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User behavior with EVOTION hearing aids

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ABSTRACT

How are hearing aids really used in everyday situations? How can insights into this enhance the rehabilitation process involving the user and the hearing care professional? Data collected with EVOTION hearing aids contribute towards the answers. For 15 years hearing aids have logged data about the sound environment and usage patterns. However, the past logging data provided descriptive statistics about the usage, and not detailed insights with timestamps stating which situations, at what time, and which settings of the hearing aid. The EVOTION hearing aids connects over Bluetooth to a smartphone that stores a snapshot of the sound environment one time every minute to provide enough insight in the sound environments whilst preventing any eavesdropping based on the data. The sound environment data consists of sound pressure level, noise floor, and signal-to-noise ratio and a classification into quiet, noise, speech or speech in noise. Data spanning hearing aid users' behavior over weeks and months provides an in-depth view in how they cope with different sound environments and throughout the day. Insights from this data enables the hearing care professional to guide the individual user towards optimal outcomes and follow their individual journeys.

Keywords: Hearing Aids, Behavior, Preferences, Logging data

1. INTRODUCTION

Hearing care professionals, researchers, and hearing aid developers share a joint question: How are hearing aids really used in everyday situations. For the hearing care professionals, it's a matter of understanding the auditory environments and the preferred listening behavior for the individual hearing aid user. For researchers and hearing aid developers it is a matter of learning the hidden relationships that that enables compensation for hearing loss. A modern hearing aid entails compressive amplification, advanced signal processing systems that filter out unwanted sounds from the rear and the sides, simpler adaptive beamforming, simpler noise reduction, and sometimes reallocation of frequency components. A larger set of parameters define the behavior of each of these algorithms ending up with several thousand parameters in a hearing aid. Given the amount of time available for each fitting session many hearing aid fittings rely on starting from a compressive amplification function defined by the audiogram and number of generic settings based on the dialogue with the hearing aid user. From this starting point the hearing care professional and the hearing aid user discuss situations to optimize the overall fitting. For almost 15 years hearing care professionals have had access to aggregated data about the sound environments and use of the hearing aid[1] so that objective metrics could supplement the dialogue. With the EVOTION hearing aid the stored data is timestamped and each individual event is stored via a smartphone[2].

2. EVOTION DATA LOGGING

The first releases in 2016 of Oticon Opn featured a new Bluetooth based data interface that made them the first Internet of Things (IoT) hearing aids. The new IoT features allowed the hearing aid to interact with services on the net[3] through a smartphone, and e.g. inform parents with a text message when a child's hearing batteries run low or enable the definition of geofences for automatically changing into a preferred hearing aid program at a given place [4]. The same IoT interface also enabled the timestamped collection of program changes hearing aid users [5] when the alerts from the hearing aid to the phone was stored in a spreadsheet on the phone. For the EVOTION prototype hearing aids extended the Opn IoT with the transmission of 21 sound environment parameters one time every

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minute. The 21 parameters are the Sound Pressure Level (SPL), Noise floor, Signal-to-noise ratio, modulation envelope, and modulation index in 4 frequency ranges (full bandwidth, low frequency, mid frequency, and high frequency) and the output of a four-class sound environment classifier with the outputs: quiet, noise, speech, and speech in noise. The Sound Pressure Level and sound environment classifier are comparable to the variables has been logged in the aggregated manner for the last 15 years. The additional data logging from EVOTION was adopted with slight modifications for the 2018 release of Oticon Opn [6] for the HearingFitness™ feature.

