The Future of Audiology: A Survey of Different Hearing Aid Fitting Methods

A cross-sectional quantitative survey of perceptions of hearing aid consumers towards alternative hearing aid delivery methods

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Abstract

Introduction: Hearing loss affects a large proportion of people in Aotearoa/NZ, but not everyone seeks to address it. This may be due to cost, travel, and/or stigma. Untreated hearing loss can have negative effects on relationships, mental and emotional health. The current method of providing hearing aids in clinics is not accessible for everyone in Aotearoa. Accessibility needs to be addressed to reduce the societal burden of untreated hearing loss. This study investigates different methods of providing hearing aids and aims to explore whether consumers would be interested in these methods, thus establishing the potential uptake of proposed delivery methods.

Method: This study employed a cross-sectional quantitative survey. Data was collected from 120 participants who voluntarily completed an anonymous online survey that assessed their perceptions of alternative hearing aid delivery methods, such as teleaudiology, over the counter hearing aids and traditional audiology. We were primarily interested in whether the methods were perceived to be appropriate/easy to use, accessible, the participant's willingness to pay values for each method and their willingness to use each method. The Spearman Correlation Coefficient test was used to identify significant relationships between variables, along with Binary Logistic Regression.

Results: Most participants wanted access to/were willing to try traditional audiology, followed by teleaudiology. The fewest participants wanted access to/were willing to try over the counter, user-programmable hearing devices. Participants believed all three hearing aid delivery methods would be neither too easy nor too difficult to use. There were several additional features and settings that participants thought would make each

method easier to use. On average, the study participants somewhat agreed with the idea that teleaudiology and over the counter, user-programmable hearing devices could improve access to hearing health care. Participants were willing to pay more for traditional audiology than over the counter, user-programmable hearing devices and the least for teleaudiology.

Conclusion: The findings of this study have revealed several benefits of using alternative hearing aid delivery methods, as well as several concerns that consumers have. The benefits highlighted in this study can be used to advocate for alternative forms of hearing aid delivery to improve access to hearing health care across Aotearoa. The concerns highlighted in this study should be addressed and could be used for further research in this area in order to develop suitable products and services that will have a high chance of successful uptake by consumers. The findings of this study have implications for hearing aid delivery services, highlighting the aspects of importance for patients for their hearing care (audiologist involvement and various sources of help/information) and their willingness to try and pay for newer fitting methods that could lead to these new methods coming into the hearing aid market in New Zealand. The findings are of relevance to policymakers, audiologists, hearing care providers and researchers.

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Glossary

ACC = Accident Compensation Corporation

APD = Auditory Processing Disorder

BM = Basilar Membrane

BTE = Behind the Ear

CIC = Completely in the Canal

DALYs = Disability-Adjusted Life Years

dB = decibel

dBSPL = decibel Sound Pressure Level

DHB = District Health Board

DPOAE = Distortion Product Otoacoustic Emission

EAC/EAM = External Auditory Canal/Meatus

ENT = Ear, Nose and Throat

FDA = (US) Food and Drug Administration

GP = General Practitioner

HCIA = Hearing Care Industry Association

IHC = Inner Hair Cell(s)

ITC = In the Canal

ITE = In the Ear

MoH = Ministry of Health

MRI = Magnetic Resonance Imaging

NIDCD = National Institute on Deafness and Other Communication Disorders

NZ = New Zealand

NZD = New Zealand Dollar

OHC = Outer Hair Cell(s)

OTC = Over the counter

QoL = Quality of Life

REAR = Real Ear Aided Response

REIR = Real Ear Insertion Response

REMs = Real Ear Measurements

REUR = Real Ear Unaided/Unoccluded Response

RIC = Receiver in the Canal

SLA = Satisfaction with Life Areas

QWB = Quality of Well-Being

TM = Tympanic Membrane

TV = Television

US = United States

USD = United States Dollar

WHO = World Health Organisation

WTP = Willingness to Pay

YLD = Years Lived with Disabilities

Chapter One: Literature Review

1.1 Introduction to hearing loss

The World Health Organisation (WHO) defines a hearing loss as a hearing threshold at or above 25 decibels (dB). A 'disabling' hearing loss is defined as a hearing loss greater than 35dB in the better hearing ear (WHO, 2021). Individuals with hearing at this level or worse are considered 'functionally impaired' and generally benefit from amplification/hearing devices, such as hearing aids or cochlear implants (National Institute on Deafness and Other Communication Disorders (NIDCD), 2011). Disabling hearing loss can result in communication difficulties as they have trouble recognising and understanding speech, especially in background noise. Communication difficulties can have a large impact on the individual, their interpersonal relationships and their economic independence (Mason & Mason, 2007), potentially leading to social isolation, depression, anxiety, cognitive decline and reduced quality of life (QoL) (Lewis, Loss, Loss & Impaction, 2014). Over 1.5 billion people (about 20% of the global population) has hearing loss, with over 5% experiencing 'disabling' hearing loss (WHO, 2021). Hearing loss is classified by two factors: the type and degree of hearing loss.

Degree of hearing loss

Clark (1981) defines hearing ability as a continuum from normal hearing (15dB HL threshold or lower in both ears) to complete inability to perceive any sounds; a hearing loss is classified as a threshold above 15dB HL. The degree of hearing loss refers to the extent of the hearing loss, typically across the standard frequency range (250Hz to 8000Hz). The extent of hearing loss can be described as slight, mild, moderate,

moderately severe, severe and profound based on pure-tone thresholds (Table 1; Clark, 1981).

Table 1. Classification of the Degree of Hearing Loss

Degree of Hearing loss (dB HL)	Average Hearing Threshold Level in dB HL
-10 to 15	Normal Hearing
16 - 25	Slight Hearing Loss
26 - 40	Mild Hearing Loss
41 - 55	Moderate Hearing Loss
56 – 70	Moderately severe Hearing Loss
71 - 90	Severe Hearing Loss
91+	Profound Hearing Loss

Retrieved from "*Uses and abuses of hearing loss classification*" by J.G. Clark, 1981, *American Speech-Language Hearing Association, 23,* 497.

Discrepancies in defining the degree of hearing loss exist, e.g. WHO (2021) defines a hearing loss as a threshold above 25dB whereas Clark (1981) defines it as a threshold above 15dB. Importantly, there exists a discrepancy between the audiometric results and the hearing handicap a client may report. For example, a client with *mild* hearing loss may be finding it harder to hear than an individual with *moderate* hearing loss. Thus, an audiogram is not always a reliable indicator of the difficulties an individual may experience with hearing and communicating (Brainerd & Frankel, 1985; Manchaiah & Freeman, 2011; Schow & Gatehouse, 1990). Therefore, it is important to approach hearing loss from a holistic point of view to ensure any limitations an individual may

experience are addressed (Manchaiah & Freeman, 2011).

Types of hearing loss

The type of hearing loss depends on where along the auditory system any dysfunction has occurred; called the site-of-lesion. Hearing loss that arises within the peripheral auditory system is classified as either conductive, sensorineural, or mixed hearing loss (Pickles, 2013). There is a range of underlying causes for each type of loss. Hearing losses can be congenital (present at birth due to genetic or non-genetic causes) or acquired throughout an individual's life (Zeng & Djalilian, 2010). The type of hearing loss is an important factor to consider when determining individual treatment/rehabilitative options and outcomes. Thus, an understanding of the anatomy of the peripheral auditory system is crucial to determine the type of hearing loss.

Overview of the peripheral auditory system

The peripheral auditory system is comprised of three sections – the outer, middle and inner ear (Figure 1). The outer ear consists of the pinna, external auditory canal/meatus (EAC/EAM) and the tympanic membrane/eardrum (TM). The middle ear consists of the tympanic membrane laterally, the middle ear ossicles (the malleus, incus, and stapes) and the inner ear medially. The inner ear consists of the semi-circular canals (involved in balance and spatial orientation) and the cochlea (the hearing organ) (Alberti, 2001).

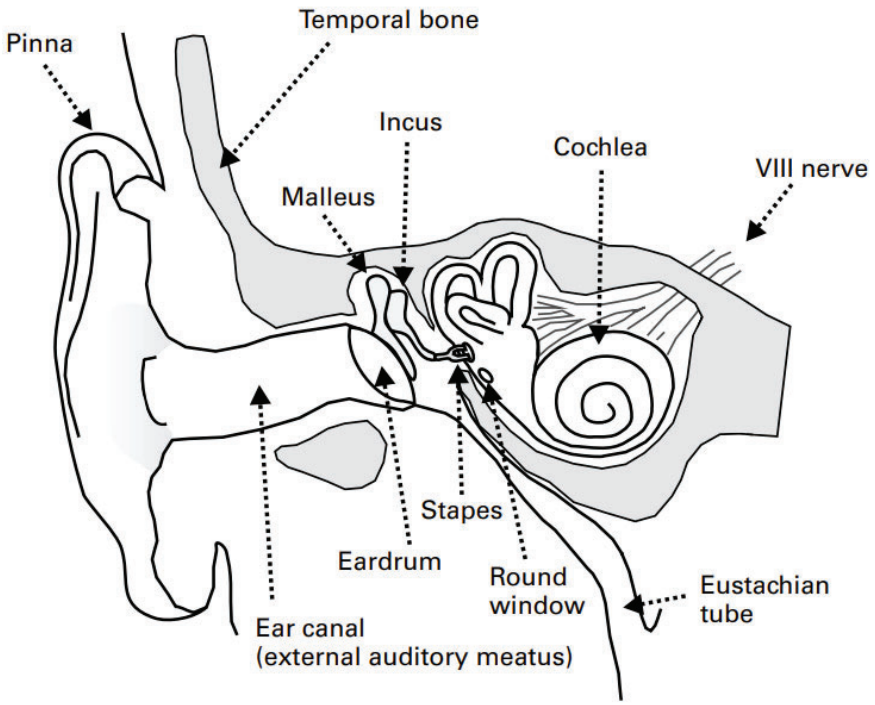

Figure 1:

The peripheral auditory system, comprising of the outer, middle and inner ear. Retrieved from "Auditory Neuroscience: Making sense of sound" (p. 52) by J. Schnupp, I. Nelken & A. King. Copyright (2011) Massachusetts Institute of Technology.

For the perception of sound, sound pressure waves travel through the air and are directed into the EAM by the pinna, where they travel towards the TM (Schnupp, et al., 2011). The pinna plays an important part in sound localisation by altering the spectrum of the sound signal and the ear canal has a resonance that increases the sound pressure at the TM at important speech frequencies (2000Hz-4000Hz). The sound pressure waves cause the TM to vibrate, and this is transferred into the air-filled middle ear by vibrating the middle ear ossicles as the malleus is connected to the TM. The malleus is connected to the incus, which connects to the stapes. The stapes footplate inserts into the oval window of the

cochlea leading to the sound pressure waves being transferred into the fluid-filled cochlea. Therefore, the middle ear is an impedance transformer as it allows the signal to travel from an air-filled environment to a fluid-filled inner ear. Without this impedance transforming ability, sound travelling from the low-impedance environment to a high impedance environment will be reflected at the boundary of both environments and only 0.1% of the sound energy will reach the inner ear (Rosowski, 1994). The middle ear uses two different processes to impedance-match. Firstly, the energy from the large area of the TM is concentrated on the smaller area of the oval window. Secondly, the lever action of the ossicles increases the force and pressure of the sound energy at the oval window (Alberti, 2001).

The cochlea is the hearing organ, housed in the inner ear. It is a spiral-shaped, bony organ consisting of three fluid-filled compartments: the scala vestibuli, scala media and scala tympani. The scala media and scala tympani are separated by the basilar membrane (BM), which runs along the length of the cochlea. Situated on the BM is the Organ of Corti, which has the sensory hair cells that transduce the acoustic signal from the inner ear to the auditory nerve, which sends the signal to the auditory cortex where the signal is processed. The inner hair cells (IHC) predominate the signal transduction to the auditory nerve and outer hair cells (OHC) play a crucial role in amplifying the sensitivity of the cochlea to soft-level sounds, known as the cochlear amplifier (Musiek & Baran, 2018). The stapes footplate has a push-pull action into the oval window, causing displacement of the fluids within the cochlea towards the round window leading to the formation of a travelling wave along the BM (Santi & Mancini, 1998). This travelling wave stimulates the hair cells through a shearing motion with the tectorial membrane that lies above. This shearing motion pushes the stereocilia of the hair cells back and forth, causing receptor potentials to be generated by the cyclical opening and closing of voltage-gated ion

channels. As the hair cells are depolarised, action potentials are generated that travel down and activate the afferent auditory nerve fibres, and electrical signals of acoustic stimulation are consequently sent to the central auditory system (Musiek & Baran, 2018).

Conductive hearing loss

A conductive hearing loss arises when there is an abnormality within the outer and/or middle ear of the peripheral auditory system whilst the inner ear function remains normal. This type of hearing loss occurs due to mechanical disturbances/obstructions that inhibit the conduction of the sound from the environment to the inner ear (Pickles, 2013). As a result, the intensity of the sound across the frequency range becomes attenuated as it reaches the inner ear (Steiger, 2015). Conductive hearing losses do not cause distortion of sound, therefore hearing aids can compensate for the attenuated signals through linear amplification (Schnupp et al, 2011).

Conductive hearing losses can be caused by a range of different factors impacting the outer or middle ear structures. Some factors that impact the outer ear include otitis externa (outer ear canal inflammation), exostoses (bony growth/s in the ear canal) and cerumen impaction/occlusion. Some factors that impact the middle ear structures include tympanic membrane perforations, ossicular chain damage and otitis media (middle ear inflammation) (Pickles, 2013).

Conductive hearing losses can be temporary and reversible, e.g. extraction for cerumen impaction/occlusion, surgery to insert a stapes prosthesis in cases of otosclerosis and medications such as antibiotics for inflammation. Therefore, medical intervention for conductive hearing losses may lead to the restoration of hearing, however, if this is not achieved then hearing aids are a viable option (Schnupp et al., 2011).

Sensorineural hearing loss

A sensorineural hearing loss arises when there is abnormality arises within the inner ear and/or the associated neural pathways that transmit auditory information from the cochlea to the auditory cortex (Pickles, 2013). As a result, the transmission of sound from the inner ear to the auditory nerve is disrupted regardless of whether the sound arrived at the inner ear via air conduction or bone conduction. Therefore, both air and bone conduction thresholds will be attenuated by the degree of the hearing loss. Sensorineural hearing loss causes a reduced perception of loudness, as well as reduced speech intelligibility and sound quality (Steiger, 2015).

A sensorineural hearing loss can be caused by a range of different factors impacting the inner ear and/or its associated neural structures. Commonly, a sensorineural hearing loss arises from damage to the cochlea via hair cell loss. This can occur due to loud noise exposure, ototoxic drugs, infections, or degenerative changes as a result of ageing (presbycusis). However, it can also arise due to damage to the auditory nerve, for example, an acoustic neuroma/vestibular schwannoma is a benign tumour that grows and presses on the nerve leading to hearing loss (Pickles, 2013). These are all acquired during a lifetime. Sensorineural hearing losses can also be present from birth, known as congenital hearing loss. Congenital hearing losses can occur due to genetic reasons, e.g. Waardenburg Syndrome, or non-genetic reasons, e.g. anoxia (Roizen, 1999).

Generally, sensorineural hearing loss tends to be irreversible as damage to structures within the cochlea and associated neural elements cannot be fixed or replaced. Therefore, intervention for sensorineural hearing loss is focused on managing and rehabilitating the

individual to make use of their residual hearing capabilities. Hearing aids and cochlear implants are the most common methods.

Auditory Processing Disorder (APD) is an 'umbrella' term for hearing disorders where the ear can normally process sounds, but the neural processing of the sounds is deficient/inaccurate (American Speech-Language-Hearing Association (ASHA), 2005). It is a *central* processing disorder. Individuals with APD may have trouble localising sound, difficulty understanding spoken language and taking longer to respond, difficulty following multi-step instructions, difficulty learning and becoming easily distracted. There can be many causes of APD (genetics, anoxia, hyperbilirubinemia, brain injury) but the cause can also be unknown (Chermak & Musiek, 2011). About 2 to 10% of children have APD, along with other learning and developmental difficulties (Keith et al., 2019).

Changes in anatomy and physiology for hearing-impaired individuals

Hearing-impaired individuals, specifically sensorineural hearing loss, experience physical changes in their auditory system that consequently cause changes in their auditory perception. OHC loss can lead to a reduction in basilar membrane movement for low-level stimuli, therefore the level of the stimulus must be increased for the movement to depolarise IHCs and generate receptor potentials (Pickles, 2013). Loss or dysfunction of OHCs also leads to loss of frequency selectivity and the non-linearity of the cochlea (Moore, 2007). Complete loss of IHCs and/or neurons at specific regions of the cochlea can lead to cochlear dead regions – the cochlea is unable to respond to sounds to the limits of the audiometer at these regions. Partial loss or dysfunction of IHCs and/or neurons can reduce the efficiency of sound transduction from the cochlea to the auditory cortex (Moore, 2007).

1.2 The consequences of untreated hearing loss

The global number of years lived with disability (YLD) due to hearing loss is 43.5 million, with age-related hearing loss being the third leading source of global YLDs (Carpena & Lee, 2018). Approximately 65% of hearing-loss related disability is due to moderate or higher degrees of loss, however, the extent of the impact depends more on *whether* and *when* it is addressed with effective interventions rather than the degree of hearing loss (Wilson et al., 2017) along with how responsive their environment'/s are to their hearing needs (WHO, 2001). The extent of impact can also be largely influenced by comorbidities, such as developmental disabilities or visual impairment. Untreated hearing loss can impact many aspects of an individual's life.

Listening and communication

One of the biggest challenges those with hearing loss face is communicating with others in their environment/s (Olusanya et al., 2014). These challenges can range from difficulty listening to speech with background noise or quiet speech, to failure hearing loud sounds, such as alarms and other warning signals which can become a dangerous situation (Vas, 2017). Individuals impacted by hearing loss tend to require others to repeat themselves, which can make conversations difficult to carry on in different situations, such as the workplace and family gatherings. They often rely on lip-reading and facial and body language cues to follow a conversation. Due to the COVID-19 pandemic, these listening, and communication challenges have become heightened as a result of preventative procedures such as wearing masks and social distancing (Trecca et al., 2020). Difficulties in listening and communication can significantly impact the QoL of hearing-impaired

persons (Frajtag & Jelinic, 2017).

Language and speech

In children, hearing ability is directly correlated to speech and language development. Children with hearing loss have delayed speech and language development, which can persist in adolescence and adulthood (Yong et al., 2020). The degree of hearing loss is proportional to language deficits and difficulties perceiving speech, but even mild hearing loss or unilateral hearing loss can adversely impact speech and language development in children (Lieu, 2018; Rolfe & Gardner, 2016). Outcomes for speech and language development in children is largely influenced by the age of intervention – the earlier the intervention, the better the outcomes (Yoshinga-Itano & Apuzzo, 1998).

Language development is vital for communication, interpersonal relationships, education, and cognitive development. Therefore, being able to access speech and language is important as children who do have access to this face challenges in their overall development, along with speech and language development (Hall, 2017). Infants that experience hearing loss before speech and language has developed have pre-lingual hearing loss. There is a short window where language development occurs and when there is no/reduced access to language, there are changes in the brain that can have negative implications.

Hearing loss that arises after speech and language development is called post-lingual hearing loss. Children and adults with post-lingual hearing loss will experience a reduced quality of sound/s and will tend to project their voices louder. They may have to compensate for their hearing loss by lip-reading and using facial cues and body language cues, which can be tiring for the brain (Vas, 2017). This can impact their social

interactions, cognitive abilities, and QoL.

Cognition/Dementia

Unaddressed hearing loss leads to language deprivation, which impacts cognition. Hearing loss is the leading risk factor for age-related dementia; however, it is potentially modifiable through audiological interventions and rehabilitative strategies (Livingston et al., 2017). Among older adults, unaddressed/untreated hearing loss is estimated to be accountable for over 8% of the cases of dementia (Livingston et al., 2017). For children, delayed cognitive development is risked when hearing loss is unaddressed. The earlier the intervention, the lower the risk of cognitive impairment (Cardon et al., 2012; Sharma & Glick, 2018).

The risk of cognitive impairment and dementia arises as a result of reduced stimulation to the auditory system and subsequent degeneration of associated neural networks (Hultsch et al., 1999). This results from individuals reducing their engagement in cognitive, social and physical activities in their environment/s. Golub et al. (2020) conducted a cross-sectional with 6451 older adult participants and found that with every 10dB increase in hearing threshold past 25dB, there was a significant decrease in cognitive ability. Armstrong et al. (2019) followed 194 adults without cognitive impairment were followed over 19 years and conducted magnetic resonance imaging (MRI) on all participants. It was found that those who developed hearing loss had lost volume within the temporal lobe, the hippocampus and entorhinal cortex – structures that are important for learning, retrieving and forming memories (Armstrong et al., 2019).

Several studies have found that older adults who use hearing aids have a reduced incidence of dementia compared to older adults who do not use hearing aids (Amieva et

al., 2018; Ray et al., 2018). Maharani et al. (2018) conducted a study where 2040 adults over 50 years of age had their memory tested every two years over eighteen years. Between the fourth and eleventh cycles of testing, participants were provided hearing aids and memory scores improved significantly. For those that were provided hearing aids later, their memory continued to decline until hearing aids were provided. This finding suggests that the longer persons with hearing loss go without appropriate amplification, the more cognitive decline they are likely to experience. The current literature on the relationship between hearing loss and cognitive decline indicates that hearing loss causes some degree of sensory deprivation and therefore, under stimulation of the brain which can impact cognition. Therefore, the use of hearing aids would reintroduce these stimulatory acoustic signals and subsequently, cognitive stimulation (Kalluri & Humes, 2012). Despite hearing loss being identified as one of the largest modifiable factors in the development of dementia, further research is required to understand more about this relationship (Livingston et al., 2020).

Appolonio et al. (1996) followed 1192 adults aged over 70 years of age over 6 years – there were three groups. Group A had normal auditory and visual acuity, group B had reduced visual and auditory acuity and used corrective lenses or hearing aids and group C had reduced visual and auditory acuity but did not have access to corrective lenses or hearing aids. Group C had worse cognitive abilities at the end of the 6 years compared to Groups A and B. Socio-economic status was suggested to play a significant role between the QoL and cognitive statuses between Group C compared to Group B and A after the 6 years. Similarly, Mulrow et al. (1990) studied 188 older adults with hearing loss, where half had access to hearing aids and the other half did not. Both groups were comparable – no significant differences to confound the results. The group of adults that were fitted with hearing aids had significantly improved cognitive function compared to the group

that was not provided hearing aids. Both studies suggest using aids to improve hearing and subsequently reduce its impacts on cognition.

Approximately only 20% of adults with hearing loss receive or seek rehabilitation, in the form of amplification devices, therapy, training and counselling (Oyler, 2012). On average, the delay between identifying hearing loss and accessing healthcare services is 10 years or more (Davis et al., 2007). This delay is significant, given that Lin et al. (2011) tracked 639 adults with hearing impairment and found that those with mild hearing loss had twice the risk, moderate hearing loss had three times the risk and severe hearing loss had five times the risk of developing dementia. Recent findings within the field of cognitive neuroscience indicate that the adult brain is plastic (Grady, 2012) and hearing aids may provide the chance to prevent underestimation of the parts of the brain that are crucial for memory (Daviglus et al., 2010). Generally, in audiological practice, hearing loss and cognitive skills are assessed and addressed in isolation, however, many studies suggest a relationship/connection between them and it has been suggested that hearing loss may accelerate the progression of cognitive decline, if unaddressed (Lemke, 2011). Access to hearing aids is crucial to prevent the progression of hearing loss which may impact the progression of cognitive decline – education and health promotion strategies may allow this (Pichora-Fuller et al., 2013).

Education/Employment

Hearing loss can impair the academic development and outcomes of an individual, the impacts of which can be long-standing. If hearing loss is left unaddressed, lower academic performance and a slower progression throughout education are likely to increase the risk of dropping out of school and/or not obtaining higher education. This is

in comparison to normal-hearing peers. Idstad and Engdahl (2019) found that "people with moderate to severe or mild hearing loss are about half as likely to achieve higher education as people without hearing loss" (p.1362).

Amongst adults with hearing loss, there is a higher likelihood of unemployment/underemployment and subsequently, a lower income (Jung & Bhattacharya, 2012). A longitudinal study in Finland found that people with hearing loss, aged up to 25 years, had two times the risk of unemployment compared to normal hearing people of the same age (Järvelin et al., 1997). People with hearing loss that *are* employed tend to have lower income (Jung & Bhattacharya, 2012) and retire earlier (Helvik et al., 2013). Lower income and unemployment/underemployment can impact people's QoL.

Economic impact

There are several economic costs associated with hearing loss in New Zealand, such as health system costs, productivity costs, other financial costs, welfare and efficiency loss and loss of wellbeing.

Health system costs relate to General Practitioner (GP) and specialist costs, the cost of running hospitals and administration, audiological professionals, and the cost of pharmaceuticals. Health system costs are largely paid by the government, however private payments by patients and/or health insurance are also used to pay for health system costs. In 2016, due to hearing loss, the total health system costs were approximately $131.6 million (NZD 149.68 per person annually). Of this amount, costs for audiological care (audiologists and/or audiometrists) was the largest component, comprising $78.1 million; this includes the cost of hearing tests, consultations/follow-ups, hearing aid fittings and modifications (Ministry of Health, 2004). In Australia, the total

health system costs were approximately $881.5 million in 2017 (~ NZD 921.8 million) (Hearing Care Industry Association (HCIA), 2017).

Productivity costs relate to the cost of the loss of productivity that individuals with hearing loss experience regarding employment, including the productivity loss for people who provide informal care for individuals with hearing loss. These costs arise as a result of lower employment rates, early retirement, a higher number of sick days taken and impaired ability to perform at work. In 2016, due to hearing loss, the total productivity costs were approximately $552.4 million ($627 per person) (Statistics New Zealand (NZ), 2015; Statistics NZ, 2015a). Of this amount, individuals themselves incurred the largest amount of costs ($298.9 million through reduced employment) followed by the government ($215.4 million through reduced taxation revenue) and employers ($38 million through reduced performance at work and paid days off work). The largest component of productivity costs is attributed to reduced employment amongst those with hearing loss (Statistics NZ, 2015; Statistics NZ, 2015a); the same is true in Australia. In Australia, the total productivity costs due to hearing loss were approximately $12.8 billion in 2017 (~ NZD 13.4 billion) (HCIA, 2017). Figure 2 shows the global productivity costs incurred for the individual with hearing loss in 8 different regions of the world. Figure 2 only accounts for those with moderately severe or poorer hearing, therefore, the total productivity costs are likely to be larger than shown.

Region	Prevalence of moderately severe plus hearing loss in individuals aged 15–64 years	Productivity costs ($, thousands)	Percentage of global productivity costs
High-income	5 773 196	30 115 025	28.70%
Central/eastern Europe and central Asia	3 243 370	8 585 116	8.18%
Sub-Saharan Africa	5 046 689	1 713 628	1.63%
Middle East and north Africa	310 339	2 220 428	2.12%
South Asia	20 829 200	11 481 003	10.94%
Asia-Pacific	6 764 459	8 956 213	8.54%
Latin America and Caribbean	2 461 866	4 078 223	3.89%
East Asia	20 690 857	37 772 657	36.00%
World	*65 119 976*	*104 922 293*	*100%*

Figure 2:

Global productivity losses due to hearing loss (moderately severe or poorer) in individuals aged 15-64 years. Retrieved from "*Global costs of unaddressed hearing loss and cost-effectiveness of interventions; a WHO report, 2017"*. Word Health Organization (2017).

Other financial costs refer to the maintenance costs of hearing amplification devices, the cost of formal care (private nurses, childcare, etc), the cost of programmes for the hard-of-hearing, and education. In 2016, the total of other financial costs incurred due to hearing loss was approximately $95.5 million ($108.50 per person) (Ministry of Health, 2004). Of this amount, fitting and modification costs for hearing aids was the largest component, comprising $79.3 million ($90.05 per person) (The National Foundation for the Deaf Inc, 2017). Formal care is often paid for privately, while the government pays for education services, such as sign language support for children in schools. Therefore, taxation plays a role in paying for certain services for the hard-of-hearing population in

New Zealand. With taxation, there is a movement of resources from one entity to another – this can lead to distortions within the economy. There is a cost to raising taxation (the government loses taxation revenue) – this is because individuals with hearing loss have lower income and pay lower tax, the government must make welfare payments to individuals with hearing loss and they must pay for government-provided services (The National Foundation for the Deaf Inc, 2017). In Australia, the total other financial costs attributed to hearing loss were approximately $15 million (~ NZD 15.7 million) (HCIA, 2017).

Loss of wellbeing is a non-financial cost – it relates to the disability-adjusted life years (DALYs) that examines the impact of disease on health and mortality. In 2016, the *economic value* of well-being lost by those with hearing loss was estimated to be $3.9 billion (The National Foundation for the Deaf Inc, 2017). In Australia, people with hearing loss were estimated to incur 90,223 DALYs in 2017 and the total loss of wellbeing equated to $17.4 billion (~ NZD 18.2 billion). The same Australian report found that loss of wellbeing increased with age in both males and females (HCIA, 2017).

In 2016, the total cost in New Zealand by and for individuals with hearing loss, employers and the government were $4.9 billion, with productivity costs comprising the largest component of *financial* costs (58%) (The National Foundation for the Deaf Inc, 2017). In Australia, the total cost of hearing loss in 2017 was estimated to be $33.3 billion (~34.8 billion NZD), with loss of wellbeing comprising the largest component (52.3%) (HCIA, 2017). Unaddressed hearing loss incurs high-cost burdens for the *global* economy; the total global economic burden is estimated to be approximately 750-790 billion international dollars (WHO, 2017).

Hearing aid use can lead to several positive economic outcomes, such as higher income for workers with hearing loss, higher rates of employment, a lesser likelihood of depression, improved QoL and less overall healthcare expenditure (Anovum, 2012).

Social isolation and loneliness

Commonly, in older adults, hearing loss can lead to social isolation and loneliness as a result of lower social participation. This occurs at a higher rate amongst individuals who have unaddressed hearing loss, i.e. countries where access to hearing aids is sparse. Hearing loss can make understanding and participating in conversations difficult and can lead to persons avoiding social situations altogether. People with hearing loss who *do not* have hearing aids tend to have higher levels of loneliness (Pronk et al., 2011). Hearing loss impacts relationships as communication can become difficult and lead to conflict and misunderstandings. Social isolation as a result of hearing loss can have negative ramifications – social isolation and a lack of auditory input may contribute to cognitive decline in older adults. Additionally, social isolation and loneliness can lead to depression (Shukla et al., 2020).

Mental health

People with unaddressed hearing impairment have higher rates of anxiety, depression, social anxiety and withdrawal, and overall reduced QoL (Vas, 2017). They may experience embarrassment during social interactions. Conversations become difficult not only for the hearing-impaired person but for their communication partners also, who often experience frustration (Vas, 2017). Their communication partners may also reduce their

social interactions and experience heightened stress and dissatisfaction during conversations (Kamil & Lin, 2015).

1.3 Aural rehabilitation for hearing loss

Early intervention is crucial once a hearing loss is identified to avoid further adverse effects. These early interventions must take the individuals' needs, preferences and means into account, i.e., a patient-centred approach. The type and degree of the hearing loss impact the rehabilitative approaches taken, along with contextual factors such as communication needs and environmental factors (WHO, 2001). There are a variety of measures available to rehabilitate the hard of hearing – amplification devices such as hearing aids, implants such as middle ear implants, auditory brainstem implants and cochlear implants, assistive listening devices such as frequency modulation (FM) systems, counselling and hearing and speech therapy, and sign language.

