Hearing enhancement technologies and issues of self-management: a case study

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Abstract: It is estimated that a significant proportion of the population will experience some degree of hearing difficulty, particularly later in life. But only about 25% seek technology assistance, generally in the form of a hearing aid. Some that seek help may reject such technology at different stages of potential uptake. Social, technological and cost barriers are cited. One approach to achieving better outcomes considered in this paper is to support patient self-management via the internet, and a case study of one company combining this concept with a bundle of advanced technologies is presented. What is learned from the case study is considered in relation to a health self-management model, a technology acceptance model and a business model. Each model helps to provide insights into the socio-technical issues involved, but each model on its own only provides a partial view, leading to a suggested need to adopt multiple viewpoints.

Keywords: audiology; telemedicine; innovation; entrepreneurship; socio-economic norms; continuous learning; technology marketing; business models.

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Biographical notes: Ronald C. Beckett is an industry practitioner who works at the academia – industry interface with a focus on learning to compete. He is an Adjunct Professor at the Swinburne University of Technology and has held similar positions at other universities. He has more than 25 years experience in R&D, operations and strategic management in aerospace, plus more than ten years management consulting experience implementing creative change. He is an Engineers Australia Fellow and holds a Doctor of Business Administration (UWS). He has authored or co-authored more than 100 papers related to innovation, collaboration and knowledge management.

1 Introduction

At any given time, a proportion of the population is suffering hearing impairment to some degree, and with an ageing population in many countries, the numbers are increasing. Mohr et al. (2000) noted the significant societal cost associated with hearing loss, that a person could become socially isolated, be more at risk because audible warnings are not

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heard, and be less productive in the workplace. It has been suggested that sensory decline in older adults, including hearing difficulties, challenge comprehension and memory for everyday speech, and that depression, anxiety, lethargy and social dissatisfaction are often reported (Wingfield et al., 2005; Heine and Browning, 2002).

Despite offering continuously improving technology, using a hearing aid may or may not offer an acceptable solution, with speech recognition remaining the most common concern (Arlinger, 2003; Kochkin, 2010). In researching modest hearing aid uptake, Wesendahl (2003) suggested that whilst up to 20% of all Germans might experience some hearing loss, less than 25% of those use hearing aids. "Some important reasons for these circumstances are the stigma of wearing hearing aids, an unsatisfactory solution in contrast to the marketing promises of the prescribed device, the quality of fitting in artificial conditions rather than in real soundscapes, and the price" (p.56). The research question being explored in this paper is what changes may bring about some improvement in hearing aid technology uptake.

Knudsen et al. (2010) reviewed literature over the prior 30 years where factors influencing hearing aid uptake were considered. The articles covered different stages of hearing impairment management: prior to hearing aid fitting, the period covering the fitting and the period post hearing aid fitting. Influence factors were personal (e.g., source of motivation, expectation and attitude), demographic factors (e.g., age, gender) and external factors (e.g., cost, accessible counselling). Only two studies covered the actual fitting process. Some factors (e.g., external motivation) were seen to positively impact one stage, but have no impact on other stages. Other studies have highlighted the key role of 'significant others' (e.g., parents, a spouse) and their knowledge of hearing impairment management at different stages in an individual's learning journey (e.g., Meyer et al., 2014).

There are some particular market dynamics here, where encouraging clients to investigate solutions is necessary, as is understanding why they might disengage at some point, and this is discussed in the next section of the paper. Research organisations and audiology equipment manufacturers around the world are striving to develop better technological solutions to patient assessment and hearing enhancement products, and some developments are discussed, followed by discussion of some established and some emerging delivery mechanisms and associated business models.

One approach to improving the rate of hearing aid uptake is to offer an internet-based self-service solution to provide greater access and more convenient interaction with a client. This approach is explored drawing on a longitudinal case study of a firm that integrated a number of technologies to support assessment, hearing aid selection and initial setup plus the ability to fine-tune the device in real soundscapes.

2 Some observations from the literature

The 2013 world market for hearing aids of all kinds has been estimated at US$5 Bn, and is dominated by six manufacturers (GVR, 2014). However the uptake of assistive technology is relatively low. A 2016 US study suggested it was about 30% in that country, despite significant technology advances (Kochkin, 2010). What might the sticking points be?

2.1 Observations about market dynamics

There are opportunities for the use of new technologies at different stages of a client's hearing enhancement journey, characterised in Table 1. Note that there are also points where a client may disengage (Knudsen et al., 2010).

Table 1 Stages in a client's hearing enhancement journey

Stage		*Activities*
1	Recognition of hearing impairment	This commonly involves consideration of the client's social and work environment and some form of screening. The outcome may be a medical referral and/or a personal decision to seek a more detailed assessment.
2	Assessment of hearing impairment	This involves one or more tests where quantitative and qualitative medical data are collected. The outcome at this stage is the identification of impact factors and possible future actions, one of which may be a decision not to proceed further.
3	Enhancement solution identification	This commonly considers cost-benefit tradeoffs and some experimentation with options. The outcomes may be the selection of a particular hearing aid or a decision not to proceed further
4	Enhancement solution implementation	This involves fitting and tuning the selected hearing aid, and the outcome is a functioning hearing enhancement capability. This may require the help of others.
5	Solution refinement and client learning	This involves learning about the practicalities of using and tuning a hearing aid in a variety of day-to-day situations. It also involves the client learning how to interpret the new sound signature available. Outcomes may be the regular use of the device, the occasional use of the device, or the abandonment of its use.
6	Ongoing review and adjustment	This involves monitoring client progress, routine re-assessment, and consideration of technology advances. The outcome may be a decision to acquire a different kind of hearing aid.

Hickson and Worrall (2003) highlighted the importance of engaging with and educating the hearing impaired at the awareness stage, with a suggested focus on communication skills. It was suggested that audiologists could enhance the efficiency of an overall treatment program through involvement at this early stage.