2.1 Limitations of data logging with Smartphones and Bluetooth

Hearing aids have very limited memory and therefore do not buffer the transmitted data, thus if the Bluetooth connection between hearing aid and smartphone is not present the data is lost. This can happen in situations with many active Bluetooth devices, if the hearing aid users goes away from the phone, if the connection is not restored when the hearing aid user returns, of simply if the hearing aid is not close enough to the smartphone. However, not only must the Bluetooth connection be available, the app on the smartphone which processes the data must also have sufficient priority such that it is not terminated or halted by the smartphone power management. Thus, even if the combination of hearing aids and smartphones allow the transmission of data, it cannot be taken for granted and future work includes the direct comparison of the amount of data stored in a hearing aid with the amount of data stored via the connected smartphone.

3. INITIAL FINDINGS

The modeling of data from EVOTION hearing aids is on-going and one of the first steps was to reduce the dimensionality of the feature space, where the sound environment parameters was reduced into a 3 dimensional space of Sound level, Signal quality, and Sound diversity [7], where Sound Level models the overall level, and Signal quality models the balance between signal and noise, and Sound diversity how much the sound environment parameters are changing.

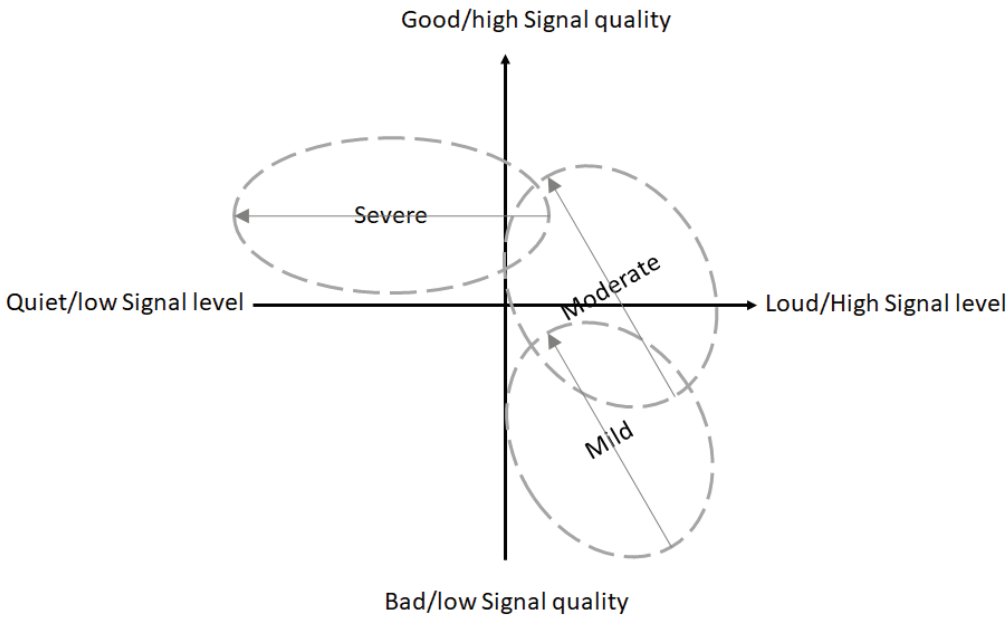

Figure 1: Sketched behavior of different groups of hearing aid users

Figure 1 shows an interesting but not necessarily surprising pattern of behavior from initial analysis following the dimensionality reduction. The horizontal axis is the Sound level and the vertical axis the Signal quality, and each oval outlines the approximate position of three groups with different degrees of hearing loss (following WHO definitions [8]) during a day. The arrow shows how the sound environment evolve during the day. The hearing aid users with Mild and Moderate hearing loss spend the day in sound environments with similar Level but where the Signal quality is higher for the Moderate group. Similarly, the group with Severe Hearing loss spend the day in quieter and higher Sound quality environments than the two other groups.

4. SUMMARY

The paper reports findings from the initial analysis of behaviors from data logged with EVOTION hearing aids. The analyses are work in progress and should therefore be considered as indicative until completed and fully validated with the full dataset collected within the EVOTION project. The further analysis may also reveal preference patterns that can guide the dialogue between hearing care professionals and hearing aid users towards better outcomes.

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