Exploring the Efficacy of Motivational Messages in Tinnitus Management: A Comprehensive Investigation

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Abstract

Objective: This study aimed to assess the effectiveness and preferred content of motivational messages within a mobile therapeutic framework for tinnitus management.

Background: Tinnitus is a prevalent auditory condition often associated with distress and reduced quality of life. Motivational messaging interventions have emerged as potential tools for managing tinnitus symptoms and enhancing coping mechanisms.

Methods: A mixed-methods approach was employed, involving quantitative analysis of participant ratings on motivational messages and qualitative thematic analysis of participant interviews. Surveys were administered to assess participant demographics, tinnitus characteristics, and preferences for motivational message content.

Results: Findings revealed that motivational support messages and education around tinnitus received the highest ratings, with significant variations observed between genders and tinnitus characteristics. Qualitative insights emphasised participants' enthusiasm for motivational messages, while also highlighting concerns regarding effectiveness and intrusiveness. Gamification elements and community engagement were suggested to enhance intervention engagement and effectiveness.

Conclusions: The study provides valuable insights into the potential benefits and challenges of motivational messaging interventions for tinnitus management. Tailoring message content to individual preferences and needs, integrating gamification elements, and fostering community engagement are recommended strategies for enhancing intervention effectiveness. Further research, including longitudinal studies and personalised messaging approaches, is warranted to optimise tinnitus management strategies and improve patient outcomes.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

CN V	Trigeminal Cranial Nerve
CN VII	Facial Cranial Nerve
OHC	Outer Hair Cells
IHC	Inner Hair Cells
BM	Basilar Membrane
CN VIII	Vestibulocochlear Nerve
CN	Cochlear Nucleus
SOC	Superior Olivary Complex
MSO	Medial Superior Olive
LSO	Lateral Superior Olive
MNTB	Medial Nucleus of the Trapezoid Body
LL	Lateral Lemniscus
IC	Inferior Colliculus
INLL	Intermediate Nucleus of the Lateral Lemniscus
VNLL	Ventral Nucleus of the Lateral Lemniscus
DNLL	Dorsal Nucleus of the Lateral Lemniscus
MGN	Medial Geniculate Nucleus
VGMN	Ventral Medial Geniculate Nucleus
DGMN	Dorsal Medial Geniculate Nucleus
MMGN	Medial Division of the Medial Geniculate nucleus
SOAE	Spontaneous Otoacoustic Emission
DCN	Dorsal Cochlear Nucleus
CNS	Central Nervous System
AN	Auditory Nerve
GABA	Gamma-aminobutyric Acid
VCN	Ventral Cochlear Nucleus
TRT	Tinnitus Retraining Therapy
SNHL	Sensorineural Hearing Loss
dB DL	Decibel Sensation Level
TFI	Tinnitus Functional Index
TSCHQ	Tinnitus Sample Case History Questionnaire
CVD	Cardiovascular Disease
AI	Artificial Intelligence
FFM	Five Factor Model
PNS	Peripheral Nervous System

1 Introduction

Tinnitus, characterised by the perception of sound in the absence of external auditory stimuli, is a prevalent condition with significant implications for affected individuals. While some manage to cope with the condition, for others, it can lead to considerable distress, affecting various aspects of their lives. Approximately one-tenth of individuals with tinnitus report a major negative impact on their daily functioning, often experiencing symptoms such as insomnia, anxiety, depression, and difficulties in concentration and hearing (McKenna et al., 2014).

The prevalence of tinnitus varies among different demographic groups, with age and gender being significant factors. Research indicates that adults aged 65 and over are three times more likely to report tinnitus compared to younger age groups, with males also exhibiting a higher prevalence than females. Moreover, there are notable differences in tinnitus prevalence among ethnic groups, with European individuals reporting the highest rates (Wu et al., 2015).

Understanding the heterogeneity of tinnitus experiences is crucial, as individual psychosocial variables play a significant role in determining the degree of distress experienced. Factors such as personality traits and coping mechanisms contribute to the diverse manifestations of tinnitus and its impact on individuals' lives. Consequently, personalised treatment approaches are essential to address the unique needs of each patient (Kleinstäuber & Weis, 2021).

In the realm of audiological interventions, digital tools, including mobile applications, are gaining traction as potential aids in tinnitus management. These tools offer accessibility and autonomy to users, presenting opportunities for personalised counselling and support. However, the effectiveness of tinnitus-related apps remains largely underexplored, highlighting the need for further investigation into methods to enhance their efficacy (Searchfield et al., 2021).

One promising approach worth exploring is the use of motivational messaging, which has demonstrated effectiveness in various therapeutic contexts. By delivering tailored messages directly to patients' phones, motivational messaging holds promise in facilitating tinnitus management by addressing individual needs, motivations, and personality traits (Hall et al., 2015; Cole-Lewis & Kershaw, 2010; De Vries et al., 2017; Ferguson et al., 2018; Liu et al., 2023).

This study aims to contribute to the understanding of motivational messaging as a potential adjunctive therapy for tinnitus management. By investigating the types of messages that individuals with tinnitus find beneficial, this research seeks to inform the development of more effective interventions and improve outcomes for those affected by this condition.

2 Literature Review

2.1 Anatomy and Physiology of the Auditory System

The auditory system allows us to understand sounds within our environment. This section aims to introduce the structure and function of the auditory system and to understand the anatomical and physiological aspects relevant to the generation and perpetuation of tinnitus, a condition that affects countless people worldwide.

2.2 The peripheral auditory system

The peripheral auditory system comprises the outer, middle, and inner ears. Sound, a form of energy, is generated as energy waves propagate through a medium, setting particles into motion and engendering fluctuations in air pressure. These oscillations, characterised by alternating compression and rarefaction cycles, possess a frequency measured in Hertz (Hz), with the human auditory range typically spanning from 20 to 20,000 Hz (Peterson, 2022).

2.2.1 The outer ear

The outer ear comprises the aurical and the ear canal. The aurical, or pinna, is a strictly mammalian feature and serves as nature's acoustic collector. It is shaped in such a way that it allows for the collection of sound waves (Carlson, 2019). Once sound waves traverse the outer ear, they travel through the ear canal to the tympanic membrane, reaching the middle ear. In some cases, cerumen, infection, or foreign objects can obstruct the ear canal. A reduction in environmental sound from the ear canal being blocked can potentially exacerbate one's awareness of tinnitus (Searchfield, 2016). Where the ear canal is unaffected, it serves as a resonator, amplifying specific frequencies crucial for the perception of speech (Howarth, 2006). The vibrations generated travel through the middle ear chamber via the ossicles, also known as the middle ear bones, to reach the cochlea within the inner ear.

2.2.2 The middle ear

Within the middle ear, complex structures orchestrate the transmission of sound waves from the tympanic membrane to the inner ear. This space hosts the tympanic membrane (eardrum), the ossicles (malleus, incus, and stapes), along with their associated muscles and ligaments, and the eustachian tube. The main role of the eustachian tube is to maintain equilibrium in air pressure between the external environment and the middle ear. (Casale et al., 2018). Notably, the tensor tympani ligament, linked to the malleus, and the stapedius muscle, connected to the stapes, play pivotal roles in modulating sound transmission, innervated respectively by the trigeminal cranial nerve (CN V) and the facial cranial nerve (CN VII) (Qing & Mao-li, 2009).

When these sound waves reach the middle ear, they set the tympanic membrane into motion, initiating a cascade of vibrations among the bones, or the ossicles, of the middle ear. Among these, the stapes, equipped with a footplate, executes a piston-like action as it articulates with the oval window, effectively transmitting these vibrations into the vestibule of the inner ear. This dynamic process serves as the gateway to auditory sensation, channelling sound energy towards the delicate structures housed within the inner ear (Peterson et al., 2022; Casale et al., 2018). The oval window serves as the entrance point to the vestibule of the inner ear.

The middle ear acts as a crucial intermediary in the process of sound perception, employing complex mechanisms to translate acoustic stimuli into neural signals for further processing in the inner ear.

2.2.3 The inner ear

The inner ear, consisting of the auditory organ, known as the cochlear, and the vestibular organ, plays a crucial role in auditory processing. Within the cochlear, three distinct regions - the scala tympani, scala vestibuli, and scala media - house different fluids essential for sound transmission. Perilymph fluid fills the scala tympani and scala vestibuli, and endolymph fills the scala media, along with the basilar membrane and the organ of Corti (Peterson, 2022). When the middle ear transmits the vibration to the inner ear, the vibrations are then sent to perilymph within the cochlear. As sound vibrations reach the inner ear from the middle ear, they propagate through the perilymph, inducing fluid waves that traverse from the scala vestibuli to the scala tympani. The scala tympani is a hollow, bony tube, and at the end of it, vibrations in the perilymph cause displacement of the round window, an opening from the middle ear into the inner ear (Benson et al., 2020). Positioned between the scala vestibuli and scala tympani, the cochlear duct is a hollow, bony tube containing endolymph. This endolymph is characterised by higher potassium and reduced sodium ion concentrations. This ion composition is crucial for maintaining the electrochemical gradient across the scala media and surrounding perilymph, which is regulated by structures like the Reissner membrane and the stria vascularis (Casale et al., 2018).