There is a trend towards the use of the internet to help engage at different stages. In a mid 2000's Canadian review of telemedicine practice in general, Jennett and Watanabe (2006) identified several influence factors, noting that each factor may be at different stages of development/maturity (e.g., ICT adoption, the development of sustainable business models):

- information and communication technology adoption, implementation and integration
- contexts and cultures – including client economic circumstances
- health system transformations
- emerging technologies
- business models and frameworks
- evaluation, and evidence

- policy, standards, regulations
- traditional practices
- partnerships.

Regardless of the extent to which telemedicine may be adopted, each of these factors can have an impact at one or more Table 1 stages. For example a National health initiative may be launched to encourage people to be assessed (stages 1 and 2) or it may fund the acquisition of approved devices (stage 4). This presents as a complex socio-technical eco-system where changing one element can have unexpected consequences elsewhere.

2.2. Recent technological developments

The term 'recent' is used here in relation to the broad uptake of a technology, recognising that experiments with a particular technology may go back some time. There have been technological advances that help in patient assessment (stage 2 in Table 1), in providing treatment (stage 4) and in optimising use of an assistive device to help in tuning a hearing aid (stage 5) in different soundscapes.

Testing usually starts with a pure tone auditory test to assess the level and profile of hearing degradation. Hofstetter et al. (2008) described an established Alaskan community network providing audiological services via store and forward digital scans and high resolution images with ear, nose and throat specialist physicians. Ciccia et al. (2011) described the use of Skype in Ohio urban community health clinics for speech, language and hearing screening of children up to six years of age. During a two-year study 411 screenings were completed. Smith et al. (2012) described an Australian telemedicine ear-screening service established in an Aboriginal community in central Queensland led by local indigenous health workers. 2,111 screening assessments were carried out at 21 schools in the region. Masalski and Kre□cicki (2013) confirmed the practicality of web-based pure-tone auditory self-assessment.

Depending on the nature of the findings, other tests such as bone conduction and hearing-in-noise tests may be needed. Some regard pure tone auditory testing as a poor indicator of the ability to interpret speech. Divenyi et al. (2005) tested 29 elderly patients over about a five-year period, considering word recognition with various kinds of distortion or interference (single speaker, babble noise, reverberation). Whilst performance declined over time, there was a larger variability in understanding speech than in audiometric measurement outcomes, suggesting to them that not only the accuracy but also the nature of speech understanding evolved as the patients matured. Hearing aid manufacturers are making web-based speech tests available over the internet, with some being packaged as a smart-phone app (Kardous and Shaw, 2014). It should be noted that, unlike some medical test situations, the client is an important part of the testing process, providing feedback about the perceived response to some stimulation.

Assistive electronic technology (stages 3 and 4) may be packaged as a kind of accessory (hearing aid) or may require a bone conduction or cochlear implant. All of the devices bring together some form of miniature sound receiver (microphone), sound processor, transmitter (speaker) and power supply. Microphone, speaker and power supply technology development is stimulated by multiple industry sectors (e.g., mobile phone, communication and health sectors). As sound-processing technology has moved from the analogue to the digital world, a wide range of possibilities has opened up.

Firstly, a hearing aid could be readily tuned to offset a particular client's hearing loss profile, and secondly signal-processing parameters could be set up as switchable 'programs' to support speech recognition in a variety of quiet or noisy soundscapes.

It may be assumed that once an assistive device is set up, it will only require occasional adjustment (stages 4 and 5), but this is not always the case, particularly where the client soundscape differs from that associated with setup. This implies an assistive device may have to be regularly re-tuned, and some devices now have Bluetooth communication capabilities so they can be easily linked with another smart device to allow client self-tuning. In a parallel development, some researchers are exploring the addition of apps to smartphones or tablet computers so they can act as hearing aids (Amlani et al., 2013).

There are some indications that continuing improvement in micro-manufacturing techniques and 3D printing applications may help further reduce the size of some components and facilitate higher degrees of customisation in hearing enhancement devices.

2.3 Delivery mechanisms and business models

Traditionally, audiologists have been the delivery point of hearing loss assessment services and of the provision of solutions in a broader health system context. The most commonly provided solution is a hearing aid, and a particular audiologist selects a range of hearing aids to offer, generally through a supply agreement with one or two manufacturers. The cost of the assessment and follow-up services are bundled in with the cost of the hearing aid, which can make the price seem relatively high, but there is commonly more than one follow-up visit to be allowed for. In some situations, the cost may be offset by contributions from a health insurance scheme that may nominate approved practitioners and hearing aids. One hearing aid manufacturer is making a hearing screening toolkit available to general practitioners to facilitate early hearing loss detection (Unitron, 2015).

Hearing aids may also be offered through specialist retail outlets that employ audiologists. The largest, Amplifon, has some 3,500 stores worldwide. There is a trend towards vertical integration as hearing aid manufacturers acquire these kinds of outlets (GVR, 2014). The large US based retailer Costco now offers low cost hearing aids, drawing on its market power to negotiate specification and price with manufacturers, and offering in-store access to an audiologist (Costco, 2016). The participating manufacturers have seen some backlash from their traditional audiologist clients.

Shaw (2016) commented on a US Government study that expressed dissatisfaction with current access arrangements. The high cost of hearing aid technologies, barriers to access for hearing aids, and low levels of innovation in the provision of broader access mechanisms were cited as areas of concern. An industry response accused the government of treating hearing enhancement technologies in the same way as consumer electronics, and discounting the valuable role of audiologists as health professionals.

