

A qualitative examination of user perceptions of user-driven and app-controlled hearing technologies

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## Abstract

**Purpose:** To examine how hearing aid candidates perceive user-driven and app-controlled hearing aids and the effect these concepts have on traditional hearing health care delivery.

**Method:** Eleven adults (three females), recruited among 60 participants who had completed a research study evaluating an app-controlled, self-fitting hearing aids for 12 weeks, participated in a semi-structured interview. Participants were over 55 years of age and had varied experience with hearing aids and smartphones. A template analysis was applied to data.

**Results:** Five themes emerged from the interviews: 1) prerequisites to the successful implementation of user-driven and app-controlled technologies; 2) benefits and advantages of user-driven and app-controlled technologies; 3) barriers to the acceptance and use of user-driven and app-controlled technologies; 4) beliefs that age is a significant factor in how well people will adopt new technology; and 5) consequences that flow from the adoption of user-driven and app-controlled technologies. Specifically, suggested benefits of the technology included fostering empowerment, and providing cheaper and more discreet options, while challenges included lack of technological self-efficacy among older adults. Training and support were emphasized as necessary for successful adaptation and were suggested to be a focus of audiologic services in the future.

**Conclusion:** User perceptions of user-driven and app-controlled hearing technologies challenge the audiologic profession to provide adequate support and training for use of the technology, and manufacturers to make the technology more accessible to older people.

## Introduction

Hearing aid users have been able to exercise some control over the setting of their devices since the introduction of on-board volume controls early last century. Over time, as hearing aid processing has become increasingly more sophisticated, the user has gradually been given control over more, and more advanced, hearing aid parameters to manipulate, for example, gain in independent frequency bands, the beam of directional microphones (Appleby, 2012), or simply to choose different settings when in different listening environments (Mangold, Eriksson-Mangold, Israelsson, Leijon, & Ringdahl, 1990). This development seems sensible, as it is well established that hearing aid users have preferences for different hearing aid settings in different listening situations (Keidser, 1996; Keidser et al., 2005) and can select preferred settings with reasonable reliability (Boothroyd & Mackersie, 2017; Dreschler, Keidser, Convery, & Dillon, 2008; Keidser & Alamudi, 2013; Nelson, Perry, Gregan, & VanTasell, 2018).

More recently, user control has extended to enable users to independently set up their devices in a prescribed manner (Convery, Keidser, Seeto, & McLelland, 2017). This is done by first having users manage a pure tone test presented through the device, the result of which will lead to a prescribed baseline setting, before they perform further adjustment or fine-tuning. Such devices are referred to as self-fitting hearing aids (Convery, Keidser, Dillon, & Hartley, 2011; Keidser & Convery, 2016). Making treatment with hearing aids more accessible, especially in areas where audiologic services are unreliable, is one factor that has motivated the development of this heightened level of user control. Currently, self-fitting technologies are not dispensed through traditional channels and are only available on the online market in the US, and investigations into user-driven fittings are still scarce. Whereas initial investigations suggest that outcomes are not significantly affected by giving users control of

setting up their devices (Humes et al., 2017; Keidser & Convery, 2018), little is known and understood about the user's perception and acceptance of independently driving the fitting process.

Before self-fitting hearing aids became commercially available, one study did present a group of 80 older, hearing-impaired adults with the concept, and asked through a structured questionnaire what they thought about it, and what they thought might be advantages and disadvantages of self-fitting hearing aids (Convery, Keidser, & Hartley, 2011). Generally, participants thought positively about the concept (83%), with one-third of the participants thinking that the main benefit of self-fitting hearing aids would be the ability to self-adjust the device's setting; that is, an operation that doesn't necessarily require the device to be self-fitting. Only one-fifth mentioned convenience, which is considered a driving factor of the self-fitting concept. Interestingly, 90% of respondents believed that hearing aid users would be able to manage the self-fitting process independently, a belief that has since been disputed through a series of research studies (Convery, Keidser, Hartley, et al., 2011; Convery, Keidser, Hickson, & Meyer, 2018; Convery et al., 2017; Convery, Keidser, Seeto, Yeend, & Freeston, 2015).

Over the same period that the level of user control has evolved, the mode of controls has expanded from on-board wheels and toggle switches to dedicated ultra-sonic remote controls, introduced in the early 1990s (Levitt, 2007), to apps that can be downloaded on to personal computers and accessed by obtaining device specific programming interfaces and cables. Today, most manufacturers of hearing devices make free apps for user-driven fine-tuning available to smartphones. Some of these apps also enable users to take control of the prescription phase (Convery et al., 2017), or to contact their provider and receive updated

hearing aid settings (Stender, Groth, & Fabry, 2017) via the app. Generally, the number of apps available for assessment and treatment of hearing loss is growing (Paglialonga, Tognola, & Pincioli, 2015). With a penetration rate of over 80% in many developed countries and the biggest growth in smartphone ownership now seen among older generations (Deloitte, 2017), the adoption of smartphones as the platform for managing hearing aids and their settings seems sensible.

In a recent study, the influence of smartphone-connected hearing aids was investigated through the experience in a group of clinicians and patients who had provided and used the technology, respectively (Ng, Phelan, Leonard, & Galster, 2017). Generally, both clinicians and patients were positive towards the integration of the smartphone with hearing aids, with some suggestions that this integration could contribute to normalising hearing aids. Patients, however, did express some frustration over time spent trouble-shooting technical issues related to smartphone integration, which for some resulted in extra visits to their clinician or direct interaction with the manufacture. They frequently commented on their technological competence and signalled a need to learn how to use the new technology. These reports resonate with observations in Convery et al. (2018) that participants, who tried to set up a pair of app-controlled self-fitting hearing aids with on-demand help on hand, requested support more frequently for steps requiring use of their mobile devices compared with steps in which the hearing aids were handled or manipulated in isolation. The findings of Ng et al. (2017), while providing some insights to the user's perception of app-controlled hearing aids, were based on one commercial product, and on the experience of patients who as a group were considered intermediate-level users of smartphones and who had decided to adopt the technology.

