Toward a more granular management of the calibration process for hearing devices

The role of design-based knowledge translation

Simeone, Luca; Picinali, Lorenzo; Atvur, Alisan

Published in:
Proceedings of Design Research Society Conference 2018

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

DRS 2018 Design Research Society 2018 Catalyst

University of Limerick
25th - 28th June 2018

Toward a more granular management of the calibration process for hearing devices: The role of design-based knowledge translation

SIMEONE Luca[a*]; PICINALI Lorenzo[b] and ATVUR Alisan[c]

[a] Aalborg University and Vianet srl
[b] Imperial College London
[c] Pomorska University in Słupsk
* Corresponding author e-mail: lsi@create.aau.dk

Suggested citation: Simeone, L., Picinali, L., & Atvur, A. (2018). Toward a more granular management of the calibration process for hearing devices: The role of design-based knowledge translation. In *Proceedings of Design Research Society Conference*. Limerick, Ireland.

This paper analyses a research and innovation action oriented toward creating various technologies to help people with hearing impairment in calibrating their hearing devices and examines how several design artefacts (e.g., sketches, mock-ups, motion graphic videos, prototypes) were used as a knowledge translation mechanism. In particular, the paper looks at how these design artifacts supported knowledge translation in a way that helped individuals with hearing impairment to better understand the calibration process of their hearing devices and to acquire a minimal but practical vocabulary to directly interact with their devices and communicate with the audiologist. Design-based knowledge translation increased the self-efficacy of hearing aids users and put them in the condition to carry out a fine-grained and more contextually-anchored calibration process and, consequently, to feel empowered to operate with a higher degree of autonomy.

Hearing impairment, design for healthcare, knowledge translation

1. Introduction

According to the World Health Organization, over 5% of the world's population has disabling hearing loss, and due to an aging population, this number will probably increase[1]. While hearing aid technologies have dramatically advanced in the last 25 years, people's perception and use of these

[1] http://www.who.int/mediacentre/factsheets/fs300/en/

devices have changed relatively little. Digital hearing aids are now smaller and incorporate several functions that go far beyond the simple amplification and equalization operation performed by the traditional analog devices. On the one hand, these digital hearing devices can be calibrated in relation to a greater variety of parameters (e.g., compression, noise reduction, directivity) and this allows responding in a better way to the specific needs of each individual suffering from hearing loss. On the other hand, the calibration process can be continuously adjusted by the individual with hearing impairment in relation to everyday activities and contexts. For example, the device can be calibrated in a specific way while the subject is sitting at a restaurant and wants to listen what the friend sitting in front of her has to say, and in a different way when the two friends leave the restaurant and go to listen to a concert. Equalization, volumes and other parameters of the hearing device can be re-adjusted in relation to the specificities of different environments.

However, the technological advancement of these new digital models of hearing devices is not always accessible or accessed by the population who have hearing impairments. The main reason is that the calibration process requires at least some basic understanding of key acoustic parameters and how these parameters can be adapted for different conditions of use (e.g., a concert, a noisy street, a phone conversation). If those with hearing impairments had a better understanding of these parameters, this would help both the initial calibration of the hearing device (that is generally done under the supervision of a professional audiologist) and the later continuous re-calibration of the device that the user could autonomously do in relation to the various contexts of use. It is, of course, difficult to imagine that individuals with hearing impairment can have the same level of technical and medical knowledge possessed by professional audiologists or by experts in acoustics. This technical and medical knowledge needs to be translated into formats that can be more easily understood and appreciated by a wider, non-professional audience, which as a result can have a more prominent role in the management of their hearing devices. Individuals with hearing impairment could more independently decide where and how to carry out calibration processes.

This is one of the research avenues of the 3D Tune-In project (Eastgate, Picinali, Patel, & D'Cruz, 2016), which brings together a variety of partners: a hearing aid manufacturer, research centers specialized in computer science and acoustics, private companies developing solutions for healthcare, and hearing associations. In particular, since this group has expertise in various areas of design (from visual design to interaction design, all the way up to service design), one of the core areas of the project was the creation of a variety of design artefacts (e.g., mockups, infographic representations, prototypes), which presented ideas, concepts and viewpoints across multiple domains. For example, diagrams and early-stage mockups were created to visually represent some complex algorithms behind the core engines of some 3D Tune-In software applications. These design artifacts helped translating technical knowledge in acoustics and computer science into visual formats that (1) could be more easily disseminated to the wider public and (2) be appreciated also by people without a strong technical background. In 3D Tune-In, a variety of knowledge translation processes has been carried out where specialized, scientific, technical knowledge has been reformulated for layperson across various formats such as written summaries, visual diagrams, motion graphics videos and prototypes.

The potential of design artefacts to support translational processes among stakeholders speaking different languages and having different needs and wants has been already explored in literature, for example in relation to contexts such as academic entrepreneurship and open innovation (Simeone, Secundo, & Schiuma, 2017a, 2017c). However, the potential of design to support knowledge translation in healthcare remains understudied. This paper intends to offer a contribution in this direction, by examining if design-based translational processes can support the calibration process of hearing devices and, if so, how. The next sections will further ground this research orientation into existing literature and will present some reflections based upon the authors' experience within 3D Tune-In.

2. Theoretical background

2.1. The calibration process for hearing devices

To properly calibrate their digital hearing device, people with hearing impairment need to undergo a fitting process with the help of an audiologist. After a preliminary calibration in the audiologist's studio, it is only when the patients wear their hearing device in real contexts of use (at home, at their work place, etc.) that they can realize whether some further calibration is needed. This process might need several weeks and several trips to the audiologist.