The Reissner membrane acts as a barrier between the scala vestibuli and the cochlear duct, as well as the stria vascularis, with specialised cells lining the lateral wall of the cochlear duct. Separating the scala tympani from the cochlear duct, the basilar membrane (BM) contains the organ of Corti, a specialised structure in auditory transduction (Casale et al., 2018). In the organ of Corti, there are hair cells that vibrate in response to sound energy and cause their stereocilia to make contact with a stationary structure known as the tectorial membrane. The hair cells are divided into outer hair cells (OHCs) and inner hair cells (IHCs). There are three rows of OHCs and one row of IHCs. When the hair cells bend against the tectorial membrane, they activate attached nerve fibres through depolarisation. The frequency nerve of the vibration propagating through the perilymph corresponds to a specific region along the BM of the cochlear that experiences maximum stimulation. Put differently, varying sound frequencies generate distinct travelling wave patterns, resulting in peaks in sound energy amplitudes at various regions of the cochlea (Casale et al., 2018).

The width and stiffness of the BM vary along its length: narrower and stiffer at the cochlear base and wider and more flexible at the apex. Furthermore, elasticity decreases with distance from the cochlear base, being most pronounced at the apex (Casale et al., 2018). The variation in the BM forms a tonotopic map, facilitating the perception of diverse sound frequencies in humans. For instance, depending on the frequency of an auditory stimulus, a particular region of the BM will be activated. High frequencies elicit responses at the cochlear base, while lower frequencies are detected towards the apex (Ruggero, 1992).

OHCs amplify low-level sounds that enter the cochlear, while the inner hair cells transduce BM vibration into electrical activity, transmitting this information though the vestibulocochlear nerve (CN VIII) or the auditory nerve (Casale et al., 2018). This allows the information to reach the central nervous system for further processing (Bordoni et al., 2022).

2.1.2 The central auditory system & auditory pathways

Auditory signals from the periphery reach the nuclei of the auditory cortex via the auditory nerve. The auditory nerve has type I and type II fibres, where type I fibres form the afferent innervation of the IHCs, and type II fibres form the afferent innervation of the OHCs. Central and peripheral axons of type I cells are thin and myelinated, while axons of type II neurons are large in diameter and unmyelinated (Liu et al., 2015). The type I afferents, which make up 95% of the afferents in the auditory nerve, are primarily responsible for carrying acoustic information to the brain. (Rutherford et al., 2021). It is thought that information projected by these type I afferents goes to the higher centres of the cochlear nuclei. Type II afferents, making up 5% of the auditory nerve afferents, project mostly to the dorsal cochlear nucleus (Casale et al., 2018). Peterson et al., (2022) state that sensory information ascends along the following pathway:

- Ipsilateral cochlear nucleus
- Superior olivary complex—most fibres cross over to the contralateral superior olivary complex; some remain on the ipsilateral superior olivary complex
- Contralateral and ipsilateral lateral lemniscus nuclei
- Contralateral and ipsilateral inferior colliculi
- Contralateral and ipsilateral medial geniculate nuclei
- Contralateral and ipsilateral transverse temporal gyrus (auditory region)

The CN is the first relay point of the brainstem along the auditory pathway. The CN is located on the dorsolateral surface of the brainstem, where the medulla and pons meet (Dublin., 1982).

The superior olivary complex (SOC) has three main nuclei: the medial superior olive (MSO), the lateral superior olive (LSO) and the medial nucleus of the trapezoid body (MNTB). These nuclei all receive input from the CN bilaterally. The MSO is believed to help with sound localisation by measuring the time difference of arrival sounds between the ears. The LSO also helps with sound localisation but does so by employing intensity. Finally, the MNTB is a crucial source of inhibition. The MNTB produces inhibitory output to sound localisation nuclei to help with timing disparities (Zhang et al., 2021). The lower tiers of the central auditory pathways are classified as monaural since they solely receive sensory inputs from the ear on the same side (ipsilateral). However, from the SOC, auditory pathway nuclei transition to a binaural arrangement, receiving inputs from peripheral auditory structures on both sides of the head. This binaural setup facilitates more precise localisation of auditory stimuli.

The lateral lemniscus (LL) is a fibre bundle connecting the CN and the SOC with the inferior colliculus (IC). There are three striae within the LL, with nuclei on each. These are the intermediate nucleus of the LL (INLL), the ventral nucleus of the LL (VNLL), and the dorsal nucleus of the LL (DNLL). These are termed by their position within the LL. Neurons in the INLL are thought to show spectral integration in complex auditory scenes. The VNLL is known to reduce spectral splatter by suppressing spurious frequencies through the generation of feedback-forward inhibition (Kladisios et al., 2022). Finally, the DNLL serves as a temporal-binaural filter, suppressing sound source information during the prolongation of a sound, by producing long lasting inhibition (Felmy & Meyer, 2020).

In the midbrain lies the nucleus, the IC. The IC is an important relay point, it receives both ascending and descending projections. Descending projections come from the cerebral cortex, while ascending projections come from multiple brainstem nuclei. The IC is a critical piece of the auditory pathway, as nearly all ascending information will pass through here on its way to the forebrain (Rees, 2020). It plays important roles in sound localisation by integrating input from both ears, the startle response, pitch discrimination, and rhythm (Driscoll & Tadi, 2023). The IC has cells that are responsive, dependent on the horizontal and vertical angles, and the rhythm by which sounds arrive.

The medial geniculate nucleus (MGN) sits in the auditory thalamus and is critical as a relay station for auditory information processing. It receives input from the lower auditory brainstem nuclei and projects its output to the primary auditory cortex and surrounding auditory cortical areas. This relay function makes it a bottleneck for auditory information for neural representations of sounds being sent to the auditory cortex (Barlett, 2013). The MGN has three major divisions, the ventral, dorsal, and medial geniculate nuclei (VGMN, DGMN, and MMGN).

Auditory nuclei in the central auditory system exhibit a tonotopic organisation. This helps aid in the representation of sound characteristics within the environment. Neurons process intensity and attenuation by adjusting their firing rates according to the sound's strength, with heightened sound levels correlating to increased neuronal activity. Specialised neurons are tuned to respond optimally to specific ranges of sound intensity. To accurately pinpoint the source of a sound, the brain relies on the binaural auditory pathways exhibited by the various nuclei mentioned, along the auditory pathway. Combination-sensitive neurons, found in regions like the IC, LL, MGN, and auditory cortex, exhibit varied responses to different acoustic elements. These neurons, which can be either facilitating or inhibitory, are believed to play a role in identifying crucial sound cues critical for communication (Peterson et al., 2022).

Descending pathways play a significant role in modulating the processing of sound stimuli. These pathways originate from the auditory cortex and extend downward, directly projecting to key areas such as the IC, SOC and CN. Modulatory signals from these pathways adjust responses based on learned behaviours, emotional states, and the allocation of attention and relevance to the stimulus. These higher-order functions originate from various brain regions, including the prefrontal cortex, hippocampus, nucleus basalis of Meynert, and limbic circuits, which possess either direct or indirect connection with each other and the auditory cortex (Peterson et al., 2022).

2.2 Tinnitus, an overview

2.2.1 History and prevalence

Evidence of tinnitus symptoms can be traced back to ancient Egyptian and Mesopotamian civilizations. Despite disagreements regarding the translation and true authorship of writings describing sounds akin to tinnitus, it is clear that tinnitus has been recognised as a symptom since ancient times (Dietrich et al., 2004). This highlights the fact that the sensation of tinnitus is not a recent discovery. During the 19th century, the contributions of Jean Marie Gaspard Itard, a Frenchman, significantly progressed the understanding of tinnitus, introducing innovative concepts that remain relevant today. Most tinnitus cases are linked with hearing impairment. Itard provided early distinctions between objective and subjective tinnitus and acknowledged the often unsuccessful nature of treatment, emphasising the importance of alleviating the distress caused by tinnitus, often through masking techniques (History of Tinnitus - Oregon Tinnitus & Hyperacusis Treatment Clinic, Inc., 2019).

The exact prevalence of tinnitus among adults in New Zealand remains uncertain, as global estimates vary significantly. This uncertainty likely stems from challenges in defining and measuring tinnitus. A systematic review carried out in 2022, covering articles across 49 years, revealed a combined prevalence of adults experiencing any type of tinnitus to be 14% (Wu et al., 2015; Tinnitus: The Sound of Silence - Bpacnz, n.d.).

Regarding gender differences in tinnitus, evidence is inconsistent. Although certain international studies propose that males are at a greater risk of experiencing tinnitus, others suggest a higher prevalence among females or no apparent disparity between genders (Cedderroth & Schlee, 2022). Occupation may serve as a contributing factor as exposure to loud noises and hearing loss, both associated with tinnitus, are more prevalent among males, particularly in industries such as automotive and construction (Le et al., 2017).

Reports indicate a higher occurrence of tinnitus among people of European ethnicity compared to other ethnic groups. The underlying reasons for this discrepancy remain unclear but are likely influenced by ethnicity-related variations in socioeconomic factors and access to healthcare services (Bhatt, 2018).

2.2.2 Definition

A concise and single definition of tinnitus is difficult to determine, as the condition is often idiopathic. The most common definition used for tinnitus is the conscious awareness of a sound in the absence of an external auditory source. Many versions of this definition are used, including "perception/awareness of sound without, lacking, or in the absence of an external sound source/stimulus" (Han et al., 2009). Commonly used descriptors for tinnitus include ringing, buzzing, roaring, or hissing, which are experienced within the ears or head of the affected individual. Mostly, it is described as a "ringing in the ears" (Messina et al., 2022). This sound can be present in both ears, one ear, inside, or outside the head. For some, tinnitus is a consistent or chronic phenomenon, while for others, it is transient or acute. Tinnitus is generally categorised into two groups: objective and subjective tinnitus (Han et al., 2009). Objective tinnitus is a rare phenomenon. It relates to sounds produced inside the body that reach the ear(s) through tissue conduction and are audible to both the patient and an outsider. Objective tinnitus can have various origins, such as muscular, respiratory, vascular, or temporomandibular joint sources (Lanksa, 2023). In contrast, subjective tinnitus refers to an auditory perception that the person experiences alone, independent of any external auditory source.