Some smaller manufacturers have been offering online purchase at modest prices for many years (America Hears, 2001). Ribera (2011) noted ten concerns expressed by audiologists related to effective telemedicine uptake. These were:

a unfamiliarity with the technology

b lack of confidence in outcomes

c initial upfront cost for equipment and connectivity

d training

e licensure issues

f reimbursement issues

g paucity of validation studies

h lack of standardisation

i safety and security issues

j patient acceptance/satisfaction.

Ribera suggested that to offer a comprehensive assessment capability, a number of tools may be required, e.g., air conduction, bone conduction, speech audiometry, electrophysiological tests (auditory brain stem response), and otoacoustic emissions. Ribera speculated however that (p.206) "The day may come when a small box is connected to a patient's PC that can be controlled by an audiologist located at a considerable distance to facilitate making adjustments to a cochlear implant or hearing aid in real-time". That day has arrived, and Eikelboom et al. (2014) have described successful arrangements for the tuning of cochlear implants in remote patients.

This raises the question – if a person with hearing loss can now do an online test, buy a hearing aid capable of linking with a tuning device, and then optimise the tuning themselves, then what is the role of an audiologist? Convery et al. (2016) suggest that audiologists may be able to help a larger number of clients and those with special needs if they embrace and support patient self-management.

2.4 Patient health self-management

In most health management arrangements, clinicians conduct tests, make an initial diagnosis and recommend/provide treatment, with patient self-management limited to taking pills and perhaps managing diet and exercise. Patients with some conditions like diabetes also use tools for self-testing (e.g., Glasgow et al., 1997), and in these circumstances patient education to some agreed standard may be needed (e.g., Funnell et al., 2009). Kramer et al. (2005) have noted that learning is also associated with the acquisition and use of a hearing aid (stages 5 and 6 in Table1). Initially, learning relates to hearing aid operation: to proper fitting, adjusting volume, selecting 'programs', cleaning, and battery management. Subsequent learning involves re-training the brain to recognise the new sound signatures, which can take several weeks/months, and they suggest a formal support program helps here, generally in conjunction with a 'significant other'. In their study comparing those with and without re-training help, they found that the group receiving re-training reported an improved quality of life compared with the group that just got help in setting up their hearing aids.

A number of authors have noted the need to recognise the social environment in which hearing enhancement technologies are used, and to recognise the role of 'significant others' in providing support (e.g., Singh and Pichora-Fuller, 2016).

3 Research approach

The introduction indicates that user access and acceptance is an issue with the adoption of hearing aid technology, and it is suggested some form of internet-based self-service arrangement may be helpful. Hultink and Robben (1995) researched what makes new technologies successful and suggested that the relative importance of 16 product success measures they identified may change over time, with initial concerns related to product launch, and later ones related to market perceptions and return on investment. The four external measures they identified were customer acceptance, customer satisfaction, perceived quality, and product performance levels. Variants of a technology acceptance model developed by Davis (1989, 1993) have been used to explore IT acceptance factors for some time. The model examines four major variables: perceived usefulness, perceived ease of use, behavioural intention, and behaviour. Variants have generally added sub-tier elements associated with each major variable, and it is suggested that matters of context are important (Lee et al., 2003).

A qualitative longitudinal case study approach has been adopted, recognising that hearing enhancement is a journey with potential technology rejection by individuals at particular stage, noting the observations of Hultink and Robben (1995) that perceptions of success may change over time and the need to consider multiple environmental factors related to technology acceptance suggested by Lee et al. (2003). The research builds on previously assembled 2014 case study data, extending the dataset back to 2008 and forward to 2016.

The case study firm, BlameySaunders hears (BSH) is bundling the technology developments described in Section 2.2 with internet-based delivery. Rich datasets have been assembled including technical and business operations data provided by the founders, six direct interviews with the founders, independent founder interviews and articles by the news media, company documents, and information from social media sites used by the firm to facilitate customer engagement. The data was sorted into approximately two-year time slices to identify emergent issues and changes over time. Over that time there have been both technology and business changes. This provided a timeline view of the evolution of the technologies used, of the business model, and of the responses of some competitors. A narrative sequence analysis (Buttriss and Wilkinson, 2006) was performed on data accumulated from multiple sources to consider changes in dominant conversations between the firm and its environment.

4 A case study: BSH

The founders of this Australian company, Elaine Saunders and Peter Blamey, are passionate about ending the negative perceptions associated with hearing loss, demystifying the buying process and offering a much fairer deal to all those who need hearing aids by drawing on emergent technology. Elaine Saunders has a background in clinical audiology research and Peter Blamey has a background in digital sound

processing research. They were not satisfied with the way traditional business models delivered benefits to the hearing-impaired at a reasonable cost, and decided to test an alternative.

4.1 Precursor activities

In the 2000s a group of Australian researchers proposed a method of selectively amplifying sound picked up by a hearing aid and demonstrated its benefits [ADRO®, Blamey (2005), Blamey et al. (2006) and Blamey and Martin (2009)]. Clinical trials of ADRO in cochlear implants and hearing aids showed 3:1 preferences and significant benefits for speech perception in quiet and in noise compared to the incumbent technologies. The sound processing technologies were commercialised using a licensing model through a spin-off company, Dynamic Hearing Pty Ltd., supported by venture capital investors. This company was acquired by Wolfson Microelectronics and is now owned by Cirrus Logic. A software operating system (analogous to Microsoft Windows) that was part of the system became a standard for some digital sound processing component manufacturers. Through their association with the establishment and growth this startup firm, Peter Blamey and Elaine Saunders gained valuable commercial experience.

4.2 Technology development

Building on that experience, BSH developed a complete system aimed at addressing all stages in Table 1 (IHearYou®, http://www.blameysaunders.com.au). IHearYou includes an online speech perception test for measurement of hearing with or without a hearing aid. Their hearing aids using the ADRO technology, and apps for adjustment of hearing aids via a proprietary Bluetooth programmer, have won multiple innovation awards. A suitable hearing aid can be purchased online, customised using the speech perception test results, and then fine-tuned by the user connecting the hearing aid to a PC or mobile phone. The combined product-service cost is relatively low, and some health insurance providers are now recognising this. For those who prefer face-to-face service, the hearing aid can be selected and optimised with the help of an audiologist. Online systems for keeping track of outcomes and providing ongoing service have also been established.