The aim of this study was to examine, from the user's perspective, advantages and disadvantages of user-driven fittings and smartphone-controlled hearing aids. In addition, potential barriers for using smartphones to manage hearing aids were examined, as well as the perceived effect these technological advancements might have on traditional hearing health care delivery. The study differs from those of Convery et al (2011) and Ng et al. (2017) by interviewing hearing aid candidates who had actually trialled a commercially available app-controlled, self-fitting hearing aid, and by tapping into a broader sample of hearing aid candidates who had diverse hearing aid and smartphone experiences and no invested interest in the technology in question, respectively.

## Methods

### Research and sampling strategy

This study used a qualitative descriptive design - e.g. (Sandelowski, 2000) - to obtain factual information about user-driven hearing technology from the perspective of experiencing hearing aid candidates. Qualitative description is a method that is used to seek accurate accounting of an event experienced by a group of individuals and that supports low-inference interpretation of data; i.e. events or experiences are described on the basis of what the researchers see and hear rather than in terms of a pre-existing theoretical or philosophical framework. A qualitative approach was used in this study to freely capture the perceptual meanings from participants, without the bias of expectations often introduced with the variables selected in quantitative research methods. The descriptive method was selected as it is considered well suited to obtaining straightforward answers to questions of relevance to practitioners and policy makers (Sandelowski, 2000).

Participants were purposefully chosen among a group of 60 hearing aid candidates who had recently completed a study in which they tried to set up a commercially available self-fitting hearing aid, using a device specific smartphone app, and subsequently trialled the device in the field for 12 weeks. During the field trial, user-driven fine-tuning was possible from the same smartphone app. Participants were all new to the self-fitting concept and to using an app for hearing aid manipulation. When entering the study, half of the participants were new to hearing aids, and one-fifth did not own a mobile device, with more participants having no or little experience with smartphone and smartphone apps. Participants who did not own a smartphone were provided with one for the duration of the study. Smartphone owners could choose to use their own phone or to borrow one. Hearing aid experience and mobile phone ownership were found to be highly and positively related to how successful participants were in setting up the self-fitting hearing aid (Convery et al., 2018). Therefore, to ensure the themes captured in this study were not similarly influenced by past experience with the technologies in question and to maximize diversity in the themes, the maximum variation sampling method (Palinkas et al., 2015) was employed. That is, at least two individuals meeting each of the four criteria: experience with hearing aids and smartphones; experience with hearing aids but no experience with smartphones; no experience with hearing aids but experience with smartphones; and no experience with either hearing aids or smartphones were recruited. A total of 11 participants (18% of the available pool of participants) were recruited. While this number is lower than desirable for theory driven qualitative research (Marshall, Cardon, Poddar, & Fonenot, 2013), it is considered acceptable for an exploratory descriptive design (Magilvy & Thomas, 2009).

## Participants

Participants were 11 older adults with an average age of 73.2 years, ranging from 56 to 85 years. All participants had symmetrical sensorineural hearing loss varying from very mild (32 dB HL - four frequency average measured across 500, 1000, 2000, and 4000 Hz) to moderately severe (56 dB HL), with an average of 42.5 dB HL. Of the 11 participants, six had previous hearing aid experience varying from 3 to 31 years, with an average of 12.7 years, and five owned smartphones. Table 1 shows an overview of the participant characteristics.

### Procedure

Semi-structured interviews were conducted face-to-face in a small meeting room at the National Acoustic Laboratories (NAL). Two of the authors (EC) and (GK) were intimately familiar with the study the participants had just completed and their results, and as the principal data gatherer of the study, EC further had a rapport with most of the participants. Therefore, to ensure that participants would talk openly about their experience with the technology in question and their views on the effect it may have on hearing health care in the future, investigator (NM) who is not an audiologist and is not affiliated with NAL, where the recent study took place, conducted the interviews. The interviewer had a broad knowledge about hearing loss and hearing aid technologies, obtained through previous research. Questions were presented around three themes: 1) thoughts on the advantages and disadvantages of taking charge of the fitting process; 2) thoughts on the advantages and disadvantages of controlling hearing aids from a smartphone, and what barriers were encountered; and 3) thoughts on the effect of user-driven fittings on the traditional hearing health care model. The interviews, which also probed into the cultural meanings of living with a hearing loss and using hearing assistive technology – themes that are not considered in this paper - varied from 36 to 109 minutes. All interviews were audio recorded and



transcribed verbatim. The treatment of participants was approved by the Australian Hearing Human Research Ethics Committee and conformed in all respects to the Australian government's National Statement on Ethical Conduct in Human Research. Participants were compensated for their travel expenses.

#### Data analysis

A template analysis was applied to data. Template analysis is a form of thematic analysis in which the coding template is developed by adding, redefining, or removing themes through an iterative process, with the option of starting coding of data from a template created based on some a priori themes identified to be relevant to the analysis (Brooks, McCluskey, Turley, & King, 2015). The iterative development of the coding template is helpful in making sense of data by encouraging careful consideration of the definition of each theme and how themes relate to one another. The analysis is further highly flexible in that it is guided by the data and includes the possibility of using both descriptive and interpretative themes.

