project borrows test stimuli from, have highlighted the need for better music-oriented assistive technologies. This study sought to fill this gap by investigating how feedback from wearable physiological sensors could enhance the music listening experience for those with hearing impairments.

Engineering / research challenge and why it matters

The primary engineering and research challenge was to develop a system that can effectively use physiological data from wearable sensors to measure response to (and ultimately help inform) the music processing of hearing aids and headphones in real time. This challenge is significant because music and hearing loss responses are highly individualistic, requiring personalized audio processing solutions. Addressing this challenge is important as it promises to enhance the quality of life for individuals with hearing loss by providing them with improved access to music's emotional and social benefits. Furthermore, leveraging consumer-grade wearable technology could make advanced audio processing more accessible, affordable and reduce reliance on specialised assistive devices, thereby increasing the adoption of such technologies.

Aims and objectives for the project

The aim of the project was to conduct a pilot study to investigate whether wearable sensors could be used to measure responses to specific music processing enhancements in hearing aids, for individuals with hearing loss using hearing aids and headphones.

There were three specific objectives:

Design and conduct experiments using Galvanic Skin Response (GSR - essentially, sweat) and photoplethysmography, PPG, a method of monitoring heart rate optically, to measure response from "normal hearing" and hearing impaired individuals to musical stimuli that have been adjusted according to music enhancement algorithms from the EPSRC funded Cadenza project.

Collect self-report data on basic audio quality and likeability, and compare these ratings with the physiological data. Present findings to music/audio engineering community.

Integrate results into a larger follow-on bid – currently targeting an EPSRC New Investigator Award submission in September 2024.

What we did

The study involved listening tests conducted with bilateral hearing aid users who have mild to moderate hearing loss. 15 Participants were invited to listen to music processed through various typical hearing aid techniques in a controlled International Telecommunication Union-standard listening environment. Each listening session reviewed 43 music segments in three conditions: no hearing aid processing, a default hearing aid processing, and the winner of the last Cadenza challenge hearing aid processing for music. Sessions thus lasted approximately 2 hours per person. Instead of using their prescribed hearing aids, amplification was provided to control the signal processing used. Physiological responses, including galvanic skin response (electrodermal activity) and blood volume pulse amplitude, were measured using consumer wearable sensors. This data was then analysed to assess the correlation between the physiological responses and music processing techniques. In addition to physiological measurements, self-report psychometric techniques were employed to capture participants' subjective experiences.

What we found

The analysis revealed that while there were some correlations between physiological responses and the different ways music was processed, these were not consistently significant across all metrics. The data suggested potential links but also highlighted the complexity of reliably measuring and interpreting physiological responses to music in individuals with hearing loss. Despite the challenges, the study demonstrated that wearable sensors could provide valuable insights into how listeners experience music, suggesting a promising direction for future research. The findings also emphasised the need for larger-scale studies to fully understand the potential benefits and limitations of using physiological feedback to enhance music processing in hearing aids.

What this means

The findings from this pilot study suggest that integrating wearable sensor technology with hearing aids and headphones could potentially improve the music listening experience for individuals with hearing loss. While the results were not uniformly significant, they point towards the feasibility of using physiological feedback to tailor music processing to individual needs. This approach could lead to more effective assistive listening technologies that not only improve speech comprehension but also enhance music enjoyment. The insights gained from this study will inform future research and development efforts, aiming to create innovative solutions that leverage consumer technology to meet the diverse needs of listeners with hearing impairments.

What next

The results of this study are currently being prepared for submission to an open-access journal, where they will be shared with the wider scientific and audiology communities. This publication will detail our methodologies, findings, and insights, providing a valuable resource for future research in this area. We will also share and disseminate to the Cadenza project team who assisted with the stimulus set and participant recruitment, and have charity partnership in the Royal National Institute for the Blind.

Additionally, early findings were presented at the CHIME Annual Workshop, where we engaged with other researchers and practitioners in the field. This presentation facilitated discussions around the integration of wearable sensors with hearing aids and headphones and gathered valuable feedback to refine our approach.

Looking ahead, the insights and data gathered from this study are being used to shape a bid for the EPSRC New Investigator Award, targeted for submission in September 2024. This funding will support an expanded research initiative aimed at developing advanced music processing technologies that leverage physiological feedback. The planned project will explore a broader range of listening environments and contexts, further investigating how consumer wearable technology can be utilised to improve the auditory experience for diverse listeners.

Dissemination:

Towards Integration of Biosensors and Hearing Aids for Music. Rory Stocks, Duncan Williams, Rebecca Vos, Trevor Cox. In Canny, N., Holland, S. and Mudd, T., 2023. Proceedings of the CHIME Music and HCI Workshop 2023.4 Dec 2023, The Open University, Milton Keynes, The Open University.

Appendix 1

Carbon calculations for travel undertaken as part of the project

Staff commuted daily using public transport, with a commute distance of 10 miles each way, over the course of 26 weeks, resulting in 267.8 kg CO_2. Conference travel, involving a 200-mile round trip by bus, added 20.6 kg CO_2. Additionally, five participants travelled within a 50-mile radius to visit the laboratory for one day, contributing a total of 25.75 kg CO_2.

Travel carbon was therefore 314.15kg in total.

If we include office and laboratory spaces, totalling 100 m^2, were used for two days a week over 26 weeks, generating approximately 482 kg CO_2. Furthermore, indirect emissions from the project's total expenditure of £38,000, using an emission factor of 0.25 kg CO_2 per £ spent, amounted to 9500 kg CO_2.

Together this totals 10296.15 kg CO_2.

Source	**Emissions (kg CO_2)**
Daily Commute	267.8
Conference Travel	20.6
Laboratory Visits	25.75
Office and Lab Space Usage	482
Indirect Emissions (Expenditure)	9500
Total	10296.15