Within the literature, the term tinnitus encompasses various forms of subjective tinnitus, each characterised by distinct severities, attributes, and causal factors (Haider et al., 2018). As a result, interpreting epidemiological studies on tinnitus can be challenging, as different studies employ varying definitions and classifications. In the context of this study, tinnitus is defined as constant, bothersome for a minimum period of six months, or tinnitus that is sufficiently severe as determined by a score of 18+ on the TFI. The diagnosis of tinnitus relies on self-report, a patient's medical history, and an evaluation of its impact on the individual's quality of life (using the Tinnitus Functional Index Scale), given the absence of standardised objective tests. Because of the complexity of tinnitus presentation and effect, management is also complex and individual (Liu, 2021). Although there is no known cure for tinnitus, therapy has shown benefits in a number of studies.

2.2.3 Causes, risk factors and comorbidities

Determining the precise origin of an individual's tinnitus can be challenging, as there are various factors that can contribute to its development (Han et al., 2009). Tinnitus is not an ailment or medical condition but rather a manifestation of an underlying issue (Patil et al., 2023). It frequently accompanies damage or disruption to the auditory system (Haider et al., 2018). Tinnitus can arise from multiple areas of the auditory system, including the outer, middle, and inner ear, and it can be sensorineural, conductive, or a mixed hearing loss, i.e., a combination of both. While not all tinnitus sufferers experience hearing loss, research indicates that around 90% of people with tinnitus also have some form of hearing impairment, whether it is detected or not (Han et al., 2021). Tinnitus can also arise from specific non-pathological circumstances, such as impacted earwax (Chan et al., 2020).

Genetic and environmental factors may influence tinnitus. A significant genetic origin of tinnitus has arisen in some of the literature, where the inheritability of bilateral tinnitus in males was estimated at 0.68 and 0.41 for females (Maas et al., 2017). Environmental factors, including noise exposure, ageing, and other factors that induce hearing loss, have been extensively examined for their impact on tinnitus. Ototoxic medications, head, or neck injuries, and various otological conditions can also be responsible. Nevertheless, the cause of tinnitus remains unexplained in many cases. Lifestyle choices can also influence the loudness perception and associated annoyance of tinnitus. These include alcohol and caffeine intake, sodium consumption, sleep patterns, smoking, stress, and hydration levels (Biswas et al., 2021). Medical pathologies such as hypertension, arteriosclerosis and arthritis are also known to coexist with tinnitus (Nondahl et al., 2011). This further supports the individualised nature of tinnitus, as each person will have their own unique lifestyle implications.

Two of the most prevalent risk factors for tinnitus are age-related hearing loss (presbycusis) and noise-induced damage. Hearing loss is considered a risk factor rather than a cause because individuals with normal hearing can also experience tinnitus. Additionally, tinnitus can manifest as a symptom of underlying conditions such as Meniere’s disease, vestibular schwannomas, and otosclerosis (Han et al., 2009). Furthermore, tinnitus has been associated with conditions such as anxiety and depression (Hackenberg et al., 2023). These risk factors and associated comorbidities underscore the intricate interplay between genetic and environmental elements that contribute to the onset of tinnitus, although it is not yet fully understood (Rhee et al., 2020).

2.3 Pathophysiology

Tinnitus is a symptom associated with various pathologies, suggesting involvement of all levels of the nervous system to varying extents (Han et al., 2009).

2.3.1 Pathophysiology in the peripheral auditory system

Spontaneous otoacoustic emissions

In the peripheral auditory system, spontaneous otoacoustic emissions (SOAEs) are sounds produced by the ear without an external acoustic trigger and can be detected using microphones inserted into the external ear canal (Young & Ng, 2023). These are produced continuously without external stimuli. These emissions generally range in frequency from 500 Hz to 4.5 kHz. While typically inaudible, unstable SOAEs, particularly in the higher frequency ranges, can be perceived as tinnitus, although usually mild. Approximately 1 to 9% of individuals can perceive their SOAE as tinnitus (Young & Ng, 2023). SOAEs are associated with normal cochlear function and are not considered the sole cause of tinnitus. SOAEs causing tinnitus are estimated to account for 1 to 2% of tinnitus patients (Samuels et al., 2003).

Edge theory

Additionally, the "edge theory" proposes that tinnitus arises from heightened spontaneous activity at the transition zone between relatively normal and damaged OHCs. This cochlear disruption, leading to tinnitus, results from a displacement of OHCs within the organ of Corti, shifting from the apical side towards the lesion located at the high-frequency basal side, where OHCs are either absent or exhibit pathological features and reduced functionality (White et al., 2023; Haider et al., 2018). The discordant theory helps to further explain edge theory (Han et al., 2019).

Discordant theory

Discordant and edge theory try to explain the generation of tinnitus after exposure to ototoxic drugs and/or noise (Dubey, 2022). Discordant theory elaborates on the dysfunction between damaged OHCs and intact IHCs as the primary mechanism (Han et al., 2009). This discordance leads to increased neuronal activity in the auditory system, perceived as tinnitus. Furthermore, discordant damage between OHCs and IHCs is implicated in noise induced tinnitus, which can manifest as either tonal or complex tinnitus depending on the extent of discordance (Han et al., 2019). Research indicates that IHCs exhibit greater resistance to ototoxic drugs and noise-induced damage when compared to OHCs (Dubey, 2023).

2.3.2 Pathophysiology in the central auditory system

Dorsal cochlear nucleus

The dorsal cochlear nucleus (DCN) has been proposed as a potential origin for signals, as it tends to become overactive after exposure to tinnitus-inducing factors like loud noise and cisplatin. Damage to OHCs triggers adaptive changes in the DCN, leading to its increased activity. It is theorised that reduced input from the auditory nerve disinhibits the DCN, causing heightened spontaneous activity within the central auditory system, resulting in tinnitus (Han et al., 2019). This may explain the brief ringing sensation that follows exposure to loud noise (Browne et al., 2012). Plastic changes in the DCN occur gradually and result in delayed onset tinnitus. Conversely, damage to IHCs prevents hyperactivity in the DCN (Han et al., 2019).

Auditory neural plasticity theory

Neural plasticity, the capacity for the brain to undergo adaptive changes in structure and function, in response to the type and pattern of neural input, is widely recognised (Dubey, 2022; Puderbaugh & Emmady, 2023). This theory posits that cochlear damage amplifies neural activity within the central auditory pathway. This phenomenon arises from abnormal pathways, with tinnitus likened to phantom limb sensations in amputees. Research has demonstrated heightened neural activity in the IC, amygdala, and notably the left temporal lobe in patients reporting tinnitus as their primary concern, during neuroimaging (Wang et al., 2002). Studies have shown that increased activity in the amygdala follows salicylate treatment, a reliable method for inducing tinnitus (Henry et al., 2014).

Tinnitus and phantom pain are suggested to have similarities. These may include their subjective nature, persistence in certain instances, and potential to vary in quality over time. Underlying brain mechanisms, associated brain areas and therapeutic responses also show similarities. Research indicates that neural plasticity plays a role in numerous instances of tinnitus. Additionally, parallels have been observed between the perception of pain and the experience of chronic tinnitus (Peker & Sirin, 2016).

Crosstalk Theory

Crosstalk theory suggests that intact auditory nerve fibres and damaged cranial nerves can develop artificial synapses, or crosstalk, leading to phase-locking of spontaneous activity among groups of auditory neurons (Kaltenbach et al., 2000). This neural pattern resembles those evoked by actual sounds, potentially resulting in tinnitus. Crosstalk typically occurs when cranial nerves are compressed at the boundary between the CNS and the PNS, where they are encased in myelin (Han et al., 2009). This compression prompts crosstalk and breakdown of this myelin sheath, establishing ephaptic coupling between nerve fibres, which can affect the synchronisation and timing of action potential firing in neurons (Kaltenbach et al., 2000). This theory is particularly relevant to the cochlear-vestibular nerve, vulnerable to compression from structures like blood vessels or tumours, potentially leading to tinnitus. Tinnitus is a significant concern among patients with acoustic neuroma or vestibular schwannoma. This theory aims to elucidate the origin of tinnitus in such cases (Dubey, 2022).

2.3.3 Non-auditory pathomechanisms for tinnitus

The somatosensory system

This system influences DCN activity, where non-auditory structures, particularly the somatosensory system, are associated with tinnitus (e.g., temporomandibular-joint syndrome and whiplash). Temporomandibular joint syndrome and whiplash injuries can lead to the onset of tinnitus due to damage to cranial nerves, V, VII, IX, and X fibres (Dubey, 2022). This results in alterations in the DCN which sends irregular signals to the central auditory pathway, creating the perception of tinnitus. Additionally, pain signals from cochlear C fibres may also be interpreted as tinnitus by the CNS (Han et al., 2019).

Limbic and autonomic nervous systems

Current theories are inadequate in explaining why certain individuals develop tinnitus while others do not. Interestingly, over 80% of those who perceive tinnitus initially do not attribute negative connotations to it and naturally adapt overtime. (Han et al., 2019). However, high levels of annoyance or anxiety upon initial perception of tinnitus, possibly due to unpleasant stimuli or stress, can lead to persistent annoyance or anxiety over time. Unconscious escalation of tinnitus can result in heightened activity in the limbic and autonomic nervous systems, leading to clinically significant tinnitus. The generation of tinnitus in individuals with underlying emotional stress or neurotic conditions such as anxiety and depression has been attributed to aberrant neural input from the limbic system (Dubey, 2022).

