

Data-driven hearing care with HearingFitness™: Oticon shares openly its innovative vision and roadmap

INTRODUCTION

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We live in exciting times of innovation and disruption. As customers, all of us are reaping benefits from this wind of change. Think of how you used to book holiday travels 20 years ago, and now fast-forward to how you booked your last holiday travels. Think of how you used to conduct your banking 20 years ago, and now fast-forward to how you conduct your banking. Digitalization and do-it-yourself has led to more rapid and flexible services and around-the-clock support for us as customers, with less need for face-to-face appointments for trivial and transactional services.

These changes are seen in many realms of society: socially, professionally, and personally, to name a few. In particular to this paper, a large and (perhaps) welcoming change has progressed in healthcare, and how the consumer can take greater ownership of their hearing healthcare/fitness.

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The four Ps of digital healthcare: Personalization, Participation, Prediction, and Prevention

Now zoom into healthcare. The digital revolution of healthcare is shaping the hearing healthcare services that tomorrow's population needs. The population needs more of four Ps: Personalization, Participation, Prediction, and Prevention. Here is Oticon's vision for digital hearing healthcare.

- **Participation.** We engage and encourage the users to be active partners in their healthcare. The user is no longer a patient, the user is a co-creator of their health. For example, the user is invited to participate through self-monitoring at home, self-adjustment of hearing aids within the realm of what the hearing care professional defined a priori. Our research shows that empowered users are loyal partners in care (Kanstrup et al, 2017). In other words, instead of giving the user a fish, we teach the user how to fish.
- **Personalization:** We ban the "one size fits all" approach. Under the supervision of the patient's hearing care provider, we personalize all hearing solutions and services to the user and their environment. Hearing aids adjust themselves not only to the user, but also to changes during the day (eg, more tired in the afternoon), during the week (such as different needs during the week when at work versus during the weekend), and also over time (for example, if hearing deteriorates). We provide personalized support based on the user's hearing aid, preferences, etc. We provide tailored tips and tricks, such as when new hearing aids / accessories / features are made available that are relevant for the specific user. This personalization reaches its full potential when combined with user participation as described above.
- **Prediction:** We know in advance, through big data, what is best for every user. We profile users into subgroups that share common features. We visualize the data so it can be understood and acted upon quickly. For example, we know through monitoring when a user is having trouble hearing and the hearing aids provide extra help. Similarly, we know when a user is in a danger zone for hearing aid rejection and we raise the flag so the hearing care professional can target an intervention to put the user back into a successful course. We can also predict need for maintenance in the hearing aid based on automated fault testing.

- **Prevention:** As Benjamin Franklin once said, "an ounce of prevention is worth a pound of cure". Baby-boomers especially want to remain healthy and active late in life. We take a life course approach, with early detection and monitoring over time of hearing and health status. We combine multiple datasets to which we apply advanced analytics to build profiles and devise profile-specific prevention strategies. For example, the user of our hearing aid receives an alert if they are exposed to loud noises that could result in further hearing loss.

Why address hearing loss: All Ears on Quality of Life

Addressing hearing loss is important to prevent sensory deprivation, social isolation, and other healthcare and quality of life consequences. We have known for a long time that hearing loss, social isolation, and dementia often go hand in hand (Lin et al, 2011, 2014). More recently, new knowledge has shown the importance of addressing hearing loss well and early. The latest research published in the prestigious journal *The Lancet* points to untreated hearing loss as a risk factor for dementia (Livingston et al, 2017). Many of the risk factors for dementia cannot be addressed. The good news? Untreated hearing loss is the single most important modifiable risk factor for dementia. By addressing hearing loss, we reduce one's risk for cognitive decline, more so than by addressing hypertension, obesity, or smoking. Hearing healthcare enables people to connect to the people that matter to them and engages them with the world. In other words, hearing healthcare maintains quality of life. Faced with these clear facts and knowledge, Oticon is pushing ahead and tackling the challenge of data-driven hearing healthcare, with the goal of increasing both effectiveness and efficiency.

In search of insights which will improve hearing healthcare

To make the four Ps a reality and to address hearing loss and its important consequences, at Oticon we took on the challenge to combine heterogeneous data that shed a light not only on hearing status, but also on health status. We need an application that does this, but also a secure location to pool this data over large numbers of users whilst maintaining their privacy. We also need advanced analytics of this data to generate easy-to-understand insights that we can act upon. Driven by curiosity and a will to shape the hearing

healthcare landscape of the future, we created a unique data ecosystem.