Regular meetings were held between the three authors while the interviews were conducted to share first impressions and specific observations made by the interviewing author. When the interviews had been completed, the first author first read all interviews in full, and then re-read the interviews while highlighting all comments made by participants that directly addressed the research questions of interest. On the basis of the research questions developed for this study and the observations made by the authors during the self-fitting trial and when conducting the interviews, respectively, eight a priori themes were identified. These included: 1) advantages of user-driven setup of hearing aids; 2) disadvantages of user-driven setup of hearing aids; 3) advantages of using a smartphone to control hearing aids; 4) disadvantages of using a smartphone to control hearing aids; 5) barriers to using a smartphone to control

hearing aids; 6) age and technology; 7) technological self-efficacy; and 8) The effect of user-driven fittings on the traditional hearing health care model. Starting with the a priori themes, coding of data began using QSR International's NVivo 11 analysis software. During coding of the first four transcripts that represented one participant from each of the four categories of hearing aid and smartphone experience, the template was redefined. Specifically, the main themes were reorganized, and sub-themes and categories were added to the template. The new template was reviewed by both co-authors and further revised. Based on the redefined template the remaining seven interviews were coded. During this process, the template was further modified in agreement with the third author to accommodate for new information. The final template was double-checked and slightly adjusted by the first author and was then reviewed and approved by the co-authors.

## Results

Five themes emerged from the interviews: 1) prerequisites to the successful implementation of user-driven and app-controlled technologies; 2) benefits and advantages of user-driven and app-controlled technologies; 3) barriers to the acceptance and use of user-driven and app-controlled technologies; 4) beliefs that age is a significant factor in how well people will adopt new technology; and 5) consequences that flow from the adoption of user-driven and app-controlled technologies. Tables 2-6 list, for each theme, their sub-themes and categories together with example quotes. Further quotes are included in the sections below in which each theme is described in more detail.

Theme 1: Prerequisites to the successful implementation of user-driven and app-controlled technologies

Two sub-themes, support and adaptation through learning, emerged as prerequisites to the successful implementation of user-driven and app-controlled technologies, see Table 2. It was clear from the interviews with the participants that they had valued the controlled environment in which they had for the first time tried and used the technology in question. During the research study the participants had volunteered for, on-demand assistance was available as needed. Reflecting on their experience, participants acknowledged that the available support, which also provided a means to learn and be reassured during the process of setting up hearing aids and using the app, was critical in them being successful at managing the technology: *“but I liked to have the assurance of the audiologist that I had done it properly” [124].*

Many of the participants suggested that adaptation to the technology had come through experiential learning. This notion came out in various ways. For example, some participants expressed an initial hesitation about user-driven technology and doubt about their ability to manage it that eventually seemed to be overcome by simply trying the task: *“Then they sat me in a room on my own with a cardboard box and said get on and fix it. I found that quite interesting. I got to one stage where I wasn't sure I could fix it, but I was able sit back and think about it and carry on. I managed to fix it myself” [139].* Similarly, participants reported gaining more proficiency with the app to perform fine-tuning of their hearing aid settings in their everyday environments through experience: *“No, I did try and use the different areas if I was in a loud place or in a cinema or something like that, but towards the end I suddenly discovered that I could have done something else” [139].* A few participants referred specifically to building up confidence in managing the technology through the supported hands-on experience, with a couple of participants highlighting the power of understanding and having knowledge of the purpose of the technology, and how it works, to get it right: *“I*

*think it's an important part of learning, is having an understanding of the logic behind something" [103].*

## Theme 2: Benefits and advantages of user-driven and app-controlled technologies

As shown in Table 3, three sub-themes were identified regarding benefit and advantages of recent advancement in hearing aid technologies. Two were pertinent to user-driven technologies and one specific to the integration of smartphones. When reflecting on the recent self-fitting hearing aid trial, participants generally reported that the experience of engaging in the fitting and fine-tuning process was empowering. This was expressed in several ways. For example, some participants felt they were less at the mercy of the professional by the sense of medicalization being broken down: *"It [self-fitting] gave me more of a sense of not being so much the patient" [156]*, and having some control over the hearing aid fitting process: *"That's where the smartphone I thought was good, because I could say, with me controlling the smartphone I cannot get the hearing aid to work, so hearing aids are possibly not suitable for me" [118]*. Others found that the experience enhanced expertise and fostered self-efficacy: *"Once I think I'm beginning to understand the process I get more confidence" [103]*. By pointing out that the more you *"train people to stand on their own two feet and to take pride in their achievements, the more they are independently able to look after themselves and the more they'll have confidence about themselves" [103]*, one person suggested that the technology could be used to foster self-care, which again would increase self-efficacy.

Some participants also praised the concept of user-driven technologies by suggesting that enabling consumers to bypass audiologists would potentially overcome problems with the current hearing aid delivery model. Specifically, several participants commented on the high

cost of hearing aids in the traditional model, and thought this could be reduced when setting up the aids independently of an audiologist: *“The positives are that you’re not paying money to go back to the audiologist, whoever it is”* [133]. Others referred to the commercial practices of audiologists, with a couple of participants finding them untrustworthy and promising too much: *“But in the world of commercial things, be it hearing aids - and I’m critical here - being hearing aids, I think they make promises they can’t keep”* [118].

Comments on benefit and advantages of integrating a smartphone with hearing aids centred around the smartphone being the tool used to manipulate hearing aids. Several participants simply found the integration natural, as carrying a smartphone with them and using it as a general tool through its arrays of apps already *“fitted into my lifestyle well”* [156]. Two participants recognized that with the right model, the smartphone could be a better platform from which to manipulate the hearing aid than on-board controls and dedicated remote controls; with one participant referring to the smartphone providing more manageable buttons and the other larger print.