Boothroyd (2007) defines aural rehabilitation as improvements that can be made to an individual's function (hearing thresholds, processing abilities, etc), activity (localising sounds, hearing alarming sounds, understanding speech, etc), participation (social interactions, relationships, employment, leisure, etc) and overall QoL (enjoyment, purpose, independence, etc). This is done through a combination of instructions (for the use of technologies), sensory management (enhancing auditory *function*), perceptual training (targets *activity* by allowing learning opportunities) and counselling (targets *participation* and *QoL*). Boothroyd (2007) suggests that there is a difference between the benefit of hearing aids as seen by audiologists and hearing aid users – this may be because there is a lack of a holistic approach.

Rehabilitation is important for improving the participation, communication, and overall QoL of those with hearing loss (Ferguson et al., 2019). This section will focus on devices for aural rehabilitation and will consider recent developments, such as over-the-counter hearing aids and teleaudiology. A 'grey literature' search was done to find different opinions about over-the-counter hearing aids and teleaudiology.

Hearing aids

Hearing aids and assistive listening devices are the most common form of rehabilitation aids, especially for those with mild to moderate hearing losses. Hearing aids are a low-risk and effective rehabilitative option that improve communication difficulties, listening ability and overall QoL (Ferguson et al., 2019).

Hearing aids can be used for both conductive and sensorineural hearing loss, and most often, digital hearing aids are prescribed. Digital hearing aids pick up the sound signal from the microphones as sound waves which are converted to a numerical code to make the signal digital (National Institute on Deafness and Other Communication Disorders, 2017). Those with conductive losses tend to have linear amplification as the sound signals are attenuated but the individual's dynamic range is unaffected (Schnupp et al., 2011). Those with sensorineural hearing loss tend to have adaptive signal processing as they experience decreased sound sensitivity, reduced dynamic range, reduced clarity and reduced temporal and frequency resolution (Schnupp et al., 2011). Therefore, hearing aids can address different issues that cause hearing loss through different signal processing and amplification algorithms.

Figure 3:

The different types/styles of hearing aids. From "Hearing Aids", by National Institute on Deafness and Other Communication Disorders, 2017. (https://www.nidcd.nih.gov/health/hearing-aids). Copyright by National Institute on Deafness and Other Communication Disorders.

There are different styles of hearing aids and each have their advantages and disadvantages – the style is dependent on the needs of the individual. There are two families of hearing aids; those that go behind the ear, and custom hearing aids that sit in the ear (National Institute on Deafness and Other Communication Disorders, 2017). Hearing aids consist of three essential components; the microphone/s that pick up the acoustic signal and process it into a digital signal, an amplifier that amplifies the signal and a receiver that delivers the amplified signal to the ear (National Institute on Deafness

and Other Communication Disorders, 2017). The hearing aid also contains a battery door and may have a volume wheel.

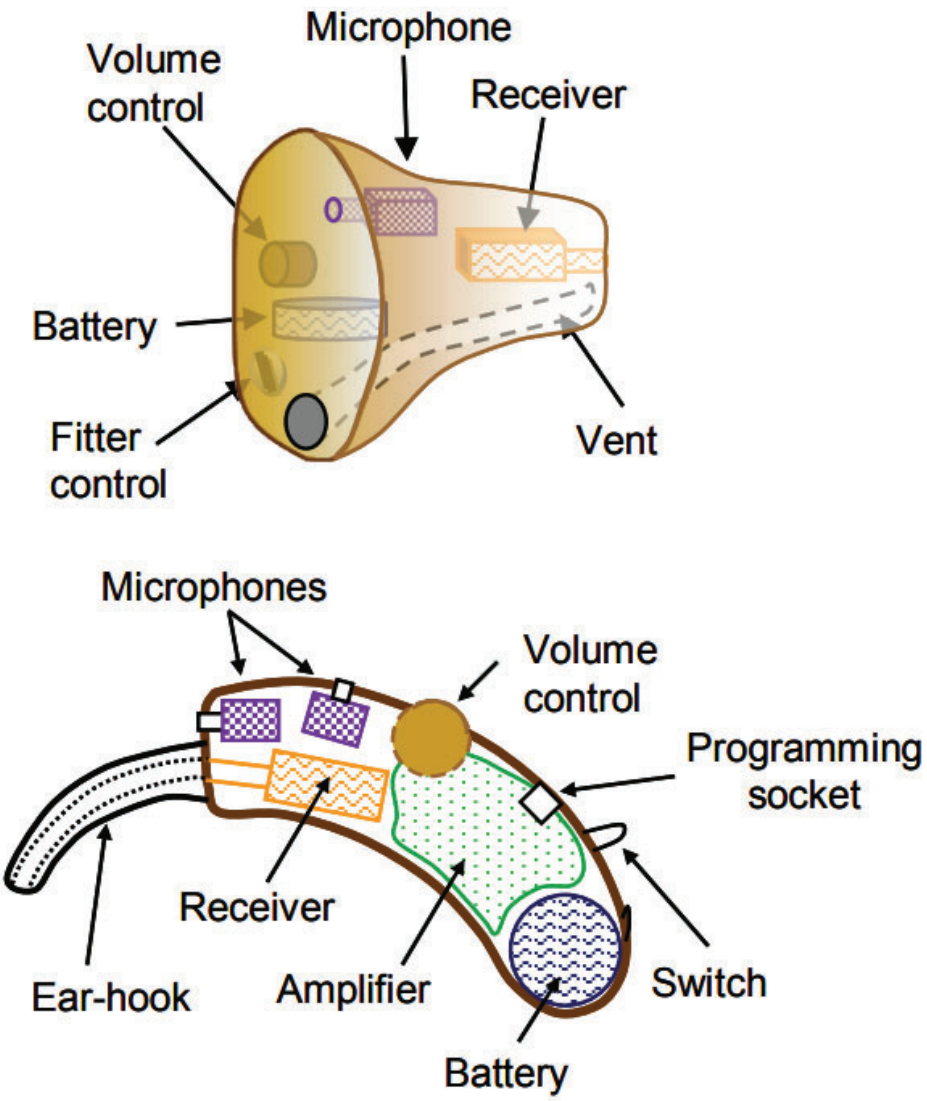

Figure 4:

The components of ITE hearing aids (top) and BTE hearing aids (bottom). From "Introductory Concepts: Types of Hearing aids" (2nd ed., p.13) by H. Dillon, 2012, Boomerang Press. Copyright (2012) by Thieme.

In those persons with severe to profound sensorineural hearing loss, very few hearing aids have the capability of amplifying to such levels, therefore individuals continue to experience difficulties in speech perception (Mamo et al., 2018).

Picou (2020) evaluated how the use of hearing aids affected communication, mental health and overall QoL by asking hearing aid users and non-users (with equivalent hearing thresholds) to complete the MarkeTrak 10 questionnaire. Those with hearing aids were 79% satisfied with their hearing abilities with hearing aid use, compared to non-users who had 41% satisfaction with their hearing abilities. Overall, hearing aids users were found to be approximately 30% more satisfied with their abilities to communicate with one person, in a workplace and a classroom, and approximately 40-50% more satisfied with their abilities to communicate with background noise. Hearing aid users were less likely to have depression and other mental/emotional disturbances compared to those without hearing aids (Picou, 2020). In fact, those without hearing aids had more than twice the risk of displaying/experiencing the symptoms of depression. Additionally, 55% of hearing aid users felt that their hearing aid significantly improved their QoL *regularly.* About 32% of hearing aids users reported improvements in their sense of humour, 41% found improvement in their social life and 43% felt more included, whereas 21% of hearing aid non-users felt embarrassed because of their hearing loss *regularly*; 43% felt embarrassed *occasionally* (Picou, 2020).

Mulrow et al. (1990) conducted a randomised control trial with 188 older adults, where half were provided hearing aids and the other half were put on a waiting list. Questionnaires to assess QoL were administered at baseline, 6 weeks and 4 months. At baseline, approximately 82% of subjects were found to have impaired QoL as a result of their hearing loss, and 24% of subjects were experiencing depressive symptoms. At each follow-up, significant improvements were seen for subjects that were provided hearing

aids: their social function, emotional and mental health improved, and their depressive symptoms were greatly reduced. It was concluded that hearing loss can have a detrimental impact on an individual's QoL, however hearing aids may reverse these impacts (Mulrow et al., 1990). A follow-up study by Mulrow et al. (1992) found that these improvements were sustained over *1 year*.

The process of hearing aid fittings with traditional audiology

The process to fit hearing aids involves several stages, such as the assessment stage, the referral stage, the planning stage, the selection stage, the verification stage, the hearing aid orientation stage, and the validation stage. This process was developed using scientific evidence; it is precise and followed by audiologists globally to lead to the best possible hearing outcomes for clients (Valente et al., 1998).

The assessment stage involves taking a detailed case history, conducting an otoscopic examination of the ears and administering a comprehensive hearing test that includes pure-tone audiometry, speech audiometry and immittance measurements (American Speech-Language-Hearing Association, 2004). These tests allow the audiologist to determine the type and degree of the client's hearing loss; they can begin planning the appropriate intervention for the client. Additionally, the audiological results may indicate that a *referral* is necessary for additional services, such as an ear nurse, MRI, or surgical intervention. These referrals are based on certain criteria, such as unilateral hearing loss and/or tinnitus, neurological symptoms, sudden sensorineural hearing loss, occluding wax, etc (Dawes & Jeannon, 1998). Medical clearance from these specialists is required before audiological intervention/management can begin (ASHA, 2004).

The planning stage involves the audiologist discussing the results of the audiological testing with the client and their family/caregivers. At this stage, the audiologist determines the situations that the client has the most difficulty hearing in and the situations that the client wants to hear better in – this is known as a 'needs assessment'. A needs assessment allows the client to inform the audiologist about their different daily circumstances and the specific difficulties they experience (Dillon, 2012). This information is valuable as it allows the audiologist to begin creating a plan for the type of amplification the client will need, along with other rehabilitative options that may be appropriate for the client, such as counselling, therapy. At the planning stage, the audiologist must consider the client's physical abilities in addition to their hearing needs, for example, dexterity, vision, cognitive status, motivation, etc (Lesner & Kricos, 1995). These factors are important to consider as they can impact the experience the client will have with the hearing aids, for example, for someone with poor dexterity, small batteries will be difficult to manage and therefore the audiologist may look into ordering rechargeable hearing aids. During the planning stage, specific goals are established that are tracked throughout the hearing aid journey; this allows the audiologist and the client to see whether the hearing aids are providing benefit in specific, prioritised situations (Dillion, 2012).

The selection stage involves determining the physical and electroacoustic characteristics of the hearing aids for a particular client. This part of the hearing aid process is defined largely by the audiologist, with some input from the client about what style of hearing aid they prefer (Valente et al., 1998). It is the responsibility of the audiologist to be transparent and informative about the advantages and disadvantages of different hearing aid styles and the advantages of binaural amplification versus monaural amplification, depending on the type and degree of the client's hearing loss. Ultimately, the selected

hearing aid must meet the needs of the client and be able to provide enough amplification for the client's specific hearing loss; they should provide audibility and intelligibility to speech signals for the client (Dillon, 2012). Generally, ITE/ITC hearing aids are more appropriate for mild to moderate hearing loss whilst BTE/RICs are more powerful and can accommodate more severe degrees of hearing loss (Dillon, 2012). The considerations taken during the planning stage are important for the selection process (dexterity, vision, cognitive status, etc). During this stage, a prescriptive formula is chosen for the client's hearing aids; there are linear and non-linear prescriptions (Dillon, 2012).

The verification stage involves the audiologist determining whether the hearing aids meet a set of standards – here, the audiologist verifies that the hearing aids are able to provide enough amplification for the client to hear better at soft, moderate and loud levels across the frequency spectrum (Dillon, 2012). Real-ear measurements (REMs) are the standard verification method for adults. REMs are conducted as the output of the hearing aids is impacted by the client's ear canal length, shape, size, and volume, along with acoustic parameters of the hearing aids, such as vent size, tube size, mould, dome type, etc (Dillon, 2012). Therefore, REMs allow the audiologist to determine the amount of sound that the client will receive at their eardrum, which differs from what the manufacturer states. The verification process begins with assessing the physical fit of the hearing aid in the client's ear(s) – they must fit well and be easily insertable/removable (Dillon, 2012). Probe microphones are placed into the ear (with the hearing aid) to measure the hearing aid response in the client’s ear to determine if the hearing aids can reach prescriptive targets, unless there are contraindications, such as wax occlusion, discharge, etc. Running speech is played from a speaker at 4 different levels: average (65dBSPL), soft (55dBSPL), loud (75dBSPL) and maximum power output (85dBSPL). Firstly, without the hearing aids in, the real-ear unaided response is measured to determine whether the probe is inserted deep

enough for accurate real-ear measures (Dillon, 2012). The probe microphone measures the output of the hearing aid in the ear canal, along with the impact that the client's natural ear canal resonance has on this output – this measure is called the real-ear aided response (REAR). The REM machine shows only the output of the hearing aids called the real-ear insertion response (REIR – this is the difference between the REUR (real ear unaided/ unoccluded response) and REAR), and the audiologist adjusts within the software to make sure the hearing aids meet the prescriptive targets. To be considered acceptable target-matching, the REIR should be +/-5dB from 250Hz to 2000Hz and +/-8dB from 3000Hz to 4000Hz (New Zealand Audiological Society, 2016). After ensuring that the hearing aids meet prescriptive targets, the audiologist will ask the client whether they want any changes to the sound level – often new clients prefer lower levels (for comfort) than prescribed which can compromise intelligibility and may provide less benefit than prescriptive target levels. New hearing aid users require an acclimatisation period (Dillon, 2012).

The hearing aid orientation stage involves the audiologist training the client on how to use and care for their hearing aids (Valente, 1998). Clients learn about battery management, how to clean hearing aids, how to change programmes, how to change the volume, where to store the aids at night, how to insert and remove the hearing aids from the ear. This is done during the hearing aid trial period, where the client returns for follow-up sessions to discuss any difficulties they are having or any changes they want to be made to the hearing aids, for example, persistent difficulty hearing TV may warrant the audiologist to order a TV streamer (an assistive device). During these sessions, the audiologist continues to relay realistic expectations of hearing aid use to the client and provides counselling for persistent difficulties, for example, facing the person speaking in a noisy restaurant (Valente, 1998).

The validation stage is important to determine whether the hearing aids are *actually* providing benefit to the client and whether the pre-determined goals at the beginning of the process are being achieved (Valente, 1998). Validation involves determining whether the disability has been reduced with the use of hearing aids. Questionnaires allow for subjective measures of hearing aid benefit. They can provide insight into the real-world benefit the client experiences due to amplification (Dillon, 2012). Examples of such questionnaires are the Client Oriented Scale of Improvement (COSI), the Hearing Handicap Inventory for Adults (HHIA), and the Abbreviated Profile of Hearing Aid Benefit (APHAB) (Dillon, 2012). Additionally, speech perception tests with hearing aids can provide valuable insight into the benefit that hearing aids give the client for communication and speech intelligibility (Valente, 1998).

Cochlear implants

Cochlear implants are effective amplification devices for people with severe to profound hearing loss, who receive little to no benefit from the use of hearing aids or those who are unable to use hearing aids. A cochlear implant is surgically implanted that provides direct stimulation to the auditory nerve, bypassing the outer and middle ears, to provide a sense of sound to improve speech perception (National Institute on Deafness and Other Communication Disorders, 2016). The auditory nerve must be healthy and present for cochlear implants to work.

A cochlear implant has two components – external and internal (Baura, 2011). The external component is worn behind the ear and comprises a microphone that converts the acoustic signal to an electrical signal, a speech processor that codes the signal and antennae that transmits the signal to the internal component. The internal component is

implanted and comprises a receiver that decodes the signal from the external signal processor, and an electrode array that stimulates the auditory nerve fibres (Diego & Maurizio, 2006).

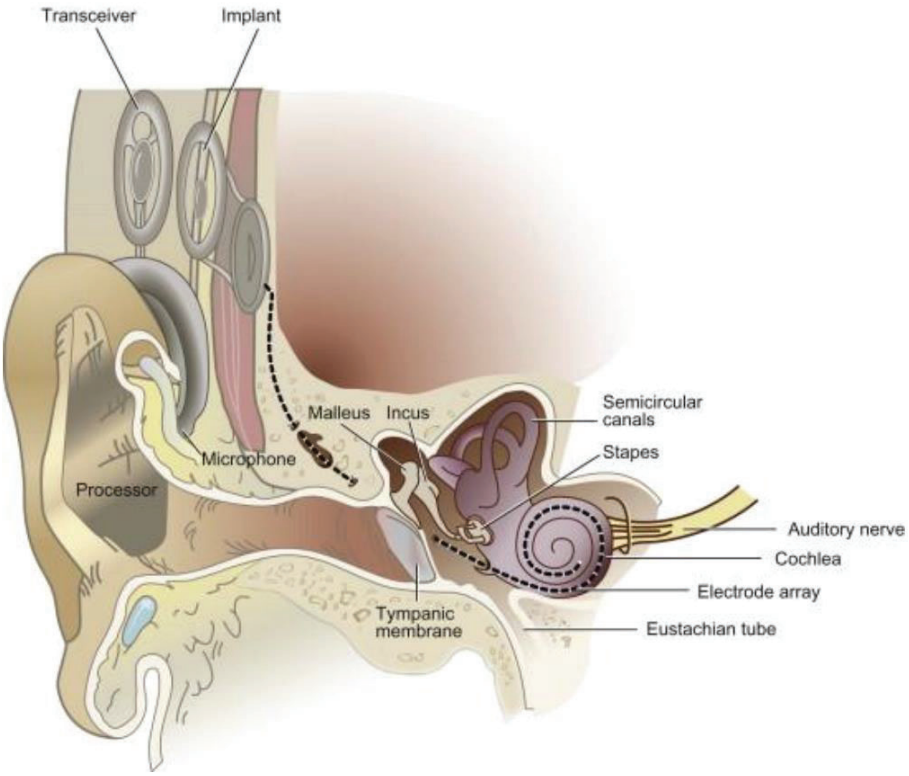

Figure 5:

The internal and external components of a cochlear implant. Retrieved from "Cochlear Implants Medical Device Technologies" by G. Baura, 2012, Academic Press, 315-334. Copyright (2012) Elsevier.

Children with cochlear implants show improved oral language skills and beneficial educational outcomes. Adults with cochlear implants show improved speech perception and overall QoL (Crowson et al., 2017). Cochlear implantation is limited and requires stringent post-implant rehabilitation, therapy, and support.

Several studies have been conducted that indicate that cochlear implants are beneficial for communication, emotional and mental health, and overall QoL.

Harris et al. (1995) conducted a study to investigate how cochlear implantation impacts emotional, economic, and QoL, with nine participants aged between 18-60 years. Many measures were administered preoperatively and at different postoperative time points up to three years. To measure audiological changes, several speech recognition assessments were done that suggested *significant* improvements. Pre-operative scores for the 'Northwestern University 6-word list' were 0.4% which rose to 28% post-implantation. Pre-operative scores for the 'CID everyday sentence test' were 2%, which rose to 72% post-implantation. Pre-operative scores for the 'Iowa sentences' were 0.3%, which rose to 66% post-implantation. To measure emotional health and QoL, the 'Satisfaction with Life Areas (SLA) scale' and the 'Quality of Well-being' (QWB) scale were administered. Both scales showed an increase in well-being and QoL post-operatively. Economic changes were measured by observing the personal income of participants, which increased post-implantation (Harris et al., 1995).

Mo et al. (2005) studied 27 post-lingually deaf adults with cochlear implants pre-operatively and 12-15 months post-implantation. They found significant improvements in the depression and anxiety scores of the participants – the participants felt like they could communicate better with their loved ones, they felt like less of a burden, they felt less isolated, and they felt that their relationships had improved. All of these improvements culminated in a significant gain in their QoL post-implantation (Mo et al., 2005).

Warner-Czyz et al. (2009) found that children with cochlear implants rated their own QoL to be at a similar level as their normally-hearing peers. They rated their self-esteem, confidence, happiness, and communication skills higher than their parents did.

A cost-benefit, cost-utility and cost-effectiveness analysis in the United States found that for each USD 1 invested in cochlear implantation to treat a child's hearing loss, there is a return of USD 2.07 (Penaranda et al., 2012). Monteiro et al. (2012) found that the economic benefits and improved QoL (through improved employment status and income) exceed the overall costs of a cochlear implant (including associated costs of rehabilitation). Using cochlear implants to treat post-lingually deaf adults significantly improves their QoL and is estimated to provide net savings to the economy (Lee et al., 2006). Mohr et al. (2000) estimate that through early intervention if an additional 10% of pre-lingually deaf children can move into mainstream education, the yield of the return on investment would more than double. The WHO states that early identification, early intervention of hearing loss and provision of hearing devices is cost-effective (WHO, 2017).

Teleaudiology

Teleaudiology means audiological care at a distance - this is possible through the advancement of technology and connectivity globally (Ravi et al., 2018). Teleaudiology through videoconferences, phone calls and emails, has the potential to increase the accessibility of audiological care and overcome economical and geographical barriers. In 2019, it was estimated that 53.6% of the global population (47% of the developing world and 86.6% of the developed world) had access to the internet, and this number was exponentially growing (International Telecommunications Union, 2020). These values indicate that teleaudiology would likely improve access to a large portion of the global population – importantly, within developing countries. The use of teleaudiology has the potential to provide opportunities to not only improve access, but to improve

affordability, uptake, and convenience of hearing amplification devices (Montano et al., 2018).

Krumm (2007) states that telehealth can be administered in two ways – synchronous (real-time, e.g., videoconference) and asynchronous (e.g., results sent to an audiologist to examine at a later time). A combined approach is also possible (e.g., some tests are in real-time while others are not).

Most of an audiological assessment and management can be done via teleaudiology including screening, diagnostic testing, and intervention/rehabilitation (Swanepoel et al., 2010).

For screening in infants and children using videoconferencing and remote facilitators, distortion product otoacoustic emission (DPOAE) amplitudes, otoscopy and tympanometry showed that results were within test-retest reliability between face-to-face testing and remote testing (Lancaster et al., 2008; Krumm et al., 2008). Additionally, pure-tone frequencies that were screened in school-aged children showed no differences between the face-to-face testing and remote testing at 188 out of 193 frequencies (Lancaster et al., 2008). Both studies used remote facilitators that prepared patients (e.g. placing the transducers correctly on the patient), whilst an audiologist supervised through interactive videoconferencing. Krumm et al. (2007) investigated the utilisation of teleaudiology in 30 adults for screening DPAOEs and results from the remote testing agreed by 97-99% with the results obtained through face-to-face testing. These studies utilised synchronous methods of screening, however, asynchronous methods are possible (e.g. the facilitator performing each test and sending the results to an audiologist to review *or* internet-based hearing screening). For diagnostic testing, a case history could be taken by an audiologist via videoconferencing or phone calls (synchronous) or the

patient could fill out an electronic case history form beforehand (asynchronous) (Swanepoel et al., 2010). Computer-based audiometers that the audiologist can control from a remote location could allow synchronous hearing testing (Elangovan, 2005) or internet-based hearing tests could be done by the patients themselves (Bexelius et al., 2008). As a result of the COVID-19 pandemic, many audiology clinics use teleaudiology to programme and fine-tune hearing aids remotely, through application sharing. Fittings and verification can also be done through this method (Wesendahl, 2003). For patients that require custom ear moulds, a facilitator could take ear impressions while an audiologist assists through videoconferencing.

Consumer welfare is an important consideration to make when implementing teleaudiology; consumer privacy must be maintained, and consent must be obtained before providing clinical services via telehealth/telemedicine (Krumm, 2014). This includes ensuring that the rooms that both clients and audiologists/facilitators videoconference from are secure. The way that electronic documentation is accessed must protect the client's privacy and confidentiality (ASHA, n.d.b). The client has the right to decide who is and isn't present during the consultation, and all individuals involved and present for the consultation should be disclosed to the consumer *and* clinician to ensure privacy and confidentiality is maintained for *both parties* (ASHA, n.d.b).

Teleaudiology must account for consumer differences/needs and provide specific solutions for clientele that are unable to participate in telehealth. A client's visual acuity must be considered as they would have to look at a screen. If a client is not able to speak or understand one language, translators should be readily available. If a client does not have access to an appropriate environment to conduct hearing tests or have poor internet, information should be provided for locations they could go to (ASHA, n.d.b). The audiologist must ensure they are also in an environment that will yield ideal results; a

quiet room with minimal distractions and good lighting so the client can see them clearly on-screen (ASHA, n.d.b).

Teleaudiology must provide audiological services to a comparable standard/quality as traditional audiology; they must be equally as effective (ASHA, n.d.b). Improving access to audiological services is futile if the services are of lower quality (Levesque et al., 2013). There are several studies (and more are constantly being done) that indicate that teleaudiology produces comparable results to that of traditional audiology. These services include video otoscopy (Biagio et al., 2013), pure tone audiometry (Visagie et al., 2015), speech audiometry and speech-in-noise tests (Ribera, 2005), hearing aid fittings (Campos & Ferrari, 2012), cochlear implant fittings (Hughes et al., 2012), paediatric hearing screening (Botasso et al., 2015) and aural rehabilitation, such as counselling, training and sensory management (Saunders & Chisolm, 2015). Importantly, for high quality and effective service provision via teleaudiology, audiologists and facilitators require ongoing education and training as telehealth is everchanging (Krumm, 2014). Audiologists and facilitators should be aware of the technological changes to ensure they always have specialised skills; especially if procedures must be modified or adapted for the needs of different clientele (ASHA, n.d.b). As technology is ever-evolving, technical support is essential. One of the concerns of audiologists is the clinical governance for teleaudiology – how will audiologists and organisations be held accountable for always providing services of high quality and high standards? It is important to provide clarity around the standards of practice for teleaudiology to ensure that clients get the best possible care (Brice, 2019).

During the COVID-19 pandemic, teleaudiology services increased dramatically. However, teleaudiology was expanding prior to the pandemic to meet the shortage of audiologists to the high demand for audiological care, for example, within rural

communities in the United States of America (Ehrnfeld & Victory, 2021). Telehealth seems promising for clientele with limited mobility, such as adults living in nursing homes. The U.S. Department of Veterans Affairs routinely uses telehealth/telemedicine for vision, dermatological, radiological, and audiological appointments (Ehrnfeld & Victory, 2021). Teleaudiology can not only allow remote hearing health care for adults but for diagnostic screening/testing of infants and children which has been shown to reduce loss of children to follow-up from newborn hearing screening programmes (Dharmar et al., 2016; Hatton et al., 2019). Eikelboom and Atlas (2005) conducted a survey to ask 116 older adults with hearing loss their willingness to try teleaudiology; 32% of participants were willing to try teleaudiology, 10% were willing to try sometimes, 28% were unsure and 30% were not willing. The most common reason for participants to be willing to try teleaudiology was the reduced cost and waiting time for appointments, while the most common reason to not be willing to try teleaudiology was a preference for face-to-face interactions (Eikelboom & Atlas, 2005). With teleaudiology, consumers save the costs of travelling to and from audiological clinics (Convery et al., 2011b).

The process of fitting hearing aids using teleaudiology

The stages of the hearing aid fitting process are not largely impacted by having virtual/remote appointments, rather, more workers and equipment may be necessary.

The assessment stage (case history taking, otoscopy, pure-tone audiometry, speech audiometry and immittance measures) can be done through synchronous and/or asynchronous measures. Videoconferencing could play a large role in this, along with the possibility of having a facilitator present for more tactile processes, such as otoscopic examination (Swanepoel et al., 2010). Automated testing procedures may also be viable

(Swanepoel et al., 2010). With a thorough examination of the case history and audiometric results, either synchronously or asynchronously, the audiologist would also be able to make referrals for medical/surgical interventions, if necessary.

The planning and selection stages would not differ largely from the traditional audiological process, as the audiologist plays the largest role in these stages. It is important to ensure that the audiologist asks relevant questions to get as much information as possible to make a well-informed and appropriate decision about the hearing aids (Valente, 1998). The needs assessment can simply be done synchronously via videoconferencing or asynchronously by sending the client an email with relevant and simple questions to answer.

The verification stage could be done through application-sharing and videoconferencing, with facilitators ensuring probe microphones and hearing aids/s are placed correctly inside the ear and the client is positioned correctly to the speaker/s. The audiologist could complete real-ear measurements and finetuning using application-sharing, then move on to counselling/orienting the client on how to clean and care for their devices (Swanepoel et al., 2010). In this same manner, follow up appointments could be carried out, where further adjustments are made to the hearing aid through application-sharing and questionnaires are completed together for validating the hearing aid fitting/s (Swanepoel et al., 2010).

Over the counter, user-programmable hearing aids

Over the counter (OTC) hearing aids are a type of direct-to-consumer product/technology. Such devices can be purchased online or in store, without consultation from a hearing expert, and are ready to use upon purchase. OTC hearing aids are targeted towards people

with mild-moderate hearing loss; they are not considered appropriate for poorer hearing loss (Manchaiah et al., 2017). OTC hearing aids could provide greater accessibility and affordability for many individuals with hearing loss – it may also increase uptake of hearing amplification devices. Contrera et al. (2016) define five barriers that consumers experience when accessing hearing health care: treatment options, awareness, access, device effectiveness and cost. Direct-to-consumer hearing devices may be able to address these barriers, such as cost and access.

Through continuous advancement of technology, hearing aids are becoming self-programmable, where the consumer can fit and program their own hearing aids. This would involve little to no involvement of an audiologist. Convery et al. (2017) conducted a feasibility study on 40 older adults (20 with hearing aid experience and 20 without) with hearing loss ranging from mild to moderately severe. About 73% of participants successfully inserted their devices into their ear without assistance and of that, 55% were able to complete a 10-step fitting process following instructions. The results of this study suggested that about half of older adults with hearing loss would be able to fit and program their own hearing aids without any assistance, but more provisions would be useful to ensure as many errors are avoided as possible.

Adults who purchase OTC hearing aids tend to be older, retired, have a low income and are often, experienced hearing aids users (Kochkin, 2014). They tend to have positive attitudes towards their OTC hearing aids – possibly due to the increased affordability.

McPherson and Wong (2005) studied the difference between the self-reported benefit that consumers perceived they got from traditionally fitted hearing aids and over-the-counter hearing aids. They found no significant differences between the device types. They conducted a prospective open trial with 63- to 83-year-olds with mild to moderate hearing

loss and found OTC devices were more affordable and provided more opportunities for individuals with hearing loss to access amplification devices. Sacco et al. (2016) studied the clinical value/benefit experienced by users of over-the-counter hearing aids and found that they often had improved hearing in quiet and background noise, as well as improved communication skills and overall QoL.

OTC hearing aids/devices are not yet available on the market, as the guidelines for getting FDA approval for such devices have not been defined (Hillpot, 2021). However, self-fitting hearing aids are a type of hearing amplification device that is said to 'fall between OTC and traditional hearing aids' – these are readily available and are similar to OTC hearing aids to be able to discuss the discussions around them (Collins, 2019). Self-fitting hearing aids are devices that the consumer can personalise to their own needs, bypassing interactions with a hearing care professional and often, bypassing the need for a formal hearing test (Weinstein, 2021).