2.3.4 Common co-morbidities and associated pathologies

Age-related hearing loss

Age-related changes in the auditory system are prevalent and multifaceted, contributing to hyperactivity as individuals age. With advancing age, both humans and animals commonly experience inner-ear dysfunction characterised by various structural alterations. These include a reduction in the number of neurons within the cochlear nucleus (CN), decline in hair cell numbers, and degeneration of spiral ganglion cells and the stria vascularis (Herrmann & Butler, 2021). The peripheral changes associated with ageing play a significant role in triggering hyperactivity within the auditory system. As hearing abilities diminish, the brain may attempt to compensate for auditory deprivation by generating these phantom sounds, or tinnitus. It is theorised that hyperactivity in ageing individuals stems from a heightened activation of neurons in response to the same stimulus input compared to younger counterparts. Moreover, the cumulative effects of ageing increase susceptibility to factors that can damage hearing over time. Prolonged exposure to loud sounds, often encountered throughout one's lifetime, can lead to acoustic injury and subsequent hyperactivity. Additionally, older generations may have been exposed to occupational noise without adequate hearing protection, reflecting evolving knowledge regarding hearing conservation practices. Furthermore, the prolonged lifespan of individuals allows for greater exposure to medications and potential ototoxic pharmaceuticals, which can exacerbate age-related changes in auditory function. The accumulation of these factors over time contributes to the increased prevalence of hyperactivity in ageing populations (Herrmann & Butler, 2021).

Drug treatment

Certain indispensable therapies, such as chemotherapy, often entail the use of ototoxic drugs, which, while crucial for treating various medical conditions, can inadvertently lead to damage within the auditory system. These ototoxic drugs, including some antibiotics and anti-inflammatories, have the potential to induce hearing loss or other auditory disorders as side effects.

Cisplatin, a prominent chemotherapy drug, exemplifies this phenomenon by selectively targeting outer hair cells (OHCs), as demonstrated in studies like that of Henry et al. (2014). The administration of cisplatin has been shown to result in the destruction of more than 50% of OHCs. Similarly, carboplatin, another chemotherapy agent, has been associated with damage to 30-40% of inner hair cells, contributing to subsequent hyperactivity in the auditory system.

In response to the damage inflicted by ototoxic drugs, the central nervous system (CNS) initiates compensatory mechanisms, including enhanced spontaneous firing rates within the DCN and increased inhibitory activity, resulting in hyperactivity, as proposed by Saunders (2007). However, it is noteworthy that the relationship between hair cell damage and hyperactivity is not linear. Studies indicate that once over 75% of hair cells are damaged, the hyperactivity response diminishes, suggesting that milder forms of damage may be more relevant in inducing hyperactivity within the auditory system.

While ototoxic drugs are sometimes indispensable for medical treatment, it is crucial to acknowledge their potential adverse effects on peripheral and midbrain auditory structures, as highlighted by Herrmann & Butler (2021). The DCN, which directly receives input from the periphery, is particularly vulnerable to detrimental impacts from ototoxic drugs, underscoring the importance of monitoring and managing auditory health in patients undergoing ototoxic drug therapies.

Ototoxic drugs play a critical role in medical treatments; however, their potential to induce damage within the auditory system, particularly in peripheral and midbrain structures like the DCN, necessitates careful consideration and monitoring to mitigate the risk of hearing-related complications which can in turn cause tinnitus.

Acoustic injury

Exposure to high-intensity sound poses a significant risk to cochlear health, potentially resulting in a range of damages such as hair cell loss, stereocilia damage, and basilar membrane damage, among others (Herrmann & Butler, 2021). While this phenomenon is well-documented in humans, it is often more extensively studied in animal models, which offer valuable insights through controlled experiments. Animal studies allow researchers to compare groups exposed to high-intensity sound with control groups, facilitating the investigation of auditory system responses. Through invasive neurophysiological procedures, such as electrophysiological recordings, researchers can observe changes in spontaneous firing rates within the cochlear nucleus following sound exposure. Studies have demonstrated that animals exposed to specific frequencies of high-intensity sound exhibit reduced activity in neurons corresponding to the exposed frequency. Consequently, neurons tuned to frequencies outside the exposure stimulus frequency become hyperactive, as elucidated by Shore et al. (2016). Moreover, animals exhibiting behavioural characteristics of tinnitus often display hyperactivity in neurons proximal to the frequency of the noise exposure.

It is hypothesised that acoustic trauma leading to reduced auditory nerve activity triggers compensatory plastic adjustments in the dorsal cochlear nucleus (DCN), aimed at counteracting the diminished activity in the auditory nerve (AN). This phenomenon, referred to as plastic adjustment, may serve as a basis for hyperactivity in the DCN and the subsequent development of tinnitus, as proposed by Pilati et al. (2022).

In human populations, ongoing exposure to damaging levels of sound, whether through occupational or recreational activities, can induce changes linked to hyperactivity within the central auditory system. However, individuals often underestimate the potential harm of prolonged sound exposure and may forgo hearing protection due to social stigma, particularly in recreational settings.

Acoustic Deprivation

Acoustic deprivation, characterised by a reduction in auditory input, can lead to hyperactivity within the auditory system. This deprivation disrupts the delicate balance between inhibition and excitation, triggering neural plasticity and subsequently causing hyperactivity. These plastic changes, once established, may prove challenging to reverse and have the potential to become permanent. Auditory deprivation can manifest at various ages, with age-related hearing loss being the most common cause. However, factors such as ear canal obstruction or infection can also contribute, particularly in children. Complications may arise, as children are less likely to recognize associated symptoms such as tinnitus (Moller, 2011). Individuals with hearing loss often experience frequency-specific deficits, gradually losing the ability to perceive certain sounds as their condition worsens. Over time, prolonged lack of auditory input leads to a 'forgetting' of this information by the brain. While contextual cues and memory may initially help fill in missing auditory information, prolonged deprivation eventually erases this memory. The reduction in auditory input prompts compensatory mechanisms within the auditory system, resulting in hyperactivity and the perception of phantom sounds, particularly in patients with tinnitus. Studies indicate that over 90% of individuals with tinnitus exhibit deprivation over a range of frequencies (Dotan & Shriki, 2021). Pathologies that tip the balance towards excessive inhibition may lead to the overexcitation of neurons, contributing to the manifestation of tinnitus. Understanding the link between auditory deprivation, hyperactivity, and tinnitus sheds light on the underlying mechanisms of this auditory disorder. By elucidating these mechanisms, researchers and clinicians can develop targeted interventions aimed at alleviating symptoms and improving the quality of life for individuals affected by tinnitus.

2.3.5 Hyperactivity in the Auditory System

The auditory system has very intricate functioning. It comprises a set of hierarchically arranged nuclei that function together to deliver information from the cochlea to the auditory cortex. Disruptions in this system can lead to a phenomenon known as hyperactivity. The functioning of the auditory system relies heavily on the balance between excitatory and inhibitory neurotransmission. This balance is critical to maintaining proper neuronal activity and information processing. In the context of hyperactivity resulting from damage to peripheral auditory structures, understanding the role of inhibition becomes key to modulating excessive neuronal firing.

Gamma-aminobutyric acid (GABA) and glycine are the two most prominent inhibitory neurotransmitters, which are primarily responsible for inhibition within the auditory system. GABA acts as the principal inhibitory neurotransmitter in the CNS, including the auditory pathway. It exerts its inhibitory effects by binding to GABA receptors, thereby hyperpolarising postsynaptic neurons and decreasing their likelihood of firing action potentials. Similarly, glycine, predominantly found in the brainstem auditory nuclei, acts through glycine receptors to inhibit neuronal excitability. The functions of these inhibitory neurotransmitters in regulating hyperactivity involve several mechanisms.

Tonic Inhibition

Tonic inhibition involves GABAergic and glycinergic neurons, providing continuous, low-level inhibition. This background inhibition serves to maintain the resting membrane potential of neurons, preventing them from firing excessively in the absence of stimulation. Dysregulation of tonic inhibition can contribute to hyperactivity by disrupting this balance. Tonic inhibition works as a sort of neural switching mechanism, with its potential to both suppress and activate motor behaviour depending on the extent of electrical activity in the inhibitory pathways.

Phasic Inhibition

Phasic inhibition works to reduce the excitatory activity that sensory inputs evoke. This occurs in response to specific stimuli, where inhibitory interneurons release GABA and glycine in a phasic manner. Where there is hearing loss, alterations in phasic inhibition may lead to disinhibition of excitatory pathways, exacerbating hyperactivity.

Feedback inhibition

Feedback inhibition is a mechanism in which feedback from higher auditory centres allows the regulation of the gain of auditory processing and filters out irrelevant or redundant signals. This occurs by modulating neuronal activity within the lower auditory nuclei from these higher auditory centres. Again, where there is hearing loss, this can create dysfunction in feedback inhibition and can therefore contribute to hyperactivity by disrupting the normal processing of auditory information.

Synaptic Plasticity

A further inhibitory mechanism is synaptic plasticity. Here, inhibitory transmission allows for the synapses to undergo long-term changes in strength. If there are problems with inhibitory neurotransmission, it can change the balance between excitation and inhibition at synapses. This can cause synaptic plasticity to go wrong and make the auditory system more active than usual.