### Theme 3: Barriers to the acceptance and use of user-driven and app-controlled technologies

Several sub-themes, as outlined in Table 4, were identified regarding barriers to some participants accepting user-driven and app-controlled hearing technologies, with three being pertinent to user-driven technologies and one specific to the use of smartphones. The two main barriers that emerged from the interviews concerned lack of technology self-efficacy and not knowing if an optimum outcome had been achieved. Half of the participants believed the technology was beyond their capabilities, with many expressing a general lack of confidence in using technology: *“So I have personally*

*considerable trouble with technology” [103].* Some of the participants specifically referred to uncertainty in their ability to manage technology due to being forgetful or lacking in understanding: *“Yes [I used the app to adjust the hearing aids] and sometimes they go out of whack and I don't know why” [133].* Many participants also expressed concerns about the outcomes with user-driven technology, with several referring to the inability of users to verify the fitting process without the correct knowledge and tools: *“I don't think the optimum result in hearing result in hearing aids is necessarily obvious” [124].* Besides the ability to verify the process, participants questioned how users, without professional oversight, would know if their hearing aids were correctly inserted, if they encountered a problem that could be fixed, or if their settings were appropriate so as not cause harm.

Other barriers to the acceptance of user-driven technology were centred around the specific product, which some participants thought was not a fully developed version of the concept: *“The technology is still not there, in my opinion. This is a cheap version” [110],* as well as not seeing a purpose of giving up the relationship with and the expertise of professionals, with one participant referring to the idea of self-fitting as an imposition: *“No, so I'm not opposed to technology. But when it comes to something like hearing aids, I feel it's an imposition on me to expect me to install a hearing aid” [124].*

A number of the participants specifically expressed a bias against smartphones, believing they had taken over our lives in a negative way to distract from direct social interaction with other people: *“So I mean technology is meant to be our servant not our master and all too often it's become our master and we forget that behind all this technology are people and we shouldn't”[103].* A couple of participants also mentioned

the smartphone was an inconvenient tool for adjusting hearing aids, referring to limited battery life and having to remember to keep it charged, as well as the device interrupting social occasions when pulled from a pocket or handbag to make adjustments: *“It's too much trouble carrying the bloody phone around and hang on a minute while I fix my ears up”* [109].

Theme 4: Beliefs that age is a significant factor in how well people will adopt new technology

When reflecting on a future of user-driven hearing aid technologies, most participants mentioned age in conjunction with the ability to adopt the technology, see Table 5. Specifically, all referred to older people being less likely to take up the technology because they are not technology savvy or lack technical literacy: *“People like me, well, my age, they would have a problem with it, because they're most probably a bit scared of it or they've had a few goes at things like this and they say oh, it's not for me, I'm a dinosaur or whatever. I don't look at these things”* [110]. Some made explicit references to mobile phones, which in the future are likely to feature as the control console for setting up and managing hearing aids: *“I'm talking about people my age, late 60s, early 70s, especially the people in the 70 to 80-year-old bracket, with a mobile phone, they haven't got a clue, most of them, about how it works. You put on an app about the hearing aids and they'll think, oh my phone is broken, or this app doesn't work, because they're just so naïve about technology”* [111]. At the same time, participants believed that younger generations would have absolutely no problems adopting to a model of user-driven hearing aid fittings and fine-tuning when their time came: *“I honestly believe that let's say the generation below myself will have no worries at all with that sort of thing”* [151]. One participant recognized that if older people

could manage it, the user-driven technology could be to their benefit as many elderly people end up homebound: *“obviously mail order and such like is going to help older people because it does get difficult to get out and do things”* [139]. The same participant recognized that such people could receive needed support via telehealth *“because older people are using Skype quite a lot”*.

#### Theme 5: Consequences that flow from the adoption of user-driven and app-controlled technologies

During the interview, participants were asked about their thoughts on the effect of user driven fittings on the traditional hearing health care model. In Australia, hearing health care is largely device focused, and provided in retail outlets. Three sub-themes emerged, with two focusing on the future need for and potential role of audiologists, see Table 6. A few speculated that the development might eventually put audiologists out of work, in part because *“the audiologist is built in the machine”* [110]. One of these participants believed audiologists would still be active in the field of research to help further advance hearing technology: *“They'd [audiologists] be very important in research and in the actual science of audiology, you could never do away with that, because without that knowledge you wouldn't have the development of new devices and improvements. So in that realm, there would be audiologists”* [111]. However, all but two participants, including some of those who speculated that audiologists could become redundant, could not imagine a future without qualified audiologists. Some believed audiologists were generally needed to provide the necessary expertise and care: *“I wouldn't like to see reduction in the number of audiologists out there available to help people because of this [user-driven technology], because audiologists are still the ones who have gone and done a Masters degree in this area, so we still need that professional oversight, that*



*professional expertise” [156], or that there at least should be a choice. Others thought audiologists were still needed to provide help with the user-driven technology: “Well, and there are going to be sufficient number of people who have problems setting it [the hearing aid] up” [128]. One participant even suggested that there is a shortage of audiologists, and that user-driven technology could be a means to manage their work load: “We don't have enough audiologists anyway so we're not trying to work them out of work. We're trying to create a situation surely where they can cope with more clients without having to work any harder” [103].*

In terms of the future role of audiologists, one participant could not see user-driven and app-controlled technologies changing it in the future. A couple of participants agreed that audiologists would continue to provide traditional services, albeit limited to those with established and more complex hearing problems: *“As soon as I started to lose my hearing, I think I would be looking at talking to these people. Because that is their speciality and the advice you get from there you've got to take notice of. As I said, self-treatment is fine, but there is a point where you do seek help from elsewhere” [151].*

One participant even expressed concern that user-driven technology would end up increasing the workload of audiologists because they would have to pick up the pieces of the users' failed attempts at setting up the hearing aids. Many participants thought that user-driven technology would push audiologists more into the roles of providing support to or educating hearing aid users. In these roles, participants tended to refer to a partner relationship between the user and the audiologist, and describing the fitting process as “interactional”: *“How do you know yourself whether you've got them on right? Obviously if you can hear better that's probably good, but you know, if they're hanging loose or they're too high or too low, somebody else can see it and tell you. So, I*

*think it's that interactional thing*" [111]. There was also mentions of audiologists increasingly providing their support-related services remotely; that is via telephone or Skype, rather than face-to-face.