Self-fitting hearing aids are marketed for individuals aged over 18 years with 'perceived mild to moderate hearing loss'. Lin and Reed (2021) suggest that the term 'mild to moderate' may confuse users into thinking that an official diagnosis of the degree of their hearing loss is required, despite self-fitting hearing aids being advertised as requiring no hearing care professional involvement at all. As a result, Lin and Reed (2021) developed a metric that could be used by non-audiological professionals to understand a consumer's hearing status to better help understand who needs self-fitting hearing aids. They define this as the average of the air conduction thresholds at 500Hz, 1000Hz, 2000Hz and 4000Hz as these frequencies are important for speech. However, there are individuals with normal audiometric results but self-reported difficulties, this is known as hidden hearing loss (Weinstein, 2021). Koerner et al. (2020) surveyed audiologists and discovered that 45% of audiologists saw one to three clients each month with normal

pure-tone audiometric results but several communication difficulties. “Hidden hearing loss” is not uncommon, and often, the normal audiometric findings disappoint clients. Therefore, the use of an audiometric average to universally determine who needs self-fitting hearing aids has its shortcomings (Weinstein, 2021). Guidelines around who can and cannot use OTC hearing aids are required.

The U.S. Food and Drug Administration regulates hearing aids to ensure efficacy and safety for use. In 2017, a federal law was passed to designate a new FDA-regulated category for OTC hearing aids, however, COVID-19 has caused delays in the publishing of the guidelines (Collins, 2019). Importantly, many of the self-fitting hearing aids that are currently on the market, such as the Bose SoundControl Hearing Aids and the MDHearingAid products are not FDA approved. They simply have FDA clearance or are FDA-registered. Due to this, there are many concerns about its safety and efficacy. A complaint written to the FDA argued that the initial study that was used to base the FDA clearance of Bose SoundControl Hearing Aids did not provide sufficient evidence that the self-fitting method was effective, as it relied heavily on the involvement of hearing care professionals (Hillpot, 2021). Therefore, the self-fitting hearings may not be efficacious or safe at all; consumers may not be able to fit the hearing aids as well as is suggested by the initial study that relied heavily on professional influence.

Direct-to-consumer hearing aids are desirable to individuals with hearing loss, as they cut out the middleman (the audiologist) and connect the hearing aids directly with the consumers, saving costs (Collins, 2019). Eargo hearing aids are an example; they come with factory pre-sets for a range of hearing losses. However, clinical audiologists argue that factory pre-sets will not work for everyone, especially considering that hearing loss does not functionally impact individuals in the same manner. Eargo CEO states that their hearing aids amplify at the frequencies that are known to be important for speech –

500Hz, 1000Hz, 2000Hz and 4000Hz. People may have the same degree of hearing loss, but these may be present at differing frequencies which could impact the success of the factory pre-sets for different individuals (Collins, 2019). Clinical audiologists highlight their concerns around how a medical problem will be addressed with OTC hearing aids and that clients having complete control over their hearing devices may lead to overamplification, which could damage hearing further, or under-amplification, which could make consumers believe hearing aids do not work and no longer seek help with their hearing concerns (ASHA, n.d.a).

Convery (2020) argues that OTC/self-fitting manufacturers believe that by simply increasing the availability of hearing aids, the accessibility of these devices will improve too. However, several factors could influence the success that consumers will have with these devices. A client's previous experience with traditional hearing aids and smartphones largely impacts the success of self-fitting devices (Convery et al., 2019). This means that people who are new to any form of amplification, who make up the majority (88%) of consumers interested in purchasing OTC/self-fitting hearing aids (Powers & Rogin, 2019), will be at a disadvantage (Convery, 2020). The study by Convery and colleagues (2019) also found that cognitive function played a large role in the success of self-fitting hearing devices, therefore some assessment of this should be done by manufacturers before allowing the purchase of the devices, such as a questionnaire on their website/s (Convery, 2020). The same study asked experienced hearing aid users to compare self-fitting hearing aids with their traditional hearing aids; users found that the self-fitting hearing aids did not have any features to deal with loud noise (maximum power output) and they did not like that the self-fitting hearing aids were larger and bulkier than their own traditional hearing aids (Convery et al., 2019).

The Bose SoundControl Hearing Aids are self-fitting hearing aids; they are RIC devices priced at USD 850 a pair (Hillpot, 2021). The Bose SoundControl Hearing Aids are adjusted/fitted by the user themselves, and they are not pre-programmed to any degree of hearing loss – in other words, the user has complete control over how much amplification they will get from these hearing aids (Hillpot, 2021). These hearing aids come with several dome sizes (with different vent sizes) to allow users choice over which domes sound best. The Bose SoundControl Hearing Aids connect to the Bose Hear smartphone app, where users can allegedly personalise their hearing aid settings in 30 minutes. The hearing aids allow users to turn directional microphones on/off, which is extremely useful for hearing in noise. The hearing aids have a volume control button and customers get free one-on-one video appointments with Bose Hear Product experts if they require assistance (Hillpot, 2021). These hearing aids cannot stream music or telephone conversations, they are not waterproof or rechargeable. The Bose Hear App does not have an in-built hearing test; if users wish to understand the degree of their hearing loss, they will have to visit an audiology clinic (Hillpot, 2021). Another example of self-fitting hearing aid is the MDHearingAid products – another RIC device, that range from $399.98 to USD 999.99. These products have additional features to that of Bose SoundControl Hearing Aids, such as feedback cancellation, background noise cancellation, rechargeability and waterproofing. Additionally, these free help/assistance sessions that are offered for MDHearingAid customers is provided by qualified/certified audiologists, which is not the case for Bose SoundControl Hearing Aids. The MDHearingAid App allows customers to complete a hearing test, and the results are used to fit the hearing aids before they are shipped to the user. On average, traditional hearing aids are sold for USD 4600 a pair (NZD 6750), compared to the $850 Bose SoundControl hearing aids and $399.98-$999.999 MDHearingAids. Additionally, with self-fitting hearing aids,

consumers save costs as no hearing care professionals are required, along with reduced travel costs (Convery et al., 2011b).

The American Speech-Language-Hearing Association recommends some guidelines for OTC hearing aids; OTC devices should be restricted to those with mild hearing loss, safe levels for gain and power output need to be established, OTC devices should only be available to adults, well-designed studies need to be done to collect information about consumer safety and potential issues with the devices, the OTC devices should have labels that strongly encourage seeking professional assistance from audiologists and labels that inform consumers of the warning signs for ear/hearing conditions that *require* medical attention (ASHA, n.d.a). They strongly encourage consumers to seek audiological assistance, as hearing loss is a medical condition and because self-prescription by OTC devices can be lacking. Individuals within the hearing aid manufacturing industry who are in favour of OTC devices tend to believe that hearing aids alone can improve hearing, which is not true (ASHA, n.d.a). Manufacturers need to focus their efforts on making sure that their devices are *usable* by their target demographic; this could be done by including users during the development and evaluation of new technologies (Convery et al., 2020).

The process of fitting hearing aids using OTC, user-programmable devices

The stages of the hearing aid fitting process differ much more between traditional audiology and OTC, user-programmable devices. Generally, the importance of clear and simple instructions and informative material is necessary for users to make use of OTC, user-programmable devices appropriately (Silman & Silverman, 1997).

The assessment stage for OTC, user-programmable devices is not well-defined – many studies have suggested different ways to do so, such as online hearing tests, automated hearing tests at testing centres (where pure-tone audiometry, speech audiometry, otoscopy and immittance measures can be done in the presence of a facilitator), etc; the main idea being that users themselves would be able to test their own hearing and order hearing aids to fit to those results. Importantly, the literature identifies that an individual who may require a medical referral (for example, due to a unilateral hearing loss) may not receive appropriate hearing health care. This can be dangerous as *this* issue may be caused by an acoustic neuroma, for example (Silman & Silverman, 1997).

The planning stage and selection stages of the hearing aid fitting process would shift from being primarily controlled by the audiologist (for a traditional hearing aid fitting) to being controlled by the client (for OTC, user-programmable devices) (Convery et al., 2011b). The client may choose a hearing aid that is not appropriate for their hearing loss and ears, such as an ITE device for a conductive loss caused by middle ear issues. As much information as possible about the advantages and disadvantages of the different hearing aid styles should be provided to users, in simple language (Convery et al., 2011b).

There is no verification stage for OTC, user-programmable devices – instead hearing aids are delivered to the client using their audiometric results. The users can then adjust the hearing aids to their preferences. The real-ear measurement process is backed with scientific evidence of its benefits to the client – it ensures that the hearing aids are able to provide the levels of amplification that the client needs to be able to hear better (Valente, 1998). Without REMs, the hearing aid fitting may not be *completely* accurate. There is no way of knowing if the hearing aids are causing distortion. The literature does not define how specific prescriptive procedures would be chosen. Additionally, allowing clients to adjust the hearing aids as soon as they receive them, may lead to clients under amplifying

(by choosing comfort over audibility and intelligibility). In other words, they will extend their acclimatisation period (Dillon, 2012).

The orientation stage would not be conducted by an audiologist, but the user would orient themselves using written material (hearing aid manuals) and/or audio-visual material (instructional videos).

There would be no validation stage of the hearing aid fitting process unless hearing aid manufacturers communicate with clients to ask about their experiences with their OTC, user-programmable devices. However, these questions would not be used to adjust the client's devices as they would for traditional audiology.

The importance of clinician involvement during the hearing aid fitting process

As highlighted in the above sections, especially for OTC, user-programmable hearing devices, without the involvement of an audiologist, there are many parts of the hearing aid fitting process that can go wrong. Audiologists are highly trained professionals that understand the different types of hearing loss that can arise and how to intervene for each of these types of hearing loss. They follow guidelines for best practices to ensure that their clients receive the best possible treatment and outcomes (Dillon, 2012). This best practice is not as negatively impacted by teleaudiology as it is by user-programmable devices, which omit audiologists' input throughout the majority of the hearing aid *fitting* process.

Audiologists identify when medical/surgical referrals need to be made to other medical specialists, as well as identifying contraindications to conducting certain tests during the audiological appointment (Dillon, 2012). Without the audiologist, the client could

complete their own hearing test and get inaccurate results or cause harm to their ears (for example, active ear infections and using insert earphones and conducting immittance measures) (Convery et al., 2011b).

A lot of thought goes into selecting appropriate hearing aids for each client – it is a highly individualised process. There are many considerations that the audiologist has to make during this process. Teleaudiology would not impact this stage as much OTC devices would. With OTC, user-programmable devices, the client could choose their own style of hearing aid which could be completely inappropriate for them (Convery et al., 2011b). For example, a client with dexterity issues may decide to select hearing aids with small, finicky batteries because they are more affordable.

Audiologists set up regular follow-up appointments to validate the fitting of the hearing aids, to finalise the hearing aids, to adjust the hearing aids and to test the client's hearing to ensure there are no significant changes in threshold (Dillon, 2012). A user-programmable hearing device may lead to clients not making appointments with an audiologist after having their devices for a certain period of time. This could mean that progressive hearing loss, recurring ear infections and similar issues would be overlooked, resulting in poor hearing aid fitting/s and potential detriment to the health of the client (Macrae, 1991). Additionally, clients may set their user-programmable hearing aids to inappropriate levels of gain/output (too loud could cause more damage, such as temporary or permanent threshold shifts, or distortion through the upward spread of masking; and too soft would provide no benefit) (Macrae, 1991). Without regularly scheduled follow-up sessions with an audiologist, these issues would never be identified.

An audiologist's job includes providing counselling and further support after a client receives their hearing aids (ASHA, 2018) and many adults require some form of support

after getting their hearing aids fitted (Lam, 2019). With the use of OTC, user-programmable devices and potentially even teleaudiology, there is a chance that clients will believe that receiving their hearing aids is an 'all or nothing' process and will not seek additional help even if they might need it. Simply having hearing aids does not guarantee better hearing outcomes (King & Brewer, 2018; Lam, 2019).

Patskanick et al. (2019) conducted a study that looked at online reviews of self-fitting/user-programmable hearing aids offered online and conducted interviews on a group of 85+ years older about their thoughts on different self-fitting/user-programmable hearing aids. Reviewers complained of the hearing devices not fitting well into their ears and getting lost as a result and they mentioned having difficulty troubleshooting the devices. Here, the value of an audiologist can be seen, as these issues would either not arise or be easily alleviated. Additionally, most of the participants trusted audiologists over any other source of advice/information for hearing aids, as seen in Figure 6 (Patskanick et al., 2019).

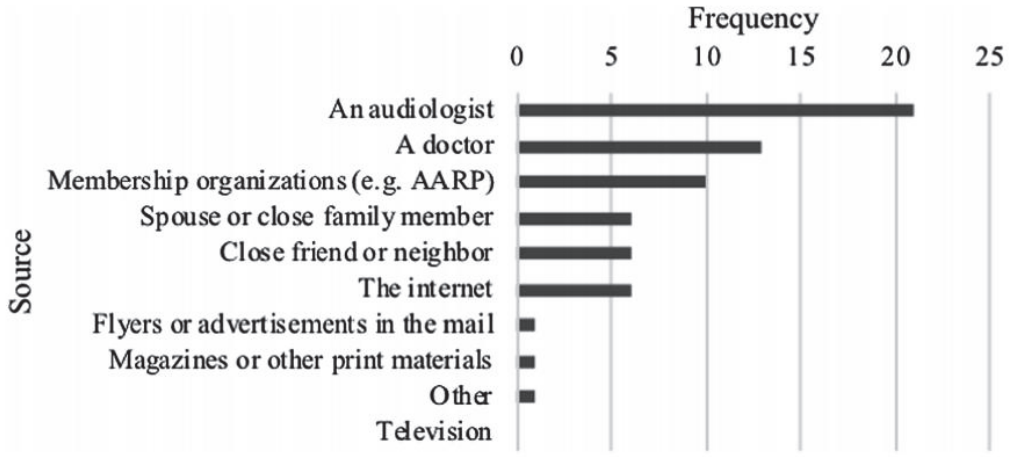

Figure 6:

Audiologists are the most trusted source of advice for hearing aids and other hearing devices among 85+ years olds. From "Mapping the Future of Hearables: Lessons from Online and the "Oldest Old" Consumers" by T.R. Patskanick, J. Miller, L.A. D'Ambrosio, C. Lee & J.F. Coughlin, 2019, International Conference on Human-Computer Interaction, 267-280.

Other innovations

Many recent developments in hearing aid technology and service provision provide a wider scope of practice that may broaden the access of devices.

One such development is that of self-fitting or trainable hearing aids. A self-fitting hearing aid requires the user to perform audiological testing and fine-tuning using the hearing aids themselves, by following instructions. The success and feasibility of self-fitting hearing aids depends on the design and the use of clear instructions. The use of trainable hearing aids would reduce the amount of audiological equipment and support required, which may increase their affordability and accessibility. However, research is required around the success of these devices across diverse populations and amongst those with varying health literacy skills (Keidser & Convery, 2016).

A potential development within the service provision of hearing aids is training individuals around the fitting and maintenance of hearing aids. Within rural communities, audiological care can be hard to find. Training individuals within these communities to fit hearing aids would improve the accessibility of these devices (Bhutta et al., 2019). Further, individuals within the community could be trained around hearing rehabilitation.

1.4 The concept of access

Access is a difficult concept to define – many people and organisations have differing definitions for this term. Lexically, access is defined as 'the right or privilege to approach, reach, enter or make use of something' (Collins English Dictionary, n.d.). In a healthcare setting, access is defined as the opportunities of consumers/communities to access services, facilities and organisations that will fulfil their needs (Daniels, 1982; Whitehead, 1992). The concept of access is generally used to outline important factors that influence a consumer's ability to enter and make use of services and organisations. However, opinions diverge regarding which factors are included within the umbrella of 'access' and if 'access' describes the *resources* available in the health system or the *consumers* and their independent characteristics. The first interpretation shares the view that 'access' relates to the availability and supply of resources within the healthcare system, where the entry and use of such resources are done so if desired. The second interpretation shares the view that 'access' relates to ensuring use based on the needs of consumers and determining factors that influence the level of use (Penchansky & Thomas, 1981).

With such an ill-defined understanding of what access is, attempting to address and change it becomes much more of a difficult task. Issues with access within the system and at the individual level can be measured through underutilisation rates of services, poorer client satisfaction and tendencies for healthcare providers to take shortcuts due to limited resources (Penchansky & Thomas, 1981).

Many factors affect the accessibility of services/facilities to consumers/clients, such as geographical location, cultural differences/racial biases, financial burden, cultural acceptability, stigma, lack of healthcare professionals and a lack of accurate information (Margolis et al., 1995). Whitehead (1992) argues that the social, economic, and

demographic characteristics pertaining to each individual, including the environments they live in, play a large role in the access and quality of care they receive. Therefore, although the individual may have the right to health care, they may not be able to access it. Frenk (1992) states that access is the sum of obstacles that each client faces. In different health systems, there are different barriers that the client faces, and they work to reduce the access of services to the client. There are ecological obstacles (location from service provider), financial obstacles (cost of services) and organisational obstacles (the resources within the health system may inhibit entry into the system or may hinder the provision of care). Frenk (1992) suggests that these obstacles are sequential and if ecological obstacles are overcome, the client may still encounter financial and organisational obstacles.

This section will focus on the conceptualisations of the five domains of access, as mentioned by Penchansky and Thomas (1981) and Levesque et al. (2013), therefore it is important to understand their definitions of access. Penchansky and Thomas (1981) define access as representing the "degree of fit between the patient and the healthcare system" (p. 128). Levesque et al. (2013) define access as "the opportunity to identify healthcare needs, to seek healthcare services, to reach, to obtain or use health care services, and to actually have a need for services fulfilled" (p. 8). The five domains of accessibility are approachability, acceptability, availability and accommodation, affordability, and appropriateness (Levesque et al., 2013; Penchansky & Thomas, 1981). Additionally, as both definitions above describe actions required from the consumer/patient, Levesque et al. (2013) proposed that there are five abilities of consumers/patients within the healthcare system to achieve access: the ability to perceive, ability to seek, ability to reach, ability to pay and ability to engage. It is important to note that these domains of access and their associated 'abilities' are not independent – there is

a significant amount of overlap between them, and they can influence other domains and 'abilities'. This section will also briefly discuss the costs of hearing aids and cochlear implants in New Zealand and the available funding.

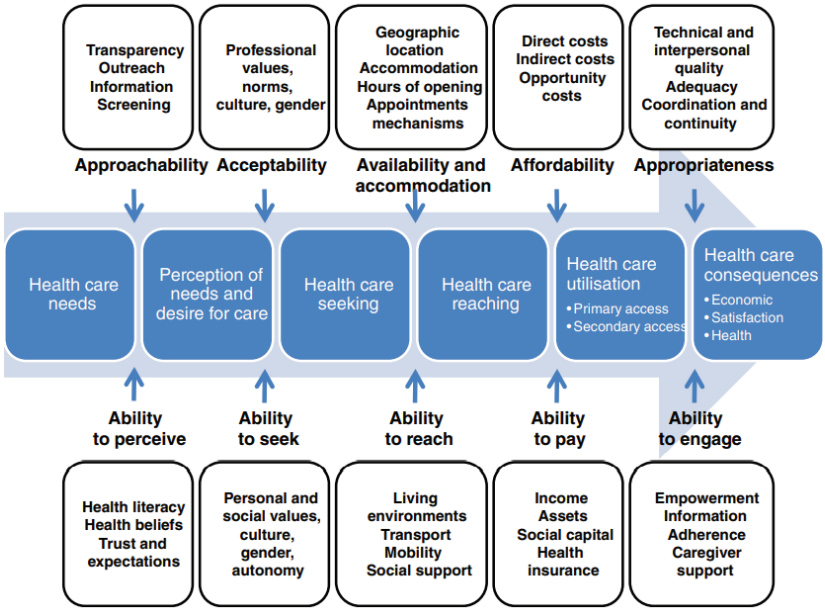

Figure 7:

The five domains of access and their associated 'consumer abilities'. From "Patient-centred access to health care: conceptualising access at the interface of health systems and populations" by J.F. Levesque, M.F. Harris & G. Russell, 2013, International Journal for Equity in Health, 12, 18.

Approachability and ability to perceive

One of the five domains of access is approachability. This domain refers to the concept that clients with a healthcare need should be able to identify that services exist for them that can be reached, and ultimately, the use of these services will impact their health (Levesque et al., 2013). Approachability includes the geographical location of clients relative to the location of services, along with client transportation to these services.

Levesque et al. (2013) identify several methods by which services can become more approachable, such as more transparency and more information around the needs they can cater to and the treatments used, screening programmes and community outreach.

Complementary to the domain of approachability is the concept of the clients 'ability to perceive'. Here, the clients must be able to identify they have a healthcare need that needs to be addressed through accessing healthcare services. The ability to perceive a need for healthcare is influenced by the health literacy status of a client, their knowledge of the healthcare system, their beliefs (or non-beliefs) of the benefits of healthcare and past experiences within the system (Levesque et al., 2013).

In the context of audiology, geographical location is a significant issue, particularly for individuals who live in rural communities as most audiology clinics are within busy cities and towns (Gladden et al., 2015). There are very few measures in place, within New Zealand to address the issues that rural communities have in accessing audiological and otorhinolaryngological care – these services have reduced approachability.

Individuals who require audiological services may not be aware that these are available for use. For example, in New Zealand, early intervention programmes for children with hearing loss were not structured formally, and parents would have to enrol their children in these programmes. This led to significant delays in therapy, counselling and learning because parents were not aware such services existed (Econtext, 2011). Their ability to perceive a need was impacted by a lack of knowledge of services available to them.

Attitudes towards hearing aids/loss can largely impact a client's decision to access audiological care. Individuals who accept their hearing loss and associated problems tend to wear their hearing aids for a longer period during the day and were more likely to have an increased uptake of hearing aids compared to individuals who did not accept that they

had any hearing problems (Brooks, 1989). Their ability to perceive a need for audiological care is impacted because they denied having a hearing loss.

Acceptability and ability to seek

Acceptability refers to the social and cultural influences on the clients' attitude towards the aspects of practices of healthcare providers. This determines whether the client will be likely to seek healthcare. The client's acceptability of services may be influenced by certain characteristics of the healthcare provider, such as sex, ethnicity or locations of facilities that are deemed 'bad neighbourhoods' in the client's mind (Penchansky & Thomas, 1981). If, for example, a particular service is dominated by male providers then women who belong to communities that look down upon physical contact between unmarried men and women would impact the acceptability of these services for these women. They would be less likely to seek appropriate healthcare for their needs (Whitehead, 1992). A provider's attitude towards specific characteristics of a client will also impact their acceptability to provide care, for example, a provider may not be willing to provide care for clients who are on welfare (Penchansky & Thomas, 1981).

Complementary to the domain of acceptability is the concept of the clients 'ability to seek'. The client's ability to seek healthcare relies on their personal and social values – it is completely autonomous. It is the client's decision whether they want to seek healthcare for their needs, and it depends largely on their capacity to seek healthcare, their knowledge of the healthcare options available to them and their rights to their autonomy (Levesque et al., 2013). For the example provided above, domination of male providers would lead to a reduced ability to seek healthcare for some women belonging to ethnic minority groups. This highlights the importance of ensuring that healthcare services are

able to meet the needs of people with different cultural and socioeconomic backgrounds/populations as these groups tend to judge the acceptability and quality of services differently (Harris et al., 2004).

One in three prisoners in New Zealand report having some degree of hearing loss, however their access to audiological services is greatly lacking (Carroll, 2015). Their ability to seek much-needed audiological care is impeded by the biases that society has towards prisoners. Prisoners' lack of autonomy in this matter is socially unjust.

Māori and Pacific persons experience the most difficulty accessing healthcare due to several factors (Chandra & Searchfield, 2016), one of them being racial biases of healthcare providers which impacts their ability to provide appropriate and equitable healthcare. Māori, Pacific and Asian persons are more likely to face racism within the healthcare system which can negatively impact the quality of healthcare and the likelihood of receiving appropriate diagnoses and treatment/s (Harris et al., 2019). As a result, these minority ethnic groups have lower uptake of hearing aids, along with other healthcare services (The National Foundation for the Deaf Inc, 2017).

Availability and accommodation, and ability to reach

Availability refers to the relationship between the number and types of healthcare services and resources and the number and types of services required to address clients' needs (Penchansky & Thomas, 1981). Availability relates to the supply of providers, facilities, and services. Accommodation refers to the idea that healthcare services or healthcare providers can be reached by the client, within a timely manner (Levesque et al., 2013). Availability and accommodation depend on factors of providers, such as length of appointment times, urban features, such as geographical locations and transportation, and

facilities, such as building accessibility, density/distribution of services within the area. Clients' access to important healthcare services is impaired if the distribution of these services is not even throughout a city or a country (Whitehead, 1992).

Complementary to the domain of availability is the concept of the clients 'ability to reach'. This refers to the way clients reach much-needed healthcare services, i.e. transportation availability, access to a personal motor vehicle and getting leave from work to attend an appointment. 'Ability to reach' also depends on the knowledge that clients have about where to get healthcare (Levesque et al., 2013).

In the context of audiology in New Zealand, as there are separate District Health Boards (DHBs), the range of services provided by each DHB and the fees charged by each DHB differs (Digby, 2016, as cited in The National Foundation for the Deaf Inc, 2017). The supply of providers, facilities and services is not consistent across different locations, which impacts the availability and accommodation of audiological services. There is an inequality in the distribution of services; some will have better access to higher quality services than others (Digby, 2016, as cited in The National Foundation for the Deaf Inc, 2017). This can impact their ability to reach audiological services as they may have to visit another DHB, further away, for the services they require.

Affordability and ability to pay

Affordability refers to the cost of services (price and insurance) in relation to the client's ability to pay (income and health insurance) (Penchansky & Thomas, 1981). It relates to the capacity of the client to access these services and spend their time and resources using these services (Levesque et al., 2013). Accessing such services depends on the client's perception of worth relative to the cost of these services – this will rely on the client's

perception of the quality of care, price for the care, clients income and travel time (Levesque et al., 2013). The affordability of healthcare services varies depending on the type of service.

Complementary to the domain of affordability is the concept of the clients 'ability to pay'. This concept describes the economic resources of the client/patient that could be used to pay for services, this could be through many avenues, such as income, loans, savings. Importantly, the ability to pay for healthcare services should not require the client to generate economic resources through drastic methods, such as selling their home or car. Factors that impact the client's ability to pay could be poverty, a lack of health insurance or debt (Levesque et al., 2013).

The most common reason that people are not able to access healthcare/audiological services is cost – they are unable to afford it (Statistics NZ, 2001). Most adults in New Zealand have to visit private audiology clinics and pay for their hearing aids privately, which can still be expensive despite the available funding/subsidy options. Older adults that require cochlear implants face a significant amount of stress, as in 2015, there was only enough funding for 20 adult cochlear implantations compared to the 122 adults that were referred (Heslop, 2015, as cited in The National Foundation for the Deaf Inc, 2017). The remainder of the adults would have had to privately pay for the procedure and post-surgical facilities (the costs are discussed below).

Costs and funding for hearing aids and cochlear implants in New Zealand

Hearing aids are free for children up to 21 years of age in New Zealand. Adults have access to different funding schemes and subsidies if they meet certain criteria. Often, children receive their audiological care through the public health system, while adults

receive it through private audiology clinics. Hearing aids for adults can range from $3000 to $12000, depending on the hearing aid technology level manager (New Zealand Audiological Society, n.d.).

The Ministry of Health (MoH) in New Zealand set up a hearing aid subsidy scheme, where residents/citizens over 16 years of age with permanent hearing loss are eligible. The subsidy amount is $511.11 per hearing aid and this renews every six years (as this is the estimated lifespan of a hearing aid). This subsidy is used if the individual does not qualify for other sources of funding/subsidy manager (New Zealand Audiological Society, n.d.).

The Ministry of Health in New Zealand has also set up a hearing aid funding scheme. Residents/citizens over 16 years of age with hearing loss are eligible if they meet one of the following criteria: complex needs (e.g. dual or multiple disabilities, significant hearing loss since childhood), hold a community services card (and additionally, are either in work over 30 hours a week, in full-time study, a jobseeker, doing volunteer work or care for a dependent person), or have had a sudden hearing loss within six months. Under the funding scheme, repairs are funded but batteries are not.

Individuals who receive Work and Income support in New Zealand can apply for a loan of up to $1000 to purchase hearing aids; the loan amount is taken off from the individuals' benefit payments manager (New Zealand Audiological Society, n.d.).

Accident Compensation Corporation (ACC) funds hearing aids if the hearing loss is proven to be caused by trauma or occupational noise exposure. A calculation is made based on the individual's thresholds to determine the percentage of loss that is due to noise or trauma. The individual's General Practitioner lodges the claim and they are seen by an ear, nose and throat (ENT) surgeon who diagnoses the hearing loss.

Veteran's Affairs has set up a scheme through the War Pension system. The process is similar to lodging ACC claims, only the claim is lodged by the veteran's case manager (New Zealand Audiological Society, n.d.).

For cochlear implants, there are certain candidacy criteria, such as poor speech perception despite well-fitted hearing aids and a diagnosed severe to profound hearing loss, and would benefit from cochlear implant/s. ACC provides cochlear implant funding, however, if persons are ineligible, then the Ministry of Health funds a limited number of cochlear implants for adults each year. The cost of one cochlear implant in New Zealand is approximately $50,000 – this includes the audiological and rehabilitative services accessed by the patient for one year after implantation, and insurance and repairs (Ministry of Health, 2021).

Appropriateness and ability to engage

Appropriateness relates to whether or not the services are a fit for the client's needs, the timeliness of services, the quality of the care (diagnosis and treatment) provided to the client and the relationship between the client and the provider/clinician (Levesque et al., 2013). The effectiveness of healthcare services to meet ones need/s and the opportunity to use these services is important. Frenk (1992) argues that a client utilising a service of poor quality (untrained clinicians) does not equate to the access a client utilising a service of high-quality experiences. This is due to the fact the outcomes and client satisfaction levels will differ between poor quality services and high-quality services. Services that differ in quality and clinician practices are not equally appropriate healthcare (Levesque et al., 2013). Patients' quality of healthcare should not depend heavily on their

geographical location and their ability to afford different services – access should allow patients to obtain effective, appropriate, and acceptable services for their needs.

Complementary to the domain of appropriateness is the concept of the clients 'ability to engage'. This concept describes a patient's ability to participate and be actively involved in the decision-making process for diagnosis and treatments. A patient's ability to engage in their healthcare depends largely on their motivation to engage, their level of health literacy and self-management. Access to high-quality healthcare requires engagement from the patient and adequate communication with healthcare providers and self-motivation (Levesque et al., 2013).

New Zealand has separate DHBs across different regions with a differing range of services and fees and facilities; one DHB may not be a good fit for the clients' needs compared to a further DHB, thus impacting the quality of care (Digby, 2016, as cited in The National Foundation for the Deaf Inc, 2017). The services available for a patient at one DHB may not be appropriate for them, thus consistency between providers is necessary.

As a result of the fractional amount of funding provided for adult cochlear implantations compared to the significant number of referrals, there is dissatisfaction with hearing aids and audiological care (The National Foundation for the Deaf Inc, 2017). Zhang et al. (2012) found in their study, 64% of participants that use hearing aids still experience hearing difficulties which could be due to poor fittings, worsening hearing, inability to repurchase hearing aids, etc. This negatively impacts the appropriateness of the audiological care they are provided, as it is neither effective nor acceptable.

1.5 Aims and hypotheses of this study

This study aims to explore hearing aid consumers' opinions as to the suitability of different methods for providing hearing aids, and their willingness to pay for these services via an online survey.

In this research, comparisons will be made between traditional hearing aid delivery methods and other proposed methods. This will inform the aspects of audiological care that hearing aid consumers find the most important, which can be used to estimate and appropriateness the success of alternative delivery methods among different groups of consumers.