The product development approach could be described as an open innovation/open source strategy where the product elements of the offering evolved over a decade or so combining inputs from researchers in several countries. One outcome of this was access to a significant clinical trials database and a platform of technology components that had been approved by regulators somewhere in the world. BSH have established strategic partnerships with a number of enterprises to facilitate advanced technology production. The common goal of the strategic partners is to address social problems related to hearing impairment and hearing aid uptake, and BSH also maintains linkages with a number of not-for-profit community organisations.

4.3 Business development

The founders first registered a company in 2007 with the trading name Australia Hears, to sell hearing aids online in conjunction with an established online provider, America

Hears. Hearing aid manufacture was outsourced, drawing on the network of contacts developed through Dynamic Hearing. There was little effort put into product promotion in the first few years, working closely with initial clients in a Beta testing style to refining the back office infrastructure. Experience with online customer engagement was pooled with that of the associated firm, America hears.

The organisation was initially hosted at the Bionic Hearing Institute in Melbourne, Australia, where the founders had worked on cochlear implant technology. The Institute is close to an Eye and Ear Hospital and surrounding specialist's rooms – a kind of technology cluster precinct. In 2010, BSH moved to their own premises in the same area. By 2016 the number of staff had grown from two to thirty. Finding the right blend of skills to support the business model adopted by BSH was an evolutionary process.

Elaine Saunders was established as the CEO with Peter Blamey as Board Chair also responsible for on-going technology research. Elaine launched a community education program, primarily through radio interviews and speaking engagements, and in 2012 established a personal wordpress blog site to share her experiences and those of clients. By 2016, the wordpress site, which allows comments on entries, had accumulated a large number of contributions, and was restructured to facilitate searching under specific topics, like 'adjusting your hearing aid'. This site and the company website were subsequently supplemented by establishing Facebook, Twitter, LinkedIn and YouTube social media sites.

In 2015 BSH opened a second office in Sydney, Australia offering a face-to-face audiology service. In 2016 the firm began a trial providing an alternative face-to-face connection with a regional pharmacy retail chain.

4.4 Establishing market credibility

Elaine Saunders is an advocate for people with hearing loss. She is a member of the Rotary Club of Melbourne, Chair of its Health Issues Committee and an Executive Director of the Rotary International Action Group on Hearing. In 2014 she co-produced a play performed in Melbourne (October 2014) – The Sound of Waves – based on the life experience of a profoundly deaf girl (Jodie Harris, actor) who received a cochlear implant as a trial patient in 1999. In 2015 she published an autobiography called the 'Sound of Silence' (Saunders, 2015), tracing her involvement with hearing impaired people from growing up with a substantially deaf father through international engagement with clinical researchers.

In 2010, Elaine Saunders won an American Audiology Academy award for her work in the field, and has continued to win regional awards for various aspects of her work. Peter Blamey, who is a co-inventor in 25 patent families, had won a similar award in 2007, and in 2012, Peter was awarded the prestigious Australian Clunies Ross Science and Technology Medal for his research and development of hearing aids. In 2016 Elaine won the Clunies Ross Entrepreneur of the Year Award in recognition of her 'outstanding efforts to establish a niche hearing aid manufacturing industry in Australia coupled with a distribution network that provides affordable access to these technologies'.

Whilst these awards may be personally gratifying for the founders, they maintain a public profile and support the development of trust in the business – that it supports ethical behaviour, and that claims of better technology are credible. This has encouraged some high profile community members to try out their hearing aids, and subsequently provide an influential endorsement.

In 2011, a representative of the Australian Professional Society for audiologists warned against the self-help approach adopted by BSH, suggesting it might be more expensive in the long run. Firstly, only treating the symptoms of hearing loss may not deal with an underlying condition, and secondly if the client cannot successfully fit and set up the hearing aid, they may have to go to an audiologist anyway. BSH address this concern by offering telephone and online support.

4.5 A focus on client solutions and learning

Narrative sequence analysis of assembled documents showed that the dominant conversations relating to client solutions changed over time, starting at company formation with a focus on the awareness stage of a potential client's hearing enhancement journey. A variety of personal stories were commonly shared to openly discuss some potential barriers and illustrate the benefits of seeking help. This moved on to conversations about what was changing in the hearing aid technology available, and about the effective fitting of hearing aids. Perhaps in response to concerns expressed by traditional audiologists, there were conversations about the variety of causes of difficulty in speech interpretation, training for hearing professionals, and the impact of a clients hearing difficulties on partners. The next theme was about the utility of devices that could help hearing aid users tune a variety of parameters and develop multiple 'programs' suited to different soundscapes. BSH have continued to refine this technology and have brought together industrial designers and engineers to deliver a user solution, not just a technology. There is some emphasis on personal learning from experience with hearing aid use. These topics are re-visited on BSH websites from time to time.

4.6 Client interaction

The founders' primary aim is to reach out to those hearing-impaired people who haven not traditionally sought help via existing health provider or retail pathways or to those that have had some difficulty with such engagement. As noted in Sections 4.4 and 4.5, both face-to-face and social media communication channels are used to encourage initial engagement and to share information about new developments and client experiences. Face-to-face audiologist services are available in Melbourne and Sydney, and help is provided to clients via a call centre and online chat facility. It is noted that people interested in exploring health support options are now more frequently researching possibilities via the internet (e.g., Fox, 2011). In BSH experience, these people may be the one with the problem or a 'significant other'. Anecdotal evidence suggests action may follow after it has been suggested by at least two trusted sources. Whilst people may conduct all transactions online, the commitment to buy most commonly follows a telephone call with the company (to confirm it is real?).