Having recently been through the experience of self-fitting a pair of hearing aids and wearing them in the field for 12 weeks, some of the experienced hearing aid users were prompted to make a comparison between the user-driven and audiologist-driven fittings. All agreed that in terms of outcomes there was no difference: *"No, it [self-fitting] didn't make my life any different or any better. It was just something I was doing and it didn't seem to make all that much difference"* [139]. A few participants warned that without the necessary support – to older people in particular – there was a risk of many hearing aids under the user-driven model ending up in the drawer: *"Without any other help, I can see quite a lot of people do the wrong thing, or even throw it [the hearing aid] in the cupboard and say it doesn't work"*[110].

## Discussion

This study sought opinions about user-driven and app-controlled hearing aids from a group of hearing aid candidates who had recently volunteered to try out a commercial, app-controlled self-fitting hearing aid. The group participated in a semi-structured interview in which they were asked about their thoughts on advantages and disadvantages of the technology, and their thoughts on the effect of user-driven fittings on the traditional hearing health care model. Overall, the themes emerging from the interviews suggested that older adults see some benefits and advantages of the new technology, but also plenty of challenges in managing the technology. The need for support and training was highlighted. Participants also speculated that the technological

change will reshape the role of audiologists, but not make the profession redundant. The points are further discussed below.

#### Benefits and advantages of the technology

Given the participants' recent experience of user-driven and app-controlled technologies, this study probed for their views of the advantages and disadvantages of such technologies. Empowerment was the key advantage identified. Empowerment was linked to the technology through the belief that it would enable, or foster, working in partnership with the audiologist, being more in control of the hearing aid settings, and even being able to better independently manage hearing problems (see Table 3). These beliefs resonate with early studies on self-adjustments of hearing aids that reported that hearing-aid users preferred being involved in the fitting process (Elberling & Vejby Hansen, 1999; Schweitzer, Mortz, & Vaughan, 1999), and a growing body of literature suggesting that audiologic treatment is too clinician led (Grenness, Hickson, Laplante-Levesque, & Davidson, 2014; Pryce, Hall, Laplante-Levesque, & Clark, 2016). They further indirectly support literature suggesting that patient involvement in the treatment of a chronic health condition is empowering and will lead to increased adherence and satisfaction (Convery, Keidser, Hickson, & Meyer, 2019; Holman & Lorig, 2004; Lorig et al., 1999).

Another advantage of user-driven technology pointed out by participants was its potentially lower cost and the ability to bypass professional assistance. The cost of hearing aids provided as medical devices has been a long-standing and widespread issue (Convery, Keidser, Dillon, et al., 2011; Franks & Beckmann, 1985; Hougaard & Ruf, 2011; Kochkin, 2007), and is one of the factors motivating the recent legislative

changes to provision of hearing devices in the USA (Blustein & Weinstein, 2016; Nieman & Lin, 2017) as well as exploration of the introduction of self-fitting hearing aids to developing countries (Convery, Keidser, Dillon, et al., 2011). Comments by participants revealed a lack of trust in the profession, particularly those seen as motivated by commercial incentives, which suggests that there may be a scope for reviewing current structures and practices.

Specific practical advantages were suggested in relation to the integration of smartphones with hearing aids. These were centred partly around the phone offering easier access to controls for managing the hearing aids than other commonly used platforms, and partly around the smartphone already being an accepted part of life. The latter observation is in line with previous reports (Raento, Oulasvirta, & Eagle, 2009), but was not an unanimous point of view.

#### Barriers to the acceptance of the technology

Rather than finding any direct disadvantages of user-driven and app-controlled technology, interviewees mentioned several barriers to their uptake and usage. A key barrier was lack of technology self-efficacy. For many participants, the process of fitting hearing aids and engaging with the multi-functionality of smartphones were considered highly technical processes that they thought were beyond them. This particular barrier is likely influenced by the age range of the participants, see Table 1. Age was referred to by all participants in reflecting on the user's capability to adopt to such technologies, with universal comment on the difficulties faced by older people and the facility with technology of younger generations. Thus, lack of technology self-efficacy was also often phrased around a lack of understanding of how the specific technologies work and

feeling slow and forgetful. The finding reflects the importance of *perceived ease of use*, a component of the Technology Acceptance Model (TAM) (Davis, 1989). The TAM is a theoretical model that describes the process by which an individual accepts and takes up new technology. While many product developers consider only their product's utility – the second component of the TAM, which is referred to as *perceived usefulness* – the ease with which the product can be used can be overlooked if the developers do not fully grasp the capabilities and expectations of the product's end users. In the context of hearing aid development, this means that ensuring the user will be able to use and manage the hearing aid easily is of great importance. Our findings underscore the need to better address ease of use when designing hearing aids and associated apps that will primarily be used by older adults. This could be accomplished by ensuring that users are active participants in all stages of development, from design to the end product.