Furthermore, exploring consumers' opinions towards alternative hearing aid delivery methods may provide insight into the appropriateness of alternative hearing aid delivery methods in New Zealand. The study will provide information on the potential costs and benefits of alternative delivery methods that may impact their uptake/success, which could be addressed when developing these alternative delivery methods.

This research explores alternative hearing aid delivery methods that may increase the accessibility of hearing healthcare services to groups and communities that have disproportionate access currently, such as rural communities, individuals with disabilities and Māori.

This research encompasses four main aims and the associated hypotheses:

Aim One: To investigate whether hearing aid consumers would be interested in trying the hearing aid services mentioned in the study by comparing each method.

Hypothesis One: Older hearing aids users would be less likely to prefer alternative hearing aid services compared to traditional audiology.

Aim Two: To determine if hearing aid consumers believe that the hearing aid services discussed in the study would be appropriate for them and what could be done to make it easier to use.

Hypothesis Two: Hearing aid users may find the alternative options provided in this study appropriate for themselves, however many different features would be required to allow them ease of use.

Aim Three: To determine whether hearing aid consumers think that the hearing aid services could increase the accessibility of audiological care.

Hypothesis Three: Hearing aid consumers will find the alternative hearing aid services mentioned in this study an appropriate means to increase the accessibility of hearing health care in Aotearoa.

Aim Four: To investigate if hearing aid consumers would be willing to pay for the services discussed in the study and approximately how much they would pay.

Hypothesis Four: Hearing aid consumers will be willing to pay the same for teleaudiology as they do for traditional audiology and less for over-the-counter hearing aids compared to traditional audiological costs.

Chapter Two: Methods

The methods described in this section were approved by the University of Auckland Human Participants Ethics Committee (UAHPEC) on the 24th of August 2021 for a period of 3 years (reference number AH22914).

2.1 Study design

The study design was a cross-sectional quantitative survey with a qualitative analysis of open-ended questions. Participants voluntarily completed the survey, which was conducted using Qualtrics (https://www.qualtrics.com/au/) online survey software, to assess perceptions about alternative ways to deliver hearing aids.

2.2 Setting, participants and recruitment

This was a pragmatic sample size (there was no set number of participants were required for this study); therefore, the number of participants reflected the outreach of advertisements and the willingness of participants to complete the survey. A pragmatic approach was used due to the potential time constraints and inability to recruit participants that arose due to the SARS-CoV-2 (Covid-19) pandemic that resulted in lockdowns across Auckland.

To be included in the study, participants were required to meet the following criteria:

- Aged 18 years or older.
- Be a hearing aid user or be considering the purchase of hearing aids.
- Able to provide consent to participate in the study.

- Able to complete the questionnaire in English.

There were no exclusion criteria for this study.

Participants were recruited from various sources, including the University of Auckland Hearing and Tinnitus Clinic, the Hearing Association, via a mass email sent to members of the University of Auckland's Faculty of Medical and Health Sciences. The letter of invitation/participant information sheet and advertisement was distributed online via social media (LinkedIn, The University of Auckland Facebook, and The University of Auckland Twitter) by the Principal Investigator and Student Researcher. The study was listed on the Faculty of Medical and Health Sciences list of research programs, accessible to anyone. The Deafblind Association New Zealand included the participant information sheet and anonymous survey link in the August 2021 edition of their monthly newsletter for members. Additionally, an email was sent to a list of clients at the University of Auckland Hearing and Tinnitus Centre (UoA H&TC) containing the participant information sheet and an anonymous link to the Qualtrics survey (ref: https://auckland.au1.qualtrics.com/jfe/form/SV_1YTbBLPl7ep0Qtw). Participants were advised to contact the student researcher or principal investigator via email if they had any questions regarding the research or if they were interested in participating in the research.

All the information that participants provided in the survey was kept anonymous. Submission of the online survey was taken as consent to participate – this was clearly stated in the participant information sheet and at the beginning of the survey. Additionally, the advertisements for the study were posted on the University of Auckland website that is available for everyone to access, along with the official University of

Auckland Facebook page that has a diverse group of followers.

2.3 Development of survey

The survey was based on the Mobile Application Rating Scale (MARS) survey, created in 2015 by Stoyanov et al. (2015), that evaluates the quality of mobile health apps. MARS has several sections that look at different aspects of the mobile health application, with several questions within each section, such as engagement (looks at interactivity, customisation, appropriateness for target group), functionality (looks at ease of use) and information (looks at the quality of information, relevancy of information and whether the information is comprehensive and concise information). The questions in this study were framed around the above concepts and re-worded/re-structured to be more suitable.

The survey consisted of approximately 40 questions divided into 4 sections: demographic information (such as age, sex, ethnicity, hearing loss), teleaudiology, over-the-counter hearing aids and traditional audiology. For the teleaudiology, over-the-counter hearing aids and traditional audiology sections, participants were asked questions on how accessible each method was for different groups of people in Aotearoa, how easy/appropriate each method sounded, the potential advantages and disadvantages of each method and how much they would be willing to pay for each method of hearing aid delivery. Participants were also asked about the factors that they find the most important when it comes to their own audiological care.

To make the survey simple to complete for participants, they were provided with options to choose from to answer each question (some questions only allowed one answer to be chosen while other questions allowed as many as the participant wished to select). Some

of the questions in the survey had scales to make it easy for the participant to express the strength of their opinions about specific statements.

Prior to publishing the survey, it was piloted by some students from the Master of Audiology programme at the University of Auckland, as well as some elderly family members to ensure that it was appropriate and easy to follow.

To ensure that the survey remained anonymous to the researcher and supervisors, the participants were provided with a link to the Eisdell Moore Centre website if they wanted a summary of the results from the study when they became available.

2.4 Outcome measures

Appropriateness of audiological care

A commonly discussed concept in health care is *appropriateness*, but the definition of the appropriateness of health care services remains to be standardised (Sanmartin et al., 2008). At the core of it, the appropriateness of a health care service refers to one that provides more benefits than risks (Lavis & Anderson, 1996).

The appropriateness of audiological care was measured using a ten-point Likert scale, where participants were asked the degree to which they agree with a statement. The higher the ranking, the more they disagree with the statement, i.e., it was reverse scored. We asked people how easy they think each treatment option would be to use for them. Participants' opinions on the ease of use of each treatment option were used as an estimation for how appropriate they felt each treatment option would be for them. The appropriateness of care was also measured by asking participants about the perceived

potential advantages and disadvantages of each treatment option to indirectly measure the benefits and risks of each treatment option.

Obtaining information about the appropriateness of the proposed treatment options is important as it is important to understand if the alternative options provided in this study will improve the quality of audiological care and be accepted by consumers (uptake). This analysis helps health professionals, companies, policymakers and researchers evaluate approaches that could alter the appropriateness of audiological care and address the quality and cost of current and alternative strategies.

Accessibility of audiological care

The concept of accessibility is ill-defined; however, this study will focus on the definitions provided by Penchansky and Thomas (1981) and Levesque et al. (2013). Penchansky and Thomas (1981) define access as representing the "degree of fit between the patient and the healthcare system" (p. 128). Levesque et al. (2013) define access as "the opportunity to identify healthcare needs, to seek healthcare services, to reach, to obtain or use health care services, and to actually have a need for services fulfilled" (p. 8).

The accessibility of audiological care was measured using a ten-point Likert scale, where participants were asked the degree to which they agree with various statements. The higher the score, the more they disagree with the statement, i.e., it was reverse scored. We asked people if they think each treatment option would increase accessibility by raising awareness of hearing health care and encouraging individuals to seek help. Participants' rankings for each statement for each treatment option was used as an estimation of how accessible they felt each treatment option would be for the wider population of New Zealand.

Obtaining information about the accessibility of the proposed (and current) treatment options is important as it is important to understand if the alternative options provided in this study will improve the reach and uptake of audiological care in New Zealand, e.g., amongst those that struggle to visit clinics or those that are wary about hearing devices. This analysis helps health professionals, companies, policymakers, and researchers evaluate approaches that could address the unequal access to audiological care that exists.

Willingness to pay

Willingness to pay (WTP) measures how much consumers of health services value a particular treatment (Pavel, Chakrabarty & Gow, 2015). WTP is a term in behavioural economics that describes the maximum price (a single value or range of values) that an individual would be willing to pay for a product or service (Bohm, 1979). It can also be defined as the maximum amount of money one would pay to gain benefit and restore to some degree of health (Pauly, 1995). Gall-Ely (2009) defines WTP as a consumer's 'price judgement' – a monetary expression of the product's/services perceived value for the individual. It is influenced by one's income and health status (the poorer the health status, the higher the willingness to pay to return to some degree of health). The survey examined potential alternatives to approach hearing aid fittings and hearing aid adjustments for people who are currently wearing hearing aids or are considering purchasing hearing aids. For the following health service delivery modes, teleaudiology, over-the-counter hearing aids, user-adjustable hearing aids and traditional audiology. WTP was measured directly using the contingent valuation method, where participants were asked an open-ended question to express their WTP for each product in the survey. We asked people how much they would be willing to pay for this service.

Willingness to pay information is important as the research explores alternative methods of hearing aid fittings and adjustments – new or yet-to-be-trialled products and services, therefore measurements of WTP would allow for appropriate price margins to be calculated. It is important to understand patient preferences for the alternative options as this informs the acceptability of these options (uptake). WTP analysis helps health professionals (audiologists), companies, policymakers and researchers understand the value that patients perceive different products and services have, and subsequently, the patient's willingness to *accept* the treatment.

2.5 Analysis

Responses from the anonymous survey were auto collated by the Qualtrics software and were received digitally. GraphPad Prism 9.3.0 was used to conduct data analysis.

Demographic and descriptive statistics

Demographic statistics was conducted to determine the significant features of the study sample, including, age, gender, ethnicity, the country they reside in, how long they have had hearing loss if any, and how long they have been wearing hearing devices if any.

Descriptive statistics were used to describe answers to each survey question. The Kolmogorov-Smirnov test showed that data was not normally distributed, consequently a Spearman Correlation was undertaken. Binary Logistic Regression was undertaken to determine the odds of variables contributing to the *willingness to use* the different delivery models. Correlation and binary logistic regression statistical evaluation were undertaken using GraphPad Prism 9.3.0.

Analysis of appropriateness of audiological care

Firstly, the Spearman correlation coefficient test was undertaken to determine the strength and direction of a relationship between the ease of use of treatment options and participant's characteristics, such as age. For all analyses, a P-value less than 0.05 was considered statistically significant. Secondly, descriptive statistics were used to examine the potential advantages and disadvantages of each treatment option.

Analysis of accessibility of audiological care

The Spearman correlation coefficient test was undertaken to determine the strength and direction of a relationship between the participant's views on the appropriateness of treatment options and participant's characteristics, such as age. For all analyses, a P-value less than 0.05 was considered statistically significant.

Analysis of Willingness to pay

Firstly, differences between WTP treatment options will be reported as mean, mode, and range WTP. Secondly, we examined whether there were significant differences between preferences for audiology service delivery. An analysis of differences in willingness to pay for the 3 delivery models was undertaken. The data was not normally distributed according to the Kolmogorov-Smirnov test. Consequently, the non-parametric Kruskal-Wallis test was used. For all analyses, a P-value less than 0.05 was considered statistically significant. Willingness to pay analysis was undertaken using Microsoft Excel.

Chapter Three: Results

Data was collected from 120 participants, (53 male and 67 females). The age of the participants ranged from 17 to 91 years old, with a mean age of 67.9 years old.

3.1 Demographics

Age

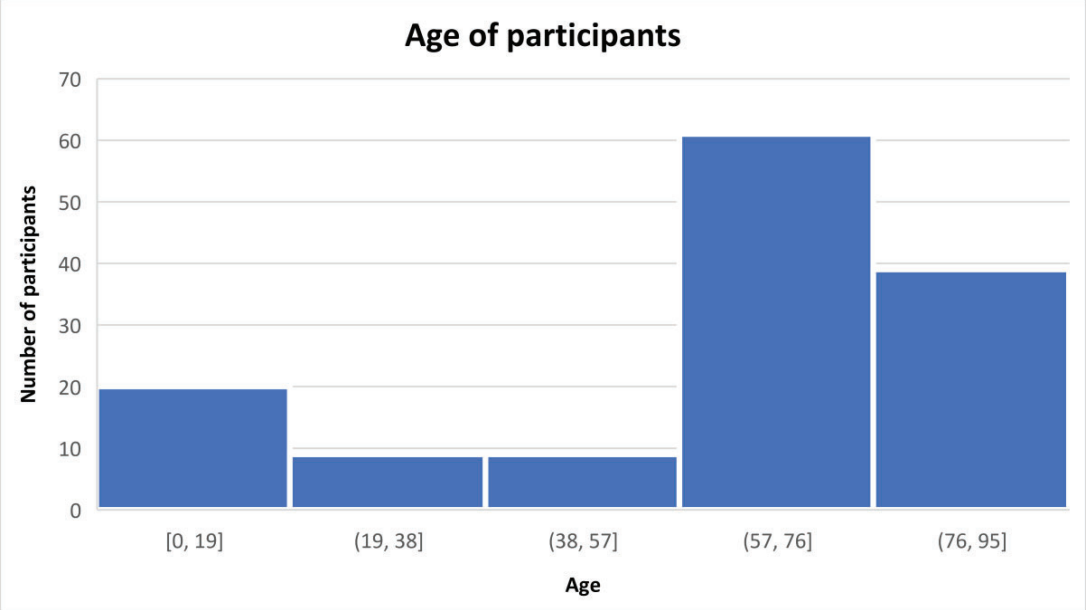

Figure 8:

Age demographics of the study population.

The age demographics of the study population grouped into age bands shows that most of the participants in the sample were within the 57-95 age groups (n=100) (Figure 8).

Gender

From the 120 participants that completed at least one question in the survey, there were 53 males and 67 females, there was no significant gender bias.

Ethnicity

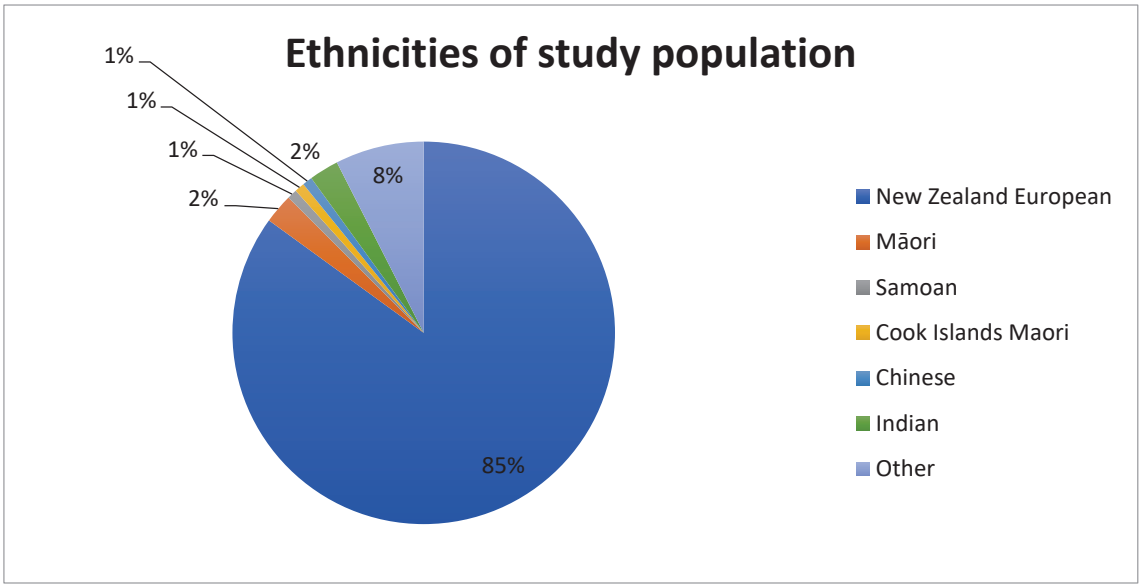

Figure 9:

Ethic background demographics of the study population.

Most of the participants (85%, n=102) in the study sample belonged to the New Zealand European ethnic group (Figure 9). The sample does not represent the ethnic diversity that exists in the New Zealand population. For participants that selected 'Other', the responses were the following: Dutch, German, Australian, Canadian European, Korean, Irish, and Asian.

Country of residence

All participants (n=120) resided in New Zealand at the time of survey completion.

How long have you had hearing loss?

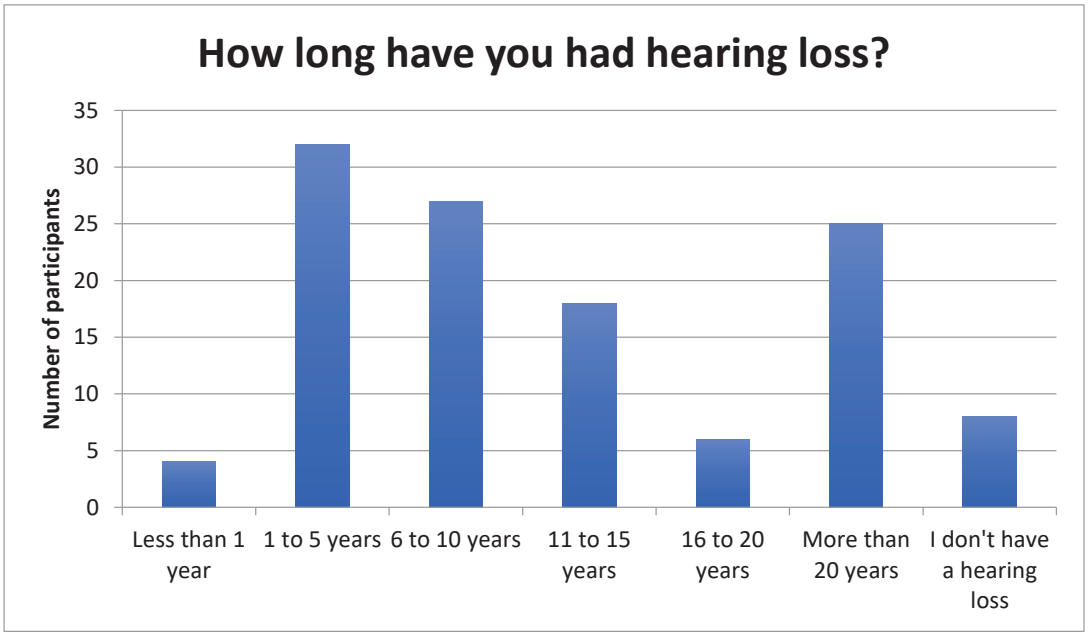

Figure 10:

Presence (and for how many years) or absence of hearing loss in the study population.

Most of the participants (93.3%) in the study had a hearing loss; the amount of time they had had this hearing loss varied (Figure 10). Most participants had hearing loss for 1-5 years (n=32), 6-10 years (n=27) and more than 20 years (n=25); very few participants did not have hearing loss (n=8).

How long have you been wearing hearing devices?

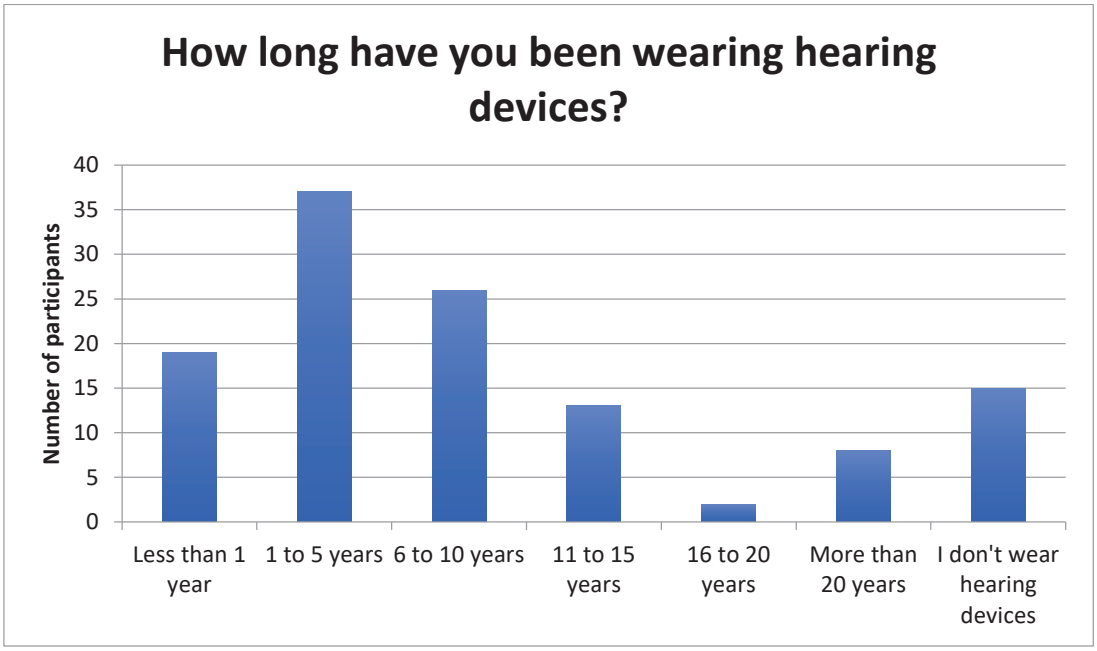

Figure 11:

Hearing aid/device users and non-users in the study population.

Most study participants were hearing aid/device users (87.5%), the amount of time that participants had worn hearing aids/devices varied (Figure 11). Most participants had been wearing hearing devices for 1-5 years (n=37) and 6-10 years (n=26). 15 participants do not have/wear hearing devices, this is 7 more people than expected from Figure 10, where 8 people reported no hearing loss – it can be assumed these individuals identify as having a hearing loss but do not have hearing aids.

3.2 Appropriateness of audiological care

Ease of use

Teleaudiology

The 'ease of use' Likert scale questions were designed to be reverse-scored, i.e. a greater score is indicative of a less positive attitude towards the ease of use of the proposed service.

The mean score for the question '*how easy do you think teleaudiology would be to use?'* was found to be 4.63 (Figure 12). This value represents a '*Neither easy nor difficult'* along the 10-point Likert scale, indicating that participants in the study were neutral to the ease of use of teleaudiology.

Over the counter, user-programmable hearing devices

The mean score for the question '*how easy do you think over the counter, user-programmable hearing aids could be to use for you?'* was found to be 5.54, sitting at '*Neither easy nor difficult'* along the 10-point Likert scale, indicating that participants in the study were neutral to the ease of use of OTC, user-programmable devices (Figure 12).

Traditional audiology

The mean score for the question '*how easy do you think traditional audiology is/would be to use?'* was found to be 2.61, sitting at '*Somewhat easy'* along the 10-point Likert scale, indicating that participants in the study had positive attitudes towards the ease of use of traditional audiology (Figure 12).

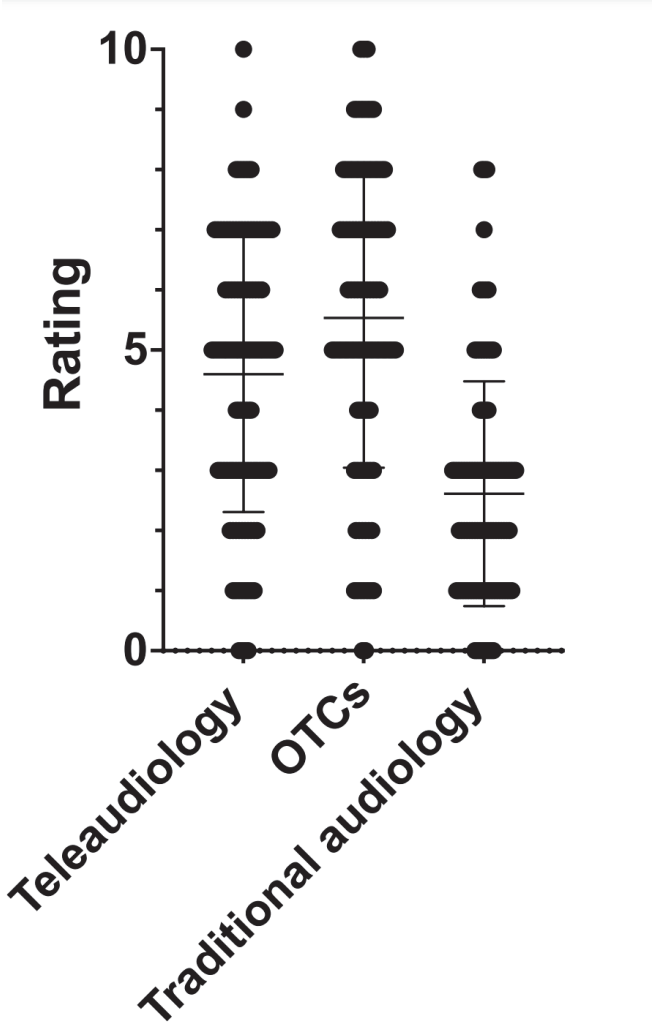

Figure 12:

Likert scale ratings for each participant on the ease of use of the proposed hearing aid delivery methods. The bars represent the mean and standard deviations (-/+) ratings by participants.

Participants felt that traditional audiology would be the easiest to use, and teleaudiology and OTC hearing devices received similar ease of use ratings (Figure 12).

Potential advantages

Teleaudiology

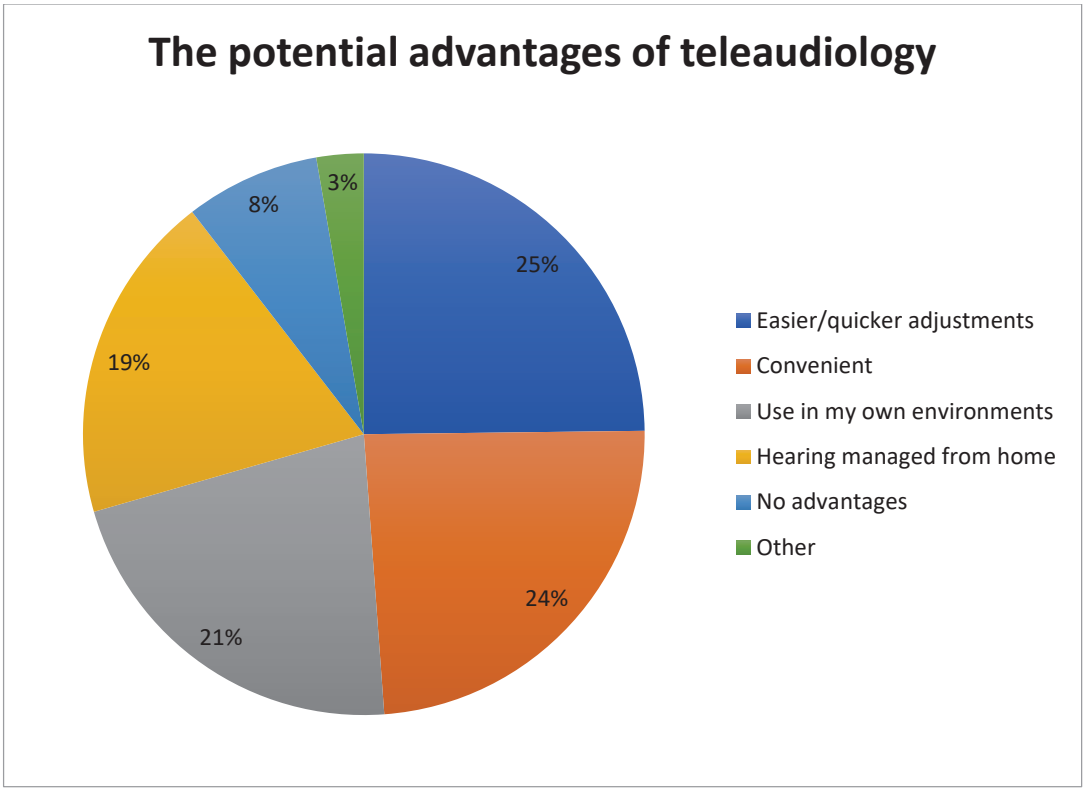

Figure 13:

The potential advantages of teleaudiology, for the sample population.

In response to the question *"Which of the following statements about the potential advantages of teleaudiology do you agree with?",* some participants felt there were no advantages to teleaudiology (8%). Three of the biggest advantages selected by participants was the fact that adjustments would be quicker and easier if their hearing were to change (25%); teleaudiology seemed convenient (24%), and participants would be able to use the hearing aids in their environments and identify issues quickly (21%)

(Figure 13). Participants were able to select as many options as possible that they felt were applicable, 35 participants chose more than one option.

Over the counter, user-programmable hearing devices

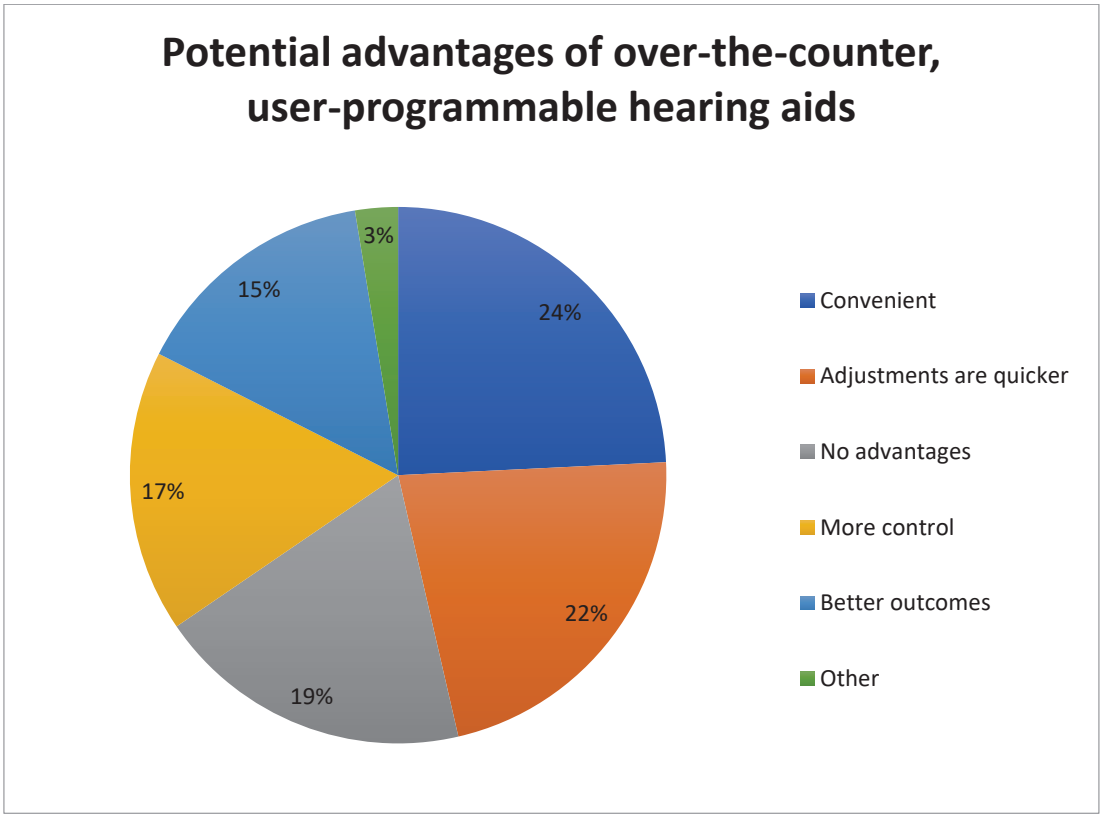

Figure 14:

The potential advantages of over the counter, user-programmable hearing devices, for the sample population.

