Research Article

User-Innovated eHealth Solutions for Service Delivery to Older Persons With Hearing Impairment

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Purpose: The successful design and innovation of eHealth solutions directly involve end users in the process to seek a better understanding of their needs. This article presents user-innovated eHealth solutions targeting older persons with hearing impairment. Our research question was: What are the key users' needs, expectations, and visions within future hearing rehabilitation service delivery?

Method: We applied a participatory design approach to facilitate the design of future eHealth solutions via focus groups. We involved older persons with hearing impairment ($n = 36$), significant others ($n = 10$), and audiologists ($n = 8$) following 2 methods: (a) human-centered design for interactive systems and (b) user innovation management. Through 3 rounds of focus groups, we facilitated a process progressing from insights and visions for requirements (Phase 1), to app such as paper version wireframes (Phase 2), and to digital prototypes envisioning future eHealth solutions (Phase 3). Each focus group was video-recorded and

photographed, resulting in a rich data set that was analyzed through inductive thematic analysis.

Results: The results are presented via (a) a storyboard envisioning future client journeys, (b) 3 key themes for future eHealth solutions, (c) 4 levels of interest and willingness to invest time and effort in digital solutions, and (d) 2 technical savviness types and their different preferences for rehabilitation strategies.

Conclusions: Future eHealth solutions must offer personalized rehabilitation strategies that are appropriate for every person with hearing impairment and their level of technical savviness. Thus, a central requirement is anchoring of digital support in the clients' everyday life situations by facilitating easy access to personalized information, communication, and learning milieus. Moreover, the participants' visions for eHealth solutions call for providing both traditional analogue and digital services.

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Hearing impairment (HI) is a chronic health condition, such as diabetes or arthritis, requiring ongoing rehabilitation and daily self-management. The service delivery for hearing rehabilitation is currently

under pressure. First, there is a short supply of audiologists (AUDs) worldwide (Mulwafu, Ensink, Kuper, & Fagan, 2017; Windmill & Freeman, 2013) and limited AUD's time available per person with hearing impairment (PHI). Second, the population worldwide is aging, and thus, the prevalence of chronic health conditions such as HI is increasing (Vos et al., 2015). This results in rising hearing care costs and threatens future availability of hearing rehabilitation (Vos et al., 2015). Third, there is increasing demand for health care services that support the "4 Ps": (a) *personalized* on-demand service, (b) *predictive* service through health analytics, (c) *preventive* service through monitoring, and (d) *participatory* and empowering service enabling self-management to save on health care costs and resources (Hood & Friend, 2011).

Unfortunately, current health care services lack support for the 4 Ps, which has resulted in little active participation by patients in the health care process (Pryce,

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Hall, Laplante-Lévesque, & Clark, 2016; Rolfe & Gardner, 2016). Most eHealth applications are developed from the basis of technological opportunity rather than user needs and expectations and are tested in pilot studies, demonstrating technical feasibility, but then stored on a shelf, never to be used again (Wyatt, 2005). eHealth research has identified the importance of co-design with relevant end users for improving requirement analysis and grasping the complexity of patient-centered solutions enabling self-management (Carroll & Richardson, 2016).

eHealth: Promises Within Audiology

The World Health Organization (2016) describes eHealth as:

The use of electronic means to deliver information, resources and services related to health. It covers many domains, including electronic health records, mobile health, and health analytics, among others. eHealth can put information in the right place at the right time, providing more services to a wider population and in a personalized manner.

eHealth has been proposed to improve access and cost-effectiveness of health care (World Health Organization, 2016). For example, increasing connectivity rates and smartphone use may improve hearing rehabilitation by enabling information and communication sharing outside the typical face-to-face session in the clinic (Clark & Swanepoel, 2014).

Connected health, using mobile health through applications (apps) and smartphones, for instance, has the potential to place the clients in the center of their own health care rather than as passive recipients of health care. Mobile health can link clients to health care providers and enable clients to monitor and manage their health conditions at home. Future technologies will allow clients to provide digital health inputs to health care providers (Qiang, Yamamichi, Hausman, & Miller, 2012). Such connected health applications in hearing health care could meet the 4 Ps in service delivery by enabling self-management and personalizing on-demand services by AUDs.

Participatory Design for eHealth in Audiology

Participatory design has been used for developing health information technology since the 1990s. Research in participatory design presents a broad variety of methods and techniques for engaging key stakeholders in design of future health information technology (Kanstrup, Madsen, Nøhr, Bygholm, & Bertelsen, 2017). Audiology research has also used participatory design to investigate different stages of the client journey. For example, Hanssen and Dahl involved AUDs and PHIs in the design of an interactive tabletop interface with pictures and sounds of listening environments to improve the communication between PHIs and AUDs during the hearing aid fitting process (Dahl & Hanssen, 2016; Hanssen & Dahl, 2016). Furthermore, the authors also investigated how the prototype shaped AUD-PHI interactions in experimental fitting

sessions. The results showed that the prototype encouraged an iterative PHI-driven approach and pace, stimulated context-specific feedback and follow-up questions to a larger extent than in traditional fitting sessions, and helped PHIs make sense of information on HI and treatment options. Both PHIs and AUDs saw that the solution was able to reduce the number of visits to the clinic.

Thorén et al. involved PHIs in an iterative development and usability testing of an online audiologic rehabilitation program consisting of weekly learning modules (Thorén, Pedersen, & Jørnæs, 2016). The study concluded that PHIs perceived advantages of the online program, such as the ability to do it from home in their own pace and the ability to study some aspects of HI in more depth. They appreciated being empowered on learnings about HI, and they especially appreciated testimonial videos from peers. Furthermore, the study observed the importance of how online rehabilitation content is presented, as it influences usability, and how a learning flow should be structured to be efficient.