Another barrier to uptake and usage of user-driven technology was concerns about outcomes. Of specific interest was that even though the participants generally had had a positive experience of the self-fitting process, several expressed concerns, and perhaps frustration, about both a lack of understanding of the specific steps in the process and the inability to verify the outcome of the process. Similarly, the question of whether users possessed sufficient knowledge to be able to optimize their hearing aid settings without audiological guidance, was raised by a clinical population when introduced to the concept of trainable hearing aids; i.e. devices that learn the user's preferred hearing aid settings from consistent user-adjustments performed in the field (Keidser, Convery, & Dillon, 2007). The former concern could be addressed through extended information provided with the devices as well as directed multimedia training. It has recently been demonstrated that enhancing access to hearing rehabilitation related information

improves self-management of devices and self-efficacy more generally (Caposecco, Hickson, Meyer, & Khan, 2016; Ferguson, Brandreth, Brassington, Leighton, & Wharrad, 2016). It is, however, difficult to imagine the implementation of a verification process that is as valid and reliable as that provided by expert equipment and knowledge in an audiology clinic, though an integrated performance-based screening to ensure amplification levels are appropriate may be possible. The latter concern may be more of an issue with technologically literate and well-educated people, than with the hearing-impaired population at large, but it is one that manufacturers of future user-driven technologies should not ignore. It should be noted that outcomes data obtained on participants in the research study on self-fitting hearing aids showed no adverse effects from the user-driven process when knowledgeable support was accessed as required (Keidser & Convery, 2018).

As mentioned earlier, some of the interviewees found using the smartphone to manage their hearing aids an advantage because the phone was already an integral part of their lives. On the other hand, others had formed a negative attitude towards the use of a smartphone, with several commenting that they did not want to become addicted to one as they felt it disrupted norms of social interaction. This attitude is likely a generational characteristic (van Deursen, Bolle, Hegner, & Kommers, 2015), but with hearing loss being more prevalent among older adults (Agrawal, Platz, & Niparko, 2008; Dawes et al., 2014), it could preclude the most applicable population from accessing functions (e.g. connectivity) that may only be available through device-specific apps. Education and more supporting evidence for the benefit of such functions may alleviate this problem. Notably, this perceived barrier points out that hearing-aid users' views and understandings of technologies, not just their skills and efficacy in using them, are

important to consider when developing devices and associated apps, and supporting information about them.

Generally, the interviewees thought that support and training would be necessary for elderly people to be successful with user-driven and app-controlled technology. These thoughts emerged in various ways, most likely influenced by interviewees' own experience when first introduced to the technology in a research study where knowledgeable support could be accessed throughout the trial. However, the suggested need for support corroborates observations that help-lines were quickly introduced by dispensers of early online releases of self-fitting technology (Keidser & Convery, 2016), and that a higher proportion of older hearing-impaired people were successful at self-fitting when knowledgeable on-demand support was available (Convery et al., 2018). The need for assistance and on-going support during the technology adoption process in hearing health was also an observation made in an earlier qualitative research study on smartphone connected hearing aids (Ng et al., 2017). Particularly, there have been calls for better design of health-apps more generally (Peng, Kanthawala, Yuan, & Hussain, 2016) and of hearing aid controlled apps more specifically (Convery et al., 2018), as they appear not to be as intuitive to use as might be assumed.

The ways in which many of the participants reflected on their experience of “being put to the task”, with support as needed, as a training or learning exercise is interesting. A couple of participants even directly referred to experiential learning, which refers to learning as a process whereby knowledge is created through the transformation of experience (Kolb & Kolb, 2009). The comments made, suggest that an opportunity to learn more about hearing aid management through engagement with user-driven

technology, while having access to expertise to validate and support learning from the experience, would be highly valued, and so should be considered a key component of future hearing health care.

#### Consequences of the adoption of the technology

The interviewees did not predict major changes to the traditional hearing health delivery model or the role of the audiologists when asked to contemplate a future in which the fitting process was more user-driven. A few did suggest that user-driven hearing technology could see audiologists made redundant. However, generally, participants believed that expert provision of hearing health care would continue for a variety of reasons, including meeting demands by those with significant hearing problems and providing consumers with choice. The fact that this group was not ready to give up access to professional services testifies to the “complexity and changeable nature of the desires, emotions and needs that characterize the patient-doctor relationship” (Lupton, 1997). In Lupton’s (1997) study people reported acting as both self-empowered and passive patient simultaneously or variously, depending on the context, when interacting with health care experts, which questions a future without audiologists and other medical professionals.

Suggestions for the future role of audiologists were not surprisingly tied in with popular views put forward when talking about perceived benefits of and barriers for using the technology. That is, overall, the role of the audiologist was thought likely to change from control to support and education. Of interest is that several participants suggested that user-driven technology could offer an entry-point to use of hearing devices for those with milder hearing loss, in agreement with the views of some professionals



(Amlani, Taylor, Levy, & Robbins, 2013). Others acknowledged that support with self-fitting may not need to be provided by a qualified audiologist, although such views could be influenced by their own experience as research participant in a study where on-demand support was provided by non-audiologist staff trained to manage the trialed self-fitting hearing aid.