In response to the question *"Which of the following statements about the potential advantages of over-the-counter hearing aids do you agree with?"*, participants found several advantages of OTC devices, such as the convenience of not having to visit hearing aid clinics often (24%) and hearing aid adjustments would be easier and quicker if their hearing was to change (22%). However, a significant percentage of participants (19%)

felt that there were no advantages to OTC devices (Figure 14). Participants were able to select as many options as possible that they felt were applicable, 33 participants chose more than one option.

Traditional audiology

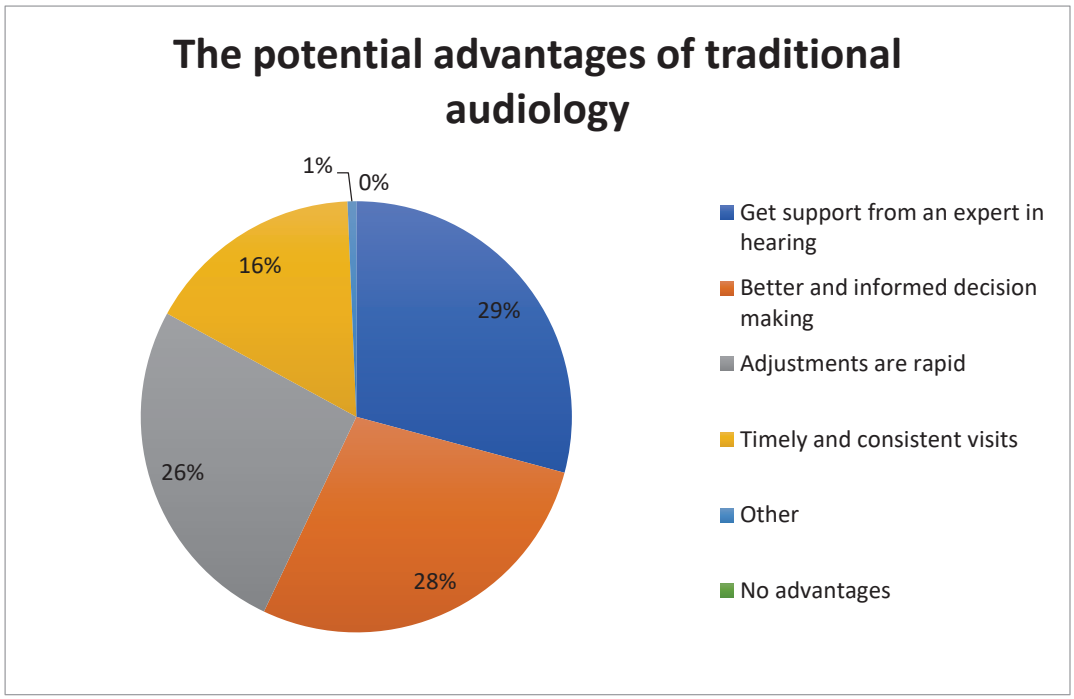

Figure 15:

The potential advantages of traditional audiology, for the sample population.

In response to the question *"Which of the following statements about the potential advantages of traditional audiology do you agree with?"*, overall, participants believed there were several advantages to traditional audiology, the most highly ranked options being the support and knowledge from an expert (29% n=89) which allows for better decision making about their hearing healthcare (28%, n=85). Additionally, no one in the sample population believed that there were no advantages to traditional audiology and

traditional hearing aids (Figure 15). Participants were able to select as many options as possible that they felt were applicable, 37 participants chose more than one option.

Potential disadvantages

Teleaudiology

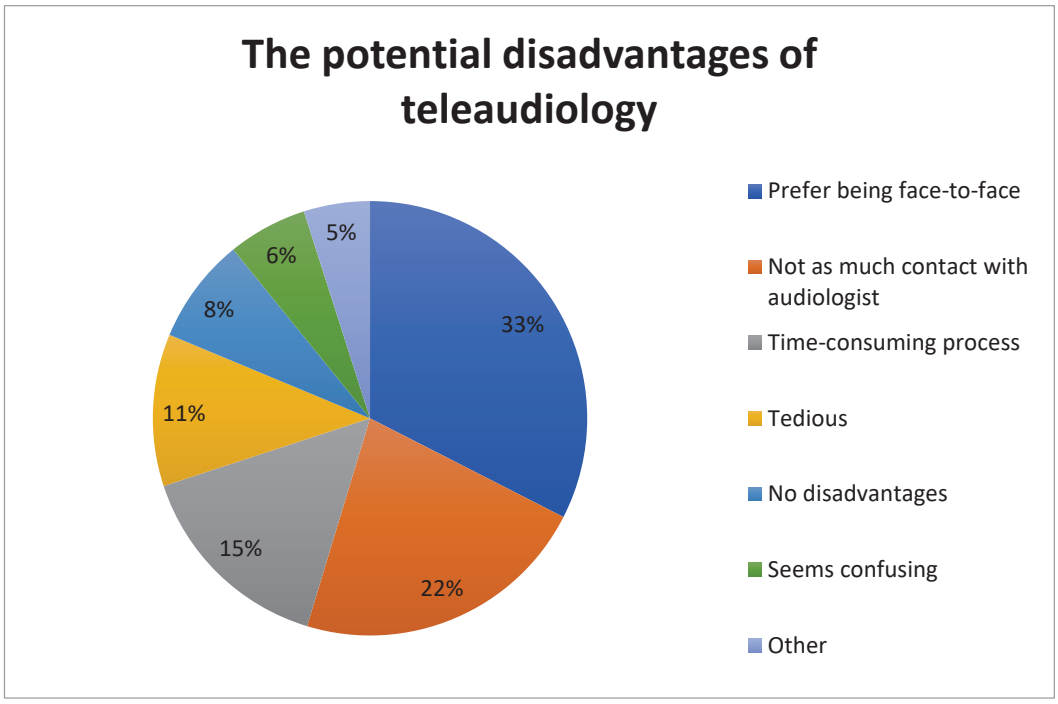

Figure 16:

The potential disadvantages of teleaudiology, for the sample population.

When asked *"Which of the following statements about the potential disadvantages of teleaudiology do you agree with?"*, the biggest disadvantage (33%) identified by participants was the inability to have face-to-face interactions with their audiologist, which several participants enjoy doing (Figure 16). Similarly, participants felt that they would not have as much contact with an audiologist using teleaudiology. Participants also believed that teleaudiology seemed tedious and time-consuming and confusing.

Participants were able to select as many options as possible that they felt were applicable, 41 participants chose more than one option.

Over the counter, user-programmable hearing devices

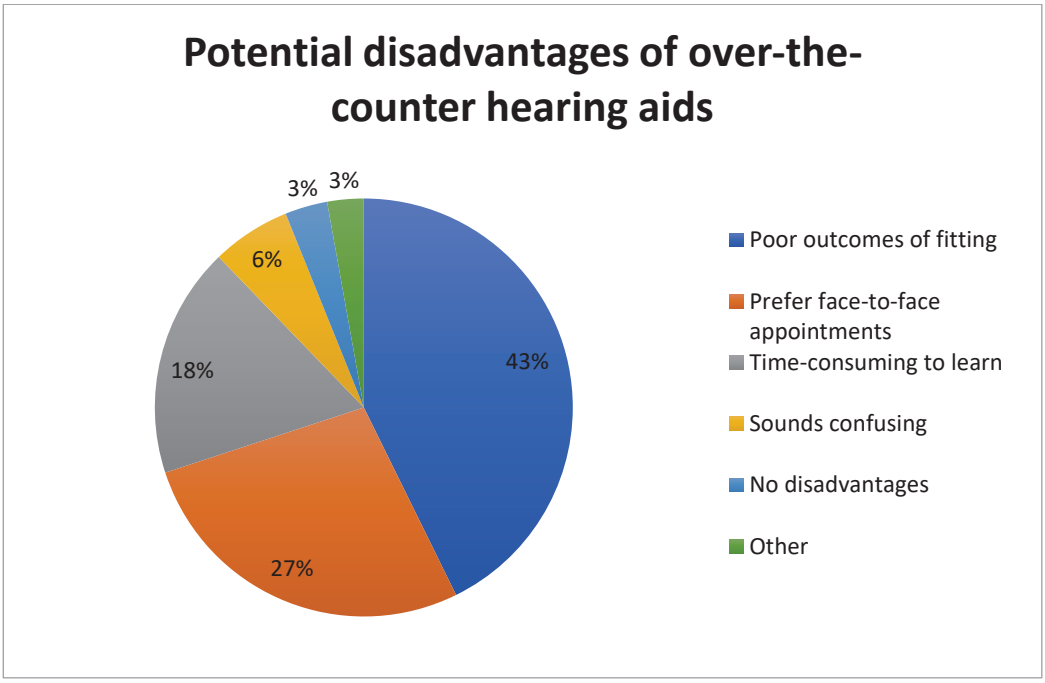

Figure 17:

The potential disadvantages of over the counter, user-programmable hearing devices, for the sample population.

In response to the question *"Which of the following statements about the potential disadvantages of over-the-counter hearing aids do you agree with?"*, participants thought the biggest disadvantage was that the outcome of the user-programmed fitting will not be as accurate compared to an audiologist's fitting (Figure 17). This was followed by the inability to have face-to-face interaction with their audiologists, which 27% of participants enjoyed doing, and the process of learning to use OTC devices would be

time-consuming (18%). Only 6% of participants felt that OTC devices sounded confusing. 34 participants chose more than one option.

Traditional audiology

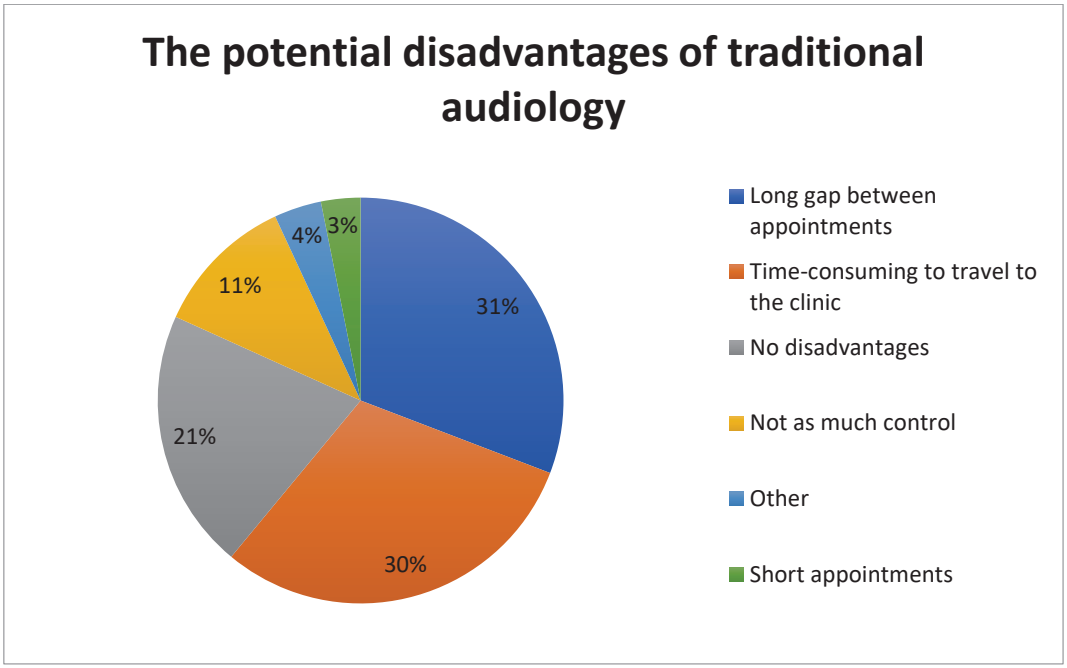

Figure 18:

The potential disadvantages of traditional audiology, for the sample population.

In response to the question *"Which of the following statements about the potential disadvantages of traditional audiology do you agree with?"*, participants felt that there were some disadvantages to traditional audiology, such as the difficulty getting appointments quickly (31%) leading them to deal with hearing aid issues and travelling to and from the hearing aid clinic being time-consuming (30%). A significant percentage of participants (21%) felt that there were no disadvantages to traditional audiology and traditional hearing aids (Figure 18). 31 participants chose more than one option.

Additional features for ease of use

Teleaudiology

What would be the easiest way to fit and adjust hearing aids for teleaudiology?

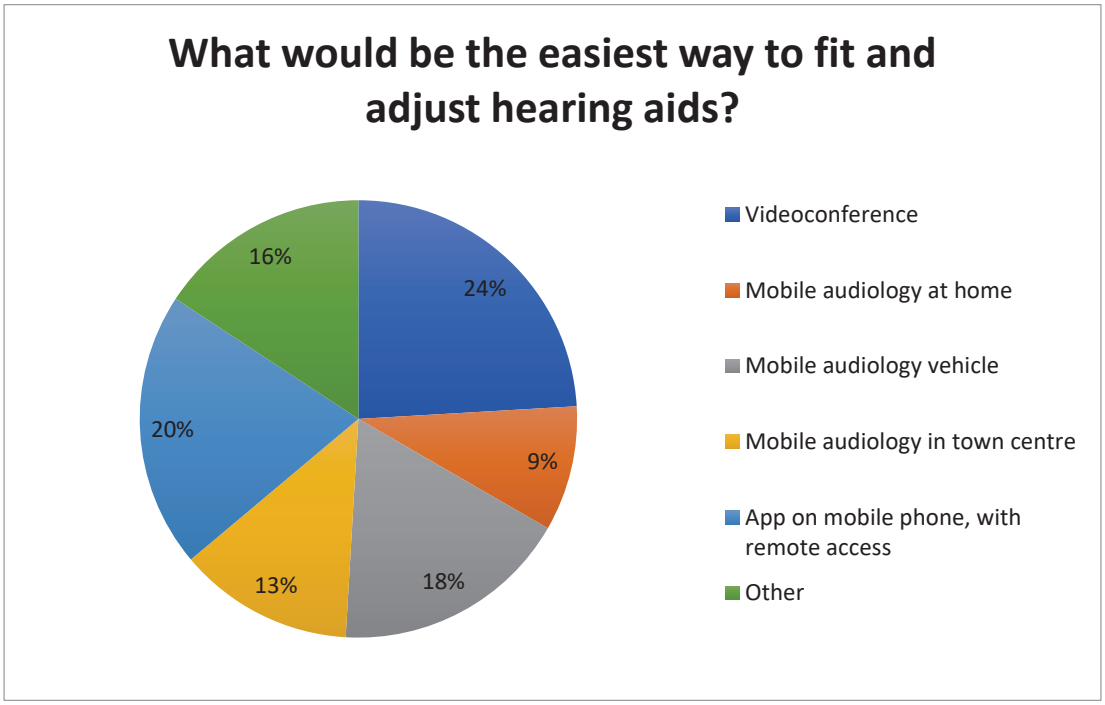

Figure 19:

Participants' view on the potential easiest ways to fit and adjust hearing aids for teleaudiology.

In response to the question *"What would be the easiest way to fit and adjust hearing aids?"* the method that was selected by the most participants (24%, n=26) was 'online via videoconferencing, e.g., Zoom, Skype', whereas the option that was chosen the least was

'mobile audiology where the audiologist comes to my home' (Figure 19). Other popular options were using a mobile app that the audiologist accesses remotely (20%, n=22); mobile audiology where the audiologist brings a hearing testing van (18%, n=19) and mobile audiology where the audiologist sets up a station in a town centre (13%, n=14).

What features would you find useful for teleaudiology?

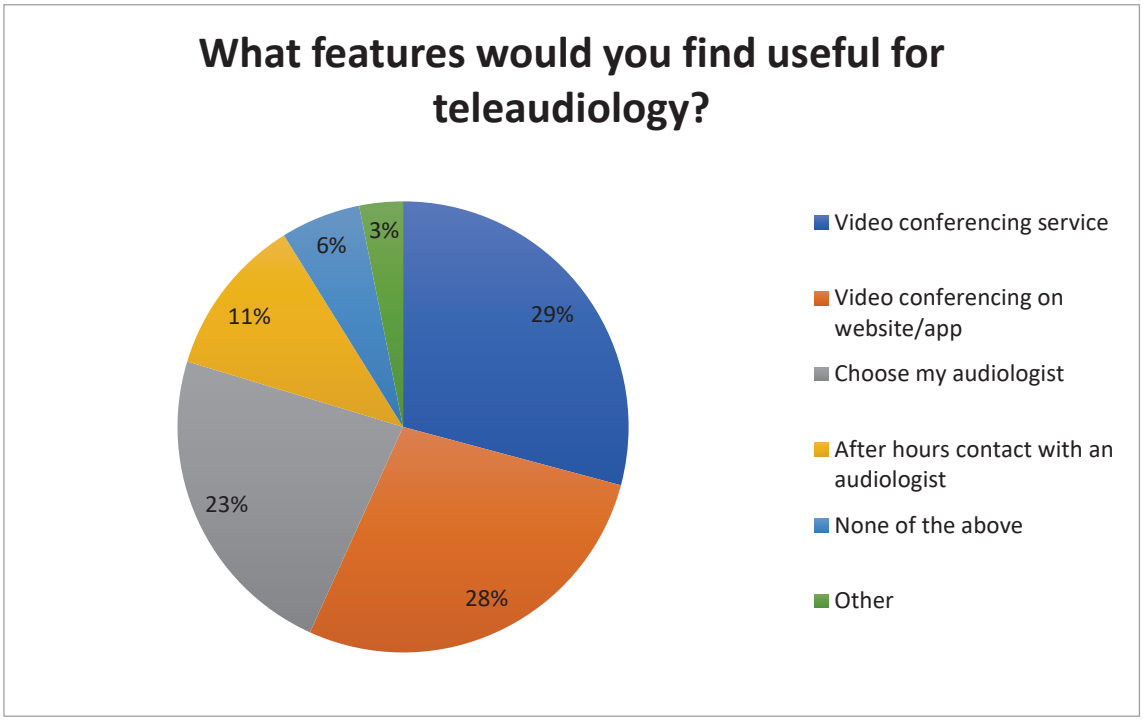

Figure 20:

Features that may be useful when using teleaudiology, for consumers.

In response to the question *"What features would you find useful?",* using a well-known video conferencing service such as Zoom and Skype (40.6%, n=56) and using a website/app to communicate with audiologists (38.4%, n=53) were two of the most popular features (Figure 20). Participants also valued being able to choose their own

audiologist (31.9%, n=44). Participants were able to select as many options as possible that they felt were applicable, 47 participants chose more than one option.

How would you like to communicate with your audiologist, using teleaudiology?

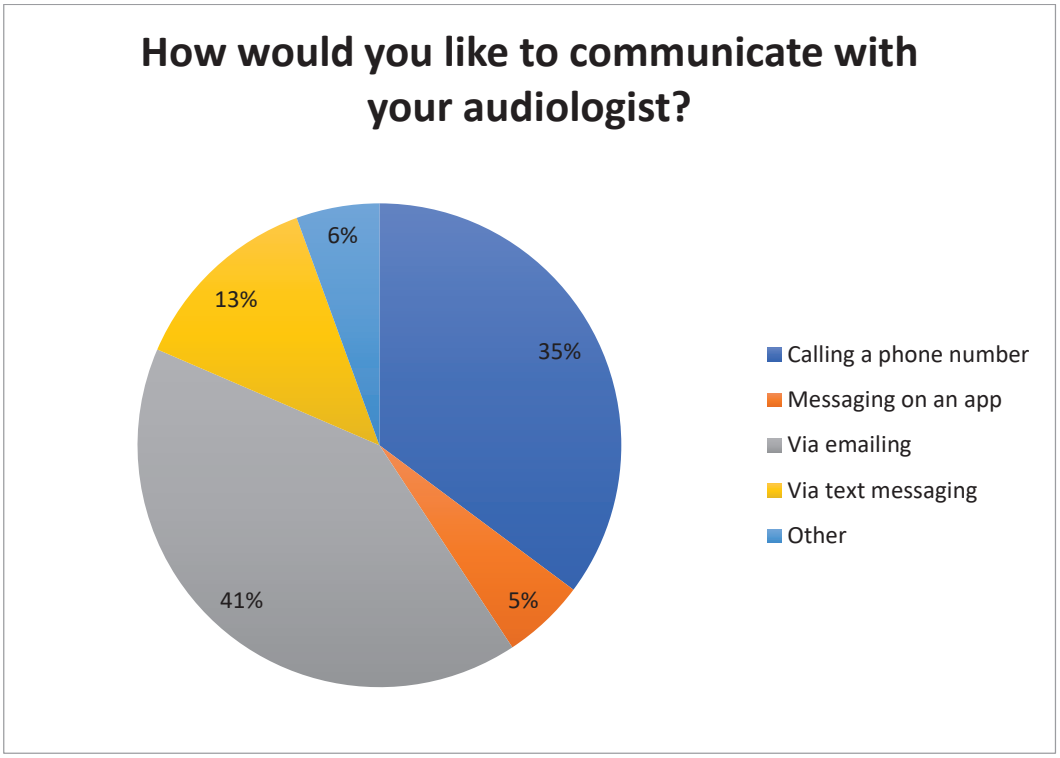

Figure 21:

Participants' preferred method of communicating with their audiologist for teleaudiology.

In response to the question *"How would you like to communicate with your audiologist?"*. more participants preferred to communicate with their audiologist/s using email (41%, n=44) and/or calling a phone number (35%, n=38). Fewer participants preferred text messaging (13%, n=14) and messaging on an app (5%, n=6) (Figure 21).

Over the counter, user-programmable hearing devices

What would make it easier to use over-the-counter, user-programmable hearing aids?

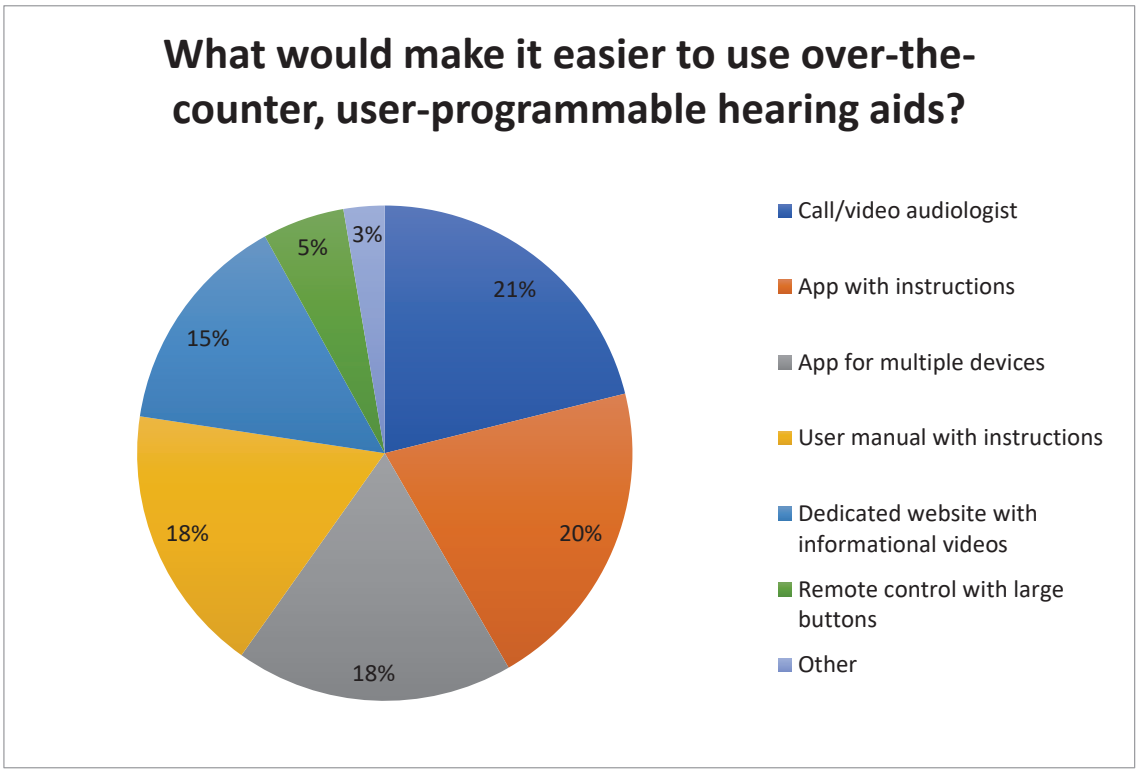

Figure 22:

Participants' views on methods/materials that would make it easier to use over the counter, user-programmable hearing aids/devices.

When asked *"What would make it easier to use over-the-counter hearing aids?"*, two of the most popular options were the ability to call or video chat with an audiologist for help (21%) and an app that has simple, easy-to-follow instructions (20%). These were followed by the options of the app being available for different devices (18%), a user manual with instructions and solutions to common issues (18%) and a dedicated website with instructional videos (15%). The option with the least number of votes (5%) was a remote control with large buttons (Figure 22). Participants were able to select as many options as possible that they felt were applicable, 43 participants chose more than one

option.

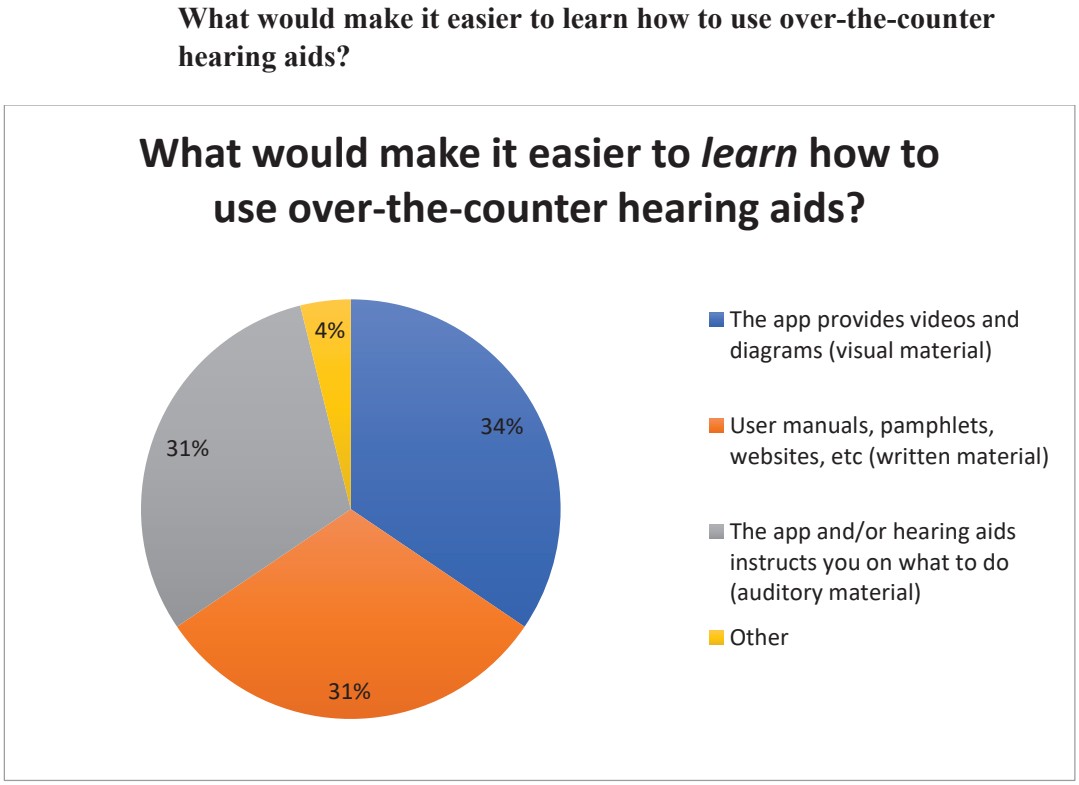

Figure 23:

Forms of information that would make it easier to learn how to use over the counter, user-programmable hearing aids/devices.

When asked *"What would make it easier to learn how to use over-the-counter hearing aids?"*, overall, all three forms of information were deemed appropriate by the sample population – visual material (34%, n=71), written material (31%, n=64) and auditory material (31%, n=63) (Figure 23). Participants were able to select as many options as possible that they felt were applicable, 20 participants chose more than one option.

What settings/features would be useful for over the counter, user-programmable hearing aids/devices?

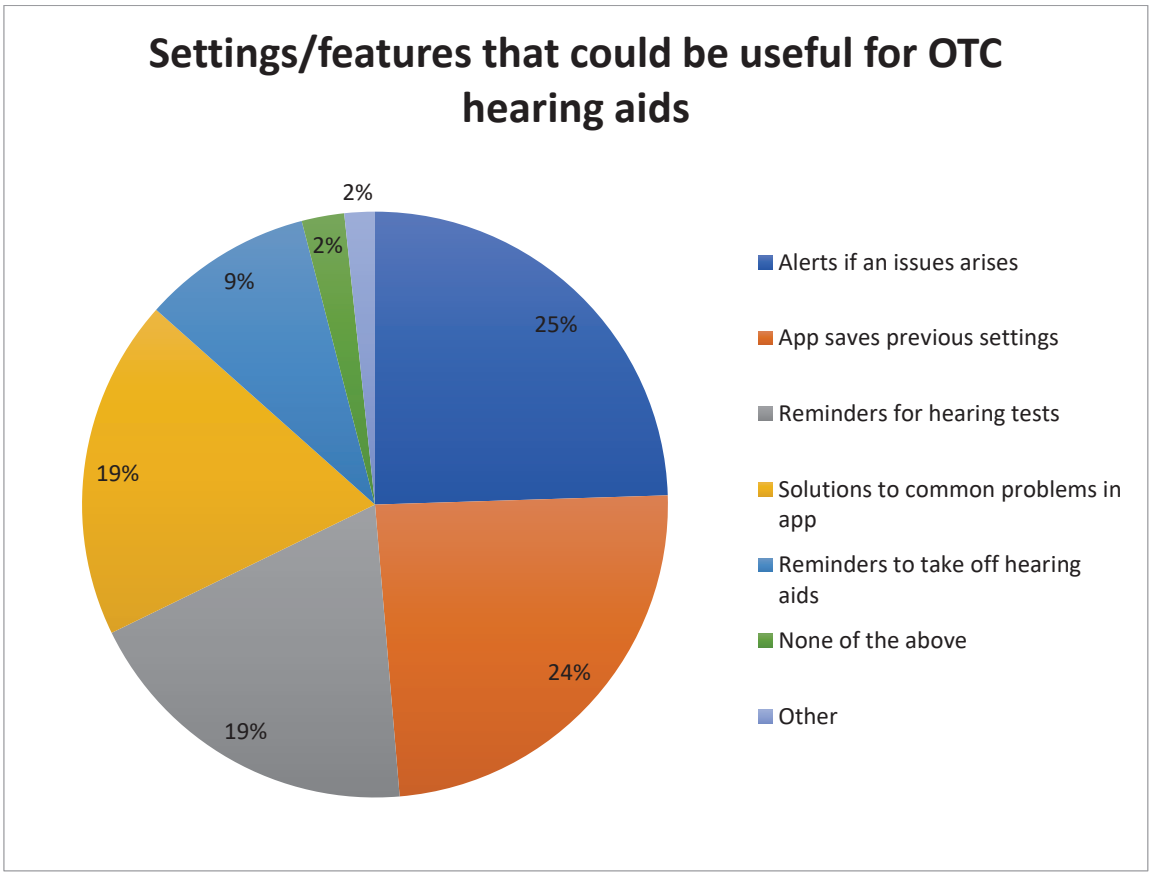

Figure 24:

Features that may be useful when using over the counter, user-programmable hearing aids/devices, for consumers.