A delicate balance between excitation and inhibition must occur to regulate hyperactivity within the auditory system. Inhibitory mechanisms play a significant role in maintaining this balance. Where inhibitory neurotransmission faces dysregulation, in the case of things such as hearing loss, the balance may be disrupted, causing excessive neuronal firing and aberrant auditory processing. This loss of excitatory and inhibitory balance can lead to an increase in activity because there is nothing keeping the neurons going from the cochlea nucleus to other centres from being active spontaneously. The inhibitory neurotransmitters are diminished. Damage to the edges of the brain is often what causes this hyperactivity. It can be seen in the CN, IC, SOC, MGN, and AC (Herrmann & Butler, 2021).

The impact of hyperactivity on the auditory system is critical in understanding auditory disorders such as tinnitus, as hyperactivity within specific auditory regions can contribute to the manifestation and progression of tinnitus. The IC, a critical relay centre in the auditory pathway, has been implicated in hyperactivity associated with tinnitus. Understanding the relationship between hyperactivity in the IC and tinnitus provides insights into the mechanisms underlying the disorder.

Hyperactivity in the cochlear nucleus resulting from damage to the peripheral auditory system triggers a cascade of adaptive responses within the auditory pathway, highlighting the concept of neural plasticity. Specifically, the DCN, a pivotal structure in auditory processing, undergoes significant changes in response to hyperactivity. These changes involve alterations in excitatory and inhibitory circuits, ultimately leading to an increase in spontaneous neural activity. Studies, such as Manzoor et al. (2012), have demonstrated that ablation of the DCN results in significant reductions in hyperactivity within the IC. It has also been proposed that the DCN acts as an initial site for hyperactivity, with subsequent relay of this hyperactivity to higher auditory structures. Early intervention targeting the DCN may prevent the progression of hyperactivity to higher auditory regions associated with tinnitus (Shore et al., 2016).

Evidence also suggests that hyperactivity may be present in the ventral cochlear nucleus (VCN). Studies have shown increased spontaneous firing rates in animals within the VCN following cochlear damage. It is hypothesised that the DCN projecting to the VCN may contribute to this hyperactivity, which could subsequently be relayed to higher levels of the auditory pathway (Vogler et al., 2011). While there is evidence implicating the VCN in hyperactivity associated with tinnitus, research predominantly supports the DCN as the primary locus of hyperactivity in the auditory system.

Hyperactivity within auditory regions, such as the DCN and IC, can lead to the perception of tinnitus by generating phantom auditory sensations. The increased spontaneous firing rates observed in these regions contribute to the generation and maintenance of tinnitus symptoms such as ringing, buzzing, or hissing sounds, as mentioned previously. Dysregulation of inhibitory mechanisms and disruption of the excitatory-inhibitory balance in hyperactive regions may amplify neural activity, leading to the manifestation and progression of tinnitus.

One mechanism underlying neural plasticity in response to hyperactivity is synaptic remodelling. Following damage to the peripheral auditory structures, the balance between excitatory and inhibitory inputs to the DCN is disrupted. This imbalance can lead to structural changes at the synaptic level, such as alterations in the number and strength of connections between neurons. Synaptic remodelling allows the auditory system to adapt to the altered input patterns and restore balance in neuronal activity.

Additionally, homeostatic plasticity mechanisms play a crucial role in regulating neuronal excitability in the face of hyperactivity. In conditions of increased spontaneous firing, neurons may undergo homeostatic adjustments to maintain overall stability in network activity. To stop neurons from firing too much and bring homeostasis back, this could be done by changing things like the scaling of synaptic strength or the modulation of intrinsic excitability.

The auditory system's capacity for plasticity extends beyond synaptic changes to encompass a broader reorganisation of neuronal circuits. In response to hyperactivity, there may be a rearrangement of excitatory and inhibitory neurons within the DCN, aimed at restoring the balance between excitation and inhibition. This reorganisation allows the auditory system to adapt to the altered sensory environment and optimise information processing.

Furthermore, changes in the release of neurotransmitters contribute to plasticity in the auditory system. Damage to the peripheral auditory structures can lead to alterations in the expression and function of neurotransmitters such as glycine and GABA, as mentioned earlier. These changes in neurotransmitter release influence the excitability of DCN neurons and contribute to the development and maintenance of hyperactivity. If the balance between excitatory and inhibitory neurons is upset, plasticity can start. This can lead to increased excitability, rearranging of excitatory and inhibitory neurons, and changes in the release of neurotransmitters (Zhang et al., 2006).

2.4 Impact on lives

It is important to manage a person's tinnitus, particularly when they find it problematic in their lives. For each individual, tinnitus will have a different effect. Tinnitus is very complex in that it is heterogenous (Cedderroth et al., 2019). The degree to which it will affect an individual will depend on a number of factors. Factors can include how severe it is, whether it is continuous, pulsed, or transient, associated comorbidities, treatment approach, and how the individual responds to it at a psychological level. Interestingly, the perceived severity of tinnitus may not always align with its clinical severity (Kennedy et al., 2004). These factors all play a pivotal role in shaping the tinnitus experience, influencing its consequence on quality of life (Cedderroth et al., 2019; Kennedy et al., 2004).

Adults experiencing chronic tinnitus frequently express that their condition is linked to emotions such as sadness, anxiety, frustration, and anger. These emotional responses can result in challenges with sleep, relaxation, and concentration. This, in turn, can lead to effects on workplace relationships and limit social activities. Productivity at work may also be affected.

Individuals may struggle to focus on tasks, attend meetings, or engage in conversations, leading to decreased efficiency and effectiveness. Tinnitus can also alter an individual's sense of self and identity, particularly if it affects their ability to communicate, socialise, or engage in activities that define who they are. The loss of identify can contribute to feelings of loss, grief and diminished self-esteem. Challenges adapting to a life with tinnitus, including past adverse events such as traumatic incidents, can also inhibit adjustment and prolong distress (Erlandsson et al., 2020).

Children may exhibit symptoms like disrupted sleep, potentially leading to challenges in focusing, maintaining attention, and experiencing fatigue. Additionally, they may face social isolation, heightened risk of mental health issues, and physiological manifestations such as dizziness and headaches (Tegg-Quinn et al., 2021). Despite these challenges, children are less likely to disclose their tinnitus compared to adults and may exhibit less distress, often being more easily distracted from its effects.

Some people will be better at managing the symptoms of their tinnitus than others, and as a result, they will cope better. Mental, physical, and social consequences will vary as a result of the individual manifestation. Consequently, the impact on the lives of individuals dealing with tinnitus can vary widely (Rademaker et al., 2021).

2.5 Factors that Sustain or Promote Tinnitus

2.5.1 Mental Health

Research has shown that those who experience conditions such as depression or anxiety will be more likely to have a larger negative impact on their lives from tinnitus. Additionally, in clinical settings, tinnitus patients commonly exhibit a heightened incidence of psychological comorbidities. Studies indicate prevalence rates for depressive disorders among tinnitus patients ranging from 14% to 80% (Stobik et al., 2005). Furthermore, a comprehensive review focusing on the relationship between tinnitus and depression analysed 20 studies, of which 90% showed a positive correlation between the two (Geocze et al., 2013). Notably, the majority of these studies were cross-sectional and only one had a substantial sample size of over 500 patients (Hiller et al., 1997). A further study with a sample size of over 50,000 showed that participants with tinnitus demonstrated notably elevated levels of anxiety and depression, alongside diminished self-esteem and well-being compared to those without tinnitus. The effect sizes were modest and remained consistent across various degrees of tinnitus symptom severity (Krog et al., 2010).

Despite tinnitus perception often being close to the audibility threshold, it can trigger emotional responses that exacerbate symptoms in certain individuals. Whether people have tinnitus because of their depression and anxiety, or whether these conditions present as a result of their tinnitus, is unknown in some cases. Halford and Anderson (1991) proposed a bidirectional relationship between tinnitus and anxiety, where each can influence the other. The severity of the anxiety or depression also relates to the severity of the tinnitus perception (Hackenberg et al., 2023). Another condition closely related to tinnitus is sleep difficulties, or insomnia. Tinnitus often results in difficulty getting to sleep or staying asleep. Irritability, mood changes, distractibility, stress, and frustration are further common complaints (Watts et al., 2018).

2.5.2 Personality

Personality refers to the distinctive pattern of thoughts, emotions, and behaviours exhibited by an individual (Van Munster et al., 2019). Personality can influence decisions and actions, as well as significantly impact a wide array of health outcomes and underlying mechanisms (Ferguson, 2013). Numerous studies have explored the correlation between personality traits and various diseases, such as cardiovascular disease and cancer. A comparable connection may exist between personality traits and tinnitus. Skewed perception of tinnitus can arise where individuals with excessively negative perceptions of their condition may lead to heightened distress thereby perpetuating factors.

In a study conducted in 2014, Mucci et al. reviewed the evidence linking tinnitus with personality. The literature reviewed spanned from 1968 to 2012 (Van Munster et al., 2019). They found that tinnitus correlates with several personality traits, particularly high neuroticism (Mucci et al., 2014). A further study identified associations between tinnitus distress and various personality traits, such as high neuroticism and low extraversion (Durai & Searchfield, 2016), supporting Mucci et al. (2014)'s study. Langguth and colleagues employed the "Five Factor Model" (FFM) to characterise the personality traits of individuals with tinnitus. Their findings indicated that tinnitus patients typically exhibit elevated levels of neuroticism and decreased levels of agreeableness (Langguth et al., 2007). Simões et al., 2019 used a cross-sectional examination to look at the relationship between personality and tinnitus distress, which reaffirmed the findings previously mentioned. Specifically, they found that neuroticism and agreeableness were positively correlated with tinnitus distress, whereas extraversion exhibited a negative association with distress (Simões et al., 2019).