### Implications and future directions

While the user-driven concept was generally embraced for the opportunities it provided to become engaged in the fitting and fine-tuning process and to learn during the experience, as well as offering a discreet and cheaper option to consumers, the technology was thought to be somewhat of a “black box”, and challenging to older people with the need for support highlighted. Assuming that the market of user-driven technology will continue to grow, there is an opportunity for the audiologic profession to adapt to provide for and meet the needs of people who choose to pursue user-driven technology. The best way to provide this service is still to be determined through future research. Opinions about integrating smartphones with hearing aids were divided, depending on to what extent the individual was a fan or not of the smartphone and its use in public spaces. This suggests that hearing devices should be provided with a choice of accessing from a dedicated control similar functions to those provided by smartphone apps, although it remains to be seen whether such a control would be better tolerated by those who viewed the smartphone as a social disrupter. More broadly, the views of users about specific technologies and their appropriate uses, rather than simply users’ ability to use such technologies, should be considered in devising consumer interfaces. Some of the more specific problems with the technology described by interviewees and the lack of a verification process for those who choose to self-fit,

suggest that more work could be done in terms of making it more acceptable and user-friendly. The richness of data generated from this small-scale qualitative research project suggests that using a participatory approach involving all stakeholders in this process could be valuable (Ferguson, Leighton, Brandreth, & Wharrad, 2018).

### Conclusion

From the user's perspective, user-driven and app-controlled technology presents some benefits: being a cheaper and more discreet option, fostering empowerment, and breaking down the sense of medicalization, as well as some challenges linked to lack of technological self-efficacy, understanding of the fitting process, and a verification process. Users further thought the technology would change the future role of audiologists, but not make the profession redundant. Their thoughts on the technology challenge the audiologic profession and hearing industry to adapt to technological advancement by providing adequate support and training, and to make the technology more accessible to older people, respectively.

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Table 1: Participant characteristics

Participant	Gender	Age (years)	4FA (dB HL)	HA exp (years)	Smartphone owner
103	M	70	32	3	N
109	M	73	46	8	N
110	M	65	49	0	Y
111	F	67	30	0	N
118	M	74	45	0	N
124	M	79	51	31	N
128	M	81	56	12	Y
133	M	85	38	10	Y
139	F	80	33	0	Y
151	M	75	44	0	N
156	F	56	44	12	Y

Table 2: Sub-themes, categories, and example quotes for theme 1: Prerequisites to the successful implementation of user-driven and app controlled technologies.

Sub-themes	Categories	Example quote
Support	Advice	Primarily it was that app - I don't know whether I was using it properly - that brought me along here to your tech guy. [128]
	Training	A person that's got that and is not that okay with the phone settings and all that, once they're shown once or twice and they see the benefit for it, they'll learn. [110]
	Oversight	<p>I still think audiological oversight of the process is - there's a place for it, a really important place for it. [156]</p> <p>Well, someone to review your work. Because particularly, again, to get back to the treble, I didn't even realise it was causing a problem. [109]</p>

	Verification	I mean, when I did it, I knew that somebody was watching me and was listening to me and if I made a mess of it, it would be sorted out. [139]
Adaptation through experience	No difficulty	The - what they said to do, it did exactly that. I was able to - it was easy technology. Okay? The technology was user-friendly. [118]
	Working it out	I felt a bit slow, but I got there eventually and managed to conform to what was put to me to set the hearing aids. [124]
	Novel and fun	I found it a novel feeling initially because I'd never fitted hearing aids to myself before. It wasn't uncomfortable. [103]
	Experiential learning	But I'm not good with technology. The first two or three times it's almost a learning experience and I get used to thinking oh no hang on, I don't do that, I do this. That's what I've got to do and I don't think I'm alone in this. [103]
	Endorsing the user-driven concept	I can see a time, as the technology improves and the self-fitting aids get more physically comfortable and smaller and less

		obtrusive, I can see a time where I would probably go to self-fitting aids. [156]
	Experimenting and engaging with app	I tried all sorts to get that right. I couldn't. I tried different settings, the treble and the bass, but it just didn't get to the finer points I need. [110]
	Understanding and knowledge	I think it's an important part of learning, is having an understanding of the logic behind something. [103]  I was able to get them out of their box and do all of that, they said, oh, you're really good at that - but it's because I watch my brother put his in and take them out, I've had some idea of it.  [111]

Table 3: Sub-themes, categories, and example quotes for theme 1: benefits and advantages of user-driven and app-controlled technologies

Sub-themes	Categories	Example quote
Empowerment	Breaking down sense of medicalization	So [self-fitting] took away from the medicalization of hearing loss and made it more into something like I've got a little bit of IT knowledge, so if I needed to, I could order these things online and I could follow how to do the testing and this would work for me. [156]
	Control	[relative to traditional fitting, self-fitting gave me] more control. But the general affect was pretty much the same. My hearing problems were fixed. [109]
	Enhancing expertise	there is a culture among GPs of very much being the expert. Audiologists are slightly lesser. But having the opportunity to go the self-fitting aids path even enhances the hearing aid user's expertise a little more. [156]
	Independence	I'm one of those people who believes that the more you can help people and to some extent train people to stand on their

		own two feet and to take pride in their achievements, the more they are independently able to look after themselves and the more they'll have confidence about themselves. [103]
	Fostering self-efficacy	Once I'd done it a few occasions and picked up the knack and also picked up what I was doing and I began to understand what I was doing I gained more confidence in it. [103]
User-driven technology will potentially overcome problems with current delivery model	Commercial world – promises and cost	But in the world of commercial things, be it hearing aids - and I'm critical here - being hearing aids, I think they make promises they can't keep. [118]
	Audiology crooked	I think most [audiologists] are so crooked that it's good if they go out of business. [128]
	Provide an alternative	I think some people just like going out like that, other people are quite okay to be at home about things. [111]
Easier manipulations from a smartphone	Better visuals	So the phone was enough that the print was big enough that I can see clearly what I was doing. [103]