Ferguson et al. developed a series of short interactive videos, or reusable learning objects (RLOs), covering both practical and psychosocial issues relevant to audiologic rehabilitation for first-time hearing aid users (Ferguson, Brandreth, Brassington, Leighton, & Wharrad, 2016; Ferguson, Leighton, Brandreth, & Wharrad, 2018). In the development of RLOs, the authors involved AUDs in a participatory design through a Delphi review, where they identified the key elements and topic areas for RLOs; this was followed by three workshops involving PHIs ($n = 32$) and AUDs ($n = 11$). The acceptability, usability, and adherence of RLOs were evaluated through a questionnaire. RLOs were evaluated in three postevaluation focus groups with PHIs and significant others (SOs). Furthermore, an iterative approach of reviewing and revising the RLOs was done by both PHIs and AUDs. The study concluded that RLOs provided valuable learning and educational support to first-time hearing aid users and could supplement clinical rehabilitation practice.

An eHealth Environment for Assisted Service Delivery of Hearing Rehabilitation

The connectivity of hearing aids to the Internet through a smartphone and Bluetooth enables new opportunities for eHealth solutions within hearing health care. An eHealth environment could enable data-driven hearing rehabilitation with easy and personalized information, learning, and communication exchange between PHIs and AUDs. For instance, PHIs could send real-time information. Ecological momentary assessment is a method for sampling an individual's real-time behavior and environment (Galvez et al., 2012). Ecological momentary assessment enables PHIs to monitor their hearing ability while in their own environment. It could empower PHIs in being active in their own hearing rehabilitation by enabling self-monitoring, self-evaluation of important listening situations, and self-management of their HI.

In this article, the eHealth solutions we aimed to co-design with AUDs, PHIs, and SOs are framed within the

described eHealth environment. We present a participatory design approach where end users of the final solutions are involved in the design process for the design of eHealth solutions within audiology. Through this participatory design, we aimed to design eHealth solutions not from technological opportunities but rather from the real needs and expectations of the end users. Personalized solutions would emphasize patient participation and self-management in future hearing rehabilitation service delivery. Our research question was: What are the key users' needs, expectations, and visions within future hearing rehabilitation service delivery?

Method

This study involved the key stakeholders in hearing rehabilitation: PHIs, SOs, and AUDs. SOs are allies in successful hearing care as HI affects verbal communication (Ekberg, Meyer, Scarinci, Grenness, & Hickson, 2015), and AUDs are the health care providers at the center of hearing rehabilitation.

We worked with a participatory design approach to ground technological innovation in the needs and expectations of its users. Our participatory design process followed the principles of International Organization for Standardization (ISO) standards for human-centered design for interactive systems (European Committee for Standardization, 2010) and applied principles and techniques from the user innovation management method (Kanstrup & Bertelsen, 2011). Central for these participatory approaches is that they aim to ground innovation of future technology understanding the target users and use situations. This is rooted in democratic ideals that people who will be affected by technology should also have the opportunity to shape the future by participating in forming future technology. It is also rooted in an ambition to improve the quality of future technology, acknowledging users as competent practitioners with valuable knowledge that can contribute to the quality of future technology.

Researchers and clinicians sometimes describe hearing rehabilitation as a series of steps arranged along a pathway, a process, a timeline, a journey, or a travel. This journey metaphor along which the patient travels frequently occurs in descriptions of health care pathways, especially in the context of chronic health conditions where a process toward self-management is put in place (Layton, Moss, & Morgan, 1998). However, adults with HI rarely describe clinical rehabilitation as a connected process or a journey (Laplante-Lévesque, Brännström, Andersson, & Lunner, 2012). For them, clinical interactions are isolated events rather than a series of connected steps contributing to an overall goal. Therefore, in this study, we chose to openly introduce the concept of hearing rehabilitation as a client journey or a travel to participants.

Four to six people participated in each focus group session together with two researchers as facilitators. Each focus group session lasted 2 hr. Table 1 and the following sections describe the three phases of our study.

Participants Recruitment and Demographics

In total, we recruited 36 PHIs, 10 SOs, and eight AUDs through online questionnaires to participate in the three rounds of focus groups (Phases 1–3). All three key stakeholder groups participated in the first round of focus groups (Phase 1) to frame insights and visions for future eHealth-assisted client journeys. Only PHIs participated in the last two rounds of focus groups (Phases 2 and 3), as the study aimed to design for this target group.

Recruitment focused on PHIs age 60+ years, SOs to these PHIs, and AUDs who could contribute to this innovative process. We focused on older PHIs as HI is an age-related chronic disease and, thus, most prevalent in the older population segment (Vos et al., 2015), and we wanted our participatory-designed eHealth solutions to have the highest impact on the population of PHIs. We included participants who had experienced the hearing aid client journey and wanted to contribute ideas and solutions to support others on this journey. Participants reported that they had an interest in technology, owned a smartphone, used apps on a regular basis (including health apps), and showed that they had the skills to complete an online recruitment questionnaire.

Exclusion criteria for PHIs were use of current hearing aids for more than 5 years and nonuse of hearing aids within the last month. We used purposive sampling to achieve maximum variation in the sample regarding age, gender, years of experience with hearing aids (PHIs) or practice as an AUD, hearing aid distribution channel (public/private/Eriksholm Research Centre) for both PHIs and AUDs, and job situation for PHIs (working at least 9 hr a week paid or unpaid or being retired). Enforcing these maximum variation criteria, we strived for extrapolation of the results to a typical hearing aid user population. We asked PHIs to provide their latest hearing test results. If results were older than 1 year, we performed a new hearing assessment. The SOs of the PHIs were only recruited if they had never tried or owned hearing aids, as to have no mix up of participant contribution to the innovation process. Table 2 presents detailed demographic information for the participants.