The challenges of calibration processes for the new-generation of digital hearing aids have been highlighted in scientific literature (Hickson & Meyer, 2014). The increasing complexity of the current digital devices is one of the issues: the devices offer a variety of functions that can be highly personalized in relation to both the specific audiological profile of the people with hearing impairment and to the real acoustic ecologies, i.e. the specificities of the context of use (Pichora-Fuller & Singh, 2006). Another important issue is related to the psycho-social factors tied to hearing loss (Knudsen, Öberg, Nielsen, Naylor, & Kramer, 2010): individuals with hearing impairment might experience difficulties in accepting and coping with hearing loss (Jerram & Purdy, 2001) or they can minimize or deny the problem, also because of the stigma they perceive as associated with hearing impairment (Meister, Walger, Brehmer, Wedel, & Wedel, 2008). An area of particular interest for this study is that self-efficacy - the level of confidence that an individual has in their ability to manage and adapt to using hearing aids - is one of the most important factors for successful hearing aid use (Hickson & Meyer, 2014). A good number of related studies point to the importance of providing individuals with hearing impairment with information, training, and counselling on how to directly manage and adapt their hearing devices and, consequently, increase self-efficacy (Bertoli et al., 2009; McCormack & Fortnum, 2013). While some authors previously focused on how design artifacts such as interactive videos can support the user in accessing knowledge helpful for the calibration process (Ferguson, Brandreth, Brassington, & Wharrad, 2015), a more systematic analysis of how design can increase the user's self-efficacy and support the various phases of this calibration process is still missing.

2.2. Knowledge translation and design

Knowledge needs to be translated in order for it to be interesting and relevant for a variety of audiences (Graham et al., 2006). Processes of knowledge translation are particularly important when an interaction occurs between service actors such as academia, industry and end-users (Grimshaw, Eccles, Lavis, Hill, & Squires, 2012), as it happens in 3D Tune-In.

Previous studies specifically explore design-based translation in relation to contexts such as academic entrepreneurship (Simeone, 2016), open innovation (Simeone et al., 2017c) or value creation in organizations that also use arts-based interventions (Simeone, Secundo, & Schiuma, 2017b). In these studies, we refer to design as a symbolic practice where the very act of designing, for example, a logo, a diagram, a prototype, a product or a service is a way to create meaning (Krippendorff, 2006). Design comprises a set of practices and methods – such as user research and user testing, rapid and frequent prototyping, visualization techniques, task-based scenario building, attention to the brand experience – which also mark a distinctive way of thinking, approaching, and solving problems (R. Buchanan, 2004). In a R&D project such as 3D Tune-In, typical outcomes of a design approach would be, for example, sketches, various visualizations (e.g., 3D renders, data visualizations, motion graphics animations and videos), and prototypes at various degree of refinement. The role of these design artifacts in supporting R&D development projects have been studied by various authors (Bogers & Horst, 2014; Gero, 1990; Leonard & Rayport, 1997; Rust, 2004, 2007). None of these authors, though, specifically focus on the construct of translation even though this concept is not new in design research. Some scholars employ the concept of translation when referring to translational processes among the languages of different design methods or techniques (Singh & Gu, 2012). Others adopt translation in another quite commonly used connotation, as to describe design processes and outcomes (such as sketches) in terms of "translation of ideas" (Leblebici-Başar & Altarriba, 2013; Lin, 2007; Yi-Luen Do, Gross, Neiman, & Zimring, 2000). The role of design in building brand value and product identity - also through semiotic processes of translation (e.g., translating the abstract core ideas behind a brand into a visually-designed identity) - is frequently praised (Borja de Mozota, 2003). These works tend to characterize the translation processes in terms of a linear and quasi-literary sense.

Other studies adopt translation in a more extended sense to describe situations where different stakeholders interact, often departing from concepts such as boundary objects that can "facilitate the translation mechanisms across different cultural configurations and contexts" (Star & Griesemer, 1989, p. 393) or from Actor Network Theory, where Michel Callon and Bruno Latour describe translation in these terms: "By translation we understand all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be conferred on itself, authority to speak or act on behalf of another actor or force" (Callon & Latour, 1981, p. 279). Other studies more particularly focus on how participation in design is tied to "problems of interpretation and translation of varying user and expert perspectives" (Reich, Konda, Monarch, Levy, & Subrahmanian, 1996, p. 177) and argue in favor of "increasing access to technical knowledge and its translation for equal participation in a dialectical process" (Reich et al., 1996, p. 174). Translation is seen as a complex process riddled with negotiations (Cooper, Bruce, Wootton, Hands, & Daly, 2003; Deni, 2015; Tomes, Oates, & Armstrong, 1998) wherein designers act as "intermediar(ies) between disparate ideas, viewpoints and even goals. Being able to translate in this manner is an essential precondition for being able to integrate many things" (Boyer, Cook, & Steinberg, 2011, p. 327).

2.3. Design for healthcare

Various authors have investigated how a design approach and design methods can be used in healthcare (Chamberlain, Wolstenholme, Dexter, & Seals, 2015; Tsekleves & Cooper, 2017). Some studies surveyed best practices in creating environments that enhance the quality of healthcare delivery with perspectives spanning from architecture (Anderzhon, Hughes, Judd, Kiyota, & Wijnties, 2012), to interior design (Marberry, 1997) and wayfinding (Miller & Lewis, 1998), all the way up to real estate design and management processes (Zwart, 2014).

Studies have also shown how within healthcare, design thinking and various design methods can support user research (Glasemann & Kanstrup, 2011), product development (Cheung, 2012) and innovative services (Bessant & Maher, 2009). Høiseth and Keitsch used phenomenological hermeneutics to gain understanding of stakeholders in healthcare contexts (Høiseth & Keitsch, 2015). Donetto et al. presented the Experience-based Co-design (EBCD) as a participatory research approach that builds upon design tools and ways of thinking to bring healthcare staff and patients together to improve the quality of care (Donetto, Pierri, Tsianakas, & Robert, 2015). Lee examined the design of ambulatory healthcare from a service design perspective (Lee, 2011). A variety of authors specifically focused on how human-centered design can be instrumental in developing information and communication technology for healthcare (Ballegaard, Hansen, & Kyng, 2008; Duarte & Guerra, 2012; Wildevuur & Dijk, 2011).