When asked *"What settings/features would you find useful?"*, the two highest-ranked options were 'alerts if an issue arises with the devices' (25%) and 'the app saving previous settings so that the consumer can return to those settings if they wish to' (24%). This was followed by the options of 'reminders for annual hearing tests' (19%) and 'the app providing solutions to different issues that could arise' (19%). The least popular options were 'reminders to take the hearing aids off before showering or sleeping' (9%) and 'none of the above' (2%) (Figure 24). Participants were able to select as many

options as possible that they felt were applicable, 23 participants chose more than one option.

3.3 Accessibility of audiological care

Teleaudiology

Accessibility of care was measured using a 10-point Likert scale that was reverse-scored. The participants were provided two statements about teleaudiology and asked the degree to which they agree with them.

The mean score for the statement '*I think teleaudiology would encourage people with hearing loss to seek help'* was 3.87, sitting at '*Somewhat agree'* along the Likert scale (Figure 25). The mean score for the statement '*I think teleaudiology would be likely to increase awareness of the importance of addressing hearing healthcare and hearing loss'* was 3.62, sitting at '*Somewhat agree'* along the 10-point Likert scale (Figure 26). This indicates that the participants in this study believed that teleaudiology may be able to provide some benefit to the accessibility of audiological services and products.

Over the counter, user-programmable hearing devices

Participants were provided with two statements about over the counter, user-programmable hearing devices and asked the degree to which they agree with each statement.

The mean score for the statement '*I think over the counter hearing aids would likely encourage individuals with hearing loss to address this and seek help'* was 3.81, sitting between the '*Somewhat agree'* and *'Neither agree nor disagree'* points along the Likert

scale (Figure 25). The mean score for the statement '*I think over the counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss'* was 3.76, sitting between the '*Somewhat agree'* and *'Neither agree nor disagree'* points along the Likert scale (Figure 26). This indicates that the participants in this study thought that over the counter, user-programmable hearing devices may provide some benefit to the accessibility of hearing health care.

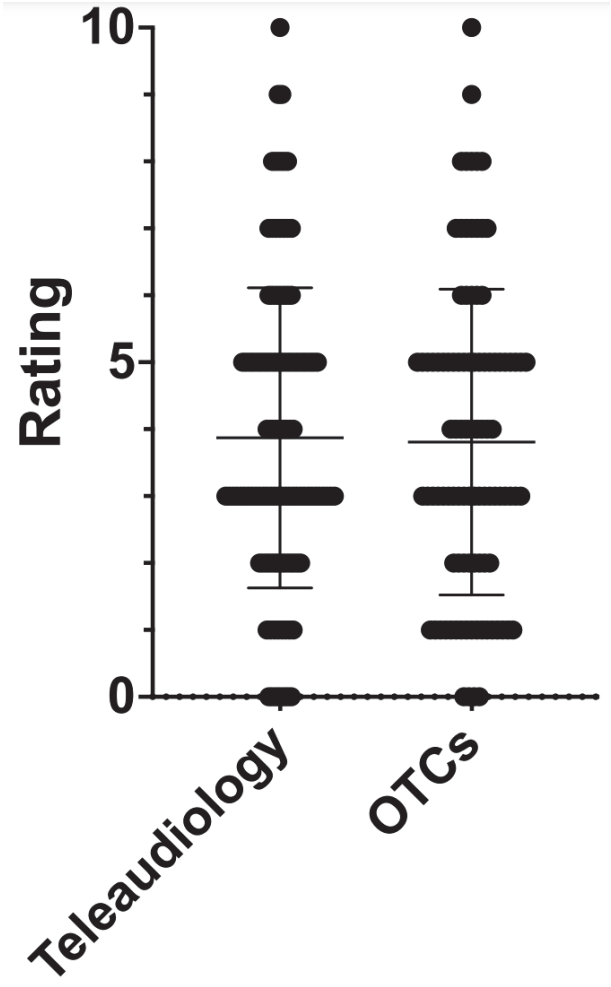

Figure 25:

Likert scale ratings for each participant on the likelihood of the proposed hearing aid delivery methods encouraging people to seek help with hearing loss. The bars represent the mean and standard deviations (-/+) ratings by participants.

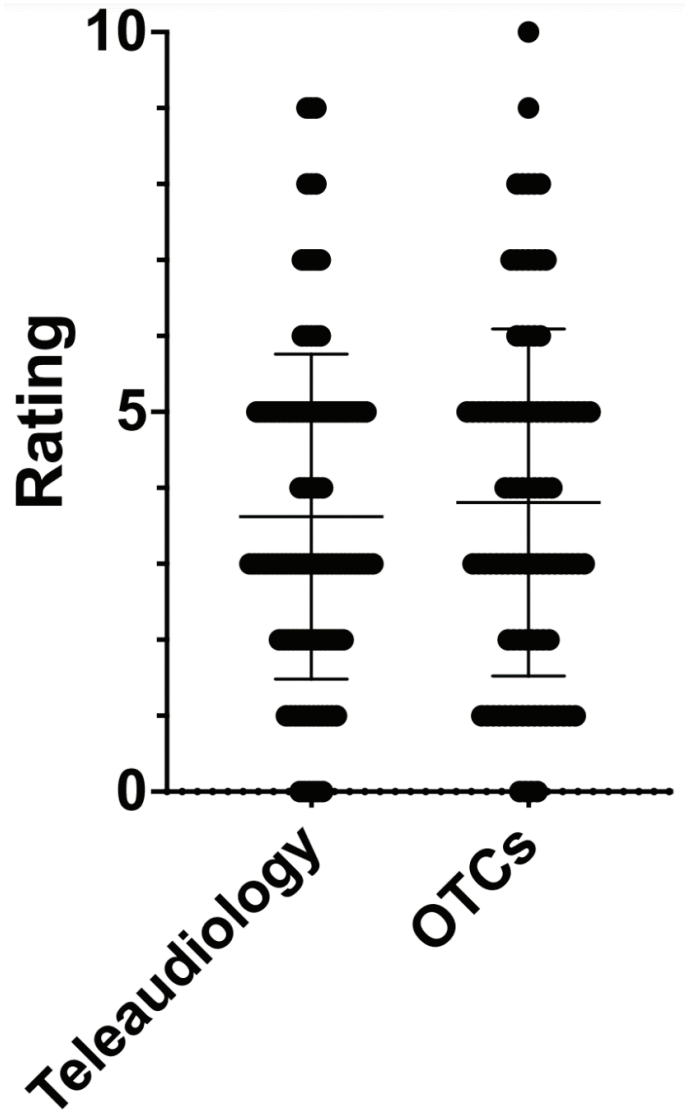

Figure 26:

Likert scale ratings for each participant on the likelihood of the proposed hearing aid delivery methods increasing awareness of the importance of hearing health. The bars represent the mean and standard deviations (-/+) ratings by participants.

There was not a significant difference in ratings for both statements between teleaudiology and OTC, user-programmable hearing devices (Figure 25, Figure 26).

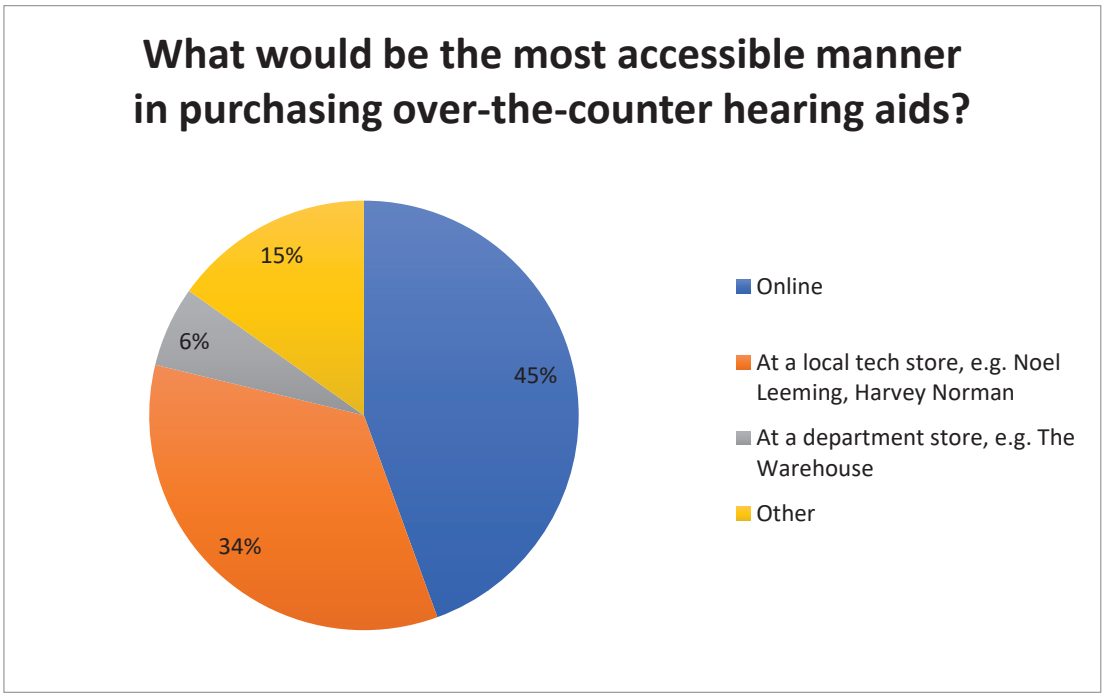

Figure 27:

The most accessible manner of purchasing over the counter, user-programmable hearing aids/devices, as deemed by the sample population.

When asked *"What would be the most accessible manner in purchasing over-the-counter hearing aids?"*, most participants (45%) felt that purchasing the hearing devices online was the most accessible manner, followed by purchasing them at a local technology store such as Noel Leeming or Harvey Normal (34%). The least number of participants felt that purchasing over the counter, user-programmable hearing devices from a department store was the most accessible manner (6%) (Figure 27).

Traditional audiology

The mean score for the statement '*I think traditional audiology is accessible for lots of different groups of people'* was 3.94, sitting between the '*Somewhat agree'* and *'Neither*

agree nor disagree' points along the Likert scale. This indicates that the participants in this study believed that traditional audiology is accessible to lots of people in New Zealand.

3.4 Preferences

Teleaudiology

When the participants were asked *"Would you like access to this type of service?"*, 60.2% of participants felt they would like access to teleaudiology.

On a 10-point Likert scale, the mean score for the question '*How likely are you to try teleaudiology to fit and adjust hearing aids?''* was 4.16, sitting around the '*Neither likely nor unlikely'* point (Figure 28). This indicates that the participants in this study were neutral towards the use of teleaudiology; they were just as likely to use it than to not use it.

Over the counter, user-programmable hearing devices

When the participants were asked *"Would you like access to this type of service?"*, more participants (59.6%) preferred not to have access to OTC devices than the percentage of participants who would want access to OTC devices (40.4%).

On a 10-point Likert scale, the mean score for the question '*How likely are you to try over the counter, user-programmable hearing devices?'* was 5.62, sitting around the '*Neither likely nor unlikely'* point (Figure 28). This indicates that the participants in this study

were neutral towards the use of OTC, user-programmable hearing devices; they were just as likely to use it than to not use it.

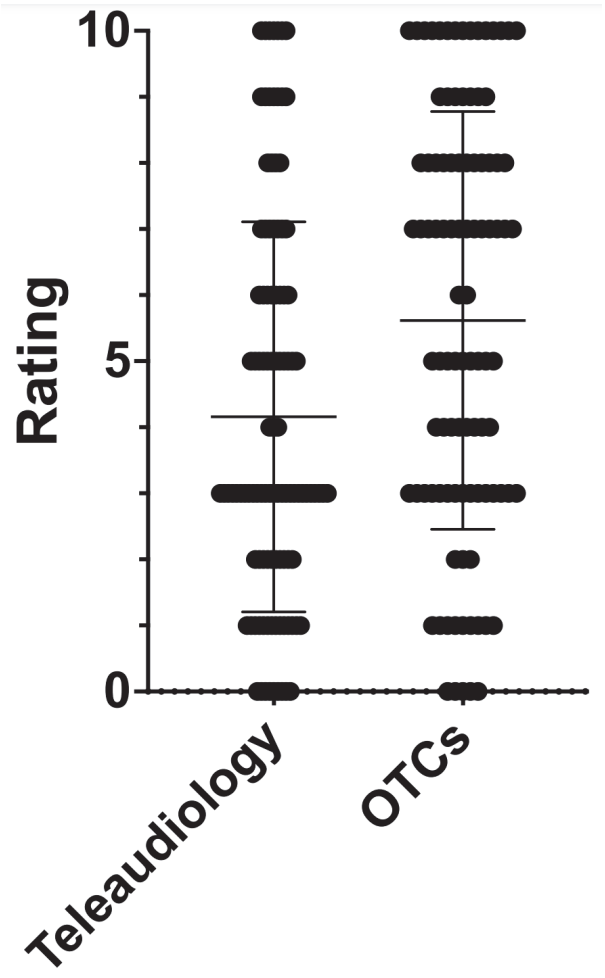

Figure 28:

Likert scale ratings for each participant on the likelihood of participants trying the proposed hearing aid delivery methods. The bars represent the mean and standard deviations (-/+) ratings by participants.

Traditional audiology

When the participants were asked *"Would you like access to this type of service?"*, more participants (88.4%) preferred to have access to traditional audiology and traditional hearing aids.

Overall preferences for audiological care

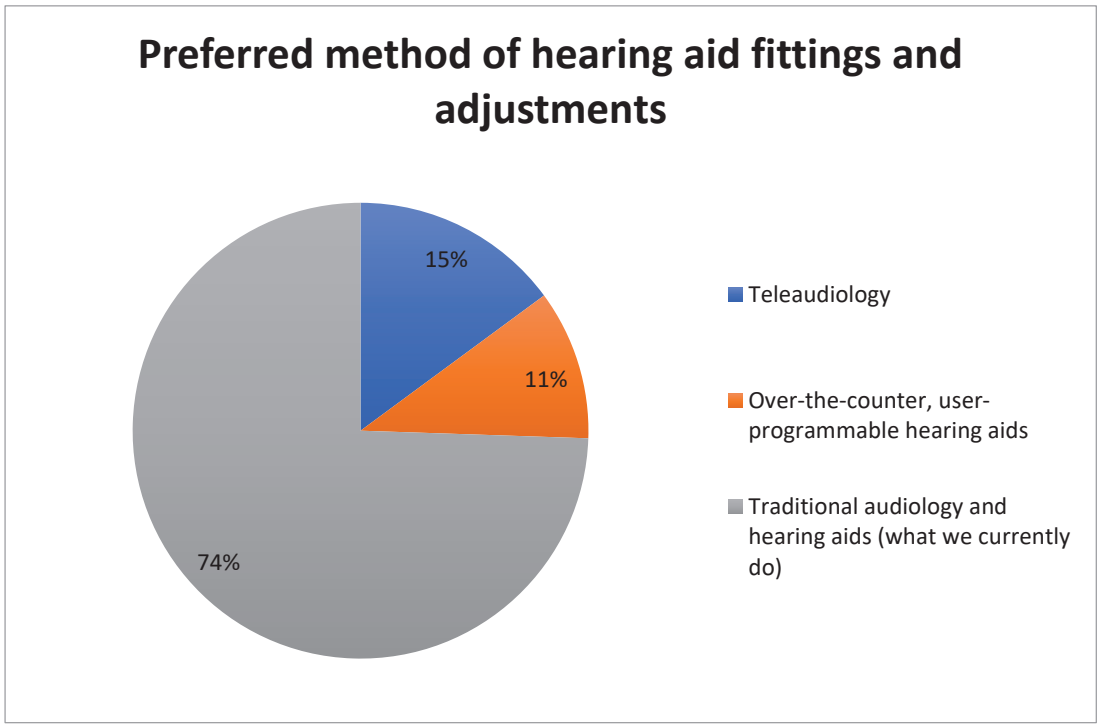

Figure 29:

The preferred method of hearing aid fittings and adjustments.

When asked *"Which method of hearing aid fittings and adjustments you prefer?"*, from the three options of hearing aid fitting and adjustment methods in the survey, most participants (74%, n=70) preferred traditional audiology and hearing aids for their own hearing healthcare (Figure 29).

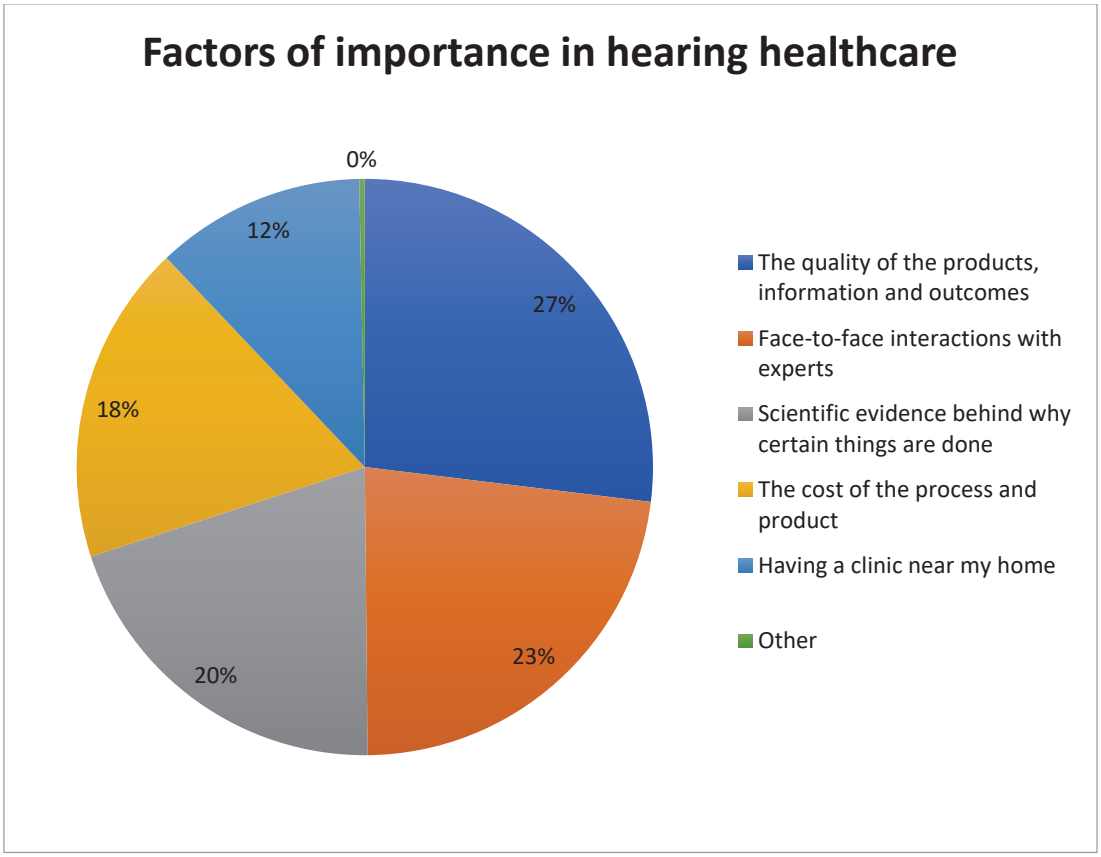

Figure 30:

The factors that participants in the sample found to be of importance in their hearing healthcare.

In response to the question *"What factors do you find the most important in hearing healthcare?"*, participants placed the most importance on the quality of products (hearing devices) and services (audiological care, information, etc) (27%), and face-to-face interactions with audiologists (23%) (Figure 30).

On a 10-point Likert scale, the mean score for the question '*How important do you think it is to have an audiologist select, fit and program your hearing devices?'* was 1.8, sitting at the *'Extremely important'* point along the scale. This indicates that the participants in

this study felt that having an audiologist program their hearing aids is a very important part of the process; they value the input of the audiologist.

3.5 Correlation analyses

Age

Age had a weak statistically significant (p=0.013) positive correlation (r=0.238) to the response to the question ‘How likely are you to try teleaudiology to fit and adjust hearing aids?’. This indicates that as age increases, participants were less likely to want to try teleaudiology services (Figure 31).

Age had a weak statistically significant (p=0.008) positive correlation (r=0.267) to the question ‘How likely are you to try over-the-counter, user-programmable hearing aids?’. This indicates that as age increases, participants were less likely to want to try OTC, user-programmable hearing devices (Figure 31).

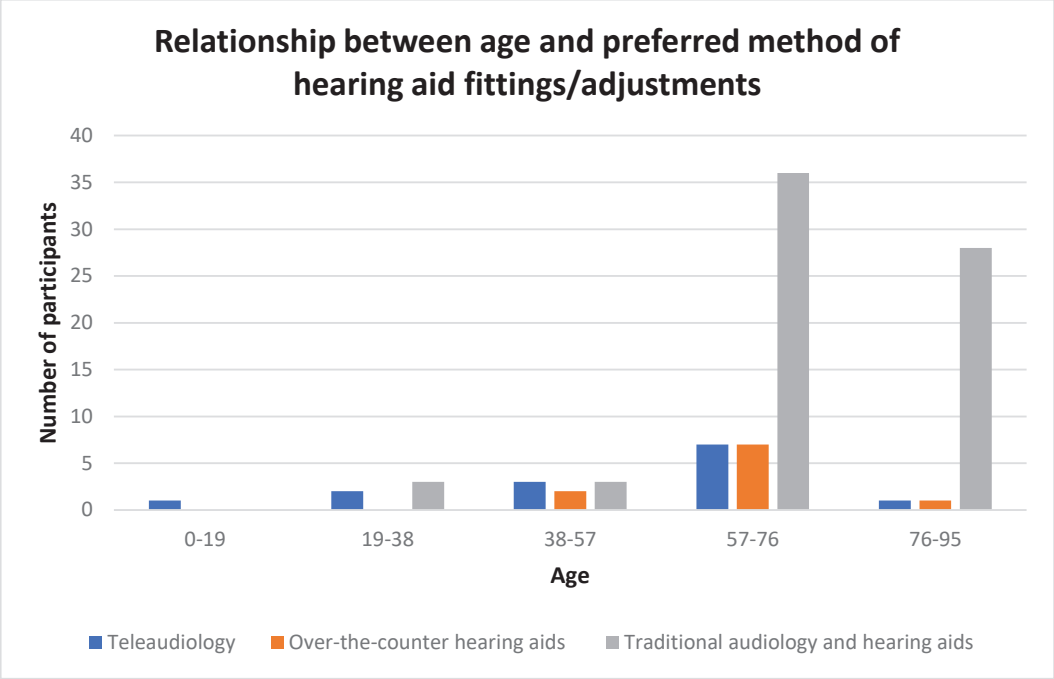

Figure 31:

Histogram illustrating the relationship between age and preferred method of hearing aid fittings/adjustments.

Age had a weak non-statistically significant (p=0.06) positive correlation (r=0.182) to the question 'How easy do you think teleaudiology would be to use?'. Age had a weakly statistically significant (p=0.006) positive correlation (r=0.275) with the question 'How easy do you think over-the-counter hearing aid could be to use for you?'. Age had a non-statistically significant (p=0.719) very weakly negative correlation (r=-0.037) to the question 'How easy do you think traditional audiology is/would be to use?'. This indicates that as the age of participants increased, the subjective ease of use for traditional audiology increased (older participants felt that traditional audiology was easier).

Age had a non-statistically significant (p=0.363) negative correlation (r=-0.094) with the statement "I think traditional audiology is accessible for lots of different groups of people'. Age had a non-statistically significant (p=0.100) weakly positive correlation

(r=0.159) to the statement ‘I think teleaudiology would be likely to increase awareness of the importance of addressing hearing health and hearing loss’. Age had a statistically significant (p=0.020) weakly positive correlation (r=0.233) to the statement ‘I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss’.

Ease of use/appropriateness of audiological care

The responses obtained for the question ‘How easy do you think teleaudiology would be to use?’ had a statistically significant ($p<0.001$) moderately positive correlation (r=0.533) with the question ‘How likely are you to try over-the-counter, user-programmable hearing aids?’. This is suggestive that both variables are related.

Responses to the question ‘How easy do you think over-the-counter hearing aid could be to use for you?’ had a statistically significant ($p<0.001$) moderately positive correlation (r=0.541) to the question ‘How likely are you to try over-the-counter, user-programmable hearing aids?’. This is suggestive that both variables are related.

Accessibility or audiological care

The responses obtained for the statement ‘I think teleaudiology would encourage people with hearing loss to seek help’ had a statistically significant ($p<0.001$) strong positive correlation (r=0.833) to the statement ‘I think teleaudiology would be likely to increase awareness of the importance of addressing hearing health and hearing loss’. This is suggestive that both variables are related.

Responses to the statement ‘I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss’ had a

statistically significant ($p<0.001$) moderately positive correlation ($r=0.524$) with the statement ‘I think teleaudiology would encourage people with hearing loss to seek help’. This is suggestive that both variables are related.

The responses obtained for the statement ‘I think over-the-counter hearing aids would likely encourage individuals with hearing loss to address this and seek help’ had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.586$) to the statement ‘I think teleaudiology would be likely to increase awareness of the importance of addressing hearing health and hearing loss’. This is suggestive that both variables are related.

Participants’ responses to the statement ‘I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss’ had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.644$) to the statement ‘I think teleaudiology would be likely to increase awareness of the importance of addressing hearing health and hearing loss’. This is suggestive that both variables are related.

Responses to the statement ‘I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss’ had a statistically significant ($p<0.001$) strong positive correlation ($r=0.862$) to the statement ‘I think over-the-counter hearing aids would likely encourage individuals with hearing loss to address this and seek help’. This is suggestive that both variables are related.

Responses to the statement ‘I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss’ had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.644$) to the statement ‘I think teleaudiology would be likely to increase awareness of the importance

of addressing hearing health and hearing loss'. This is suggestive that both variables are related.

Willingness to use services

The participants' responses to the question 'How likely are you to try over-the-counter, user-programmable hearing aids?' had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.533$) to their ratings for the question "How easy do you think teleaudiology would be to use?". This is suggestive that both variables are related.

Participants' responses to the question 'How likely are you to try over-the-counter, user-programmable hearing aids?' had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.529$) to the statement 'I think teleaudiology would encourage people with hearing loss to seek help'. This is suggestive that both variables are related.

Participants' responses to the question 'How likely are you to try teleaudiology to fit and adjust hearing aids?' had a statistically significant ($p<0.001$) moderately positive correlation ($r=0.613$) to the question 'How likely are you to try over-the-counter, user-programmable hearing aids?'. This is suggestive that both variables are related.

3.6 Multiple logistic regression for willingness to use services

Age

Teleaudiology

Increasing age increased the odds of willingness to use teleaudiology services (1.019, 0.991 – 1.051 95% CI) but this was not statistically significant (p=0.205).

Over the counter, user-programmable hearing devices

Increasing age increased the odds of willingness to use over-the-counter devices (1.04, 1.010 – 1.077 95% CI) and this was statistically significant (p=0.014).

Traditional audiology

Increasing age increased the odds of willingness to use traditional audiological services and hearing aids (1.019, 0.974 – 1.082 95% CI) but this was not statistically significant (p=0.478).

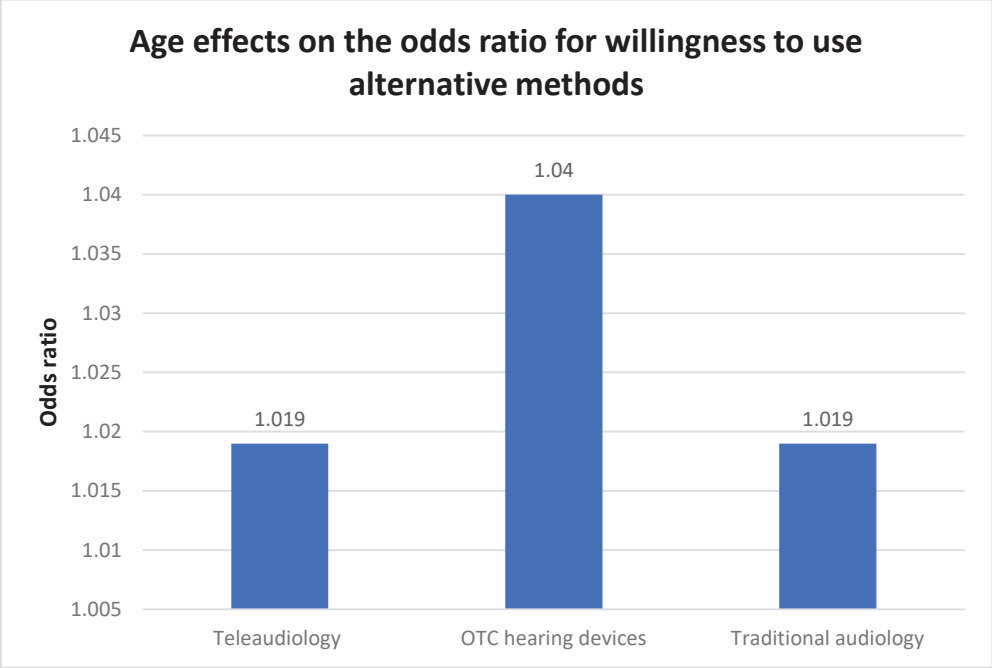

Figure 32:

The effects of age on the odds ratio for participants' willingness to use the alternative methods of hearing aid fittings/adjustments.

Gender

Teleaudiology

Using females as the reference group. Females have 1.463 (0.665 – 3.277 95% CI) higher odds of choosing teleaudiology compared to males but this was not statistically significant (p=0.348).

Over the counter, user-programmable hearing devices

Using females as the reference group. Females have 1.288 (0.555 – 2.996 95% CI) higher odds of choosing over-the-counter devices compared to males but this was not statistically significant (p=0.554).

Traditional audiology

Using females as the reference group. Females have 0.399 (0.098 – 1.431 95% CI) lower odds of choosing traditional audiology and hearing aids compared to males but this was not statistically significant (p=0.168).

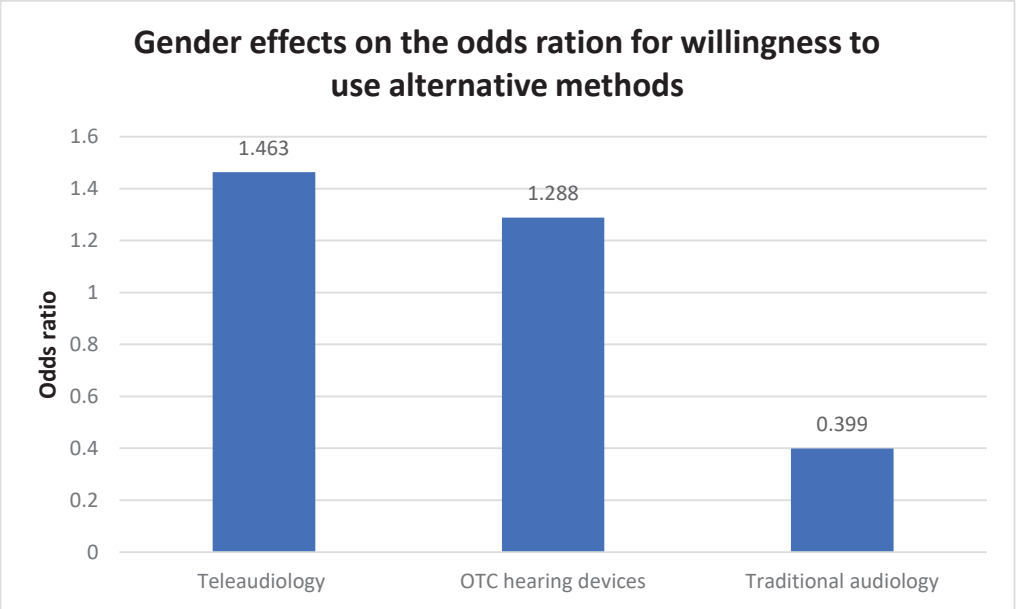

Figure 33:

The effects of gender on the odds ratio for participants' willingness to use the alternative methods of hearing aid fittings/adjustments.