Tinnitus patients also exhibited a higher likelihood of Type D personality (characterised by negativity and decreased socialisation). Personality factors in a tinnitus New Zealand longitudinal birth cohort were examined which found participants reporting more frequent tinnitus exhibited higher levels of stress, estrangement, and hostility, and lower levels of social intimacy, self-restraint, averting injury, and conservatism. Additionally, the development of chronic tinnitus, suggesting personality may influence tinnitus suffering and perception (Durai & Searchfield, 2016)

A personality trait that helps in coping with negative life circumstances, including health conditions, is resilience. Psychological resilience not only serves as a safeguard against anxiety and depression, but also aids in alleviating insomnia (Xin et al., 2022). Because these are symptoms that often accompany tinnitus distress, resilience could be inversely linked to tinnitus distress. A cross-sectional study by Wallhäusser-Franke et al. (2014) investigated the relationship between tinnitus distress and resilience. They utilised self-report questionnaires to collect data on tinnitus-related distress, subjective tinnitus loudness, resilience, and emotional well-being. 4705 participants with tinnitus responded, revealing an inverse correlation between resilience and tinnitus distress. Subjective tinnitus loudness showed a lesser effect. Mediation analysis showed that emotional well-being influenced the link between resilience and tinnitus distress. This implies that higher resilience is associated with improved emotional health, characterised by reduced levels of depression, anxiety, and somatic symptoms, consequently leading to less distress associated with tinnitus (Wallhäusser-Franke et al., 2014).

Longitudinal studies would be warranted to further investigate the interplay between personality traits, resilience, and tinnitus perception overtime. However, there is consistent evidence showing personality may have an influence on tinnitus distress and persistence.

2.6 Current tinnitus management methods

Currently, there is no cure for tinnitus, but there are various options available for its management (Cooke et al., 2018). Yet, there exists a substantial body of literature addressing disparities in the beliefs and attitudes of audiologists regarding its clinical management (Thompson et al., 2018). It is important to note that what works for one tinnitus patient may not be effective for another (Theodoroff et al., 2014). Management plans may need to adapt based on an individual's unique circumstances and any additional comorbidities or conditions they are managing alongside their tinnitus (Cima et al., 2019). In some cases, a combination of management modalities may be necessary, depending on the patient (Esmali & Renton, 2018). Tinnitus treatments may target reducing the severity of tinnitus directly, or easing the distress associated with tinnitus (Han et al., 2019). The former approach includes methods like pharmacotherapy and electrical suppression, while the latter involves using strategies such as using hearing aids, pharmacotherapy, cognitive behavioural therapy, sound therapy, habituation therapy, massage and stretching (Han et al., 2019).

2.6.1 Hearing aids

Hearing aids have been shown to alleviate tinnitus awareness by reducing stress levels and modulating central auditory processing, implicating them in the management of tinnitus. Hearing loss ranks among the most common and persistent chronic conditions, contributing significantly to disability. The ramifications of hearing loss on the overall wellbeing of the affected individual are substantial. Notably, diminished physical and mental engagement, as well as resultant social isolation, elevate the susceptibility to cognitive decline and dementia, mental health issues, and depression. Even though hearing loss and tinnitus are closely related, hearing loss cannot directly predict the severity of tinnitus. Surprisingly, only 50% of hearing-impaired patients encounter tinnitus, even those with profound deafness (Del Bo & Ambrosetti, 2007). Moreover, 10% of tinnitus sufferers exhibit normal pure-tone audiometry. Furthermore, the occurrence of tinnitus varies in various patient groups with different causes of hearing loss, ranging from 30% (in cases of ototoxicity) to as high as 90% (in instances of acoustic trauma). Extensive evidence from the literature supports the significant advantages of hearing aids in managing hearing difficulties, including associated tinnitus. It has been theorised that amplifying a broader range of frequencies may enhance their effectiveness. Hearing aids are engineered to enhance speech audibility and amplify ambient sounds. By amplifying speech, attention is diverted from tinnitus, while amplification of other background sounds can help to mask the tinnitus sensation (Han et al., 2019). The use of hearing aids has the potential to permanently reduce the neural activity responsible for generating and perceiving tinnitus, making them a primary intervention for patients with hearing loss. Many hearing-impaired individuals retain normal or near-normal hearing at lower frequencies and since common environmental sounds contain substantial energy at particularly low frequencies, they provide constant sound stimulation, helping to mitigate issues associated with increased gain in the auditory system. Hence, hearing aids with open moulds are useful in preventing the blocking of these low frequencies and allowing natural low-frequency sound to come through. Nonetheless, research indicates that hearing aids offer effective tinnitus relief to only a subset of patients. Findings from the literature suggest that wearing hearing aids appeared to provide benefits to individuals, but primarily when their tinnitus occurred within the amplification range of hearing aids (McNeill et al., 2012).

Cochlear implants have relatively limited users; however, many studies have shown their positive effects on tinnitus for those with severe sensorineural hearing loss (SNHL) (Cima et al., 2019). After receiving the implants, studies have shown that noticeable tinnitus relief was achieved, and scores on tinnitus impact questionnaires demonstrated notable improvements, with some patients experiencing a complete elimination of their tinnitus (Arts et al., 2012; Yang et al., 2021).

2.6.2 Pharmacological interventions

Intravenous lidocaine serves as the only medication providing reliable tinnitus reduction. It has similarities with inhibition of sensory epilepsy, reducing CNS activity, thus ridding of abnormal hypersensitivity (Kim et al., 2021). Despite its efficacy, lidocaine's clinical application is not present due to the necessity of injection, short duration effects, and frequent occurrence of adverse side effects (Han et al., 2009). Side effects include things as severe as speech disorders and breathing inhibition (Kim et al., 2021). Duckert & Rees (1983) investigated the effects of lidocaine on tinnitus through a double-blind randomised trial. They found that 40% of the lidocaine group reported a reduction in tinnitus, however, over 30% experienced an increase in tinnitus and some exhibited side effects such as slurred speech and numbness or tingling of the extremities.

Many other medications have been shown to exhibit greater efficacy than placebo from comprehensive analysis of randomised clinical trials. These medications include nortriptyline, amitriptyline, alprazolam, clonazepam, and oxazepam (Duckert & Rees, 1983). However, with some of these medications, discontinuation results in tinnitus recurrence to its prior or exacerbated level. Many also have unpleasant side effects.

2.6.3 Cognitive behavioural therapy

Cognitive behavioural therapy can help patients manage their tinnitus by replacing pessimistic thoughts with more positive ones. It encompasses counselling and cognitive restructuring, wherein patients are guided to cope with tinnitus-related thoughts (Jun & Park, 2013). Counselling involves informing patients about the unlikely significant improvement in tinnitus annoyance, highlighting the benefits of tinnitus self-help groups, assisting in minimising exposure to activities or conditions exacerbating tinnitus, and emphasising the importance of avoiding noise exposure due to its association with noise-induced hearing loss and tinnitus.

Cognitive restructuring involves encouraging patients to change their internal dialogue, emphasising that tinnitus should not monopolise their attention (Jun & Park, 2013). On the other hand, behavioural therapy emphasises an approach which aims to desensitise the patient (Han et al., 2019). This involves using positive imagery to divert attention from tinnitus and attention management to redirect attention away from tinnitus when it becomes bothersome, starting with visual and auditory stimuli presented alongside tinnitus, gradually transitioning to pairing thoughts with tinnitus. Relaxation training is a further element of behavioural therapy where participants engage in progressive muscle relaxation, involving the deliberate tension and subsequent relaxation of various muscle groups in the body (Han et al., 2019).

2.6.4 Tinnitus retraining therapy

The framework of Jastreboff's neurophysiological model (Jastreboff, 2015) led to the development TRT, the approach that aims to address tinnitus by disrupting the functional connections between the auditory system and the limbic and autonomic nervous systems, leading to habituation of reactions triggered by tinnitus and subsequently habituation of perception (Jastreboff, 2015). TRT primarily targets non-auditory systems, particularly the limbic and autonomic nervous systems, under the premise that tinnitus is a byproduct of normal compensatory mechanisms in the brain. By harnessing the brain’s inherent plasticity, TRT aims to habituate individuals to the physiological reactions and perception of tinnitus. Traditional habituation methods, which involve repeated exposure to a sensory stimulus, cannot be directly applied to tinnitus due to the persistence of autonomic nervous system reactions acting as negative reinforcement. Therefore, TRT focuses on reducing both the stimulus and reinforcement despite them still occurring (Han et al., 2019).

TRT includes counselling and sound therapy, both grounded in the neurophysiological model of tinnitus. The primary aim of retraining counselling is to redefine tinnitus as a neutral stimulus, whereas the primary objective of sound therapy is to reduce the intensity of tinnitus-associated neuronal activity. An exclusive feature of TRT is that since the treatment targets processes above the origin of tinnitus and focuses on connections between the auditory system and other brain systems, the cause of tinnitus becomes irrelevant (Jastreboff, 2015).

However, TRT typically requires 18 months to achieve the desired effects, and its efficacy may vary among individuals. Successful implementation of TRT necessitates patience and discipline from both the patient and professional (Han et al., 2019). The professional must be experienced and have the required training in TRT.