These are all important perspectives on the use of design in healthcare and, as such, are currently explored by dedicated labs and research groups (Reay et al., 2016)[2]. However, in spite of some preliminary attempts (Jones, 2013), comprehensive studies on how design can be used in relation to

---

[2] http://centerforinnovation.mayo.edu/design-in-health-care/
https://www.id.iit.edu/design-healthcare-certificate/
http://cfchd.org/

the specificities of various areas of healthcare are still missing (Bate & Robert, 2007). In the words of Koomans & Hilders:

> *as design thinking continues to evolve in its application for value creation, organizational change, and culture setting, the quest for value in healthcare has just begun: value-based healthcare as the foundation for patient-focused and outcome-driven value creation. Unfortunately, this process needs acceleration. We claim that it is necessary to adopt and learn from design thinking practices to identify meaning, purposeful thinking, and patient- oriented innovation (Koomans & Hilders, 2016, p. 43).*

The purpose of this study is to offer a contribution to the area of design for healthcare, by particularly focusing on translational processes supported by design.

3. Approach

The article is based on the case study approach (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Yin, 2009) wherein we examine the phenomenon with depth. Such an approach may be considered suitable for the exploratory nature of this research (Dell'era, 2010). Case studies enable the author to identify and analyze key insights which occur over time (Paré, 2004). This approach works especially well in situations where behaviorally-oriented questions regarding 'how' or 'why' are posed and when the focus of such a study is a contemporary phenomenon within a real-life context (Glaser & Strauss, 1967; Pettigrew, 1990; Yin, 2009) that is investigated using multiple sources of evidence (Robson, 2002). Case studies have been consistently and regularly used in organizational research for more than half a century (Berg, 1968) and more recently (Breslin & Buchanan, 2008; D. A. Buchanan, 2012). Researchers are also aware of the limitations of such a method (Dasgupta, 2015). In line with Yin's view (2009), a case study approach enables the researcher to accommodate single cases or situations with small numbers of experiences; to gather relevant, periodic feedback; to accommodate one's study to the presence of different types and forms of evidence; to review outcomes and experiment with new theories and challenge old theories; and to develop lessons which can be extrapolated to the some of the substantive themes within a domain.

Within the 3D Tune-In project, three separate stages for the involvement of end users and other stakeholders have been organized. The first stage focuses on participatory design, aiming therefore at engaging end-user stakeholders in the project, capturing stakeholder needs and requirements, and finally specifying the 3D Tune-In development requirements. This stage was based on semi-structured conversations and interviews with hearing aid users and audiologists, following both a bottom-up (e.g., incorporating end user characteristics, their scenarios of use and their requirements) and a top-down approach (e.g., considering the available hearing aid functionalities and the needs of the other stakeholders) for requirements generation. 18 hearing aid users were involved in this stage across UK, Spain and Italy. In addition, a questionnaire study was conducted with 20 audiologists to elicit information about processes and issues during the hearing aid selection phase with clients during sessions intended for adjusting these hearing aids.

The second stage focused on evaluations within the formative stage of development by adopting an iterative design to feed results into the technical development as soon as possible. The formative evaluation was divided into two separate stages, one in the middle of the project and one at the end of the third quarter. Two separate groups have been involved: experts and general stakeholders (adults and children, both with and without hearing aids, and audiologists). Considering the latter group, 93 subjects were involved in the two stages. Interviews were carried out with adult and children participants in UK, Spain and Italy. For hearing aid users, a short questionnaire was also administered to collect information about the type of hearing aid users wore; how well they could hear with a hearing aid; situations they find it difficult to hear in when wearing their hearing aid; and their use of digital games. The whole questionnaire took approximately 5 minutes to complete.

The final stage, a summative evaluation of the final outcomes of 3D Tune-In with regards to enhancing social inclusion in society and improving quality of life, is currently in progress and already produced preliminary results.

A target of 75 participants for each application has been set. This final summative evaluation stage aims at measuring the 3D Tune-In success by assessing engagement, acceptance, usability, attitudes towards the final applications and perceived usefulness of the apps by adult and child hearing aid users, audiologists and children without hearing loss. To assess these factors, we are considering the use of custom questionnaires, interviews, and standardised questionnaires (e.g. Speech Spatial Qualities questionnaire) as needed once the main functionalities in each app have been fully implemented.

Within all these stages, data has been mostly collected through ethnographically-inspired methods such as participant observation, semi-structured conversations, and archival research. Surveys, user testing sessions, and interviews with audiologists and individuals with hearing impairment have also been conducted in various moments of the project to validate the initial user requirements and two iterations of the software applications. Two of the authors were part of the 3D Tune-In consortium and had the chance to directly participate in these activities.

4. Findings

Within the course of 3D Tune-In, a variety of software applications were developed including 3D virtual environments and videogames with hearing aid and hearing loss simulators (Levtov, Picinali, D'Cruz, & Simeone, 2016; Picinali, D'Cruz, & Simeone, 2015). By using the core audio engine developed within the project, named the 3D Tune-In Toolkit (Cuevas-Rodriguez et al., 2017), developers can create applications/videogames which allow users to test various functionalities of their hearing aids and to calibrate them within simulated environments that recall real world situations (e.g. at a concert, in a restaurant, on a street, at a train station, in a classroom). Although high-end models of hearing aid devices allow people to calibrate their devices directly through a connected mobile application, the 3D Tune-In Toolkit mostly operates using a hearing aid simulator within 3D virtual environments. Key characteristics of the 3D Tune-In Toolkit are:

Audio spatialisation. This allows the positioning of virtual sound sources around the listener, emulating different distances and different environmental acoustic characteristics. The spatialisation can be performed for devices other than hearing aids, such as headphones (employing the binaural technique) and loudspeakers.