3.7 Willingness to pay

The mean amount that participants were willing to pay for teleaudiology services was NZ$113, while the mode amount was NZ$100. The range of responses was NZ$0-$1000. The mean amount that participants were willing to pay for over the counter, user-

programmable hearing devices was NZ$300, while the mode amount was NZ$100. The range of responses was $0-NZ$3600. The mean amount that participants were willing to pay for traditional audiological services was NZ$446, while the mode amount was NZ$100. The range of responses was NZ$0-9000. The individual data indicate a cluster of responses at lower levels of NZ$, with two clear outliers for traditional care (Figure 34).

A Kruskal-Wallis test comparing the 3 methods as to NZ$ willingness to pay found no statistically significant difference H (2) = 2.89, P = 0.24.

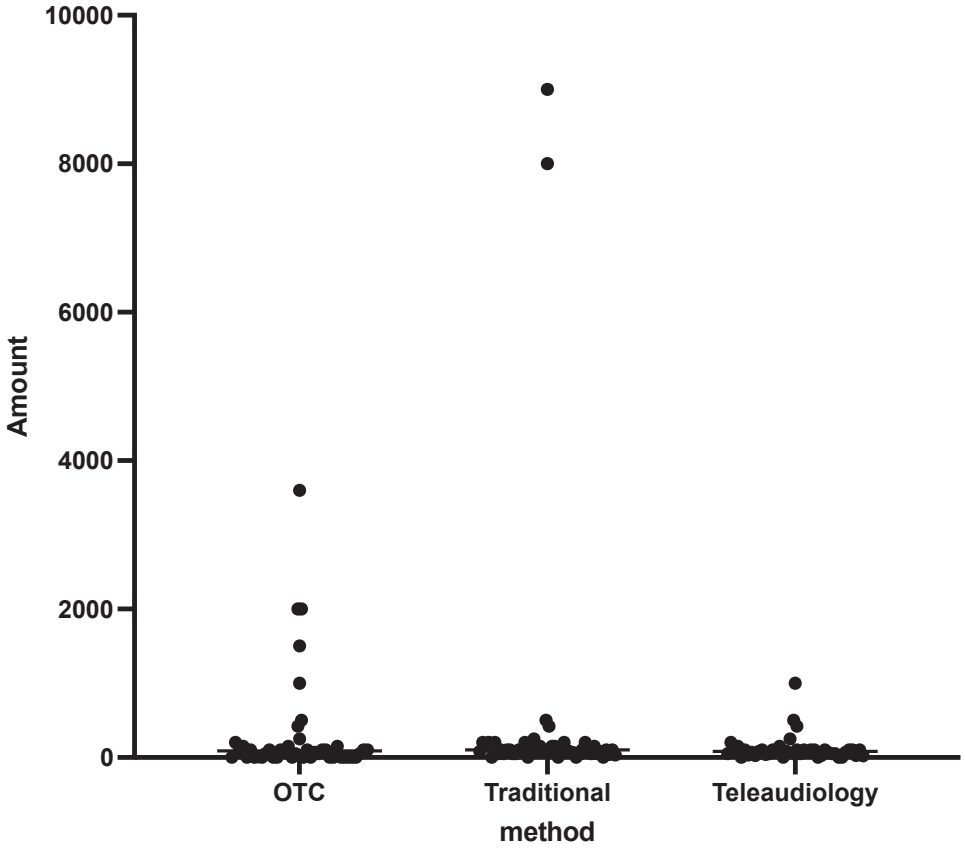

Figure 34:

The individual willingness to pay values for the proposed hearing aid fitting/adjustment methods.

3.8 Qualitative analysis of open-ended questions

Preference for in-person/face-to-face appointments

Several participants valued in-person and face-to-face appointments with their audiologist.

"Person to person with the audiologist rather than remote" (Male, 77 years, what would be the easiest way to fit and adjust hearing aids with teleaudiology?).

"Face to face in [the] audiologist's clinic' (Male, 55 years, what features would you find useful for teleaudiology?).

"Direct recommendation from an audiologist who knows me" (Male, 75 years, what would make it easier to use over the counter hearing aids?).

There were several reasons that could be assumed for why participants preferred in-person appointments over the proposed remote appointments. One respondent elaborated on the reason why they prefer face-to-face interactions.

"Personally, I struggle using a phone and I prefer communicating face to face" (Female, 61 years, which of the following potential disadvantages of teleaudiology do you agree with?).

However, another participant thought that remote appointments may be a viable option for them if these appointments were virtual (video conferences).

"Face to face interactions with experts by virtual methods is good enough [for me]" (Male, 75 years, what factors do you find most important in hearing healthcare?).

Accessibility of services

More accessibility of the services was an important concern of several participants, this included better availability of appointments, availability of specialists to contact, availability of these services for larger degrees of hearing loss and different styles of hearing aids and availability of specialists in the community

"Appointments after school hours, even evenings" (Female, 72 years, what features would you find useful for teleaudiology?).

"I don't think my hearing loss type would work for the hearing test [used for over-the-counter hearing aids]" (Female, 58 years, what would make it easier to use over the counter hearing aids?).

"Availability over the phone of someone to clarify problems, if necessary" (Male, 77 years, what would make it easier to use over the counter hearing aids?).

"My hearing aids are in-ear, [I] suspect these could not be supplied over the counter as they are moulded to fit" (Female, 66 years, which of the following potential disadvantages of over-the-counter hearing aids do you agree with?).

"The traditional model might not be easily accessed by some groups in society – I wonder if audiologists visit Mare or Pacific churches, etc" (Female, 73 years, which of the following potential disadvantages of traditional audiology do you agree with?).

Video conference appointments

A few participants felt that appointments could be done through video conferencing services for more accessible services.

"Zoom" (Female, 58 years, how would you like to communicate with your audiologist?).

"Zoom, Microsoft Teams, Facetime" (Male, 55 years, how would you like to communicate with your audiologist?).

Work hours limit face-to-face appointments

One respondent highlighted that one of the biggest disadvantages of traditional audiology that they face could be alleviated with teleaudiology. There were frustrations about the fact that it is difficult to find appointments that can line up well with participants' daily schedules.

"I am a schoolteacher, [it is] very difficult to find an appointment that isn't a major fuss at me being absent [from work]." (Female, 72 years, what would be the easiest way to fit and adjust hearing aids?).

Accessible forms of communication

Several respondents emphasized the fact that they valued being able to talk to another person about any problems that may arise with their hearing aids/hearing devices.

"Telephoning" (Female, 69 years, what features would you find useful for teleaudiology?).

"Instructions and training from a human being, verbal advice is the best" (Male, 66 years, what would make it easier to use over-the-counter hearing aids?).

"Contact person, not FAQ section of webpage" (Female, 70 years, which settings/features would you find useful for over-the-counter hearing aids?).

However, one participant highlighted the fact that not all consumers will be able to use products or services, and this could be due to personal, behavioural, financial or a myriad of other circumstances.

"I don't own a mobile phone" (Female, 90 years, what would make it easier to use over-the-counter hearing aids?).

Knowledge and expertise of specialists

The participants in this study highly valued the knowledge and expertise of specialists in the field of hearing health care and their presence during the hearing aid fitting process. Having someone who knows them is very important for the consumer in the hearing aid selection and fitting process.

"Audiologist won't be able to ensure that the hearing aids are fitted properly" (Male, 55 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"My audiologist let me try several models and loaned me hearing aids and let me try each for a week or more and didn't charge me anything until I'd found one that I was sure worked for me" (Male, 55 years, which of the following potential advantages of traditional audiology do you agree with?).

"I would need somebody with knowledge to help" (Female, 77 years, what would be the most accessible manner in purchasing over-the-counter hearing aids?).

A few participants mentioned that they would purchase over-the-counter hearing aids from a store that has experts on the product/service, highlighting the importance of having someone knowledgeable present.

"Specialist store" (Male, 81 years, what would be the most accessible manner in purchasing over-the-counter hearing aids?).

"Need a specialist shop" (Female, 79 years, what would be the most accessible manner in purchasing over-the-counter hearing aids?).

Reviews

One person commented that a feature they would find useful for the use of teleaudiology would be "*client reviews"* (Male, 55 years, what features of teleaudiology would you find useful?). The opinions of other individuals who have hearing loss and have consumed a product/service is highly valued – it creates a basis for the consumer to make decisions about the product/service (Burton & Khammash, 2010).

Inconvenience

Some respondents mentioned that the services in this study can inconvenience them, in terms of time and the amount of comfort they feel when receiving care. Once again, the participants valued the rapport they build with their audiologists.

"Doing the test and then having to come in anyway would really annoy me, I don't have the time" (Female, 58 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"I would not want to see a different audiologist each time" (Male, 33 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"Have to wait quite a while for an appointment" (Female, 69 years, which of the following disadvantages of traditional audiology do you agree with?).

"If you have issues with your hearing aids, finding a day that the audiologist is at the clinic [can be difficult]" (Female, 69 years, which of the following disadvantages of traditional audiology do you agree with?).

Cost

Cost was a large concern for many participants in this study, and it is a large factor in their choice to seek or not to seek a particular service.

"Lower cost than hearing aids" (Male, 33 years, which of the following advantages of over-the-counter hearing aids do you agree with?).

"Cost of visits and aids is definitely a disadvantage" (Female, 68 years, which of the following disadvantages of traditional audiology do you agree with?).

"Most audiologists are told what products to sell and rarely recommend a better product if it has a high cost to them" (Male, 33 years, which of the following disadvantages of traditional audiology do you agree with?).

"Unlikely that there will be a try before you buy option for customers" (Male, 55 years, which of the following disadvantages of over-the-counter hearing aids do you agree with?).

Distrust in a highly technical process/too difficult as it is too technical

Some participants felt they were too old to learn to use new technologies, such as over-the-counter hearing aids, they felt that the concept itself sounded too difficult and complicated for them. They felt they would need more guidance with these new technologies.

"Technology for linkage may not be easy for an older person to be able to set up and follow. Easier for a younger, tech savvy person" (Male, 77 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"Great except for my age: old dog new tricks" (Female, 90 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"I am a bit too old to cope well on the computer; no advantage for me" (Female, 90 years, which of the following potential disadvantages of teleaudiology do you agree with?).

"I think I would find this very difficult" (Female, 77 years, what would make it easier to use over-the-counter hearing aids?).

"Not applicable as I believe it would be difficult for an older person to master" (Male, 77 years, what would make it easier to use over-the-counter hearing aids?).

"I need more than apps etc, they are hard to follow" (Female, 79 years, what would make it easier to learn to use over-the-counter hearing aids?).

Other participants didn't understand how new technologies and services could work for them.

"I don't see how in-ear hearing aids could be fitted remotely, only adjusted remotely" (Female, 66 years, which of the following potential disadvantages of teleaudiology do you agree with?).

Family involvement

One participant found that a potential advantage of using teleaudiology could be better family involvement in their hearing aid journey.

"*Easier to have whanau with you so they can be 'involved'"* (Female, 73 years, which of the following potential advantages of teleaudiology do you agree with?).

Chapter Four: Discussion

4.1 Summary of main findings

Willingness to use

The first aim of this study was to investigate whether hearing aid consumers would be interested in trying the hearing aid service delivery methods presented in this study (teleaudiology, over the counter hearing devices and traditional audiology). The hypothesis formulated to investigate this aim was that older hearing aid users would be less likely to prefer alternative hearing aid services compared to traditional audiology. To assess this hypothesis, the mean score along a ten-point reverse-scored Likert scale for the question *"How likely are you are to try [proposed method]?"* was analysed. Additionally, participants' responses to the question "*Would you like access to this type of services?"* was analysed – this was a simple would try/would not try question. To analyse the influence of age on participants' willingness to access/use services, multiple logistic regression was carried out.

The mean score along the reverse-scored ten-point Likert scale was 4.16 for participants' willingness to use/try teleaudiology and 5.62 for participants' willingness to use/try over the counter hearing devices. These results indicate that participants were neutral in their opinions towards using teleaudiology and over the counter, user-programmable hearing devices, with a very slight preference for teleaudiology compared to over-the-counter hearing devices – however, this was not a statistically significant difference.

Around 60% of participants wanted access to teleaudiology, while 40.4% of participants wanted access to over-the-counter hearing devices and 88.4% of participants wanted access to traditional audiology for their hearing health care. These results suggest that

most participants preferred the traditional methods of hearing aid fitting and adjustments the most, followed by teleaudiology and even fewer participants wanted access to over-the-counter hearing devices.

The results from the multiple logistic regression analysis indicated that the older the participants, the increased odds of their willingness to use traditional audiology (traditional= 1.019). The odds ratio for teleaudiology and traditional audiology were not statistically significant (teleaudiology=1.019, OTC= 1.04).

Qualitative analysis of several questions showed that *older participants* were less likely to be willing to try teleaudiology, and particularly, OTC, user-programmable hearing devices because the process sounded confusing, and they were not familiar with using complicated programs on their phones/personal devices. They were interested in the idea of these alternative delivery methods but were not confident in their ability to use the internet, apps, etc. The literature also suggests that older adults aged over 65 years have lower confidence in their ability to use the internet, compared to older adults between 45 and 65 years. As a result of their lower confidence, older adults use the internet far less than those with higher confidence levels (Depallo, 2000). A qualitative study conducted in New Zealand also found that older adults' perceptions towards modern communication devices (mobile phones, emailing, texting, etc) and the internet were influenced by their confidence and lack of familiarity with modern technologies (Jerram, Kent & Searchfield, 2010).

The findings from the present study indicate that older adults with hearing loss are more likely to be willing to use traditional audiology for their hearing healthcare needs over teleaudiology and OTC, user-programmable hearing devices. In particular, the participants in this study were most unlikely to be willing to use OTC hearing devices,

most likely due to their lack of confidence and familiarity with modern technology. While teleaudiology is a hearing aid delivery method that could be used to narrow the gap in access to hearing health care to underserved communities, there is a risk of teleaudiology further emphasising inequalities. There is a "digital divide" (access to technologies, internet, lack of digital literacy) that could be exacerbated through the use of teleaudiology and negatively impact those that are in need of telehealth most – the elderly, ethnic minorities, individuals with low socioeconomic status, individuals living with disabilities, etc (Blandford et al., 2020). During the COVID-19 pandemic in New Zealand, thousands of people began working and learning from home – digital devices became the access point to the outside world (Cavanagh, n.d.). The Digital Inclusion Action Plan 2020-2021 estimated that 1 in 5 New Zealanders lacked at least one of the four factors that allow digital inclusion – *motivation* to understand how the internet can help us connect and learn, *access, skills* to know how to use the internet or *trust* in the internet and online services (Cavanagh, n.d.). A 2019 report by the Department of Internal Affairs in NZ used surveys to identify groups who were prone to low internet access – individuals with disabilities, Māori and Pasifika, older adults over 75 years of age, unemployed people and those living in social housing (Grimes & White, 2019).

Appropriateness of audiological care

The second aim of the study was to determine if hearing aid consumers believed that the hearing aid services mentioned in this study would be appropriate for them and what could be done to make it easier to use. The hypothesis formulated to investigate this aim was that hearing aid users would find the alternative options provided appropriate. The hypothesis also states that participants will want *extra* features/settings that would make the use of the service/product much easier, specifically, participants will want more than

one extra feature for each proposed hearing aid delivery method. These extra features are not features that are often mentioned in the literature but could be useful to make the use of the devices/services easier. To assess this hypothesis, the mean score along a ten-point reverse-scored Likert scale for questions about the ease of use of each treatment option; additionally, participants' responses to the perceived advantages and disadvantages of each treatment option was used to estimate the appropriateness of audiological care.

For the ease of use of each service, the mean score along the ten-point Likert scale was 4.63 for teleaudiology (neutral), 5.54 for over the counter, user-programmable hearing devices (neutral) and 2.61 for traditional audiology (somewhat easy). These results indicate that participants felt that the services would be neither too easy nor too difficult to use, i.e. they believed these services to be appropriate for use.

Agreeing with the hypothesis, participants believed that having additional features would make teleaudiology and over the counter hearing devices (the alternative options) easier to use. For teleaudiology, videoconferencing through well-known services such as Zoom and Skype and/or a mobile app where adjustments can be made easily and which the audiologist has access to were popular additional features (Figure 19; Figure 20). For OTC hearing devices, several participants agreed that being able to contact an audiologist for help with their devices, having a dedicated app/website/user manual with simple to follow instructions and solutions to any issues and alerts if the hearing device is experiencing issues were some features that would make it easier to use OTC devices (Figure 22; Figure 24). These results suggest that participants want a specialist available for assistance if an issue arises, or at least, simple information sources that will allow for them to fix the issue/s themselves.

The potential advantages of each proposed hearing aid fitting and adjustment method were used to determine the appropriateness of the service/device. For teleaudiology (Figure 13) and OTC hearing devices (Figure 14), quicker and easier adjustments and convenience was an advantage selected by several participants. Participants felt there were several advantages to traditional audiology, such as support and knowledge of an expert in the field and the audiologist would provide them with as much information as possible for better decision making (Figure 15). A study undertaken by Patskanick and colleagues (2019) found that most hearing aid users prefer getting advice/information about their hearing and hearing aids from an audiologist over any other source, including the internet. Interestingly, from all three proposed methods, OTC hearing devices were the option where more participants reported no advantages to the service (19% for OTC, 8% for teleaudiology and 0% for traditional audiology).

The potential disadvantages of each proposed hearing aid fitting and adjustment method were used to determine the appropriateness of the service/device. For teleaudiology (Figure 13) and OTC hearing devices (Figure 14), one of the largest disadvantages was that these services would limit the face-to-face interactions between the client and the audiologist. Several participants raised concerns about the lack of contact with an audiologist for teleaudiology and OTC hearing devices. A study that surveyed older adults' perceptions of self-fitting hearing devices found that there was a large preference for specialist advice and professional guidance for their hearing health care (Convery et al., 2011a). Participants value the input and expertise of the audiologist highly and perceive this to be lacking for teleaudiological services and OTC, user-programmable hearing devices. Participants also believed that the process of learning how to use teleaudiology and OTC hearing devices sounded confusing, tedious, and time-consuming. Additionally, for OTC hearing devices, participants were concerned about the accuracy of

the fitting they would get themselves (programming their hearing devices and ear mould/dome fitting) compared to the fitting an audiologist would provide for them. A feasibility study conducted on 40 older adults with hearing loss ranging from mild-moderate to severe (half had hearing aid experience, the other half did not) found that 73% of the participants were successful in inserting their devices into their ears without assistance and 55% were able to follow simple instructions to complete a 10-step fitting process (Convery et al., 2017). This literature suggests that about half of the older adults who use OTC, user-programmable hearing devices will be able to fit and program their devices themselves. For traditional audiology, several participants felt that getting an appointment was difficult, and travelling to and from a clinic was time-consuming. Eikelboom and Atlas (2005) found that adults living in Perth, Australia had a higher likelihood of being willing to use teleaudiology if it led to reduced travel time to and from the clinic. Reduced waiting time for appointments and reduced travel time were some of the largest factors contributing to participants' willingness to use teleaudiology (Eikelboom & Atlas, 2005). percentage considerable proportion (21%) of participants felt there were no disadvantages to traditional audiology, compared to 3% for OTC hearing devices and 8% for teleaudiology. These results indicate that the survey participants believed traditional audiology to be the most appropriate form of hearing health care for themselves, followed by teleaudiology and over the counter, user-programmable hearing devices.

Accessibility of audiological care

The third aim of this study was to determine whether hearing aid consumers thought that the hearing aid services evaluated in this study could increase the accessibility of audiological care. The hypothesis formulated to investigate this aim was that the hearing

aid consumers would find the alternative hearing aid fitting and adjustment methods provided in this study to be an appropriate means to increase the accessibility of hearing health care in Aotearoa. To assess this hypothesis, the mean score along a ten-point reverse-scored Likert scale was analysed, in response to being directly asked if they believed each treatment option would increase accessibility by *raising awareness of hearing health care and encouraging individuals to seek help*.

On whether the three proposed services would be likely to encourage people with hearing loss to seek help, the mean score along the reverse-scored ten-point Likert scale was 3.87 (somewhat agree) for teleaudiology and 3.81 (between somewhat agree and neutral) for over-the-counter hearing devices. On whether the three proposed services would be likely to increase awareness of the importance of addressing hearing healthcare and hearing loss, the mean score was 3.62 (between somewhat agree and neutral) for teleaudiology and 3.76 (between somewhat agree and neutral) for over the counter, user-programmable hearing devices. In general, these results indicate that the participants in this survey thought that teleaudiology and over the counter, user-programmable hearing devices may be a viable option to increase the accessibility of hearing health care services across Aotearoa. These results agree with the hypothesis.

The mean score along the Likert scale was 3.94 when participants were asked if they believed traditional audiology was accessible to many different people/groups of people in Aotearoa – this score is suggestive that participants neither agree nor disagree with this statement. Traditional audiology is effective in New Zealand, but it is not widely accessible, especially to individuals living with disabilities, living in rural communities (Digby, 2016, as cited in The National Foundation for the Deaf Inc, 2017) and Māori and Pasifika communities (The National Foundation for the Deaf Inc, 2017). These findings may be a result of most of the study population being NZ European (as the largest group

of participants likely came from the University of Auckland Hearing and Tinnitus Clinic located in metropolitan Auckland - Grafton), who do not often face difficulties accessing hearing healthcare. From the 2018 Census data, only 7.7% of the population in Grafton is Māori and only 3.9% are Pasifika, while 60.5% of the population is European (Statistics New Zealand, n.d.). For all of New Zealand, the NZ European population comprises 70.2% of the total population, Māori comprises 16.5%, Pasifika people comprise 8.1%. For the present study, 85% of the study population were New Zealand European and 2% were Māori (Figure 9). Therefore, the present study does not accurately represent the ethnic diversity of New Zealand.

Willingness to pay

Another aim of this study was to investigate if hearing aid consumers would be willing to pay for the services discussed in this study (teleaudiology, over the counter hearing devices and traditional audiology) and approximately how much they would be willing to pay. The hypothesis formulated to investigate this aim was that hearing aid consumers will be willing to pay the same for teleaudiology as they would for traditional audiology, and less for over-the-counter hearing devices than for traditional audiology. To assess this hypothesis, the contingent valuation method was used and the mean, mode, and range willingness to pay values were analysed for each treatment option.

The mean willingness to pay value was NZ$ 113 for teleaudiology, NZ$ 300 for over the counter, user-programmable hearing devices and NZ$ 446 for traditional audiology. These results do not agree with the hypothesis; participants were willing to pay far less for teleaudiology than traditional audiology, and a similar value for OTC devices as for

traditional audiology. When analysing the individual WTP data for each method, there is generally a large cluster at low NZD$ values. However, there are two outliers for the traditional audiological care method, placed above NZ$8000. The participants may have included the cost of aids in their value estimation when asked how much they would be willing to pay for the *service* - "*How much would you pay for this service?".* More clarity about what the question specifically wanted the participants to think about may have helped to avoid these outliers for traditional audiology, e.g. "*How much would you pay for this service? (Exclude the cost of the hearing aids from your response)"*.

Participants placed a higher value on traditional audiological services. This could be suggestive that participants place a higher value on services that provide face-to-face interactions with an audiologist, the lack of which was one of the largest disadvantages identified in the present study (Figure 16, Figure 17). Patskanick et al. (2019) surveyed hearing aid users and found that they preferred getting information about their hearing and hearing aids from an audiologist over other sources, such as the internet. This highlights the importance of having an audiologist involved in the hearing aid process for patients.

There are several other factors that may have influenced participants' WTP, such as income, education level, geographic location, experience with hearing aids, years with hearing loss, and many more. However, the present study did not explore these points.

For OTC, user-programmable hearing devices, the NZ$ 300 mean WTP value can be assumed to be the total cost of the hearing device itself, along with the accompanying computer/phone app that was included in the service description in the Qualtrics survey (Appendix D). It may be what participants believe the mark-up price for the device would be if they were to be purchasing the product from their local electronics/department store

or pharmacy. Additionally, the concept of OTC, user-programmable devices was introduced in the present study as being much more automated than traditional hearing aids – those who have experience with hearing aids in New Zealand may have been aware that the more automatic a hearing aid is, the higher the price (Styles, 2020). Participants may have valued OTC hearing devices lower than traditional audiology due to the lack of clinician involvement.

4.2 Significance of this research

This research explored the perceptions of those who use hearing aids (or are considering purchasing hearing aids) towards alternative forms of hearing aid fittings and adjustments being administered, such as teleaudiology and OTC hearing devices and compared this to perceptions of traditional audiology. This area of research has not been explored in New Zealand and there is little research internationally. The findings from the present study have implications for hearing aid delivery methods. The findings are of relevance to audiologists, hearing care providers, researchers, and policymakers.

A qualitative study in New Zealand by Chandra and Searchfield (2016), asked older adults what their perception towards internet-based delivery of hearing aids was. The research produced broad themes of participants' perceived benefits and concerns about an internet-based hearing aid delivery method. The themes identified in their study were *awareness of hearing aids sold online, the lower cost online, the convenience of purchasing online, concerns regarding clinical procedures, trustworthiness, lack of personal contact, lack of familiarity.* Similar themes were found throughout the present study, such as *distrust in a highly technical process/too difficult as it is too technical, cost, preference for in-person/face-to-face appointments.* This indicates that patients still

have similar concerns and thoughts about alternative hearing aid delivery methods, which need to be addressed. The present study used a mainly quantitative approach, asking direct questions to participants using an anonymous survey. The present study also discussed *specific* alternative hearing aid delivery methods – teleaudiology and over the counter, user-programmable hearing devices. As such, specific information was obtained from the participants about their likelihood/willingness to use each method, their willingness to pay for each method and the potential advantages and disadvantages of each method. This information is useful for identifying the uptake rate of each delivery method. The research by Chandra and Searchfield (2016) was one of the first to assess the perception of alternative hearing aid delivery methods. It used interviews, only 18 participants were questioned and there was a male bias. The present study had 120 participants without a gender bias, therefore the results from the present study are much more generalisable to the New Zealand population.

Convery et al. (2011a) employed a qualitative and quantitative approach to assess the perceptions of 80 adults with hearing loss on self-fitting hearing aids. Participants were asked whether they liked the idea of self-fitting hearing aids, whether they could perceive benefit from their use and any advantages/disadvantages they perceived compared to traditional hearing aids. They found that participants thought that self-fitting hearing aids were a good concept, which could provide personal benefit and the participants felt they could self-manage the devices (Convery et al., 2011a). Participants cited increased independence and control over their hearing as an advantage and an inaccurate/inappropriate self-fitting compared to that of an audiologist as a disadvantage (Convery et al., 2011a). Keidser et al. (2007) administered two questionnaires to assess demographic information and the perceptions of self-adjustable and trainable hearing aids of 247 adults in Sydney, Australia. They asked similar questions to their participants as

Convery and colleagues (2011a), in addition to asking more specific questions such as whether they would want a remote control or onboard buttons to help them to train their hearing aids. They found that 91% of participants liked the idea of trainable hearing aids, but this percentage dropped when participants were asked about the personal benefit they would get from the aids (Keidser et al., 2007). Participants cited the ability to adjust to their own preferences without repeatedly visiting the clinic as an advantage and the potentially high cost of the device as a disadvantage (Keidser et al., 2007). The present study differed from the above-mentioned studies in that it asked specific questions, such as "*what features/settings would make it easier to use [service]?"* and provided more than one feature that could make things easier. Additionally, the present study asked participants whether they would like access to each service rather than whether they *like the idea* of the service or not – this provides more specific information on a population's willingness to use the proposed products/services. The above-mentioned studies assumed that because a participant *liked* the idea of a product, that equates to their willingness to use said product.

Eikelboom and Atlas (2005) employed a quantitative questionnaire to assess 116 audiology patients' perceptions of the use of telemedicine for their hearing-related appointments in Perth, Australia. It focussed on the travel time and distance to and from appointments and how telemedicine could reduce this drastically, as well as the advantages/disadvantages and why or why not participants would be willing to use telemedicine for audiology. The present study differed in that it didn't ask specifically about how travel time/distance affected participants' willingness to use but was much more general. The use of general questions in the present study opened up the opportunity to ask about several aspects of each service, such as ease of use and potential impact on the accessibility of hearing health care.

There is little to no literature available about participants' willingness to pay for alternative hearing aid delivery methods – the present study is one of the first to do so. WTP is a key indicator of consumer demand – it is the value that participants place on the service/product. Uptake is one of the largest issues for health services, as a result of inaccessibility. WTP was indirectly used to support the willingness to use analyses undertaken in the present study, and thus uptake – this could inform new techniques of hearing aid provision in New Zealand for underserved communities and individuals.

Beyond the main findings, the present study investigated specific features and settings of the alternative hearing aid delivery methods (teleaudiology and OTC hearing devices) that would make these technologies easier for participants to use. As such, the present study has provided some information on how the development of these delivery methods can be improved, which can lead to higher success/uptake rates.

The findings from this study inform the potential 124uccesss and uptake of alternative hearing aid delivery methods in New Zealand, specifically, teleaudiology and OTC, user-programmable hearing devices.

The participants in the present study highly valued their interactions with a knowledgeable audiologist that they trust. They perceived teleaudiology and OTC, user-programmable hearing devices having limited or a lack of contact with an audiologist. Therefore, the results from the present study demonstrate that it may be important for alternative hearing aid delivery methods to include audiologist involvement somewhere in the process. This could be through phone conversations, video calls or emails for support and knowledge, for example, to help in the selection of the appropriate devices or to help the patient through how to fit the device in their ears.

Several participants emphasised that informational videos or manual guides may make the use of alternative hearing aid delivery services easier for them. These videos/guides could include information on what to do if an issue arises, how to insert the device in the ear, how to change batteries, how to clean the device, etc. Thorén et al. (2014) showed that video tutorials and/or reading material alongside email contact with an audiologist could increase hearing aid use in older adults and hearing aid benefits. The video tutorials and reading materials were considered to be important because patients often forget most of the information that is provided at the clinic during the hearing aid fitting. Participants in the present study also thought that a helpline to call for advice could be extremely useful. These are some methods that could be used to increase the likelihood of success for alternative hearing aid delivery methods in New Zealand.

Some older participants were not confident in their abilities to use the alternative hearing aid delivery methods due to a lack of familiarity and experience with new technologies and the internet. They felt that these delivery methods were better for the younger generation. To address this, creating websites and apps that are 'elderly-friendly' should be considered. For example, reducing the amount of scrolling, choosing a large-sized font, minimizing jargon, providing a speech function so patients can *hear* the text (Williams, 2017). This could make navigation through the websites/apps much easier and more palatable for those that are not confident in using new technologies.

This study provides a basis for future research to focus on alternative methods of delivering different aspects of the hearing care journey, and improvements that can be made to allow for better uptake/success of these alternative delivery methods, especially for communities with reduced access.

4.3 Strengths of this study

One of the biggest strengths of this study is its contribution to a topic that has limited literature across the globe and little to no literature in New Zealand. Although it is well-known that there is a disproportionate burden of disease across Aotearoa, especially for the Māori, Pacific communities and rural communities, there has been little research done to look at ways to improve access to hearing healthcare. In this research, participants were asked about their view of the feasibility, appropriateness of and accessibility that alternative hearing aid fitting and adjustment methods could have, along with their willingness to pay for these alternative services/products. This information provided a basis to understand the potential uptake of these alternative products/services and highlighted aspects of the hearing health care system that consumers value highly, such as audiologist involvement and cost. This study explored current and future audiological services from the perspective of the user.