Despite an almost equal gender distribution of PHIs (see Table 2), female SOs outnumbered male SOs with only one male SO participating. All SOs, except for one niece, were spouses of PHIs. AUDs had a fair gender distribution and a wide range of years of practice (1.5–25 years). The PHIs had varying levels of years of experience with hearing aids, from being a new user (0.5 years) to having used hearing aids for most of their life (62 years). As seen in Table 2, 78% of the PHIs had an education level of 12 or more years, and 36.1% had used a private or public hearing aid distribution channel (i.e., not having received hearing aids through the Eriksholm Research Centre). Most PHIs had a slight or moderate HI, and five PHIs had a severe or profound HI. Twenty-eight percent (10) of the PHIs were still employed even though their mean age was 70.3 years.

All participants received information on the research and provided written informed consent prior to participating. Eriksholm Research Centre has ethical clearance for its

Table 1. Description of the participatory design processes and the involved participants.

Project phase	Participants (<i>n</i> = 54)	Design activities
Planning phase	Researchers	Online recruitment Purposive sampling for maximum variation Inclusion criteria based on innovation potential Client journey context chosen
Phase 1: First round of focus groups	4 groups of PHIs (<i>n</i> = 24) 2 groups of SOs (<i>n</i> = 10) 2 groups of AUDs (<i>n</i> = 8)	Specify user requirements in the client journey: Barriers in experienced client journey and visions Pack a future client journey suitcase of insights
Phase 2: Second round of focus groups	4 groups of PHIs (<i>n</i> = 23)	Produce design solutions: Sketch ideas from visions Transform ideas to app like paper wireframes Include action and sharing information Prioritize app functionalities
Phase 3: Third round of focus groups	4 groups of PHIs (<i>n</i> = 17)	Produce design solutions: More mature digital solutions Mock-up app with appetizers User interaction and alterations
After phase	Researchers	Evaluate the mock-up app to meet user requirements

Note. PHIs = persons with hearing impairment; SOs = significant others; AUD = audiologists.

research activities from the Committee for Health Research Ethics, Capital Region, Denmark. For more details on the participant recruitment and selection, see Kanstrup, Rotger-Griful, Laplante-Lévesque, and Cleveland-Nielsen (2017).

Data Analysis

The data consisted of video recordings of all focus groups and photographs of the materials that each focus group generated (e.g., wireframes and digital prototype alterations and suggestions). We conducted an inductive thematic analysis after each round of focus groups (Phases 1, 2, and 3) to identify, organize, and describe the data related to user innovation and design of eHealth solutions for hearing rehabilitation. Following the principles of inductive thematic analysis (Braun & Clarke, 2006; Kvale, 2007), we made a transcript of verbal utterances in the focus group conversations. These transcripts were analyzed through rereading of the conversations in a process where we first

identified themes in the participants' conversations and, second, labeled the identified themes with codes (i.e., thematic coding). Hence, our coding process focused on reading and coding semantic content. As a third step, we looked for patterns and relationships across the codes progressing to key themes that appeared in the different focus groups, themes that appeared across all focus groups, and themes that captured core elements of the participants' needs and requirements for successful hearing rehabilitation. The analysis was an iterative process of moving backward and forward between single themes and quotes and the entire video-recorded data set. The key themes were reviewed by authors A. C. N., S. R. G., and A. M. K., and suggested revisions were made. Photographs of produced materials from the focus groups (Phases 1, 2, and 3) were used in combination with the inductive thematic analysis to look for consistency in verbal utterances and decisions taken in the groups (e.g., participants' priorities of functionality, barriers).

Table 2. Demographic information on participants.

Participant group	Gender (female/male)	Age	Hearing aid usage (years)	Education level/practice (years)	Distribution channel (private/public/ERH)	Grade of hearing impairment and PTA	
						Grade	Grade in dB
PHI (<i>n</i> = 36)	16/20	70.3 (5.6; 61–81)	14.2 (14.8; 0.5–62)	9–11: 8 12–13: 18 > 13: 10	7/6/23	Slight: 11 Moderate: 20 Severe: 4 Profound: 1	L: 50.5 (15.2) R: 49.0 (13.9)
SO (<i>n</i> = 10)	9/1	64.9 (14.0; 31–76)	—	—	1/1/8	—	—
AUD (<i>n</i> = 8)	5/3	—	—	8.9 (8.2; 1.5–25)	2/6/0	—	—

Note. Mean values with standard deviations and ranges in parentheses are shown for the continuous data: age, hearing aid use in years, AUDs' years of practice, and PTA. Education level is shown as years of education and number of PHIs on that level and, for AUDs, number of years of practice. Distribution channel indicates private or public clinics or Eriksholm Research Centre test person (ERH) for SOs dependent of PHIs' distribution channel. Grades of hearing impairment (dB) are based on better ear PTA (0.5, 1.0, 2.0, and 4.0 kHz). Em dashes indicate data not available. PTA = pure-tone average; PHI = person with hearing impairment; L = left; R = right; SO = significant other; AUD = audiologist.

Phase 1: First Round of Focus Groups

Participants

In the first round of focus groups (Phase 1), we met with all key stakeholders: four groups of PHIs ($n = 24$), two groups of SOs ($n = 10$), and two groups of AUDs ($n = 8$).

Method

We met with all key stakeholders to identify via conversations insight, visions, and barriers of the current and future client journey (see Figure 1). First, we presented the current client journey as this was used as framework across the Phase 1 sessions (e.g., identify insights of different phases of the current client journey and visions for the future). The focus group activities enabled the participants to express themselves not only through self-reflection (e.g., individual card sorting) but also through group discussions. In the card sorting activities, participants were provided with some predefined cards in addition to blank cards to provide their own ideas. For more details on the methods followed on the first round of focus group, see Kanstrup, Rotger-Griful, et al. (2017).

Results

Results of the first round of focus groups (Phase 1) are described elsewhere (Kanstrup, Rotger-Griful, et al., 2017). In the following section, we summarize the findings from Phase 1 that were used to prepare for subsequent rounds of focus groups.