Hearing loss simulator. A given hearing loss can be then simulated within the virtual environment, causing the listener to hear sounds filtered through the hearing loss model. This includes dynamic equalization, multi-band compression/expansion, non-linear distortion, and degradation of temporal and spatial resolution.

Hearing aid simulator. The emulation of a hearing aid can be then added at the end of the processing chain. This includes functions such as selective amplification, high/low pass filters, dynamic equalization, directional processing, dynamic range compression/expansion, and signal re-quantisation.

Applications developed using the Toolkit allow the users to calibrate functions such as directivity (e.g., the hearing aid amplifies more sounds from the front rather than from the back), tone control (high, mid and low frequencies), compression (amount, attack and release), noise control, etc. The 3D Tune-In Users are generally not familiar with this medical and technical knowledge. A series of design artifacts in 3D Tune-In helped the user in better understanding by translating this medical and technical knowledge into formats that could be more easily understood and appreciated. Such artifacts include:

- Sketches, visual diagrams, infographics representations, motion graphic videos (Figure 1)

- Impactful and easy-to-use interactive interfaces where patients (and their relatives and, more broadly, people not suffering from hearing loss) could play with various acoustic parameters and see in real-time how their hearing changes
- Videogames where users were immersed in designed 3D simulated environments where both hearing loss and virtual hearing aids are implemented and can be calibrated (Figure 2)

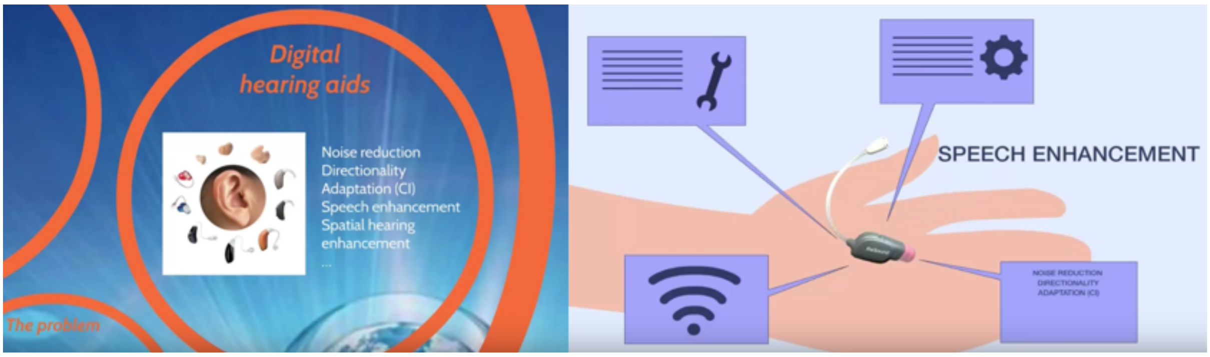

Figure 1 Still frames from motion graphics videos created by 3D Tune-In, where key technological and acoustic concepts are translated into cinematic sequences

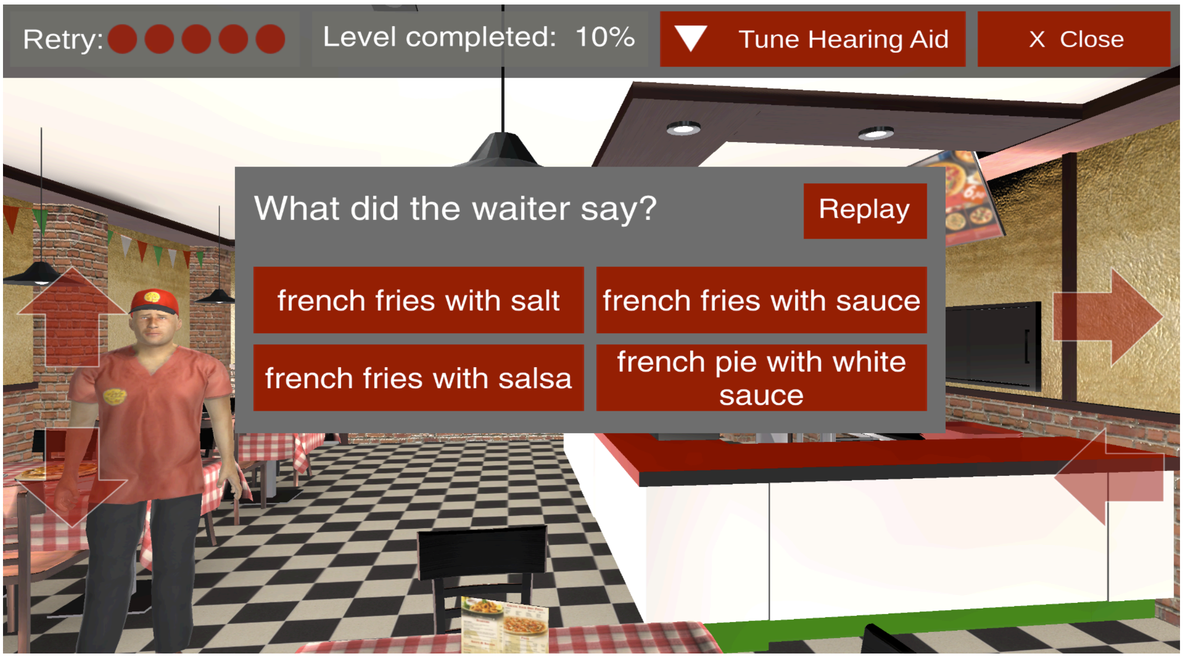

Figure 2 Virtual environment where users have to perform some hearing-related tasks in various contexts (restaurants, noisy street, living room). Users also have to calibrate a virtual hearing aid in these different conditions of use.

Figure 1 shows an example of a design-based translational process where knowledge related to key technological and acoustic features of hearing devices is translated across different semiotic systems: starting from the medical knowledge – as codified in the technical and scientific literature from which 3D Tune-In departed – into a cinematic sequence that worked as an external communication material that also speaks to non-expert and non-academic target audiences.