HearingFitness™, Oticon's ecosystem for data-driven hearing healthcare

To encourage users to benefit from hearing healthcare, we have created the HearingFitness™ ecosystem. HearingFitness™ contains an application (app) that collects heterogeneous data.

- **App:** The app collects different types of data. Hearing-related data, such as hearing aid usage and sound environments analysis, allows a continuous monitoring of not only how much the hearing aid is used, but also in which situations the user is in. The app collects also other relevant and available health and lifestyle metrics gathered from sensors such as the user's cellphone or smart watch. This includes physical activity, heart rate, sleep patterns, etc.
- **Cloud-based repository:** In short, big data analytics mean that a single user agrees to share their data so their data can be pooled with other people's data, and from there be transformed back into individualized guidance. In HearingFitness™, the breadth of data from all users is passed to a cloud-based data repository that is secure and that respects the privacy of users. This data is made available for processing in an anonymized way.
- **Data processing:** Data scientists use algorithms to perform advanced analytics to process the raw data into insights regarding hearing aid usage, environmental patterns, and other health indicators. The brightest minds of big data analytics take part in this task, which is repeated to continuously enhance the performance as more and more relevant data is available.

- **Insights communication:** It is important to process the raw data before communicating it. Simply put, data points are just data points: unique patterns and associations between these data points are the insights we can act upon. We communicate insights rather than raw data to avoid information overload. We share the processed insights with the relevant users through tailored data visualization, insights, messages, and advice.

- **From insights to actions:** We want to provide valuable and meaningful insights that hearing care professionals and users can act upon. Armed with these insights, they may choose to further change and optimize the hearing healthcare solution. Even hearing aid developers and other healthcare professionals can use these insights for their daily work. The insights and findings are also used both to further open research as well as optimization of the next generations of hearing aids from Oticon. The more data we collect and learn from, the better personalized and individualized solutions we can offer. HearingFitness™ is the snowball at the top of the hill, which will start an avalanche of data learning and user behavior insights. HearingFitness™ will define the future of data-driven hearing healthcare.

What is Oticon doing now

HearingFitness™ is the first element that introduces data-driven hearing care in Oticon's products. The first release of HearingFitness™ provides the user with feedback on their use of hearing aids and their features. This feedback enables the user to monitor their use of hearing aids and adaptation of features. A simple yet meaningful example is soft "nudging" which helps first time users meet their individual listening goals. A user may be "nudged" to re-adjust personal goals "good job, you just exceed your listening goal the last two weeks - do you want to change your goals?"

Figure 1 shows how one user adopted features over time and changed behaviour (Johansen et al., 2017). Our data shows that these patterns vary tremendously from one user to another, hence the importance to give each user the opportunity to see their own personalised data.

The next step after knowing how long the hearing aid is used is how much hearing training every user has achieved. We want to motivate users to be active in their hearing healthcare and use their hearing aids in varying and challenging conditions, just like fitness apps motivate people by showing how fast and how long they exercise. With the next version of HearingFitness™, the app continuously visualizes the current effort based on the sound environment data, and the data logged from the hearing aid is transformed into an individual overview of difficult and noisy situations. This enables the user to monitor their hearing fitness training in detail and at a glance. This update also opens the door for hearing aids that learn personalized and contextual settings with user input in the form of a preference test. The outcome of the preference test adjusts the processing of the hearing aid in the relevant sound environments.

Research is also taking place to prepare for further development of HearingFitness™. The European Union provided 5 million euros of funding for the research project EVOTION (www.h2020evotion.eu). Oticon's Eriksholm Research Centre leads EVOTION, a project

which investigates self-management and learning from user patterns (Pontoppidan et al., 2017), auditory training, and prevention of noise-induced hearing loss. Researchers in the EVOTION project include hearing care professionals working in public and private clinics in the United Kingdom and in Greece, data and security scientists, and policy makers. The project will show how individual data from hearing aid users, pooled into a large dataset, improves the outcomes of hearing healthcare for the individual users. Furthermore, EVOTION aims to lead to evidence-based practices and evidence-informed public health policies (Spanoudakis et al., 2017). The project uses open-source big data analysis tools to process the heterogeneous data coming from different vendors and domains as a first step towards open data and open research.

We are also investigating sound preferences of individual users to lead to better personalization. The Oticon Foundation is supporting a collaboration with the Department of Applied Mathematics Computer Sciences at the Danish Technical University and the Copenhagen Centre for Health Technology. This collaboration explores how users change their hearing aid program in different sound environments. Figure 2 shows how one user prefers different programs in seemingly similar situations. Together with the EVOTION project these activities will enable us to learn the many complex interaction patterns between sound environment and the preferred processing in the hearing aid.