When clients wish to re-tune their devices they connect to a computer, and if they wish, a BSH expert can also access their computer via the internet whilst discussing suitable adjustments over the telephone. The relative frequency of assistance is similar to that observed in a traditional audiology practice. BSH also maintains client records in a form that is suitable for storing in an Australian Government health database if the client wishes. This can enable the client to access the information in conjunction with other medical practitioners if desired.

4.7 On-going research

The BSH founders have a long history of engagement with hearing research organisations, and that continues today. Young researchers are invited to work on a succession of short-term R&D projects, some with an audiology orientation, and some with a technology orientation. These projects consider specific issues associated with each of the stages in Table 1. In 2015 the firm also became a partner in an Australian university entrepreneurial PhD program called 'bioreactor' where biomedical students undertake a blend of technology and business studies. Instead of drawing on literature research as a foundation for their future studies, they spend their first year working with an industry partner to finalise the focus of their research (Maritz et al., 2015).

5 Discussion

There are suggestions in the literature that particular technologies used in combination can help people with a hearing impairment help themselves, but this is not supported by the dominant business models. The case study firm, BSH introduced an internet based self-help alternative offering a relatively low cost advanced technology solution. This solution shifted some responsibilities for health management from the domain of the practitioner to the client, however many audiologists have concerns about the self-management of hearing health. But as also noted in the literature, self-management is a necessary part of some health management regimes, e.g., diabetes. Three issues are now discussed: health self-management from a social acceptance viewpoint, technology acceptance, and sustainable business models.

5.1 A social acceptance viewpoint

The first self-management issue though is how to encourage those with a hearing problem to get any kind of help. A Dutch study of 1,491 people aged 55+ showed that 67% mentioned hearing problems, but only half sought help (Duijvestijn et al., 2003). Survey responses suggested that help-seeking behaviour was strongly dependent on the degree of hearing complaints, reported social pressure and a willingness to try a hearing aid. It was suggested that active promotion of technology solutions and some emphasis on the social activities that people are already missing out on or were uncomfortable with might improve the situation. Some that did consult a GP did not proceed further if that particular GP did not see a significant benefit in doing so. The case study firm, BSH, is putting some emphasis on the social aspects of patient engagement, and is offering an independent pathway (internet and self-testing) to support initial self-assessment. The firm is marketing through local community networks rather than mass marketing channels, highlighting the quality of the technology offered and building on user stories. BSH has made its speech-based test available to other audiologists free of charge, and some larger hearing aid manufacturers are following their lead. As noted earlier, another firm is making a toolkit available to GPs to conduct a preliminary hearing assessment in recognition of their important role (Unitron, 2015).

There is reference in the literature to the role of a 'significant other' who may influence the person with hearing difficulty to do something about it, but in a family

situation that person may also experience a reduced quality of life (Brooks et al., 2001). If a person acquires a hearing aid, a 'significant other' may assist in learning to use the hearing aid and in enhancing their speech interpretation skills via a program of learning (Hickson and Worrall, 2003). In an online purchase and support situation, it is speculated that a significant other may help by providing IT skills to facilitate hearing aid setup and optimisation. In the BSH case, they are trialling the idea of engagement with a local pharmacist as a trusted 'significant other'.

Leventhal et al. (1998) proposed a model for exploring health self-management that had three primary components: representations of reality, coping procedures and relevance to self. Table 2 presents a view of the BSH case from this perspective.

Table 2 Exploring a health self-management viewpoint

Component of health self-management	*BSH case perspective*
Representations of reality with subsidiary influence factors – the basic parameters of the experience (nature of threat, degree of control), adaptive action goals (threat patterns, cyclic conditions, adaptive action goals (threat patterns, cyclic conditions, stimulation to activate a response). Stimulation to activate a response may evolve over time.	Community engagement educating potential clients and 'significant others' about the downsides of not seeking help early (e.g., Wingfield et al., 2005; Heine and Browning, 2002; Wallhagen et al., 2004). Sharing the experience of some every-day and high profile clients.
Coping procedures with subsidiary influence factors – influenced by how the problem is represented, classes of response (e.g., urgency), dimensions of coping procedure (e.g., complexity), alternative if-then options, outcome expectations (consequences, timelines, benefits), comparative risk/benefit of a particular class of procedures	The non-engaged may cope simply by turning up the volume on the TV, or by developing complementary skills in lip-reading. Some may rely on a 'significant other', but this can also have downsides. BSH represents the problem as an opportunity and offers an option that covers the whole hearing enhancement journey (see Table 1)
Relevance to self with subsidiary influence factors – overlap between representations of problem and representations of self, attributes of self related to risk, attributes of self that can moderate procedures for self-regulation	Social stigma may be seen as a risk. Offering private self-assessment anytime, anyplace to get started plus different forms of education/help may optimise outcomes to show that the benefits outweigh the risks

Source: After Leventhal et al. (1998)

The social stigma associated with hearing loss arises from difficulties in social engagement that may reflect poorly on the individual, and the presence of an obvious wearable device may advertise this potential shortcoming. A research focus on technology to both enhance the effectiveness of hearing aids and to make them even smaller is one outcome of this situation. Experience with the uptake of other wearable technology devices such as smart watches (e.g., Diefenbach et al., 2016) and augmented reality smart glasses (e.g., Rauschnabel et al., 2016) is that there is an interplay between perceptions of them as a useful assistive technology and as a fashion item. Conventional glasses have been made more acceptable by presenting them as a fashion accessory, which raises the question of how this tactic might be adopted with hearing aids. As noted earlier, some work has been done on the adaptation of smartphones to include hearing aid functionality (Amlani et al., 2013), and with further development, this may offer a more socially acceptable proposition in some circumstances.