The 3D environments such as the one represented in Figure 2 go a step further. The translational process here still starts from quite technical knowledge (e.g., how to calibrate various functions of the hearing device in different conditions of use) and goes across semiotic shifts as to become a material re-adaptation, i.e. a gamified virtual environment where the user is immersed into and is asked to perform activities such as guessing the right word, locating a sound source or modifying the directionality of her virtual hearing aid. These virtual environments simulate either typical daily life situations (e.g., talking to a friend while sitting at a restaurant or while walking in a noisy street) or unusual and magical situations (e.g., talking to a flying wizard in a magic garden). A variety of environments and game goals, increasing levels of difficulties while progressing the game and a scoring system as a reward mechanism are the mechanics behind the user engagement.

The translational process here goes beyond the intent to better communicate or disseminate. The latter could, potentially, also be done by simply paraphrasing or re-writing medical or technical knowledge in a simplified form as to be better understood by layperson. Conversely, the specific role of design in 3D Tune-In is that translational processes are strictly grounded into what the semiotician Umberto Eco would term as variation of 'matter' (Eco, 2003), where a certain specialized knowledge in audiology - typically codified into written or spoken words - is translated across multimodal semiotic systems (visual, auditory, graphic, tactile) as to engage the audience in an immersive and actionable environment. A constant use of various forms of design (including graphics, motion graphics, interaction design, and service design) is what allowed a continuous material articulation and re-adaptation of project results in a way that individuals with hearing impairment could better understand and appreciate as strictly tied to their medical needs.

5. Discussion and conclusions

At the moment of writing, 3D Tune-In is still carrying out an extensive summative evaluation that involves individuals with hearing impairment, their families and audiologists. Preliminary results show that design-based knowledge translation supported various phases of the calibration process (Table 1).

Table 1. Phases of the calibration process for hearing devices and role of design-based knowledge translation

Phases	What happens in this phase	How design-based knowledge translation supported this phase
Diagnosis	Health impairments (e.g., difficulty in hearing in specific situations) motivate the patients to understand certain fundamentals about their condition. Typically, patients meet the audiologist and have hearing tests. *Challenges for this phase*: the patients might not have the same medical knowledge as the audiologists. Their meetings can be troubled by differences in language and vocabulary.	Specialized medical knowledge was translated into diagrams and motion graphics videos and embodied into specific software applications for patients and their families as to allow them to grasp the meaning of basic audiology vocabulary and, consequently, better interact with the audiologist.
Choice of the device and preliminary fitting	Once the problem has been identified, a hearing device must be chosen and calibrated. The patient is generally guided by the audiologist in the choice of a hearing device. The preliminary fitting (initial calibration of the hearing device in relation to the specific hearing problems of the patient) is performed by the audiologist in his or her studio. *Challenges for this phase*: a variety of hearing devices are available in the market and they generally have differences in technical features and costs. Understanding these different technical features (e.g., different algorithms for noise reduction) can be quite difficult for the patient.	3D Tune-In developed a virtual environment where the users can experiment with a virtual hearing device and related key sound parameters. This specific process was oriented towards translating medical conceptual models of how hearing works into a virtual environment where the individuals with hearing impairment and their families could directly experiment with various acoustic parameters and form their own (simplified) conceptual model of how these parameters influence hearing.
Finalization of fitting	After the preliminary fitting, the patient goes back home and starts wearing their hearing aids in their daily life. By wearing their device in their typical environments (e.g., at work or in a noisy street), the	The 3D Tune-In virtual hearing aid was also used to create videogames. Individuals with hearing impairment and their

	patients may realize that the preliminary calibration needs to be tweaked. The patient typically goes back to the audiologist and reports problems and the audiologist performs the calibration. The entire process might need the patient to go back to the audiologist several times. *Challenges for this phase*: while wearing the hearing device in real contexts of use, the patients might feel that there is still something to tweak, but they do not generally have the working vocabulary to precisely report to the audiologist (e.g., a patient would rarely be able to report a problem with the directivity while listening to a female voice in a restaurant with high pitched background noise). At the same time, the audiologist might feel frustrated because they cannot grasp what exactly the patient needs.	families were asked to enter different virtual 3D environments with different sound conditions (noisy streets, restaurants, concert halls) and perform some calibration actions. The design was intended to further enrich the (simplified) conceptual model that a non-professional has in relation to how hearing works and to equip the individuals with hearing impairment with a richer vocabulary to interact with the audiologist. Typically, in this phase, users would understand the benefits of changing the calibration of their device in relation to the environments in which they typically live.
Continuous calibration of the hearing device	After the fitting is finalized (i.e., the hearing device is calibrated in relation to the specific needs of the patient), the patient will still need to periodically recalibrate the device. The new-generation devices can be continuously recalibrated by the patient in relation to specific contexts of use (e.g., the patients can change some parameters when they go to a concert, or when they are in a particularly noisy room and want to hear the voice of a speaker in front of them). *Challenges for this phase*: this continuous calibration should be performed autonomously by the patient. This means that the patient should be in the condition of understanding key parameters that can be calibrated and have some basics notions of acoustics. Moreover, user interfaces of hearing devices might not always be user-friendly.	For this final stage, as already described for Figure 2, a variety of videogames were developed to show people with hearing impairments that a continuous recalibration of the hearing device is needed in relation to different sound environments. This calibration can be done also autonomously and without the continuous support of the audiologist even in spite of complex user interfaces.

Table 1 illustrates how various design artifacts supported knowledge translation in a way that helped individuals with hearing impairment to better understand the calibration process while acquiring a minimal but practical vocabulary to communicate with the audiologist. In particular, what the audiologists have historically lacked is clear information on what happens when people with hearing impairment go back to their life after the calibration of the hearing devices in the audiologists' studio. How can this preliminary calibration be better tuned keeping in mind the specificities of the sound environments experienced by individuals with hearing impairment (e.g., specific work or leisure environments, specific areas of the city, etc.)?