Key Stakeholders' Visions for Future eHealth-Assisted Client Journeys

The first round of focus groups identified the three key stakeholders' (PHIs, AUDs, and SOs) requirements for information, communication, and learning along the future client journey, as illustrated in Figure 2, the key stakeholders' envisioned eHealth-assisted future client journey. As visualized in Figure 2, we introduced four stages within the client journey: (1) prefitting (prepare), (2) fitting (departure), (3) follow-up (explore the new world), and (4) aftercare (established in the new world). The stakeholders described a motivation stage before the prefitting stage. In the motivation stage, the PHIs and SOs become aware of a possible HI, and the SO is often supportive in motivating the PHI to investigate a possible HI. All stakeholders described their requirements for every stage of the client journey.

PHIs desired personalized information delivery with the right timing of the information to their daily listening needs; timely on-demand communication with AUDs; and ongoing learning about hearing, hearing aids, new assistive technologies available, and self-management. The SOs expressed requirements for access to the same information as PHIs in the client journey and involvement in the hearing rehabilitation process. The AUDs desired efficient communication with PHIs and for greater empowerment of PHIs. AUDs wanted PHIs to take responsibility for their own HI rehabilitation to increase efficiency.

The PHI requirements for each stage of the client journey were as follows:

- Stage (1) Prefitting: to have access to trustworthy information and learning on HI and hearing aids from the Internet and to trustworthy HI tests.

Figure 1. First round of focus groups (Phase 1) on present and future client journeys (November 2016): two groups with audiologists, two groups with significant others, and four groups with persons with hearing impairment.

Figure 2. The hearing rehabilitation client journey that the key stakeholders (persons with hearing impairment, significant others, and audiologists) envisioned for the future.

- Stages (1) Prefitting and (2) Fitting: to share one's own description of hearing problems, personalized prefitting information, and rehabilitation expectations to AUDs, thus giving AUDs and PHIs insights for a personalized fitting session.
- Stages (3) Follow-up and (4) Aftercare: to receive personalized information and rehabilitation through eHealth solutions by facilitating rehabilitation through connected health.

All key stakeholder groups had design requirements on empowering the SOs on their close one's HI and rehabilitation for a more effective rehabilitation process. All key stakeholders suggested a digital solution where the SOs could experience the PHI's individual hearing loss by simulating the PHI's hearing loss and his or her need for communication strategies. Key stakeholders also suggested a digital solution that enables PHIs to train communication strategy, hearing aid use and maintenance, and so forth, in the first weeks after fitting. This training would empower PHIs and prepare them for self-management with ongoing self-monitoring, self-testing, and learning. For instance, they could follow their own development over time through self-evaluation and self-reported ratings of listening tests or important listening situations. PHIs also had a requirement for sending audio recordings on the fly to the AUDs to

access on-demand problem solving. As illustrated in Figure 2, some PHIs would prefer to fine-tune their hearing aids themselves, whereas others would prefer to visit the AUD or receive remote fine-tuning prescribed by the AUD.

Based on all the identified requirements, we selected three main concepts upon which we built the second round of focus groups (Phase 2): *My information*, *My hearing*, and *My development*. The developed future client journey was used in the subsequent focus groups sessions (Phases 2 and 3) to provide the desired contextualization for digital hearing rehabilitation. It allowed us to explore and sketch ideas that met the elicited user requirements.

Phase 2: Second Round of Focus Groups

Participants

In the second round of focus groups (Phase 2), we met with four groups of PHIs ($n = 23$). Not all PHIs that participated in the first round of focus groups (Phase 1) also participated in the second round (Phase 2). Seven PHIs were excluded because they provided little input during the first round of focus groups, and six PHIs could not participate in the second round because of schedule conflicts. Thus, a total of 13 new PHIs were recruited for this second phase following the same selection criteria as in Phase 1.

Although including only participants from the first round of focus group would have been an advantage, we prioritized involving innovative PHIs.

Method

In the second round of focus groups (Phase 2), we went from the visions for a future eHealth-assisted client journey identified in Phase 1 to co-design more concrete solutions for future eHealth solutions. Specifically, we obtained participants' feedback on large smartphone wireframes that were created based on the insights and visions of PHIs who were in the first round of focus groups. Smartphone wireframes are visual tangible artifacts, which, in this case, emulated the screen of an app. We encouraged individual self-reflection and group discussion about the wireframes, which included the envisioned functionality shown in Table 3.

We created a big wireframe for each of the main features in Table 3 (*My information*, *My hearing*, and *My development*). By use of cards and stickers, we engaged participants in reflection and discussion about priorities and opportunities for future eHealth solutions presented in the wireframes. The stickers included "share cards," naming the people with whom the information should be shared (e.g., AUD, SO, peer groups), and "action cards," describing which actions (e.g., contact AUD, think) they would take in the specific subfeature (see Table 3). Blank cards were also provided to motivate additional reflections. Figure 3 shows some of the PHIs of the focus groups interacting with the wireframes.

Results

Three Key Themes for Future eHealth Solutions Targeted Older PHIs

In the second round of focus groups (Phase 2), the PHIs prioritized their favorite eHealth solutions from the wireframes as follows: *My fine-tuning* (ID F2.5 in Table 3) where PHIs fine-tune their hearing aids themselves had top priority; followed by *Try my HI* (ID F2.2 in Table 3), where SOs could try their close one's HI; *My hearing tests* (ID F2.7 in Table 3), where PHIs could self-test their hearing over time; and *My development* (ID F2.9 in Table 3), where PHIs

could follow their self-rating of important listening situations or hearing test results over time. Even though *My fine-tuning* and *Try my HI* were prioritized highly by the PHIs, we chose not to include these eHealth solutions in the digital prototype of the third round of focus groups (Phase 3), as the solutions were already part of solutions commercially available at the time of the study.

Based on the analysis of the results in Phase 2, we identified three key themes to explore by means of a digital prototype in the last round of focus groups (Phase 3): (a) expectations for hearing rehabilitation, including information and reflections on one's own hearing abilities and rehabilitation needs; (b) learning and training with hearing aids; and (c) monitoring one's own hearing development.