5.2 A technology acceptance viewpoint

The second self-management issue relates to trust in the technology. The Hearing Journal (http://www.journals.lww.com/thehearingjournal/pages/default.aspx) has been publishing hearing aid user survey data since 1990, which have indicated:

a there has been an improvement in satisfaction levels with hearing aid performance since the introduction of digital sound processing.

b the most common complaint continues to relate to hearing in noise.

c there is a reduced, but still significant number of people who discontinue use of their hearing aid (e.g., Kochkin, 2010).

In other words, there are still some technology acceptance issues. In the BSH case, there is regular telephone follow-up with clients to identify any concerns with the product and its use, and to explore potential reasons for lack of use of a hearing aid.

Table 3 Exploring a technology acceptance viewpoint

Component of technology acceptance	*BSH case perspective*
Perceived usefulness with subsidiary influence factors – perceive ease of use, attitude to perceived usefulness, social presence, task relevance, result demonstrability, compatibility, management support, experience.	BSH clients are not buying technology as a value-add base, but buying technologies that deliver a solution in a particular compatible social context with clear task relevance. The credibility of the founders demonstrates management support (see comments below).
Perceived ease of use with subsidiary influence factors – attitude, accessibility, playfulness, perceived enjoyment, social influence/subjective norms, management support, experience.	Ease of use is an emphasis along the whole hearing enhancement journey (see Table 1), with playfulness allowing the exploration of hearing test and device tuning outcomes under different conditions.
Attitude/behavioural intentions with subsidiary influence factors – perceived ease of use, perceived usefulness, management support, experience, complexity, playfulness.	Positive attitudes to the technology are stimulated by the shared experience of other everyday and respected users and the pedigree of the technology. Some years of beta testing preceded full system launch.
Behaviour/use with subsidiary influence factors – perceived usefulness, attitude, management support, experience, perceived enjoyment, self efficacy, end user support, relative advantage.	The perceived enjoyment of a new hearing aid is quickly apparent (or not). Self-efficacy is an important influence, and BSH puts significant effort into user education and support. Relative advantage has both cost and technical performance elements to consider.

Source: After Lee et al. (2003)

Hu et al. (1999) explored the utility of a technology acceptance model (Davis, 1989, 1993) in the context of hospital physician adoption of telemedicine technology. They found that the model provided reasonable insight into the physician's decision to accept the technology. They noted that in this case, ease of use was not a large influence factor for this group, who had well-developed personal capabilities, but noted some additional influence factors could be considered. Lee et al. (2003) undertook a meta-analysis of 101 academic papers plus 32 leading author interviews related to the use of a technology acceptance model in the information systems field. They identified a large number of

contextual factors that may in some way influence the primary model components of perceived ease of use, utility, attitudes to adoption or the final decision to adopt a technology, with some interaction between them. A representation of the BSH case in the context of each component is shown in Table 3.

The subsidiary influence factors shown above were generally identified in a corporate setting, and were interpreted in the BSH case as follows:

- compatibility is consistency with personal values and needs (not technical compatibility)
- management support is taken as a proxy for legitimation.
- playfulness is interpreted as an ability to try out different possibilities
- relative advantage, originally defined in relation to a precursor technology, has been viewed in comparison with alternative technologies
- self efficacy is the personal belief in the ability to perform a particular activity.

In considering extensions to the technology acceptance model, Venkatesh and Davis (2000, p.740) observed that "Both social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use) significantly influenced user acceptance", and this was observed in the BSH case reported here.

King and He (2006) undertook an analysis of 88 empirical studies of technology acceptance models using a statistical meta-analysis technique. They suggested that the kinds of subsidiary factors indicated in Table 3 could be summarised as:

- external precursors such as prior usage or IT self-efficacy that mainly influenced perceived usefulness and perceived ease of use
- the incorporation of factors from other theories such as expectation, risk and trust that mainly influenced behavioural intention
- contextual factors such as gender, culture and technology characteristics that could influence several aspects of the model
- consequence measures that influenced actual usage and attitudes.

Their analysis confirmed that perceived usefulness was a primary driver of acceptance, and it was noted that professional and general users could put different emphases on the relative importance of ease of use and usefulness. Ease of use influenced perceived usefulness to a greater extent with general users than with professionals. This is reflected in the literature on hearing aid utilisation (stage 4 in Table 1) which suggests some people may give up prematurely if the technology seems too hard to use. King and He (2006) observed that internet usage showed a pattern where ease of use was of greater importance than for other types of application. In the BSH case, access via the internet makes access to hearing tests and hearing aid purchase easier for many individuals, but does not feature so strongly in supporting use of a hearing aid (stage 5 in Table 1). BSH clients are seeking a solution to their individual problem, and have limited interest in the enabling technology.

The majority of applications described in the technology acceptance model literature relate to the recurring use of IT tools in a workplace situation, where use of the

technology may be mandated. As noted earlier, more recent articles about the use of technology wearables considered a situation where usage was voluntary, but the practical consequences of NOT using the devices were of limited significance. In the BSH case described here, use of the technology is voluntary, but the consequences of not adopting it can be significant. It is suggested this leads to a stronger focus on client education as an aspect of marketing and utilisation.

5.3 A sustainable business model viewpoint

The third self-management issue is finding a business model that minimises cost to the client whilst providing clinical support when needed. In the traditional models this is achieved by bundling anticipated support requirements in with the cost of the hearing aid. In the large retailer model, low cost is achieved by negotiation with hearing aid manufacturers based on high volumes. In both of these situations, access to support is only available in short time slices by appointment, which may present access difficulties for some clients. In the BHS model, face-to-face arrangements can also be arranged, but the cost of the hearing aid is separated from the cost of face-to-face services. The dominant BHS model involves interaction via the internet.