Until now, this process has been troubled by knowledge gaps. For example, the individual with hearing impairment can sense that when she sits at the restaurants there is something that needs to be tweaked on her hearing device, but she cannot explain exactly what. She cannot describe the acoustic characteristics of the restaurant either. Processes of knowledge translations such as the ones supported by the design artefacts of 3D Tune-In can not only provide the individuals with hearing impairment and their families with a vocabulary to better understand how to describe the nuances of acoustic processes and report to the audiologists. Knowledge translation can also put the people with hearing impairment in the conditions to know how to directly and autonomously recalibrate their devices in the very moment in which these devices are used in specific contexts and sound environments. Early results from workshops and testing sessions show how individuals with hearing impairment felt an increased self-efficacy, a greater level of confidence that they could manage and adapt their hearing devices on the go and according to the specificities of the moment.

Currently, the process of calibration is mostly anchored to the studio of the audiologist as a pivotal element. Increasing the self-efficacy of hearing aids users means putting them in the condition to manage their hearing devices with a different level of granularity. We see this as a fine-grained and more contextually-anchored calibration process where patients feel empowered to operate with a higher degree of independence.

The case of 3D Tune-In shows how this self-efficacy and more granular management of hearing device was supported by processes of knowledge translation. In these processes, design was used to create a variety of artefacts, which could be easily circulated (e.g., diagrams), understood and appreciated (e.g., motion graphics videos) and which could immerse the individuals with hearing impairment and their family into emotionally and cognitively engaging virtual environments (e.g., simulators and videogames).

All this comes with some challenges, which are currently emerging when the audiologists use the 3D Tune-In apps. In particular, some of these audiologists are worried that the individuals with hearing impairment might feel that they do not need their professional support for the calibration process. These audiologists are convinced that a constant communication between patient and the professional remains a central element of the calibration process: increasing the self-efficacy of the individuals with hearing impairment might change established dynamics and put at risk validated medical protocols. In a way, the knowledge translation processes activated by 3D Tune-In might challenge the conventional power relations and the authority of the audiologist, echoing Callon and Latour's points about power dynamics and negotiations in the act of translation (Callon & Latour, 1981).

At this stage, all this remains an open area of investigation, which will be further explored in the next months when the summative evaluation of 3D Tune-In comes to an end.

Acknowledgements: The research leading to this contribution has received funding from the European Community's H2020 Programme under Grant Agreement No. 644051. This article reflects the authors' views. The European Commission is not liable for any use that may be made of the information contained therein.

6. References

Anderzhon, J. W., Hughes, D., Judd, S., Kiyota, E., & Wijnties, M. (2012). *Design for Aging: International Case Studies of Building and Program*. Hoboken, N.J: John Wiley & Sons.

Ballegaard, S. A., Hansen, T. R., & Kyng, M. (2008). Healthcare in Everyday Life: Designing Healthcare Services for Daily Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1807–1816). New York, NY, USA: ACM. https://doi.org/10.1145/1357054.1357336

Bate, P., & Robert, G. (2007). *Bringing User Experience to Healthcare Improvement: The Concepts, Methods and Practices of Experience-Based Design*. Oxford: Radcliffe.

Berg, C. (1968). Case Studies in Organizational Research and Education. *Acta Sociologica*, *11*(1/2), 1–11.

Bertoli, S., Staehelin, K., Zemp, E., Schindler, C., Bodmer, D., & Probst, R. (2009). Survey on hearing aid use and satisfaction in Switzerland and their determinants. *International Journal of Audiology*, *48*(4), 183–195. https://doi.org/10.1080/14992020802572627