Regarding the key theme on expectations related to IDs F2.1 and F2.2 in Table 3, the PHIs would use these eHealth solutions for ongoing reflection on their HI and rehabilitation. The PHIs emphasized willingness to share data with their SOs such as their hearing test results and tools, such as the speech banana, to explain the impact of hearing loss.

Regarding the key theme on learning and training related to IDs F2.3 and F2.4 to F2.6 in Table 3, the PHIs would use these solutions for ongoing learning. The digital solution should promote self-management and PHI empowerment. For example, it could provide tips and tricks for changing batteries.

The PHIs should be able to train on issues that are personally important to them, and they should be able to access help if needed. Solutions should include a possibility to share learnings and problems with SOs, AUDs, mentors, or a group of peers.

With regard to the key theme on following one's own hearing rehabilitation development related to IDs F2.7 to F2.9 in Table 3, the PHIs would use these for ongoing monitoring and analysis of their own development. The digital solutions should collect and display the PHIs' monitoring data over time (i.e., from tests and self-ratings). The PHIs would use the knowledge themselves for reflection, personal awareness, and empowerment in their rehabilitation process or share the data with AUDs, SOs, a mentor, or a group.

All the findings mentioned above were used to develop the digital prototype used in the last round of focus

Table 3. Envisioned functionality of the eHealth tool discussed in the second round of focus groups (Phase 2) by means of wireframes.

Main feature	Subfeature	ID	Description
My information	My expectations	F2.1	PHI's expectations on hearing rehabilitation
	Try my hearing loss	F2.2	SOs try spouses' HI and communication problems
	My tips and tricks	F2.3	Links to information
My hearing	My personal hearing coach	F2.4	Two weeks of training and empowerment
	My fine-tuning	F2.5	PHIs preferred fine-tuning
	My audiologist fine-tuning	F2.6	Remote fine-tuning based on PHI's audio input
My development	My hearing tests	F2.7	Regular self-testing and pushed reminders
	My log	F2.8	Self-rating of important listening situations
	My development	F2.9	Own development over time is visualized from data

Note. PHI = person with hearing impairment; SO = significant other; HI = hearing impairment.

Figure 3. Second round of focus groups (Phase 2) on visions for future eHealth solutions using wireframes (March 2017): four focus groups with persons with hearing impairment.

groups (Phase 3) to gather the PHIs' reactions to digital solutions that attempt to address these themes. For description and examples, please see Phase 3 below.

Phase 3: Third Round of Focus Groups

Participants

In the third round of focus groups (Phase 3), we met with four groups of PHIs ($n = 17$). All PHIs who participated in this last round of focus group also participated in at least one of the previous rounds' focus group (Phase 1 and/or 2). Participation on a previous focus group was important for the consistency in the design of the eHealth solution.

Method

In the third round of focus groups, the PHIs were presented with an interactive prototype (mock-up app) on an iPad exemplifying how the envisioned solutions developed in the previous rounds of focus groups (Phases 1 and 2) could look like. The digital prototype evolved around three main features identified in the previous phase: *My expectations*, *My personal coach*, and *My development*. Table 4 shows the main features of the mock-up app.

The interactive digital prototype gave participants appetizers of possible eHealth solutions for future hearing rehabilitation based on the results in Phases 1 and 2. The prototype was similar to an app, with many opportunities for the PHIs to interact with the prototype based on their experiences. Screenshots of the interactive digital prototype translated to English are available as Supplemental

Material S1: "App(etite) for life with hearing loss—Mock up app."¹ For example, the PHIs could play sounds above and below a hearing curve to illustrate hearing loss implications and expectations related to the main feature *My expectations* (described, e.g., in ID F3.1 in Table 4 and illustrated in Screenshots 5/21 or 7/21 in Supplemental Material S1). Related to *My personal coach*, they could watch video testimonials from other PHIs or videos on handling skills (IDs F3.5–F3.8 in Table 4 and Screenshots 9/21, 10/21, 12/21, and 13/21 in Supplemental Material S1). Related to *My development*, they could describe their hearing difficulties and developments (described in IDs F3.2, F3.3, F3.9, or F3.13 to F3.15 in Table 4 or illustrated in Screenshots 6/21, 19/21, to 21/21 in Supplemental Material S1). Through this approach, we intended to evaluate, further co-design, and innovate future eHealth solutions with the PHIs and pinpoint the most essential features in designing future digital eHealth solutions.

In each focus group, we presented each main feature according to Table 4 and its subfeatures one at a time in plenum and gave instructions on how to navigate the digital prototype. The PHIs then used the digital prototype themselves on an individual iPad, one feature at a time. As Figure 4 illustrates, the participants wore headsets to hear the audio provided in the digital prototype. They had opportunities to reflect on the prototype, prioritize features, suggest new ideas, and comment on lacking content and actions. They took notes on their individual digital prototype flowchart followed by a group discussion.

¹Supplemental Material S1 for this article is available online at <https://doi.org/10.23641/asha.7310729>.

Table 4. Functionality of the eHealth prototype discussed in the third round of focus groups (Phase 3) by means of mock-up app in an iPad.

Main feature	Subfeature	ID	Description
My expectations	My hearing	F3.1	Personal hearing curves, the speech banana, and so forth
	My important listening situations	F3.2	Tick off and send to AUD or the cloud
	My listening preferences	F3.3	Try out sounds and send preferred sounds to the AUD or the cloud
My personal coach	My training configurations	F3.4	Training schedules
	Tips & tricks	F3.5	Video on handling hearing aids
	Tasks	F3.6	Listening to surroundings and report back to AUD
	Reading material	F3.7	Book or other media for PHI's empowerment
My development	Mentor testimonial	F3.8	Example of a mentor testimonial
	My hearing tests	F3.9	PHI's selection of a tests or questionnaires
	My speech understanding test	F3.10	PHI tries the test
	My satisfaction with hearing aids	F3.12	PHI fills in the questionnaire example
	My important listening situations	F3.13	Data visualizations of self-reported ratings
	My data on "My hearing tests"	F3.14	Data visualizations of PHI's speech understanding test related to norm data
	My data on "My important listening situations"	F3.15	Graph showing PHI's rating of selected important listening situations over time

Note. AUD = audiologist; PHI = person with hearing impairment.