	Better dexterity	[The app is] really good, and that could be really good for older people as their sense of touch starts to deteriorate, that it may be easier to use something handheld than the tiny little buttons on the back of your hearing aid. [156]
	Smartphone integrated part of life	Oh yes, this [using the app to manipulate the hearing aid] has had nothing - no bearing on all this [my experience]. It's merely an adjunct. [133]

Table 4: Sub-themes, categories, and example quotes for theme 3: barriers to the acceptance and use of user-driven and app-controlled technologies

Sub-themes	Categories	Example quotes
Questionable capability in managing technology	Lack of self-efficacy	I'm always hesitant and nervous with technology the first few times I use it. [103]
	Lack of knowledge and understanding	No, I did fiddle with it [the app] from time to time, but I think my knowledge of how to operate it wasn't sufficient. [111]
	Forget how to	But there was a time - I did find that I am a bit absent-minded and I did forget that I could do something with it [the app]. I knew how to change the settings and it must have been - I can't remember now. But anyway, I did have a bit of trouble with the technology. [139]
	Unsure	I'm hesitating, because I'm not 100 per cent sure. I didn't find it easy. I was not at all sure of how to do it properly and whether I was doing it properly or not. [128]



	Lack of physical capacity	I mean I've got Parkinson's, I shake. Tiny little keyboards [unclear]. [109]
Concerns about outcome	No verification process	How do you know yourself whether you've got them on right? [111]
	Lack of professional oversight	Oh, once they were done yes, but I liked to have the assurance of the audiologist that I had done it properly. [124]
	Harm or damage	but out there in the world of future self-fitting hearing aids, yeah, are people going to go into this gung-ho and never consult an audiologist and never have any professional testing and are they then going to do themselves some harm because of that? [156]
Negative attitude towards the use of smartphone	Now wanting phone to be the master	I can't see the point of it. I do not wish to be one of these people that goes through life at every step with one of these monsters in front. [124]
	Not phone happy	The kids, they have all iPhones and I'm not that phone happy. I always want to throw it down, throw it away. [110]

		Yeah, I enjoy technology. I'm open to technology, but I'm not going to get a smartphone. [124]
	An inconvenient tool	My [phone] battery is giving up at five o'clock every afternoon which is really annoying. [139]
Hesitations toward user-driven concept	Want contact or connection with audiologist	So I would still keep connection with the audiologists. This is good, but it doesn't make me think that I know everything, and I would still be keeping a connection. [156]
	The approach not there yet	The technology of the app-driven hearing aid is not yet there, I don't think. [128]
	Don't see the point of user-driven technology	Well, what's the point of getting me to do something that somebody else does three or four years fulltime training to achieve. [124]
	Didn't engage with the technology	I have not got involved with the app after that [completing the self-fitting process]. [151]

Table 5: Sub-themes, categories, and example quotes for theme 4: beliefs that age is a significant factor in how well people will adopt new technology

Sub-themes	Categories	Example quotes
Older adults	Technical literacy	Well I know that there a lot of elderly people - and I do deal with a lot of elderly people - that technology puts them in a very uncomfortable situation. They just feel it's way beyond them. [151]
	Slow learners	You know if you get a 105 year old man in one day you mightn't be able to teach him as much as you could teach a 50 year old person. But you still need them to feel that they are part and parcel of an ongoing process. [103]
	Technology can benefit older adults	obviously mail order and such like is going to help older people because it does get difficult to get out and do things. [139]
Younger adults	Digital natives	It's going to become less and less of a problem as time goes on, because the next generation is digital natives, so this stuff is

		going to be totally intuitive to them, but at the moment there's a transitional generation where the amount of digital literacy varies really widely. [156]
	Future happy users	See, when my nephew, who was then in high school at that stage, found out, he wanted hearing aids as well, because he realised that if he had that set up, he would be able to have his music playing while he was in class and no one would know. [156]

Table 6: Sub-themes, categories, and example quotes for theme 5: consequences that flow from the adoption of user-driven and app-controlled technologies

Sub-themes	Categories	Example quotes
Consequences for audiology as a field	Audiology remain a field for research	They'd be very important in research and in the actual science of audiology, you could never do away with that, because without that knowledge you wouldn't have the development of new devices and improvements. So in that realm, there would be audiologists. [111]
	Audiology done by a machine	That audiology work is getting done by the machine, like a robot can do things, providing the robot has been taught the right or been pushed the right way [110]
	Audiologists still needed to provide expertise and oversight	I wouldn't like to see reduction in the number of audiologists out there available to help people because of this, because audiologists are still the ones who have gone and done a Masters

		degree in this area, so we still need that professional oversight, that professional expertise. [156]
	Audiologists out of work	They'd be out of work, they'd be having to reskill probably. [111]
Consequences for the role of audiologists	Similar role	It will be a similar role. [103]
	Providers for people with real hearing problems	If I had difficulty [hearing] I'd go and seek proper attention, but at the present moment I'm quite comfortable. [151]
	Double workload	Well, it's not going to be satisfactory for the user and it's going to double the work of the professional. [124]
	Educator	Someone has got to train you to do it and show you how to do it. I'm not 100 per cent believer in the Steve Jobs approach. I think you need a bit of guidance to get the maximum [of those things]. [109]
	Remote support	I think you do need some guidance, but I'm not saying that it has to be guidance directly one-to-one. [110]

	Partner relationship	We can be like driver and co-driver. I want to have a partner relationship with my practitioners. [156]
Consequences for outcomes	No difference	Now the question is, which one gives me the better hearing? I can't tell. [128]
	Device in drawer	Without any other help, I can see quite a lot of people do the wrong thing, or even throw it in the cupboard and say it doesn't work. [110]