Bessant, J., & Maher, L. (2009). Developing radical service innovations in healthcare—the role of design methods. *International Journal of Innovation Management*, *13*(4), 555–568.
Bogers, M., & Horst, W. (2014). Collaborative Prototyping: Cross-Fertilization of Knowledge in Prototype-Driven Problem Solving. *Journal of Product Innovation Management*, *31*(4), 744–764. https://doi.org/10.1111/jpim.12121
Borja de Mozota, B. (2003). *Design Management: Using Design to Build Brand Value and Corporate Innovation*. New York: Allworth Press.
Boyer, B., Cook, J. W., & Steinberg, M. (2011). *Recipes for Systemic Change*. Helsinki (Finland): Sitra / Helsinki Design Lab.
Breslin, M., & Buchanan, R. (2008). On the case study method of research and teaching in design. *Design Issues*, *24*(1), 36–40.
Buchanan, D. A. (2012). Case studies in organizational research. In G. Symon & C. Cassell (Eds.), *The Practice of Qualitative Organizational Research: Core Methods and Current Challenges* (pp. 373–392). London: SAGE Publications.
Buchanan, R. (2004). Management and design. In R. J. Boland & F. Collopy (Eds.), *Managing as Designing* (1st ed., pp. 54–63). Stanford, Ca.: Stanford University Press.
Callon, M., & Latour, B. (1981). Unscrewing the big Leviathan: how actors macro-structure reality and how sociologists help them to do so. In K. Knorr-Cetina & A. V. Cicourel, *Advances in social theory and methodology* (pp. 277–303). Boston, London and Henley: Routledge & Kegan Paul.
Chamberlain, P., Wolstenholme, D., Dexter, M., & Seals, L. (2015). *The state of the art of design theory and practice in health: an expert-led review of the extent of the art and design theory and practice in health and social care*. Sheffield: Sheffield Hallam University. Retrieved from http://shura.shu.ac.uk/10634/
Cheung, M. (2012). Design Thinking in Healthcare: Innovative Product Development through the iNPD Process. *The Design Journal*, *15*(3), 299–324. https://doi.org/10.2752/175630612X13330186684114
Cooper, R., Bruce, M., Wootton, A., Hands, D., & Daly, L. (2003). Managing design in the extended enterprise. *Building Research & Information*, *31*(5), 367–378. https://doi.org/10.1080/0961321032000107555
Cuevas-Rodriguez, M., Gonzalez-Toledo, D., de La Rubia-Buestas, E., Garre, C., Molina-Tanco, L., Reyes-Lecuona, A., … Picinali, L. (2017). An open-source audio renderer for 3D audio with hearing loss and hearing aid simulations. In *Audio Engineering Society Convention 142*. Audio Engineering Society. Retrieved from http://www.aes.org/e-lib/browse.cfm?elib=18650
Dasgupta, M. (2015). Exploring the Relevance of Case Study Research. *Vision: The Journal of Business Perspective*, *19*(2), 147–160. https://doi.org/10.1177/0972262915575661
Dell'era, C. (2010). Art for Business: Creating Competitive Advantage through Cultural Projects. *Industry & Innovation*, *17*(1), 71–89. https://doi.org/10.1080/13662710903573844
Deni, M. (2015). For a history of semiotics of design. In *Proceedings of 11th European Academy of Design Conference*. Paris.
Donetto, S., Pierri, P., Tsianakas, V., & Robert, G. (2015). Experience-based Co-design and Healthcare Improvement: Realizing Participatory Design in the Public Sector. *The Design Journal*, *18*(2), 227–248. https://doi.org/10.2752/175630615X14212498964312
Duarte, J., & Guerra, A. (2012). User-Centered Healthcare Design. *Procedia Computer Science*, *14*, 189–197. https://doi.org/10.1016/j.procs.2012.10.022
Eastgate, R., Picinali, L., Patel, H., & D'Cruz, M. (2016). 3D Games for Tuning and Learning About Hearing Aids. *The Hearing Journal*, *69*(4), 30. https://doi.org/10.1097/01.HJ.0000481810.74569.d8
Eco, U. (2003). *Mouse or Rat: Translation as Negotiation*. London: Weidenfeld & Nicolson.
Eisenhardt, K. M. (1989). Building Theories From Case Study Research. *The Academy of Management Review*, *14*(4), 532–550.
Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25–32.
Ferguson, M., Brandreth, M., Brassington, W., & Wharrad, H. (2015). Information Retention and Overload in First-Time Hearing Aid Users: An Interactive Multimedia Educational Solution. *American Journal of Audiology*, *24*(3), 329–332. https://doi.org/10.1044/2015_AJA-14-0088
Gero, J. S. (1990). Design Prototypes: A Knowledge Representation Schema for Design. *AI Magazine*, *11*(4), 26–36. https://doi.org/10.1609/aimag.v11i4.854
Glasemann, M., & Kanstrup, A. M. (2011). Emotions on diabetes: a design case of user mock-ups by young people living with diabetes. *CoDesign*, *7*(2), 123–130. https://doi.org/10.1080/15710882.2011.609894
Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. London: Wiedenfeld and Nicholson.

Graham, I. D., Logan, J., Harrison, M. B., Straus, S. E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in knowledge translation: Time for a map? *Journal of Continuing Education in the Health Professions*, *26*(1), 13–24. https://doi.org/10.1002/chp.47

Grimshaw, J. M., Eccles, M. P., Lavis, J. N., Hill, S. J., & Squires, J. E. (2012). Knowledge translation of research findings. *Implementation Science*, *7*(1). https://doi.org/10.1186/1748-5908-7-50

Hickson, L., & Meyer, C. (2014). Improving uptake and outcomes of hearing aid fitting for older adults: What are the barriers and facilitators? *International Journal of Audiology*, *53*(sup1), S1–S2. https://doi.org/10.3109/14992027.2013.875265

Høiseth, M., & Keitsch, M. M. (2015). Using phenomenological hermeneutics to gain understanding of stakeholders in healthcare contexts. *International Journal of Design*, *9*(3). Retrieved from http://search.proquest.com/openview/d3d0b6c534a084df09b2ee8925d02ce6/1?pq-origsite=gscholar&cbl=466416

Jerram, J. C., & Purdy, S. C. (2001). Technology, expectations, and adjustment to hearing loss: predictors of hearing aid outcome. *Journal of the American Academy of Audiology*, *12*(2), 64–79.

Jones, P. (2013). *Design for Care: Innovating Healthcare Experience*. New York: Rosenfeld Media.

Knudsen, L. V., Öberg, M., Nielsen, C., Naylor, G., & Kramer, S. E. (2010). Factors Influencing Help Seeking, Hearing Aid Uptake, Hearing Aid Use and Satisfaction With Hearing Aids: A Review of the Literature. *Trends in Amplification*, *14*(3), 127–154. https://doi.org/10.1177/1084713810385712

Koomans, M., & Hilders, C. (2016). Design-Driven Leadership for Value Innovation in Healthcare. *Design Management Journal*, *11*(1), 43–57. https://doi.org/10.1111/dmj.12031

Krippendorff, K. (2006). *Semantic turn: new foundations for design*. Boca Raton, FL: CRC Taylor and Francis.

Leblebici-Başar, D., & Altarriba, J. (2013). The Role of Imagery and Emotion in the Translation of Concepts into Product Form. *The Design Journal*, *16*(3), 295–314. https://doi.org/10.2752/175630613X13660502571787

Lee, S. (2011). Evaluating serviceability of healthcare servicescapes: Service design perspective. *International Journal of Design*, *5*(2). Retrieved from http://search.proquest.com/openview/e4d74962d04fb45673385416b2cbc2b5/1?pq-origsite=gscholar&cbl=466416

Leonard, D., & Rayport, J. F. (1997). Spark Innovation Through Empathic Design. *Harvard Business Review*, *75*(6), 102–113.

Levtov, Y., Picinali, L., D'Cruz, M., & Simeone, L. (2016). 3D Tune-In: The Use of 3D Sound and Gamification to Aid Better Adoption of Hearing Aid Technologies. In *Audio Engineering Society Convention 140*. Audio Engineering Society. Retrieved from http://www.aes.org/e-lib/browse.cfm?elib=18172

Lin, R.-T. (2007). Transforming Taiwan aboriginal cultural features into modern product design: A case study of a cross-cultural product design model. *International Journal of Design*, *1*(2), 45–53.