2.6.5 Sound therapy

Sound therapy utilises natural environmental sounds to diminish the activity of neurons related to tinnitus within the auditory system (Henry, 2022). Sound can provide a feeling of relief or serve as a distraction from their tinnitus. Any form of sound, whether it be music, speech, or environmental noise, is acceptable, so long as it is a low-level, continuous, neutral sound that is easy to overlook, thus increasing background neuronal activity in the auditory system (Henry, 2022). Stability and non-overwhelming characteristics are essential. Some patients may find sounds like waves, bird calls, or thunderstorms distracting due to their tonal instability (Han et al., 2019). Different sound sources can be employed for sound therapy. Patients are encouraged to utilise existing resources, like smart-phones and sound therapy applications, many of which are either free or of a minimal cost. The sound intensity should be set lower than the level at which the patient perceives their tinnitus, and it is important to apply the sound bilaterally to avoid uneven stimulation of the auditory system. We want to avoid asymmetrical stimulation as this could lead to a recognisable shift in the location of tinnitus (Han et al., 2019). The use of open-ear moulds is preferred to minimise occlusion, if using headphones or hearing aids, allowing normal access of environmental sounds. The goal of sound therapy is typically to alleviate the emotional impact, such as anxiety and depression, as well as the functional consequences like disrupted sleep and problems with concentration, caused by tinnitus (Henry, 2022).

2.6.6 Massage and muscle stretching

The practice of manual therapy and stretching of the neck and jaw muscles has shown notable improvements in tinnitus. Somatic tinnitus is linked to issues in the cervical spine or temporomandibular region, which have the potential to alter the pitch and volume of tinnitus in affected individuals (Sharma et al., 2022). Additional symptoms may include pain in the head, neck, and shoulders, as well as restrictions in movement (Han et al., 2019). Addressing disorders in the jaw and neck region has demonstrated positive effects on tinnitus. Sharma et al., (2022) investigated a systematic review that included eight articles concluding somatic tinnitus could be helped by manual therapy. Additionally, administering lidocaine injections into the jaw muscles has been observed to reduce tinnitus (Han et al., 2019).

In some cases, massage and muscle stretching may not directly target tinnitus physically, but it can potentially aid in promoting relaxation, calming the nervous system, and coping with stress. While stress is not a direct cause of tinnitus, it can exacerbate the condition, as it is often the case with various health issues where stress and anxiety play a role in worsening symptoms (Grossan & Peterson, 2017).

2.6.7 Digital tinnitus therapeutics

Current digital tools for tinnitus treatment are continuously evolving, with ongoing research and technological advancements shaping new management strategies. These tools are often utilised alongside traditional clinical methods and are increasingly used for self-management of tinnitus symptoms by patients (Lee & Jung, 2023). The efficacy and availability of these digital tools vary widely and encompass a range of interventions, including internet CBT, smart-phone delivered Ecological Momentary Assessments (EMAs), tinnitus-related apps, auditory training, sound therapy and artificial intelligence (AI) technology (Searchfield et al., 2021).

Internet CBT combines online counselling, peer support, and customised sound to assist individuals in managing the distress caused by tinnitus. This therapy typically involves text-based modules that patients work through, with programs like the Tinnitus E-program offering structured courses over several weeks. Research supports the effectiveness of internet CBT in training patients to better cope with tinnitus-related stress and dispel misconceptions about their condition (Kaldo et al., 2013).

EMAs utilise smartphones to gather real-time data on patients' experiences in their natural environments, providing valuable insights into fluctuating tinnitus symptoms. While smartphone-based tinnitus management has gained popularity due to its accessibility, sustaining patient engagement remains a challenge, emphasising the importance of personalised motivation factors and engaging content (Wilson et al., 2015).

Tinnitus-related apps offer a wide range of features, including white noise, sound masking, and activity tracking, providing users with tools to manage their symptoms on-the-go. While these apps are widely used, evidence regarding their efficacy is limited, with popular options including White Noise Free, Oticon Tinnitus Sound, and Relax Melodies-Sleep Sounds (Sereda et al., 2019).

Auditory training involves exercises to help participants distinguish between sounds, aiming to habituate them to their tinnitus and reduce distress. While the effectiveness of such therapies varies, incorporating gaming aspects into auditory training has shown promise in some studies (Barros et al., 2024).

AI technology holds potential for personalised tinnitus treatments by analysing individual features and tailoring interventions accordingly. Although AI applications in tinnitus treatment are still in the early stages, they may become more prevalent in the clinical space as research progresses (Searchfield et al., 2021).

2.7 Tinnitus Assessment Procedures

At present, there is no objective measure that can determine an individual's sound characteristics of their tinnitus (Neff et al. 2019). Therefore, we must rely on subjective assessment and description, where the participant matches their perceived tinnitus as closely as possible to an external sound source, whether that be a pure tone or a narrow-band stimulus.

2.7.1 Tinnitus Pitch-Matching

Patients with a purely tonal tinnitus pitch are rare. A population of surrounding neurons is often involved in the generation of tinnitus, therefore creating a spectral effect (Wollbrink et al. 2019). However, most people are still able to identify a pure-tone frequency that is most like the subjective perception of their tinnitus (Neff et al., 2019). If participants have a hissing tinnitus and are unable to identify a single pure-tone frequency, narrow band noise can be used as the stimulus. To determine the closest pitch to the participants' tinnitus, two tones are presented to the contralateral ear, one at a time. It is useful to start with one lower frequency tone and one higher frequency tone (i.e., tone one at 1 kHz and tone two at 6 kHz) and continue in a bracketing fashion, bracketing upwards or downwards depending on the participant’s response. Of the two tones presented, the participant must decide which tone is closer in pitch to their predominant tinnitus sound. This continues until the participant reliably and repeatedly matches a tone to their tinnitus. This is then noted at the ‘Tinnitus Pitch Match’ on the audiogram. Tones are presented at 10 dB above their hearing threshold at that frequency, as intensity can affect how pitch is perceived (Thompson et al. 2012).

2.7.2 Tinnitus Loudness Matching

Tinnitus loudness matching was achieved by first finding the threshold at the tinnitus-matched pitch in 2 dB steps. Once the threshold is obtained, an ascending technique is used, increasing the intensity of the tinnitus-matched pitch slowly in 1 dB increments until it matches the perceived loudness of the tinnitus. The loudness level is then recorded, which allows us to determine the tinnitus sensation level (dB SL), which is obtained by subtracting the tinnitus pitch match frequency’s threshold from the tinnitus loudness match. Results often show a sensation level that is only a few decibels above the participant's threshold (Fournier et al. 2018). This sometimes leads the participant to feel like the sound should not be affecting them if the results are not explained properly. It should be clarified that this does not mean the sound is quiet, nor that it should not cause distress where one is experiencing it.

2.7.3 Tinnitus Functional Index

The Tinnitus Functional Index (TFI) is a self-reported questionnaire designed to gauge the impact of tinnitus on an individual's life. Initially developed by Meikle et al. (2012), it comprises 25 items distributed across eight domains: intrusiveness, sense of control, cognitive interference, sleep disturbance, auditory difficulties, relaxation, quality of life, and emotional distress. Each domain is assigned a score, and the cumulative scores across all eight domains provide an overall TFI score, offering a valid and reliable assessment of tinnitus severity in both clinical and research settings (Meikle et al., 2012).

The intrusiveness domain evaluates the extent to which tinnitus interferes with daily activities. Sense of control measures an individual's perceived ability to manage their tinnitus, while cognitive interference assesses its impact on concentration and memory. Sleep disturbance examines how tinnitus affects sleep quality, and auditory difficulties consider its impact on speech comprehension and hearing. The relaxation domain gauges the ease with which individuals can relax while coping with tinnitus, while quality of life provides a comprehensive assessment of its overall influence. Lastly, emotional distress evaluates the emotional response to tinnitus, including feelings of anxiety and depression (Meikle et al., 2012).

Beyond assessing the impact of tinnitus on various life domains, the TFI also serves as a valuable tool for evaluating the effectiveness of different tinnitus treatments. For example, Fackrell et al. (2016) utilised the TFI to measure the efficacy of mindfulness-based cognitive therapy, observing significant differences in overall TFI scores between patients who underwent therapy and control patients who did not. Thus, the TFI not only aids in understanding the multifaceted effects of tinnitus but also facilitates monitoring changes associated with tinnitus treatments.

2.7.4 Tinnitus Sample Case History Questionnaire

The tinnitus sample case history questionnaire (TSCHQ), developed by Sørensen et al. (2020), serves as a clinical tool for obtaining comprehensive information about a patient's tinnitus, medical background, and lifestyle factors. It encompasses inquiries about the onset, duration, and localisation of tinnitus, as well as the characteristics of the perceived sound and any accompanying balance or auditory issues such as vertigo or hearing loss. Additionally, the questionnaire delves into the patient's medical history, current medication, and lifestyle factors such as occupation and exposure to loud noises Sørensen et al. (2020).

Primarily utilised in clinical settings, the TSCHQ assists clinicians in tailoring appropriate treatments for their tinnitus patients (Kojima et al., 2017). For instance, it aids in identifying underlying medical conditions that may contribute to tinnitus and assessing any ototoxic medications that could exacerbate symptoms. Furthermore, the questionnaire sheds light on other potential exacerbating factors like high stress levels or exposure to loud noises in the patient's lifestyle, enabling clinicians to address these factors to enhance the patient's coping mechanisms.

Due to its widespread clinical utility, the TSCHQ has been adapted into multiple versions and language (Sørensen et al., 2020). Its extensive use has been validated across various studies, demonstrating its reliability and validity as a measure of tinnitus severity (Kojima et al., 2017).

As a result, clinicians and researchers have access to a range of validated questions to gather comprehensive information about patients' tinnitus experiences and its impact on lives.