In studying the economics of eHealth applications van Limburg and van Gemert-Pijnen (2010) adopted a business model view combining four key questions. The BSH model is outlined using these four questions in Table 4.

In relation to customer interaction, the BSH CEO cited anecdotal evidence that the decision to buy followed verification of potential benefits by two independent sources, generally including a 'significant other': "a (community) example is Finley (an Australian agricultural centre) where one person helped equip everyone with hearing aids. One our Melbourne customers were born in China, and he took our hearing aids back to his father on a visit, helping him to set it up in conjunction with us via an internet link. We had a similar situation in Finland". This has implications for targeted marketing campaigns, and is consistent with the observations of Young (2009, p1899) in relation to innovation diffusion: "people may realize different benefits and costs from the innovation, hear about it at different times, or have different amounts of information, different predispositions to conform". Young considers three kinds of drivers that have different adoption rate characteristics:

1 *Contagion*. People adopt when they come in contact with others who have already adopted; that is, innovations spread much like epidemics.

2 *Social influence*. People adopt when enough other people in the group have adopted; that is, innovations spread by a conformity motive.

3 *Social learning*. People adopt once they see enough empirical evidence to convince them that the innovation is worth adopting, where the evidence is generated by the outcomes among prior adopters. Individuals may adopt at different times due to differences in their prior beliefs, amount of information gathered, and idiosyncratic costs.

It is suggested here that the social learning mechanism seems the most credible in the BSH case. BSH draws on the internet to facilitate client learning and technology diffusion, however DiMaggio et al. (2001) have suggested that the internet complements

rather than displaces other practices. Whilst BSH expanded their internet presence via social media some years ago, current developments in their business model involve innovative collaboration mechanisms for face-to-face engagement with potential clients in regional centres.

Table 4 Exploring a business model viewpoint

Business model component	*The BSH case*
What is the customer value proposition, what products/services are offered?	The particular promise is better hearing of speech in a variety of circumstances. Clinically proven, award-winning technology developed for bionic ear and Bluetooth headsets, fully customisable. Relatively low prices. Customers set up and adjust hearing aids themselves. Proven results – 10,000+ customers all over Australia.
Who are the customer segments serviced, and how is interaction with them organised?	The target beneficiary is the individual consumer client with hearing difficulties who may not have ready access to traditional services, or who may not be satisfied with other products available. At the time of writing, the focus was on serving an Australian market, however some international clients have purchased the hearing aids.
What organisational arrangements are needed to deliver value?	The client can come to a BlameySaunders clinic, or order hearing aids on the internet or by phone. The client receives hearing aids, the IHearYou® accessories, and instructions, and sets up the hearing aids. Help is available through the clinic or via a telephone/online help desk. BlameySaunders can monitor the changes clients make in their hearing aids to help them manage changes to their hearing a strategic partner network model is used to support manufacturing and R&D activities.
What are the costs and revenue flows that support economic sustainability?	Income is derived from direct sales of hearing aids and advisory services plus product sales made through partners The most important cost is people that can multi-task as required.

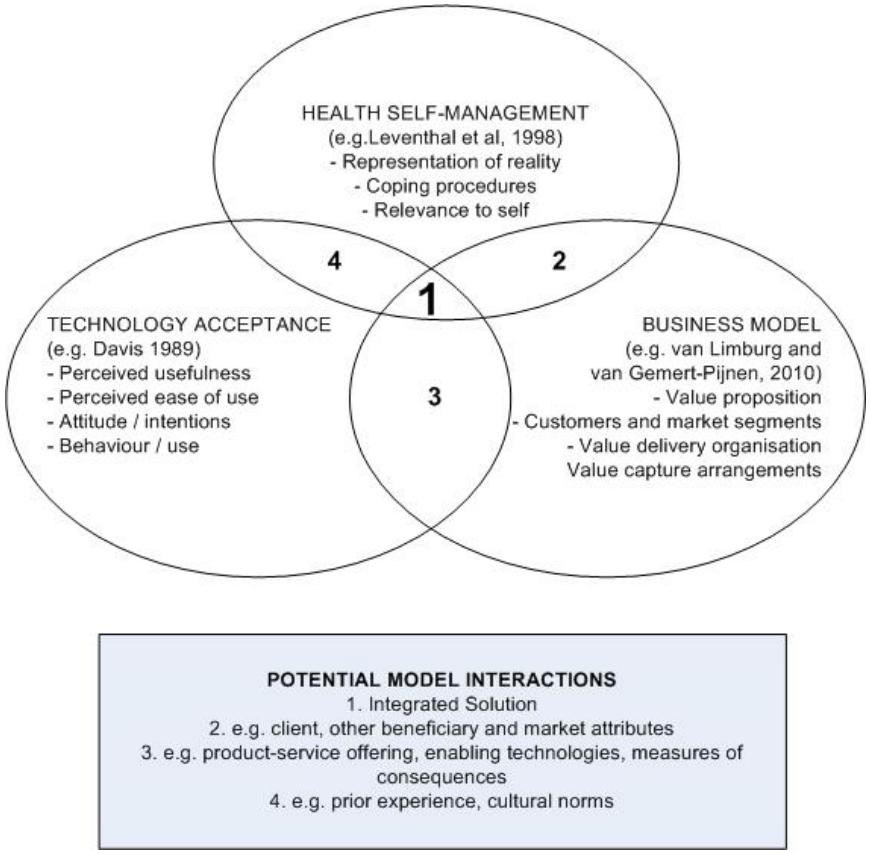
Source: After van Limburg and van Gemert-Pijnen (2010)

Product-service bundling is the norm in the hearing aid industry, but with product design/manufacture separated from retail/service. In contrast, the BSH operations are vertically integrated, facilitated by a network form of organisation. The value proposition presents innovative client health self-management ideas, technology embedded in the product/service system, and enabling technology to facilitate value chain integration. A relationship-oriented front office is focused on market education, client speech recognition testing and sales. A task-oriented back office is focused on order fulfilment (including customising initial hearing aid settings), record-keeping and client problem-solving (both before and after purchase). The CEO commented: "We have a triage call centre where people raise questions before they buy, asking quite sophisticated questions".