Marberry, S. O. (Ed.). (1997). *Healthcare Design*. New York: John Wiley & Sons.

McCormack, A., & Fortnum, H. (2013). Why do people fitted with hearing aids not wear them? *International Journal of Audiology*, *52*(5), 360–368. https://doi.org/10.3109/14992027.2013.769066

Meister, H., Walger, M., Brehmer, D., Wedel, U.-C. von, & Wedel, H. von. (2008). The relationship between pre-fitting expectations and willingness to use hearing aids. *International Journal of Audiology*, *47*(4), 153–159. https://doi.org/10.1080/14992020701843111

Miller, C., & Lewis, D. (1998). Wayfinding in complex healthcare environments. *Information Design Journal*, *9*(2), 129–160. https://doi.org/10.1075/idj.9.2-3.04mil

Paré, G. (2004). Investigating Information Systems with Positivist Case Research. *Communications of the Association for Information Systems*, *13*(1). Retrieved from http://aisel.aisnet.org/cais/vol13/iss1/18

Pettigrew, A. M. (1990). Longitudinal Field Research on Change: Theory and Practice. *Organization Science*, *1*(3), 267–292.

Pichora-Fuller, M. K., & Singh, G. (2006). Effects of Age on Auditory and Cognitive Processing: Implications for Hearing Aid Fitting and Audiologic Rehabilitation. *Trends in Amplification*, *10*(1), 29–59. https://doi.org/10.1177/108471380601000103

Picinali, L., D'Cruz, M., & Simeone, L. (2015). 3D-Tune-In: 3D sound, visuals and gamification to facilitate the use of hearing aids. In *Proceedings of EuroVR*. Lecco, Italy.

Reay, S., Collier, G., Kennedy-Good, J., Old, A., Douglas, R., & Bill, A. (2016). Designing the future of healthcare together: prototyping a hospital co-design space. *CoDesign*, *0*(0), 1–18. https://doi.org/10.1080/15710882.2016.1160127

Reich, Y., Konda, S. L., Monarch, I. A., Levy, S. N., & Subrahmanian, E. (1996). Varieties and issues of participation and design. *Design Studies*, *17*(2), 165–180.

Robson, C. (2002). *Real World Research* (2nd edn). Oxford: Blackwell Publishers.

Rust, C. (2004). Design enquiry: Tacit knowledge and invention in science. *Design Issues*, *20*(4), 76–85.
Rust, C. (2007). Unstated Contributions – How Artistic Inquiry Can Inform Interdisciplinary Research. *International Journal of Design*, *1*(3), 69–76.
Simeone, L. (2016). *Design Moves. Translational Processes and Academic Entrepreneurship in Design Labs*. Malmö University, Malmö, Sweden. Retrieved from https://dspace.mah.se/handle/2043/21426
Simeone, L., Secundo, G., & Schiuma, G. (2017a). Adopting a design approach to translate needs and interests of stakeholders in academic entrepreneurship: The MIT Senseable City Lab case. *Technovation*, *64*, 58–67. https://doi.org/10.1016/j.technovation.2016.12.001
Simeone, L., Secundo, G., & Schiuma, G. (2017b). Arts and design as translational mechanisms for academic entrepreneurship: The metaLAB at Harvard case study. *Journal of Business Research*. https://doi.org/10.1016/j.jbusres.2017.10.021
Simeone, L., Secundo, G., & Schiuma, G. (2017c). Knowledge translation mechanisms in open innovation: The role of design in R & D projects. *Journal of Knowledge Management*, *21*(6), 1406–1429. https://doi.org/10.1108/JKM-10-2016-0432
Singh, V., & Gu, N. (2012). Towards an integrated generative design framework. *Design Studies*, *33*(2), 185–207. https://doi.org/10.1016/j.destud.2011.06.001
Star, S. L., & Griesemer, J. R. (1989). Institutional Ecology, “Translations” and Boundary Objects: Amateurs and Professionals in Berkeley’s Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.
Tomes, A., Oates, C., & Armstrong, P. (1998). Talking design: negotiating the verbal–visual translation. *Design Studies*, *19*(2), 127–142. https://doi.org/10.1016/S0142-694X(97)00027-6
Tsekleves, E., & Cooper, R. (Eds.). (2017). *Design for Health*. London; New York: Routledge.
Wildevuur, S. E., & Dijk, D. van. (2011). Scottie: design for social connectedness in healthcare. *CoDesign*, *7*(2), 131–138. https://doi.org/10.1080/15710882.2011.609892
Yi-Luen Do, E., Gross, M. D., Neiman, B., & Zimring, C. (2000). Intentions in and relations among design drawings. *Design Studies*, *21*(5), 483–503. https://doi.org/10.1016/S0142-694X(00)00020-X
Yin, R. K. (2009). *Case study research: design and methods. Fourth Edition.* Thousand Oaks: Sage.
Zwart, J. van der. (2014). *Building for a better hospital: value-adding management & design of healthcare real estate*. Delft, the Netherlands: TU Delft.

About the Authors:

Luca Simeone: My work is situated at the intersection of design practice, research and entrepreneurship. I have founded the design agency Vianet and conducted research activities at universities such as Harvard, MIT and Malmö University. I am currently affiliated with Aalborg University.

Lorenzo Picinali: I am a Senior Lecturer in Audio Experience Design in the Dyson School of Design Engineering at Imperial College London. My research interests include 3D sound rendering, audiology and hearing aids, and, more in general, acoustic virtual and augmented reality.

Alisan Atvur: I am a design researcher who focuses on healthcare user experiences. I am also a research advisor for the Copenhagen Institute of Neurocreativity and a regular guest editor of Touchpoint – The Journal of Service Design.