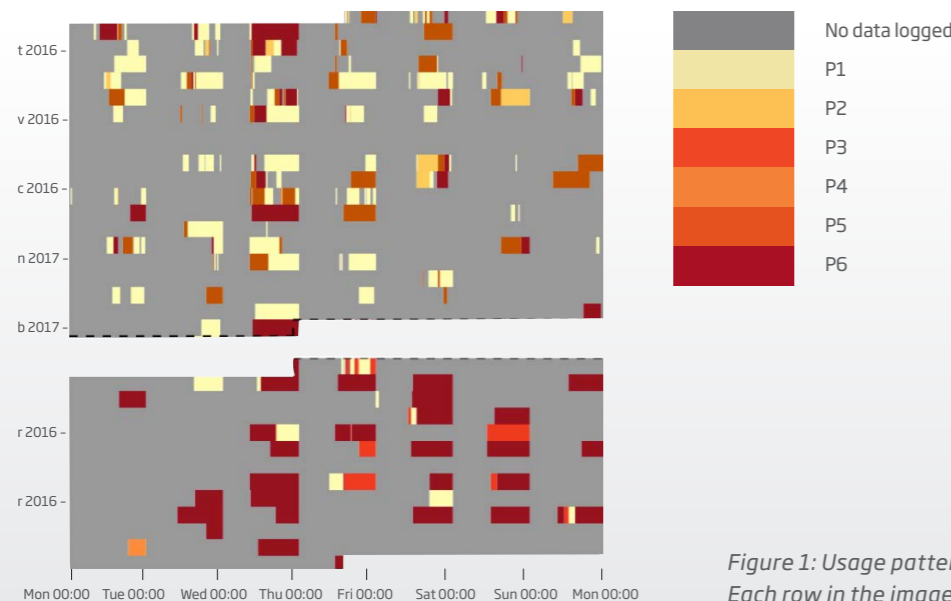


Figure 1: Usage pattern for a single user over 8 months. Each row in the image is a week and the chosen program indicated with color-coding.

Hearing healthcare aims to preserve health, social participation, and quality of life. Therefore, the data from the hearing aids must be combined with other data that inform on the user's well-being. Oticon has several projects that aim to integrate data from other sensors, e.g., heart rate and electroencephalography (EEG), both measured with commercially available sensors and potentially through sensors embedded in hearing aids, to further understand how hearing aids and body and mind fitness interact together for every user. With additional sensors and data in HearingFitness™, Oticon will take a leap towards open data and open research.

A Call for Action. We call upon:

- Scientists, researchers, and data analysts: Get in touch with us to hear about collaborations with HearingFitness™ data using an open innovation / open research mindset. We wish to inspire a new generation of scientists and researchers to contribute to data-driven hearing healthcare. We believe in open science whilst preserving user privacy.

We want this dataset to be available for scientists and researchers to uncover new important insights that will lead to better hearing healthcare.

- Wearable vendors and innovators: Approach us to tell us how your products and services, including wearable sensors, health trackers, etc. could interact with our products and services to create an even more comprehensive healthcare solution of our hearing care professionals and hearing aid users.
- Healthcare providers: Come to us with your visions and your ideas. We want to partner with the most innovative healthcare providers to shape hearing healthcare of the future. We believe in personalized, participatory, predictive, and preventive hearing healthcare, and want to make it a reality with you.