Results

Increased Personalization of eHealth Solutions

We developed the interactive digital prototype based on the results from the first and second focus group rounds concerning the three key themes (*My expectations*, *My personal coach*, and *My development*). Acknowledging the PHIs'

need for personalization, we strived for a high degree of personalization in our design of the interactive digital prototype by, for example, having your personal hearing curve in relation to the speech banana (ID 3.1 in Table 4 and Screenshot 5/21 in Supplemental Material S1), your personal listening problems or preferences, own choice of empowerment videos or other materials, and self-rating of own development, as illustrated in Table 4 and in Supplemental Material S1.

PHIs with a keen interest in technology and its possibilities (tech-savvy PHIs) requested personalization of most aspects, for example, having access to (a) data displays of their test results over time and with possibilities to compare with other PHIs, (b) a variety of sound examples in the subfeature *My hearing* (ID F3.1 in Table 4), (c) creating own listening situations to rate and monitor, and (d) receiving AUD feedback on *My hearing tests* (ID F3.9 in Table 4) or self-reported ratings in the feature *My development* (IDs F3.9–F3.15 in Table 4). Less tech-savvy PHIs, being less familiar and interested in technology, had concerns about technical language and abstract displays.

Interests and Willingness of the PHIs to Invest Time and Effort in Different Digital Solutions

Based on the thematic analyses of Phases 2 and 3 with identification of the three key themes (Phase 2) and the rich interaction with the digital prototype and pinpointing of the most essential future eHealth solutions (Phase 3), we identified four different levels of interest and willingness of the PHIs to invest time and effort in different digital solutions. We labeled these different four levels (a) *No go*, (b) *Automatization*, (c) *Nice to have*, and (d) *Need to have*, as described in Table 5.

The first level, *No go*, with no investment from the PHIs, related to training schedules. These PHIs were not

Figure 4. Third round of focus groups (Phase 3) on digital concepts using a digital prototype (April 2017): four focus groups with persons with hearing impairment.

Table 5. Person with hearing impairment (PHI) levels of interest and willingness to invest time and effort in using different digital solutions.

Level of interest	Investment	Identifiers	Features
1. No go	None	Training schedules	Scheduled training packages
2. Automatization	Low	Fix my HI	Automatic hearing aid updates Automatic hearing aid fine-tuning
3. Nice to have	Medium	Quick and easy info Monitoring Sharing experiences Empowerment in a group	FAQs Testimonials from other users on specific problems Many self-tests for instance on speech intelligibility and HI Monitor and relate your test results to other PHIs Share self-tests or experiences with SOs, AUDs, or a group
4. Need to have	High	Situated and personalized support in important listening situations Individual empowerment Responsibility for HI	Customized important listening situations and support Self-management and self-evaluation of a list of specific personal problematic listening situations Audio files for easier problem description to AUDs Self-exploration of and self-fine-tuning of hearing aids in specific individually important listening situations Self-evaluation of developments and tests

Note. HI = hearing impairment; FAQs = frequently asked questions; SO = significant other; AUD = audiologist.

interested in any form of training involving fixed training schedules. In the digital prototype, we asked the PHIs to select the amount of time they would be willing to use on *My personal hearing coach* training (IDs F3.4–F3.8 in Table 4), choosing from 30 to 90 min of training daily. Instead, PHIs suggested that we divide training into training packages for beginners, intermediate, and advanced PHIs in hearing rehabilitation, with a possibility for the PHIs themselves to choose the different training features from a drop-down list (IDs F3.4–F3.8 in Table 4 and Screenshot 8/21 in Supplemental Material S1).

The second level, *Automatization*, with limited PHI investment, concerned automatizations and fixing of the HI without PHI involvement or engagement, for instance, automatic hearing aids updates, automatic fine-tuning, and voice commands to adjust hearing aids.

The third level, *Nice to have*, was characterized by medium PHI investment related to quick and easy access to information such as frequently asked question (FAQ) lists, learning and empowerment through self-tests, self-monitoring, and group empowerment or through partnership with SOs or AUDs (illustrated in Screenshots 7/21, 9–10/21, 12–14/21, and 16–21/21 in Supplemental Material S1).

The fourth level, *Need to have*, with a high investment from the PHIs, was related to both situated and personalized support with customized digital solutions to select from when experiencing daily HI problems (e.g., illustrated in Screenshots 9–10/21 and 13/21 in Supplemental Material S1). Moreover, this level was also concerning PHIs' need for self-evaluation, self-exploration, and self-management of daily HI problems before contacting the AUD, thus taking responsibility for own rehabilitation (illustrated in Screenshots 5/21, 6–7/21 [self-grading], and 17–20/21 in Supplemental Material S1). The possibility of sending audio files for problem description to the AUDs was also a *Need to have* digital solution.

Technical Savviness and Difference in Obtaining Rehabilitation Strategies

When we introduced the interactive digital prototype, PHIs appeared broadly to be divided into two different types regarding technical savviness (tech-savviness). This was expressed in their interaction with the digital prototype, and this again influenced their preferences on rehabilitation strategies. The first type consisted of very tech-savvy and progressive PHIs who were highly interested in functionality and had an abundance of ideas for further design and development of the digital prototype. The second type consisted of less tech-savvy PHIs who found some of the functionalities of the prototype confusing and needed extensive instruction on the technology. Despite their insecurity, they also expressed a motivation to explore, train, and learn to use the prototype. The less tech-savvy PHIs typically related to the *Automatization* and the *Nice to have* levels of interest (see Table 5) with wishes for automatization and quick and easy information, but still with an interest in self-testing and sharing and comparing results with others. In contrast, the tech-savvy PHIs typically were on the *Need to have* level with interest in self-rating, self-exploration, self-evaluation, self-fine-tuning, and taking responsibility of their own HI both today and tomorrow by having access to information on the newest available HI technology and getting feedback from AUDs on their self-monitoring. Nevertheless, both types thought it was essential to include situated and personalized support, as illustrated in the *Need to have* level.