Participants in this study were recruited from several sources, including the University of Auckland Facebook and Twitter pages, the monthly newsletter for The Deafblind Association New Zealand, on the Faculty of Medical and Health Sciences website and to the University of Auckland Hearing and Tinnitus Clinic email list. Therefore, this study achieved a degree of diversity concerning the clinics/associations through which recruitment for the study was done and audiological care had been received. This was evident in the large age range of the participants in this study (17 years – 91 years) and the number of participants recruited in the study (120). This was an important factor in this study as differing clinics/associations provide different experiences to clients and these experiences influence clients' opinions on hearing health care.

There was no significant gender bias in this research, therefore the findings are representative of the perceptions and experiences of both the female and male population in New Zealand with some degree of (self-perceived and diagnosed) hearing loss.

In this study, two alternative methods to hearing aid fittings and adjustment were proposed (teleaudiological services and over the counter, user-programmable hearing devices) along with the current method that is used (traditional audiology). This is allowed for some degree of comparison during the survey-taking process for the participants. It created the opportunity to make comparisons between methods for important variables such as willingness to pay values, ease of use, likelihood to use the product/service, etc. This comparison is crucial to understand the potential uptake rates of these alternative methods and the factors that consumers value about their hearing health care.

4.4 Limitations of this study and future considerations

The participants in this study were recruited from various sources, such as the University of Auckland Facebook and Twitter pages, and LinkedIn, however the largest pool of participants came from the University of Auckland Hearing and Tinnitus Clinic email list. This led to a lack of variation and diversity in terms of the ethnic backgrounds (and potentially socioeconomic status) of the individuals who completed the survey, as the University of Auckland Hearing and Tinnitus Clinic caters to a large proportion of NZ Europeans and fewer Māori and Pasifika. As a result, this study was unable to reach individuals who have difficulty accessing hearing health care, such as those who live in rural communities and Māori and Pasifika – a very important group who often face the inequitable spread of healthcare in Aotearoa. The perceptions of alternative hearing aid

fitting and adjustment methods and their feasibility and accessibility should be explored in other ethnic groups, such as Māori and Pasifika.

The sample size of the present study was 120, which is a larger sample than most similar studies (116, Eikelboom & Atlas, 2005; (80, Convery et al., 2011a), but less than another (247, Keidser et al., 2007).

In this study, it was evident from the responses to the willingness to pay questions that participants were confused about the price they would be willing to pay for the alternative methods (teleaudiology and OTC hearing devices). Several participants responded with question marks *"?????"*. Future studies could choose to provide some frame of reference or make use of a choice-based question format for the price of each alternative option; however, it would be important to consider that this may lead to a degree of bias in the willingness to pay values (Wertenbroch & Skiera, 2002).

It is possible that participants' willingness to pay was influenced by an unmeasured characteristic. Future research on this topic should investigate the factors that could influence an individual's willingness to pay, such as age, gender, experience with hearing devices, socio-economic status, education level, etc.

One of the factors that participants in this study felt was extremely important in their hearing health care, was the involvement of an audiologist. Participants highly valued the knowledge, support, and expertise of an audiologist during their hearing aid fitting and adjustments, and they raised concerns on how teleaudiological services and over the counter, user-programmable hearing devices would work without or with reduced input from an audiologist. Therefore, these services would need to incorporate the audiologist into the process. However, there are few studies exploring the opinions of audiologists on these alternative methods of hearing aid fittings and adjustments. Future research should

investigate the perceptions of audiologists towards these alternative methods and their potential involvement, in New Zealand.

This study focussed on how the alternative services/products could be used for hearing aid fittings and adjustments. However, there is literature from across the globe that suggests that these alternative services/products could be used throughout the entire hearing journey – from diagnostic hearing tests to hearing aid adjustments and everything in between. Future studies should explore consumers' opinions on the use of these alternative methods for the diagnostic process of the hearing journey.

Chapter Five: Conclusion

This study explored the perceptions of consumers towards different hearing aid delivery methods, such as teleaudiology and over the counter, user-programmable hearing devices. Greater convenience and quicker adjustments were specified as potential benefits for the alternative methods, however, there were also a number of concerns. Most of the concerns were related to the lack of face-to-face contact with an audiologist and the lack of expert care they would experience – this highlighted the importance that hearing aid users place on the role of the audiologist and the support and knowledge they provide. Unfamiliarity with new technologies and therefore, a lack of confidence with the proposed alternative hearing aid delivery methods was also expressed as a concern. There were also concerns raised about the current method of hearing aid delivery (traditional audiology), such as difficulty finding appointments that fit participants' daily schedules. These concerns need to be addressed if teleaudiology and OTC, user-programmable hearing devices are to be implemented in New Zealand.

Overall, there was a greater willingness to use and pay for traditional audiology compared to the two proposed alternative methods – teleaudiology and OTC, user-programmable hearing devices, although the difference was not statistically significant between groups. The findings from this study could be used to direct the development of alternative hearing aid delivery methods and subsequently improve the accessibility of hearing health care in Aotearoa, especially for individuals with low socioeconomic status, individuals with disabilities, ethnic minorities, and rural communities. The findings of this study have implications for hearing aid delivery services, highlighting the aspects of importance for patients for their hearing care (audiologist involvement and various sources of help/information) and their willingness to try and pay for newer fitting methods that could

lead to these new methods coming into the hearing aid market in New Zealand. The findings are of relevance to policymakers, audiologists, hearing care providers and researchers.

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Appendices

Appendix A: Ethical approval

AUCKLAND HEALTH RESEARCH ETHICS COMMITTEE (AHREC)

24/08/2021

Assoc Prof Grant Searchfield

Audiology

Re: Application for Ethics Approval (Our Ref. AH22914): Approved

The Committee considered your application for ethics approval for the study entitled "**The Future of Audiology: A survey of different hearing aid fitting methods**".

We are pleased to inform you that ethics approval has been granted.

The expiry date for this approval is **24/08/2024**.

Amendments to the approved project: Should you need to make any changes to the approved project, please follow the steps below:

- Send a request to the AHREC Administrators to unlock the application form (using the Notification tab in the Ethics RM form).
- Make all changes to the relevant sections of the application form and attach revised documents (as appropriate).
- Change the Application Type to "Amendment request" in Section L.
- Add a summary of the changes requested in the text box.
- Submit the amendment request (PI/Supervisors only to submit the form).

If the project changes significantly, you are required to submit a new application.

Funded projects: If you received funding for this project, please provide this approval letter to your local Faculty Research Project Coordinator (RPC) or Research Project Manager (RPM) so that the approval can be notified via a Service Request to the Research Operations Centre (ROC) for activation of the grant.

The Chair and the members of AHREC would be happy to discuss general matters relating to ethics approvals. If you wish to do so, please contact the AHREC Ethics Administrators at ahrec@auckland.ac.nz in the first instance.

Additional information:

- Do not forget to fill in the 'approval wording' on the PISs, CFs and/or advertisements, using the date of this approval and the reference number, before you use the documents or send them out to your participants.

All communications with the AHREC regarding this application should indicate this reference number: **AH22914**.

AHREC Administrators

Auckland Health Research Ethics Committee

Appendix B: Participant information sheet

Participant Information Sheet

Section of Audiology
Faculty of Medical and Health Sciences

The University of Auckland
Private Bag 92019 Auckland 1142
New Zealand
Section of Audiology
School of Population Health
Building 507, Level LG
20-30 Park Avenue

Telephone: +64 9 373 7599
Email: audiology@auckland.ac.nz

PARTICIPANT INFORMATION SHEET

Project title: The Future of Audiology: A Survey of different hearing aid fitting methods.

Principal Investigator: Assoc Prof Grant D Searchfield (Audiology)
Co-Investigator: Dr Braden Te Ao (Health Systems)

Master of Audiology Research Student: Ayusi Patel (Audiology Intern)

Study invitation

You are invited to take part in a survey of consumer opinions about different ways of fitting and adjusting hearing aids. Whether or not you take part is your choice. If you don't want to take part, you don't have to give a reason, and it won't affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you'd like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. Your completion of the survey will be taken as consent.

Researcher introduction

The research project is under the supervision of the Principal Investigator, Grant Searchfield, and Co-Supervisor, Braden Te Ao. The data collection will be undertaken by Ayusi Patel, an Audiology Intern (second-year Master of Audiology intern) at the Section of Audiology, School of Population Health, the University of Auckland, Grafton Campus. Funding for this study has been obtained from the School of Population Health, University of Auckland.

Project description and invitation

Hearing loss impacts over 20% of the world's population, however, not everyone has access to services that diagnose and rehabilitate their hearing loss. Undiagnosed and unaddressed hearing loss for adults can result in social isolation, depression, occupational stresses and strained interpersonal relationships. The introduction of new and more affordable technologies may encourage more individuals to seek help for their hearing loss – thus increasing the accessibility of audiological services and hearing devices. This study aims to understand consumer opinions around potential alternative technologies of hearing aids and the predicted uptake of such technologies across Aotearoa. It also aims to investigate how much consumers would be willing to pay for such technologies.

Volunteers are invited to participate in this research project, which will explore potential technologies that may be used in the future for hearing tests and hearing aid fittings/programming. You will be asked approximately 40 questions, in total, about your opinions on the use of tele-audiology (audiology from a distance using video conferencing and phone calls), over-the-counter hearing aids and how they could compare to traditional audiology. Participants will also be asked about factors they find important when it comes to their own audiological care.

Participants who take part in the study should be 18 years or older and be able to complete a questionnaire in English. They must be current hearing aid users or considering the purchase of hearing aids. Participation in the study is voluntary and data is predominantly acquired from the completed surveys.

There are no risks to participants in this study, as the survey is online and anonymous. The completion of the survey will benefit the Deaf and Hard of Hearing communities by providing insight into whether alternative technologies are a viable option for the future, thus potentially providing more means for individuals to learn about and try hearing aids.

Project Procedures

Participants will each be asked to fill out an online survey on Qualtrics, which should take up to 25 minutes. The online survey has 4 sections: demographic information, teleaudiology, over-the-counter hearing aids and traditional audiology.

Participation in this study provides an opportunity for individuals who know people with hearing loss, or individuals with hearing loss themselves to discuss the accessibility of current audiological services and how potential new technologies may change this.

Anonymity

Participation in this research study is anonymous. All information provided will remain anonymous, no participant will be individually identified. Submission of the online survey will be taken as consent to participate.

Data Storage/Retention/Destruction/Future Use

During the study, data will be recorded with electronic documentation. Participants will remain non-identifiable throughout the study and published data. Any non-identifiable information that is required for the analysis of results will be stored for 6 years before being destroyed. Data obtained from the online survey will be stored in Qualtrics storage for 6 years.

A summary of the study results can be made available to participants via email if they choose to receive it. There will be a link at the end of the survey, which will send participants to another webpage where they can enter their contact details. This will ensure the anonymity of participants.

Contact Details

Further questions regarding this research project may be directed to:

Ayusi Patel (Researcher)
Audiology Intern
Section of Audiology
School of Population Health
Faculty of Medical and Health Sciences
University of Auckland
Email: apat464@aucklanduni.ac.nz

Dr Grant D Searchfield (Supervisor)
Associate Professor
Section of Audiology
School of Population Health
Faculty of Medical and Health Sciences
University of Auckland
Email: g.searchfield@auckland.ac.nz
Ph: (09) 373 7599 ext. 86316

Dr David Welch
Head of Section

(Head of Section)

Section of Audiology
School of Population Health
Faculty of Medical and Health Sciences
University of Auckland
Email: d.welch@auckland.ac.nz
Ph: (09) 923 8404

For concerns of an ethical nature, you can contact the Chair of the Auckland Health Research Ethics Committee at ahrec@auckland.ac.nz or at 373 7599 ext 83711, or at Auckland Health Research Ethics Committee, The University of Auckland, Private Bag 92019, Auckland 1142.

If you require Māori cultural support, talk to your whānau in the first instance. Alternatively, you may contact the administrator for He Kamaka Waiora (Māori Health Team) by telephoning 09 486 8324 ext. 2324.

If you have any questions or complaints about the study, you may contact the Auckland and Waitematā District Health Boards Māori Research Committee or Māori Research Advisor by phoning 09 486 8920 ext. 3204.

APPROVED BY THE UNIVERSITY OF AUCKLAND HEALTH RESEARCH ETHICS COMMITTEE ON 24/08/2021 FOR 3 YEARS, REFERENCE NUMBER AH22914.

Appendix C: Thesis advertisement

THE UNIVERSITY OF AUCKLAND
FACULTY OF MEDICAL AND HEALTH SCIENCES

Do you have hearing loss?

Are you interested in new and easier ways to purchase and use hearing aids?

If you are interested in participating in this research investigating consumers' opinions on newer hearing aid fitting technologies, please contact:

Ayushi Patel
Email: apat464@aucklanduni.ac.nz

OR

Dr Grant Searchfield
Email: g.searchfield@auckland.ac.nz

Participants must be 18 years or older and be able to complete an anonymous questionnaire in English. They must be hearing aid users or be considering purchasing the purchase of hearing aids.

Project Title: The Future of Audiology: A survey of different hearing aid fitting methods

APPROVED BY THE UNIVERSITY OF AUCKLAND HEALTH RESEARCH ETHICS COMMITTEE ON 24/08/2021 for (3) years, Reference Number AH22914.

Please contact one of the following if you are interested in volunteering for this research project:
Ayushi Patel
Email: apat464@aucklanduni.ac.nz
Dr Grant Searchfield
Email: g.searchfield@auckland.ac.nz

Please contact one of the following if you are interested in volunteering for this research project:
Ayushi Patel
Email: apat464@aucklanduni.ac.nz
Dr Grant Searchfield
Email: g.searchfield@auckland.ac.nz

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Email: apat464@aucklanduni.ac.nz
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Email: g.searchfield@auckland.ac.nz

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Dr Grant Searchfield
Email: g.searchfield@auckland.ac.nz

Please contact one of the following if you are interested in volunteering for this research project:
Ayushi Patel
Email: apat464@aucklanduni.ac.nz
Dr Grant Searchfield
Email: g.searchfield@auckland.ac.nz

Appendix D: Survey

The Future of Audiology: A survey of different hearing aid fitting methods

Introduction

Welcome to "The Future of Audiology" Survey!

This survey is designed to look at potential alternatives to approach hearing aid fittings and hearing aid adjustments. We would like to know your honest opinions about the proposed solutions if you currently wear hearing aids or are considering purchasing hearing aids.

This survey should take *up to 20 minutes* to complete. By proceeding with the survey, you consent to your data being used. Your participation is voluntary and will remain anonymous.

We appreciate you for taking the time to complete this survey. Your contribution is valuable.

If you would like a summary of the results from this study, information about this can be found at the end of this survey!

This study has been approved by the University of Auckland Health Research Ethics Committee on 24/08/2021 for 3 years, Reference Number AH22914.

Demographic Information

Age:

_____

Sex:

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Other
- ○ Prefer not to say

Ethnicity:

- ○ New Zealand European
- ○ Māori
- ○ Samoan
- ○ Cook Islands Maori
- ○ Tongan
- ○ Niuean
- ○ Chinese
- ○ Indian
- ○ Other, e.g. Dutch, Japanese, Tokelauan. Please Specify

_____

What country do you reside in?

- ○ New Zealand
- ○ Other. Please specify _____

How long have you had hearing loss?

- ○ Less than 1 year
- ○ 1 to 5 years
- ○ 6 to 10 years
- ○ 11 to 15 years
- ○ 16 to 20 years
- ○ More than 20 years
- ○ I don't have a hearing loss

How long have you been wearing hearing devices?

- ○ Less than 1 year
- ○ 1 to 5 years
- ○ 6 to 10 years
- ○ 11 to 15 years
- ○ 16 to 20 years
- ○ More than 20 years
- ○ I don't wear hearing devices

Teleaudiology

Teleaudiology refers to audiological services at a distance (i.e. video conferencing on computers such as “Zoom”. In this scenario, you can call the audiologist and set up an appointment for them to conduct a hearing test at your home. The hearing aids are pre-programmed for your hearing loss and sent to your home. Videoconferencing can allow the audiologist to fine-tune and adjust your hearing aids from the clinic, without you having to leave your home. If any changes need to be made, you can message the audiologist and they will set up a time to make these adjustments online and have any discussions you may want to have.

Would you like access to this type of service?

- ○ Yes, it sounds like something I would like to try
- ○ No, I would rather visit a clinic

How easy do you think teleaudiology would be to use?

	Extremely easy			Somewhat easy		Neither easy nor difficult		Somewhat difficult		Extremely difficult
	0	1	2	3	4	5	6	7	8	9	10
											

How would you like to communicate with your audiologist?

- ○ Calling a phone number
- ○ Messaging on an app
- ○ Via emailing
- ○ Via text messaging
- ○ Other. Please specify _____

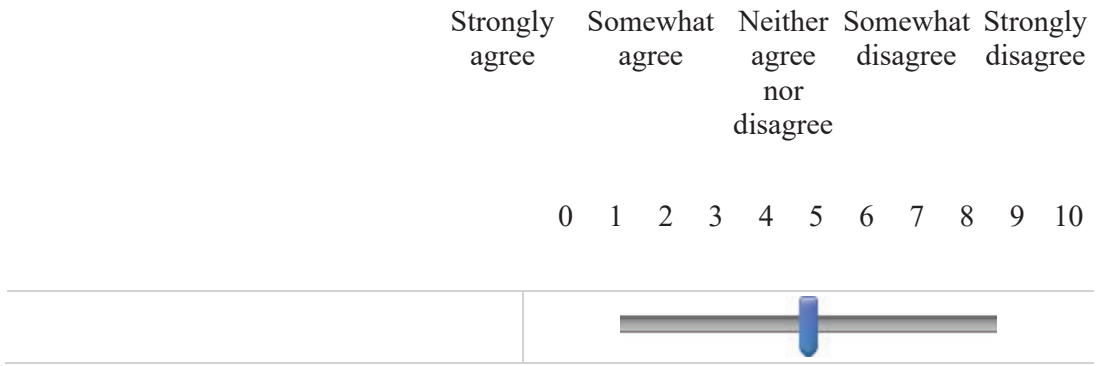
What would be the easiest way to fit and adjust hearing aids? Please choose one.

- ○ Online via videoconferencing .e.g. Zoom, Skype
- ○ Mobile audiology where the audiologist comes to my home
- ○ Mobile audiology where the audiologist comes in a hearing testing vehicle (e.g. a van)
- ○ Mobile audiology where the audiologist sets up a station in my town centre and I would visit them
- ○ On an app on my mobile phone, which the audiologist can also access remotely
- ○ Other. Please specify _____

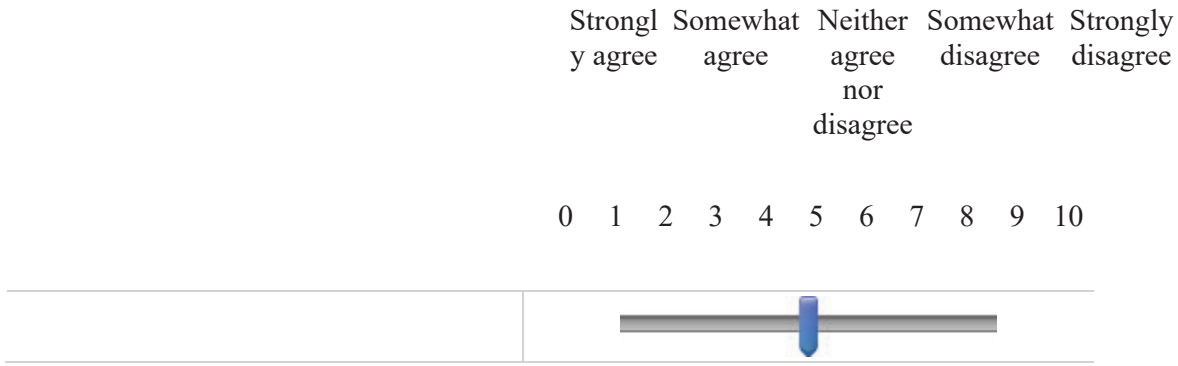
What features would you find useful? Select all that apply.

- ☐ A website/app to communicate with an audiologist (through messaging, video calls, etc)
- ☐ Using a well-known video conferencing service, e.g. Zoom, Skype
- ☐ After hours and weekend contact with an audiologist
- ☐ Being able to choose my audiologist
- ☐ None of the above
- ☐ Other. Please specify _____

I think teleaudiology would encourage people with hearing loss to seek help.



I think teleaudiology would be likely to increase awareness of the importance of addressing hearing health and hearing loss.



Which of the following statements about the potential advantages of teleaudiology do you agree with? Select all that apply.

- [ ] Convenient - the clinic comes to me instead of me going to the clinics, at the times of the day I want
- [ ] I would be able to use the hearing aids in my own environment and identify issues quickly
- [ ] Adjustments would be easier/quicker when and if my hearing and preferences change
- [ ] My hearing health could be managed from my home
- [ ] I don't think there are any advantages to teleaudiology
- [ ] Other. Please specify _____

Which of the following statements about the potential disadvantages of teleaudiology do you agree with? Select all that apply.

- ☐ Time-consuming, especially if the hearing aids don't suit me and I want to try another pair of hearing aids
- ☐ The process and concept of teleaudiology is confusing
- ☐ Seems tedious - I would rather go to the same clinic each time
- ☐ Prefer face-to-face appointments with my audiologist - I enjoy visiting my audiologist
- ☐ I wouldn't have as much contact with an audiologist compared to traditional clinic visits
- ☐ I don't think there are any disadvantages to teleaudiology
- ☐ Other. Please specify _____

How likely are you to try teleaudiology to fit and adjust hearing aids?

Extremely likely	Somewhat likely	Neither likely nor unlikely	Somewhat unlikely	Extremely unlikely

0 1 2 3 4 5 6 7 8 9 10

How much would you pay for this service?

_____

Over-the-counter, user-programmable hearing aids

In this scenario, everything would be done by you, you will be able to buy the hearing aids from an electronics or department store or pharmacy and you will be able to set the hearing aids yourself. An app on your phone or a computer program will help you set the aids yourself, without a clinician. You can put the hearing aids on and do a hearing test, pushing a button on the hearing aid or remote control when you hear each beep – the results pre-program the hearing aids. You can use the app to fine-tune the hearing aids. This type of hearing aid tracks the changes you make over time and begins to anticipate these in different environments.

Would you like access to this type of service?

- ○ Yes, it sounds like something I would like to try
- ○ No, I would rather visit a clinic

How easy do you think an over-the-counter hearing aids could be to use for you?

Extremely easy	Somewhat easy	Neither easy nor difficult	Somewhat difficult	Extremely difficult

0 1 2 3 4 5 6 7 8 9 10

What would make it easier to use over-the-counter hearing aids? Select all that apply.

- [ ] The app is available for phones, laptops, tablets, computers, etc.
- [ ] The app has simple, easy-to-follow, step-by-step instructions
- [ ] A user manual with step-by-step instructions and solutions to problems that may arise
- [ ] A dedicated website with informational videos
- [ ] Being able to call or videoconference an audiologist for help
- [ ] Remote control with large buttons
- [ ] Other. Please specify

_____

What would make it easier to learn how to use over-the-counter hearing aids? Select all that apply.

- [ ] User manuals, pamphlets, websites, etc (written material)
- [ ] The app and/or hearing aids instructs you on what to do (auditory material)
- [ ] The app provides videos and diagrams (visual material)
- [ ] Other. Please specify

_____

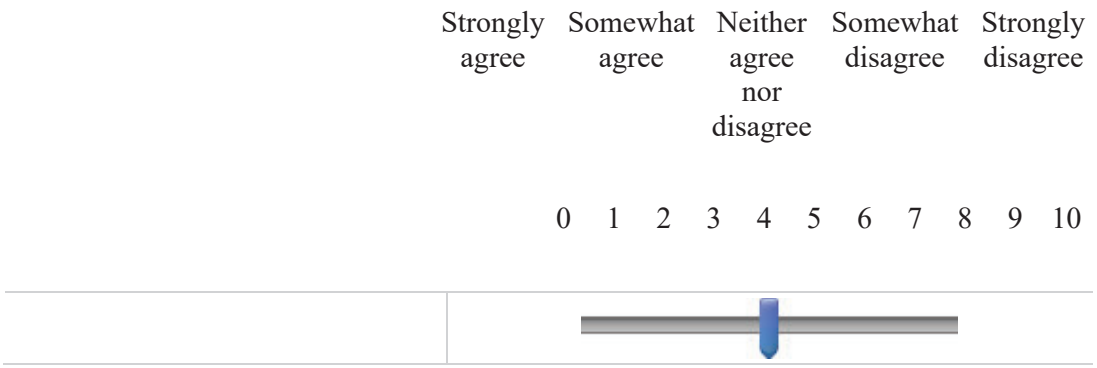
What would be the most accessible manner in purchasing over-the-counter hearing aids?

- ○ Online
- ○ At a local tech store, e.g. Noel Leeming, Harvey Norman
- ○ At a department store, e.g. The Warehouse
- ○ Other. Please specify _____

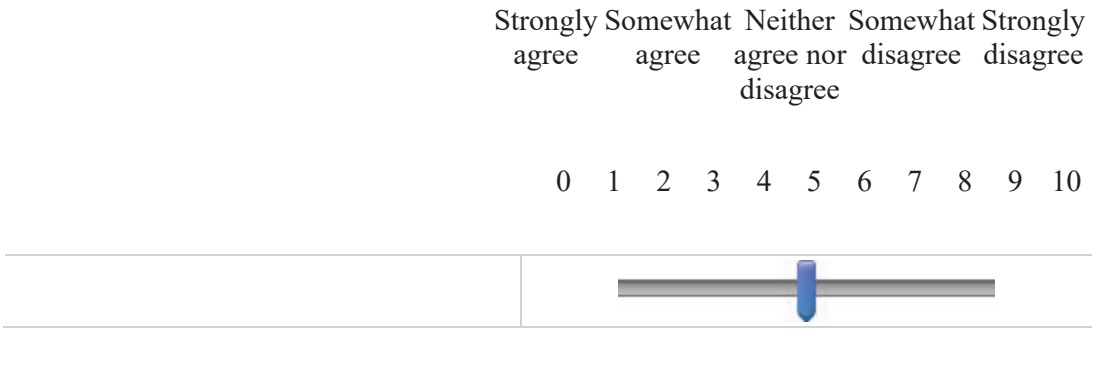
Which settings/features would you find useful? Select all that apply.

- ☐ Reminders to take off hearing aids before showering and sleeping
- ☐ Reminders to get annual hearing tests done
- ☐ Alerts if an issues arises, e.g. a little alarm plays in your ear
- ☐ Scroll-down menu in the app with different issues and how to solve them
- ☐ The app remembering previous settings so you can go back to them if you want to
- ☐ None of the above
- ☐ Other. Please specify _____

I think over-the-counter hearing aids would likely encourage individuals with hearing loss to address this and seek help.



I think over-the-counter hearing aids would be likely to increase awareness of the importance of addressing hearing health and hearing loss.



Which of the following statements about the potential advantages of over-the-counter hearing aids do you agree with? Select all that apply.

- [ ] Convenient - fewer visits to the clinic
- [ ] I would have control over my own hearing needs
- [ ] Better outcomes because over-the-counter hearing aids are personalised to my own preferences
- [ ] Adjustments would be easier/quicker when and if my hearing and preferences change
- [ ] I don't think there are any advantages to over-the-counter hearing aids
- [ ] Other. Please specify _____

Which of the following statements about the potential disadvantages of over-the-counter hearing aids do you agree with? Select all that apply.

- [ ] Time-consuming to learn how to fit, use and adjust the hearing aids
- [ ] I might not be able to get a good outcome by myself compared to a trained audiologist
- [ ] The process and concept of over-the-counter hearing aids sounds confusing
- [ ] Prefer face-to-face appointments with my audiologist - I enjoy visiting my audiologist
- [ ] I don't think there are any disadvantages to over-the-counter hearing aids
- [ ] Other. Please specify

_____

How likely are you to try over-the-counter, user-programmable hearing aids?

Extremely likely	Somewhat likely	Neither likely nor unlikely	Somewhat unlikely	Extremely unlikely

0 1 2 3 4 5 6 7 8 9 10

How much would you pay for this service?

_____

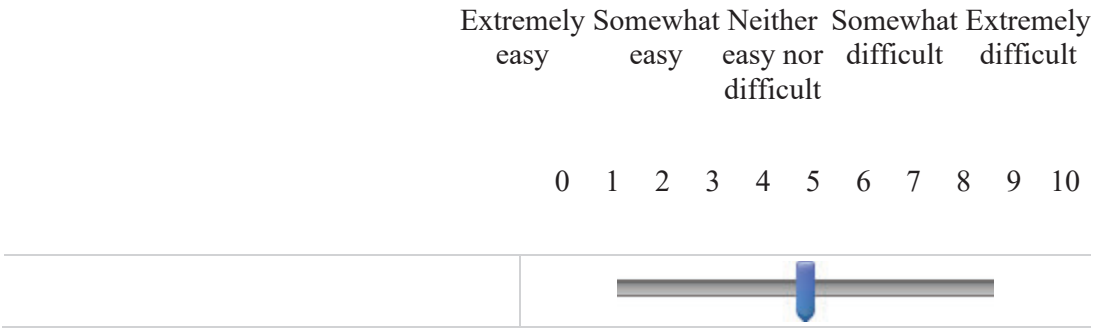
Traditional Audiology

This is how audiology is *currently* done across the world. You would visit an audiologist with concerns around your hearing – they conduct a hearing test and explain the results and talk through how hearing aids could help. They help you to decide on the style and size of the hearing aid, which are fit and programmed in the following couple of days. Every couple of weeks, you visit the audiologist again for adjustments until you are ready to finalise. The audiologist requests annual reviews of your hearing and your hearing aids.

Would you like access to this type of service?

- ○ Yes, it sounds like something I would like to try/I have already tried
- ○ No, I would rather try something else

How easy do you think traditional audiology is/would be to use?



How important do you think it is to have an audiologist select, fit and program your hearing devices?

Extremely important | Very important | Moderately important | Slightly important | Not at all important

0 1 2 3 4 5 6 7 8 9 10

I think traditional audiology is accessible for lots of different groups of people.

Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree

0 1 2 3 4 5 6 7 8 9 10

Which of the following statements about the potential advantages of traditional audiology do you agree with? Select all that apply.

- [ ] Timely and consistent visits
- [ ] Get support from an expert in hearing
- [ ] Better and informed decision making
- [ ] Adjustments are rapid because the audiologist is knowledgeable of different issues
- [ ] I don't think there are any advantages to traditional audiology
- [ ] Other. Please specify

_____

Which of the following statements about the potential disadvantages of traditional audiology do you agree with? Select all that apply.

- [ ] Time-consuming to travel to the clinic
- [ ] Have to deal with the hearing aid issues between clinic appointments
- [ ] I wouldn't have as much control over my own hearing needs
- [ ] The appointments are very short
- [ ] I don't think there are any disadvantages to traditional audiology
- [ ] Other. Please specify

_____

How much would you pay for this service?

_____

What factors do you find the most important in hearing healthcare? Select all that apply.

- [ ] The cost of the process and product
- [ ] The quality of the products, information and outcomes
- [ ] Scientific evidence behind why certain things are done
- [ ] Face-to-face interactions with experts
- [ ] Having a clinic near my home
- [ ] Other. Please specify

_____

Which method of hearing aid fittings and adjustments would you prefer? Please choose one.

- ○ Teleaudiology
- ○ Over-the-counter, user-programmable hearing aids
- ○ Traditional audiology and hearing aids (what we currently do)