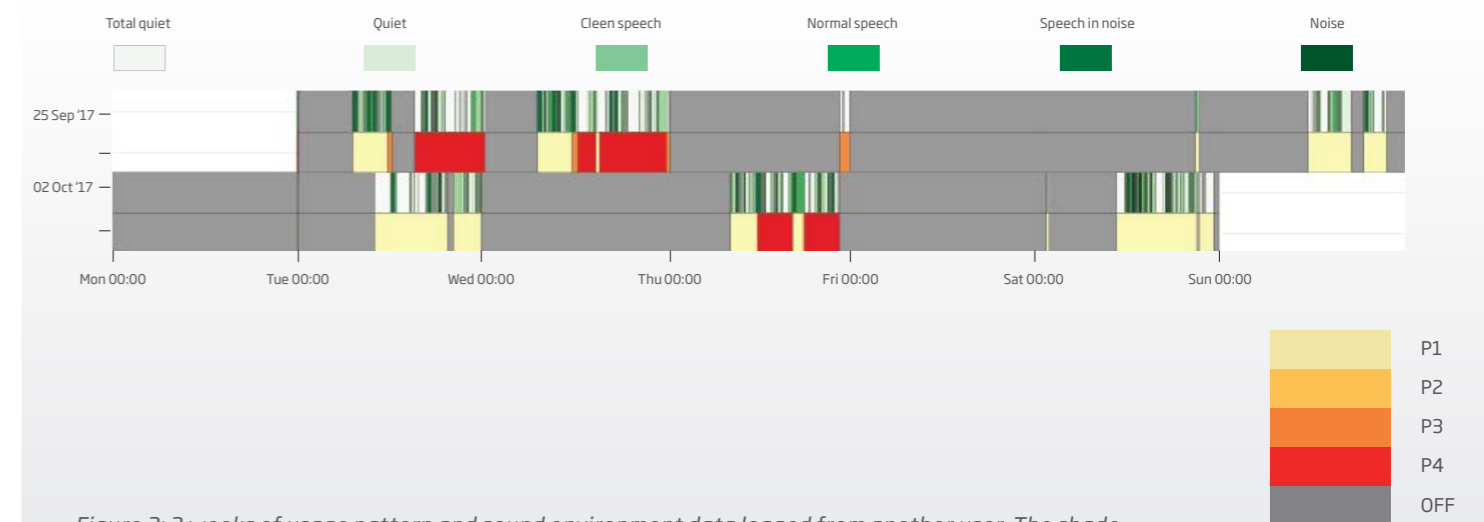


Figure 2: 2 weeks of usage pattern and sound environment data logged from another user. The shade of green indicate which sound environment the hearing aid logged at each time point, and the beige-to-red color scale indicate which program which was in use at that given time. [Korzepa et al., in prep]

References

Hood, L. & Galas, D. 2008. P4 Medicine: Personalized, Predictive, Preventive, Participatory: A Change of View that Changes Everything: A white paper prepared for the Computing Community Consortium committee of the Computing Research Association. <https://cra.org/ccc/resources/ccc-led-whitepapers>

Johansen, B., Flet-Berliac, Y.P.R., Korzepa, M.J., Sandholm, P., Pontoppidan, N.H., Petersen, M.K., & Larsen, J.E., 2017. Hearables in Hearing Care: Discovering Usage Patterns Through IoT Devices, in: International Conference on Universal Access in Human-Computer Interaction. Springer, 39-49.

Kanstrup, A.M., Rotger-Griful, S., Laplante-Lévesque, A., & Cleveland Nielsen, A. 2017. Designing Connections for Hearing Rehabilitation: Exploring Future Client Journeys with Elderly Hearing Aid Users, Relatives and Healthcare Providers. In Proceedings of the 2017 Conference on Designing Interactive Systems. ACM, 1153-1163.

Korzepa M.J., Petersen, M.K., Johansen, B., Pontoppidan, N.H., Larsen, J., Larsen J.E., Learning soundscapes and behavior from data, manuscript in preparation.

Lin, F. R., Metter, E. J., O'Brien, R. J., Resnick, S. M., Zonderman, A. B., & Ferrucci, L. 2011. Hearing loss and incident dementia. *Archives of Neurology*, 68(2), 214-220.

Lin, F.R., Yaffe, K., Xia, J., Xue, Q.L., Harris, T.B., Purchase-Helzner, E., Satterfield, S., Ayonayon, H.N., Ferrucci, L., Simonsick, E.M. and Health ABC Study Group. 2013. Hearing loss and cognitive decline in older adults. *JAMA Internal Medicine*, 173(4), 293-299.

Livingston, G., Sommerlad, A., Orgeta, V., Costafreda, S.G., Huntley, J., Ames, D., Ballard, C., Banerjee, S., Burns, A., Cohen-Mansfield, J., & Cooper, C. 2017. Dementia prevention, intervention, and care. *The Lancet*.

Pontoppidan, N.H., Li, X., Bramsløw, L., Johansen, B., Nielsen, C., Hafez, A., & Pedersen, M.K., 2017. Data-driven hearing care with time stamped data-logging, in: Proceedings of International Symposium on Auditory and Audiological Research (ISAAR). Presented at the International Symposium on Auditory and Audiological Research (ISAAR), Denmark.

Spanoudakis, G., Kikikidis, D., Bibas, A., Katrakazas, P., Koutsouris, D., & Pontoppidan, N.H., 2017. Public health policy for management of hearing impairments based on big data analytics: EVOTION at Genesis. 17th IEEE Int. Bio-Inform. Bio-Eng. Conf. 23-25 Oct 2017 Wash. DC USA.



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