The tech-savvy PHIs desired rehabilitation strategies related to personal problem-solving, self-efficacy, and self-tailoring by self-evaluation of problematic listening situations, self-reporting of tests and listening situations, self-monitoring of personal data, and self-tuning. Thus, this type of PHI wanted to engage in a high degree of self-management. The less tech-savvy PHIs were more inclined to use traditional information solutions for empowerment. That is, they

wanted social support in all steps and preferred AUDs or an automated solution to act on their behalf. Thus, the less tech-savvy PHIs obtained rehabilitation strategies related to utilizing already available resources such as FAQ lists and lists of common problems, as well as social support, where they could discuss and share problems with SOs, mentors, a group, or the AUDs. They also desired to partner with AUDs in problem solving.

Discussion

This study used participatory design to involve key stakeholders in innovating eHealth solutions for service delivery to older PHIs. Our research question was: What are the key users' needs, expectations, and visions within future hearing rehabilitation service delivery? The participatory design process was staged via focus groups, and data were analyzed using an inductive thematic analysis. This resulted in these findings: (a) all key stakeholders' visions for a future eHealth-assisted client journey, (b) three key themes for future eHealth solutions targeting older PHIs, (c) PHIs' interest and willingness to invest time and effort in different digital solutions, and (d) PHIs' tech-savviness and its influence on PHIs' desired rehabilitation strategies. In this section, we discuss these results in relation to future eHealth solutions and related work.

The Future eHealth-Assisted Client Journey for Hearing Rehabilitation

Fitting and fine-tuning of hearing aids today are minimally personalized through digital prefitting or fine-tuning information from PHIs. This contrasts the key stakeholders' proposed design solutions for future eHealth-assisted client journeys in hearing rehabilitation, which are based on the 4 Ps in future health care: personalized, participatory, preventive, and predictive (Hood & Friend, 2011). Personalization was central in all digital solution features: sending personalized prefitting information and hearing aid expectations to AUDs, thus giving AUDs personalized insights on PHIs for planning of the fitting session and enabling more effective and personalized communication during the fitting session. For example, both types of PHIs wished to send audio files to the AUD to describe experienced hearing problems. PHIs reported that they had experienced a mismatch between the situations in which they were tested in clinical settings and their experiences in real life. This resulted in dissatisfaction with hearing aid performance when they moved out of the controlled clinical settings and out in real life, as also mentioned in previous studies (Dahl & Hanssen, 2016; Hanssen & Dahl, 2016). Moreover, using daily listening environments in the rehabilitation process during fitting have enabled PHIs to reflect and communicate more easily about self-perceived HI in real-life situations and have a feeling for how their hearing aids would perform in real-life situations (Hanssen & Dahl, 2016).

Support toward patient participation is lacking in today's service delivery (Pryce et al., 2016; Rolfe & Gardner, 2016). The future client journey developed in this study empowers PHIs and SOs by giving access to information, education, and training possibilities. This enables a participatory rehabilitation, where PHIs self-manage through access to trustworthy information on the Internet and a personal hearing coach training in the first weeks postfitting to ensure ongoing learning and reflection in their rehabilitation process. Our focus groups revealed that even very experienced PHIs have very little knowledge of realistic expectations for HI. That is, they are still not familiar with describing or having knowledge on expectations for their rehabilitation or identifying important listening situations, listening preferences, and so forth, which could otherwise empower their participation in the rehabilitation process. In our study, the PHIs claimed that the empowerment they get from seeking information from the Internet is confusing, difficult to understand, and of uncertain validity. This is in alignment with studies showing that web information on HI and rehabilitation requires 9–14 years of education to be understood (Laplante-Lévesque et al., 2012; Laplante-Lévesque & Thorén, 2015).

Participatory and preventive design solutions in future health care's 4 Ps are creating other demands for services in the future, where data-driven hearing rehabilitation with data inputs from PHIs could personalize hearing rehabilitation to new levels and enable evidence-based preventive hearing health care through self-monitoring and health analytics. The user-innovated design solutions in this study enable a predictive and preventive approach in future service delivery by giving access to outcome measures data or self-reported ratings prefitting and postfitting from PHIs' training activities and self-ratings of developments, which neither AUDs nor PHIs have access to in today's service delivery. This also fulfills the participating AUDs' requirement for effective PHI's communication and empowers participating PHIs to take responsibility for their own rehabilitation. However, these new demands in service delivery with a high degree of interaction between PHIs and AUDs could be time-consuming for the AUDs. From our first round of focus groups, including AUDs, the main constraints identified for future service delivery were time, timing, and transition; thus, a core vision was that the right information has to be delivered at the right time to the right person in the right dosage, not being time-consuming for the AUDs, but supporting efficiency by qualifying time in the clinic (Kanstrup, Rotger-Griful, et al., 2017). Both PHIs and SOs wished to involve the SOs in training of personalized communication strategies, thus expanding the participatory approach in the future 4 Ps in health care. Involvement of SOs in hearing health care is supported by Preminger (2003) and Preminger and Rothpletz (2016), who documented larger treatment effects sizes when SOs participated in the same rehabilitation groups as their PHIs.

We found that PHIs preferred to determine their own training schedules, instead of being recommended a set training time frame, and to train for solutions occurring in

their daily life here and now. Morrison, Yardley, Powell, and Michie (2012) reviewed effective design features in eHealth interventions, including activity planning, and found activity planning ineffective as an eHealth design feature. This finding supports the participating PHIs' refusal of fixed training schedules/activity planning.

Situated and personalized support in PHIs' important listening situations and personalized empowerment were needs for both tech-savvy and less tech-savvy PHIs. Thus, research has identified a need for digital solutions that contextualize listening experiences in real-life settings and anchor user's learnings from daily life experiences.