5.4 Integrating multiple viewpoints

What is the incentive for a client to choose self-management to deal with a health issue, what can technology offer, and how does the value proposition compare with alternatives? Each model presented in the previous sections draws on isolated fields of research.

Figure 1 Combining viewpoints stimulated by different business models (see online version for colours)



The BSH social innovation of supporting health self-management is of increasing interest as a means of moderating growing health system costs. Maes and Karoly (2005) conducted an extensive literature review on the subject, concluding that self management was related to goal achievement via a combined feed-forward and feed-back process of firstly, goal selection, setting and construal/representation; secondly, active goal pursuit; and finally, goal attainment and maintenance (and possibly disengagement). They identified assessment instruments and interventions supporting each phase, but did not discuss the use of supporting technologies.

The BSH technological innovations were bundled as a product-service package to facilitate self-management, which requires acceptance of the technology offered. As the core technology acceptance model (Davis, 1989, 1993) has become more widely used, adaptations and extensions have recognised the influence of context. However much of the related literature is oriented towards the acceptance of IT systems in a context where a business case has already been made for their implementation. This differs from the BHS case context where responsibility for self-management and cost are also strong determinants of acceptance.

The BSH marketing innovation offers access to a client health solution via the internet. From a technology perspective, various online facilities offer a blend of learning

management system, e-commerce and on-going support tools. There is an expanding literature related to business model innovation as a source of competitive advantage, with a large number of business model concepts being documented, but how to best design a new model is still under discussion (e.g., Bucherer et al., 2012). There seems to be an assumption technology offered/utilised provides sufficient value to be accepted.

Each model helps to provide insights into the socio-technical issues involved, but each model on its own only provides a partial view, leading to a suggested need to adopt multiple viewpoints, as illustrated in Figure 1.

How to integrate a multi-model viewpoint (social, technical, business) in planning the marketing of a multi-faceted innovation may be a topic for future research.

6 Concluding remarks

The literature indicates there are a millions of people suffering varying degrees of hearing impairment, and that as a population ages, the numbers will continue to increase. For the severely impaired, a combination of surgery and assistive technology offers new possibilities, as demonstrated in cochlear implants. For the majority, wearable sound amplification devices provide some compensation for hearing loss, yet the rate of uptake is less than 30%. It has been suggested this is due to a combination of social acceptance, technology acceptance and economic viability factors (e.g., Wesendahl, 2003).

In this context, we are exploring the research question 'what changes may bring about improved hearing aid technology uptake'? A US government study cited potential barriers as the high cost of hearing aid technologies, issues in access for hearing aids, and low levels of innovation in the provision of broader access mechanisms (Shaw, 2016).

The case study presented here describes a direct consumer approach to marketing hearing enhancement technology combined with the use of enabling technology (the internet) to reach an untapped market (hearing impaired people not getting help). *The focus is on holistic solutions, with passing reference to the underlying technology*.

The client solution offered integrates three ideas considered innovative in the BSH market sector:

1 Embracing *health self-management* facilitated by product-system technology that is easy to use combined with easy access to a hearing test and a competitively priced product over the internet. It is observed that some support from a 'significant other' may facilitate this social innovation.

2 Offering *a user-customisable hearing enhancement product-system* that is focused on the most common issue with hearing aids – hearing in noise – and a means of linking with expert advisors over the internet to resolve problems. This provides a stimulus for technology uptake.

3 Offering any-time-any-place access via *the internet supporting client and* '*significant other*' *education* plus intervention at any stage of the client's hearing enhancement journey (see Table 1).

Whilst some wearable technology devices like a smart watch may be seen as a desirable fashion item, a hearing aid can attract negative perceptions of the wearer, which puts an emphasis on marketing to demonstrate the offsetting benefits. Social networks can play

an important role in helping to appreciate such benefits, and in providing support for online access.

Following the observation of Chesbrough (2010, p.354) that: "a mediocre technology pursued within a great business model may be more valuable that a great technology exploited via a mediocre business model", the case study business model was reviewed. The BSH internet-based business model is considered by some to be disruptive, and there are some concerns about potential downsides from industry incumbents. The model includes a background emphasis on client education, and implementation in conjunction with networks of R&D and manufacturing strategic partners. The SME case study firm is regarded as successful as it is clients are enthusiastic about the benefits of the technology offered and it continues to grow, however the extent to which its current business model is scalable remains untested.

The case study is briefly viewed from three theoretical perspectives, drawing on a health self-management model, a technology acceptance model and a business model identified from the literature. It was found that the health self-management model helps identify some potential barriers to innovation adoption, but makes no direct reference to technology assistance, even though this is one of the coping procedures pursued. The technology acceptance model helps identify important adoption factors like ease of use and utility, but makes no direct reference to cost, which is identified as a concern in the literature. The business model helps frame the value proposition and delivery pathways but makes no direct reference to technology, even though use of the internet may be important in implementation. Each model helps to provide insights into the socio-technical issues involved, but each model on its own only provides a partial view, leading to a suggested need to adopt multiple viewpoints. How to integrate a multi-model viewpoint (social, technical, business) in planning the marketing of a new technology may be a topic for future research.

Implications for innovation management raised by the BSH case presented in relation to health technologies are:

- The need to focus on a combination of social, technology and business viewpoints to frame sustainable working arrangements.
- Potential opportunities arising from the adoption of client self-management and telemedicine strategies in marketing and supporting such technologies.

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