Tailoring Future eHealth Solutions to Various Users and Rehabilitation Strategies

In general, our tech-savvy PHIs were well educated and had active lifestyles enjoying both regular physical exercise and social gatherings, and almost one third of them were still employed. This group of PHIs prioritized self-tailoring designs. They craved a very high degree of personalized digital solutions and had very high participatory needs for self-management, including self-efficacy and self-tailoring. For example, they desired to have the ability to audio-record their own experiences in a problematic listening situation and self-fine-tune their hearing aids in these situations. From Phase 2 prioritization, self-fine-tuning also was a top priority for digital solution features. The same need for participation and self-tailoring was identified in a previous study (Dahl & Hanssen, 2016), where PHIs needed individual customization by being able to tailor the listening environments to recreate difficult situations. This leads to a fine-tuning process driven by the client's self-perceived disability in real-life situations.

Self-tailoring allows patients to receive solutions that are chosen based on their own characteristics, such as lifestyles and personal goals (Morrison et al., 2012). Self-monitoring is an effective eHealth intervention and particularly if combined with feedback possibilities and goal settings (Morrison et al., 2012). This is in line with the requirements from our tech-savvy PHIs, who wanted to self-monitor and get AUD feedback if their tests were over threshold levels (for instance, deteriorating HI threshold levels). Thus, the tech-savvy PHIs in our study are most likely representatives of the typical PHI of the future, who will embrace the 4 Ps in future hearing rehabilitation service delivery and take an active role in supporting their rehabilitation through connected health. Maidment, Brassington, Wharrad, and Ferguson (2016) also found an association between PHIs with more competences in Internet usage and more efficient management of HI, concluding that increased perceived self-efficacy, which goes hand in hand with increased digital literacy skills in the typical older PHI of the future, could further enhance hearing outcomes. The burden on health care costs increases due to an aging population with chronic health conditions such as HI (Vos et al., 2015), but the identified tech-savvy and self-managing group of

PHIs of the future could reduce these health care costs. These self-managing, tech-savvy PHIs could enable more efficient client journeys, saving valuable clinic time and costs. This saved time could be used for PHIs who require more intensive and time-demanding traditional hearing rehabilitation. The tech-savvy PHIs' need and preferences for rehabilitation strategies must be taken in to account when designing eHealth solutions for service delivery to older PHIs in the future.

The less tech-savvy PHIs preferred self-management strategies using social support and partnership with AUDs as health care providers, combined with learning from easily accessible information (FAQs or testimonials), as also described by Pearce et al. (2016). Previous findings support social support design needs: (a) Rehabilitation effects were improved when participants received a combination of social support from peers and information or a combination of social support and communication strategy training (Preminger & Yoo, 2010), (b) increased PHI satisfaction and improved awareness of HI problems were shown when RLOs were watched together with SOs (Ferguson et al., 2016), and (c) a design for peer-to-peer-mediated communication was associated with a positive intervention outcome (Morrison et al., 2012). Furthermore, the less tech-savvy PHIs preferred rehabilitation strategies involving automatization and a quick fix of HI. This correlates with the participating AUDs' perception that many PHIs want others to take responsibility for their HI and rehabilitation. Thus, this PHI type is probably the main type today, and their needs and rehabilitation strategy preferences must be taken into consideration when designing eHealth solutions for hearing rehabilitation service delivery in the near future.

Limitations and Future Research

The current study has three main limitations. First, the selection of innovative users with an interest in technology, health apps, and a future hearing rehabilitation client journey as participants means that the study population was not representative of the average PHI. Scandinavians, and especially Scandinavian PHIs, use the Internet at a higher rate than those in other countries, such as the United Kingdom (Ferguson et al., 2016; Thorén, Öberg, Wänström, Andersson, & Lunner, 2013). Furthermore, our selected participants included a subgroup of highly tech-savvy PHIs. Therefore, our results concerning tech-savviness and interest and willingness in different eHealth solutions can be biased in comparison to populations of PHIs with lower Internet and smartphone usage and proficiency.

Second, our research participants were familiar with hearing rehabilitation in Denmark, and hearing rehabilitation varies from country to country. We strived for a balanced sample of PHIs from both public and private clinics, but 23 (64%) out of the 36 participating PHIs received their hearing services at the clinic of the Eriksholm Research Centre. To be research participants at Eriksholm

Research Centre clinic, the PHIs need to fulfill some additional requirements (e.g., being able to express themselves). This biased our sample toward active, healthy, and high-functioning older PHIs. Finally, our eHealth solutions for service delivery were designed for older PHIs, and thus, our findings cannot be extrapolated to service delivery to younger PHIs, including children with HI.

Future development of specific digital solutions is required, but many aspects of the user-innovated eHealth solutions from this study are already influencing upcoming commercial rehabilitation apps. The effect of the user-innovated eHealth solutions in our study should be tested in matched controlled trials in a more typical population not selected for their innovation potential to shed light on the effectiveness of eHealth-assisted hearing rehabilitation compared with traditional hearing rehabilitation. Focus should be on investigating the feasibility and effectiveness of hearing rehabilitation when more interaction between PHIs and AUDs are imposed through the 4 Ps in future service delivery.

Conclusions

Our results show that future eHealth solutions for older PHIs must be anchored in everyday life situations, with the ability to tailor solutions to provide personalized information, communication, and learning milieus. Despite the quite homogeneous group of participants in the study, our results have identified that PHIs have various needs, expectations, and visions for future hearing rehabilitation service delivery. The types of rehabilitation strategies and services that PHIs envision for the future appear to be influenced by their level of tech-savviness. Future eHealth-assisted hearing rehabilitation must facilitate these broad needs, expectations, and visions by enabling PHIs' adaptation of personalized rehabilitation strategies on an appropriate level of tech-savviness. Moreover, the key stakeholders' visions for eHealth solutions for service delivery call for connecting both digital and analogue services.

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