2.8 Motivational Messages

2.8.1 Motivational Messages for Health Interventions

The utilisation of mobile applications or messages has gained popularity in recent years due to the proliferation of new emerging apps on the market and the growing prevalence of smartphone usage in everyday life. The arrival of digital connectivity and the shift towards personalised medicine have positioned mobile health as a promising avenue for more equitable healthcare delivery and enhanced health results (Gonzalez at el., 2021). They can help increase access to health services (Nguyen, 2023). Services provided via mobile health may include health monitoring, disease tracking, and promoting health behaviours. The importance of mobile health services became evident during the COVID-19 pandemic. Social distancing measures necessitated a shift towards mobile and telehealth modalities for treatments and assessments. This shift persists today, with mobile health services such as remote cochlear implant mapping and hearing aid adjustments extending to individuals at risk or residing in remote areas. Even before the pandemic, the increasing ubiquity of mobile devices had propelled mobile health services into prominence. Recent studies in health communication investigate how mobile health applications influence behavioural changes concerning fitness, diabetes, depression, sleep, and other health aspects. Despite the increasing prevalence of mobile health apps, research by Chib and Lin (2018) revealed limited explanations regarding how the impacts are achieved, with a greater focus on accessibility rather than individual health outcomes. However, the rise in randomised control designs signals a growing interest in assessing the effectiveness of these interventions (Gonzalez et al., 2021). An SMS or in-app message intervention that holds potential for enhancing things like medication adherence, disease condition awareness, and providing clinical appointment reminders, ultimately leading to an improved quality of life (Ebuenyi et al., 2021). Motivational text and in-app messages offer a promising solution in health interventions, offering a convenient and accessible way to deliver supportive content and encourage positive behaviour change.

One area which has seen success with mobile intervention is cardiovascular diseases (CVD). Cardiovascular diseases stand as a leading cause of global mortality, with several known causal risk factors. A critical strategy in CVD prevention involves mitigating modifiable risk factors, including unhealthy diet, physical inactivity, alcohol consumption, and smoking (Agher et al., 2022). Encouraging behavioural changes in patients, particularly regarding these risk factors, is pivotal. Mobile health interventions have been shown to offer a promising avenue for promoting lifestyle modifications related to CVDs, some of which also transfer to tinnitus management. With tinnitus, sometimes we too see unhealthy diet, physical inactivity, alcohol consumption, and smoking worsen symptoms (Alateeq et al., 2023; Özbey-Yücel et al., 2021). Several studies have demonstrated the significant impact of mobile health interventions on managing and ameliorating modifiable risk factors in CVD prevention. For instance, several studies have reported encouraging outcomes for mobile health interventions in enhancing patient metrics like body measurements (e.g., weight, waist circumference), metabolic and physiological parameters (e.g., blood pressure, glucose levels), medication adherence and safety, physical activity levels, dietary habits and awareness of health conditions and treatment options. While these interventions have shown positive effects, these are largely on single risk factors, where efforts to address multiple risk factors have yielded limited success (Agher et al., 2022). These endeavours often lack personalization in delivering recommendations or selecting suitable intervention formats (e.g., SMS, email) based on patient profiles. Additionally, many apps face the risk of rapid obsolescence due to the swift pace of technological advancement, necessitating consideration of new technological innovations. Modern mobile technologies enable seamless connectivity, real-time health data tracking, and personalised alerts, coinciding with the increased adoption of smartphones in recent years (rising from 35% in 2011 to 81% in 2019) (Laricchia, 2022).

This approach has also been applied in diabetes management (Watterson, 2018). This study focused on adults with poorly controlled diabetes and investigated the efficacy of an individually tailored, text message-based self-management support intervention (Dobson et al., 2018). This study looked at 366 participants with type 1 or 2 diabetes. Participants in the intervention group received personalised text messages designed to provide the appropriate support tailored to their specific needs. In contrast, the control group received standard care without tailored text messages. The intervention resulted in improved self-management of glycemic control among those who received the personalised text messages. The findings underscored the importance of further research around the use of motivational messaging in chronic disease management (Watterson, 2018).

Examining the effectiveness of motivational messaging interventions in diabetes and other chronic health conditions, provides insights into the potential application of motivational messaging for tinnitus treatment.

2.8.2 Motivational Messages for Tinnitus Management

Motivational messaging has the potential to be used as an intervention for treating tinnitus. To delve deeper into its efficacy, this section will elaborate on examples and discuss how mobile therapies can induce lasting changes in tinnitus management. Additionally, factors affecting the success of tinnitus treatments and the potential role of motivational messaging in addressing them will be explored.

Studies have demonstrated some success in using mobile health therapies for tinnitus management. For instance, Kutyba et al. (2021) conducted a study involving 52 hospitalised patients and examined the use of an application called "ReSound Tinnitus Relief". While some patients derived little benefit from masking their tinnitus, further research is warranted to refine mobile applications and tailor them to individual needs.

Similarly, a study investigated the factors influencing patients' initiation and sustenance of internet-based CBT. Four key categories emerged: treatment objectives, motivational triggers, attitudes toward treatment, and training features. These findings underscore the importance of addressing specific targets and unique circumstances to ensure the success of digital therapies (Heinrich et al., 2016).

Moreover, studies exploring smoking cessation through mobile health motivational messaging have shown promising results. One study involving post-angioplasty patients found that those receiving motivational messages had significantly higher success rates in quitting smoking compared to the control group. Another meta-analysis revealed that frequent motivational messages positively influenced healthy behavioural changes, emphasising the potential of mobile health interventions in promoting positive health outcomes (Santarossa et al., 2018; Mobaraki et al., 2023).

By extrapolating from these studies, personalised mobile health therapies tailored for tinnitus management could yield similar success. Such interventions empower individuals to drive their treatment goals and expectations, thereby enhancing self-efficacy. This approach could help address existing challenges in audiological service delivery, particularly the lack of specialised training and standardised guidelines for tinnitus treatment (Turton et al., 2020).

Furthermore, understanding the disparities in expectations between audiologists and patients regarding tinnitus treatment highlights the need for patient-centred interventions. Motivational messaging can align with patients' priorities and empower them to set treatment goals, fostering a collaborative and effective care delivery approach (Krist et al., 2017); Dineen-Griffen et al., 2019).

Digital tools such as mobile health can play a vital role in healthcare delivery, offering a means to address existing gaps and challenges. Mobile health technologies are constantly advancing, showing promising developments in emerging areas (Chib & Li 2018). Exploring the effectiveness of motivational messaging in tinnitus interventions sheds light on factors influencing successful treatment outcomes and the challenges inherent in tinnitus care delivery. Motivational mobile therapies offer a promising avenue for bridging these gaps by providing patient-centred, tailored interventions that promote self-efficacy and enhance treatment effectiveness. With ongoing technological advancements and their integration into healthcare delivery, further research into mobile motivational messaging remains all-important. For tinnitus management, this involves getting a clearer picture of what people want from messages if they were to receive them.

2.9 Purpose of the Study

2.9.1 Aims

1. To determine whether people find motivational messages useful in managing their tinnitus.
2. To determine what types of motivational messages people find useful in managing their tinnitus.
3. To determine if people would engage with a mobile therapeutic.

3 Methods

3.1 Ethical Approval

This study was approved by the University of Auckland Health Research Ethics Committee on 14/09/2023. All procedures in the study were carried out in accordance with this approval.

3.2 Participants

3.2.1 Recruitment

A third-party administrator independent of the research sent an email inviting people with tinnitus in an existing database of the University of Auckland Audiology clinics to participate. The email contained both the Participant Information Sheet and the consent form. From here, people responded, expressing their interest, and a link was sent with the survey information and a calendar to book a time to come into the University of Auckland clinic for audiological testing and the in-person interview.

3.2.2 Inclusion criteria

Participants recruited needed to meet certain eligibility criteria. Participants who met these requirements had to be 18 years of age or older, and their tinnitus had to have been sufficiently severe and stable for a minimum of six months. Participants were also required to understand English and consent to participate.

3.3 Study Design

This study employed a mixed-methods design involving online surveys, a face-to-face interview, and audiological testing to comprehensively investigate the effectiveness of motivational messages in tinnitus management.

3.3.1 Survey Design

A mixed-methods design was used, with audiological data, multi-choice questions, Likert scale questions, and face-to-face interviews used for data collection. Participants completed three surveys, the first of which was the 'Tinnitus Case History Questionnaire'. This is a standardised instrument for gathering patient case histories as well as characterising the condition into subgroups (Kojima et al. 2017). It asks about general demographics such as age, gender, and handedness, as well as questions pertaining to one's tinnitus. Tinnitus questions include things such as the duration and characteristics of their tinnitus. Participants then completed the 'Tinnitus Functional Index Scale', a self-report scale measuring the severity and negative impacts of tinnitus on a person (Meikle et al. 2012). Finally, participants completed a questionnaire in which they rated how helpful various motivational messages were on a scale from 1 to 5, with 1 being not very helpful and 5 being very helpful. These questionnaires were completed online before coming into the clinic for audiological testing. The Likert scale responses to the messages allowed participants to have an open and honest anonymous response to the messages, where some people may not feel confident giving feedback face-to-face.

3.3.2 Interview Design

Interviews were conducted in-person, in a semi-structured nature. They were utilised to explore perceptions, attitudes, and experiences with motivational messages more in depth. A list of questions was developed to guide the interview, but conversation was allowed to flow with how the interviewee felt, to allow for flexibility and to probe into specific areas of interest. Interviews were deemed a more effective way of gaining insight on participants' thoughts about receiving messages for tinnitus management. A free-flowing conversation may reveal more insight than a typed survey response.

3.3.3 Audiological testing

Otoscopy, pure-tone audiometry via air conduction and tinnitus assessment and characterisation were performed. Otoscopy was performed to ensure there were no observable obstructions or contraindications before testing. Pure-tone air conduction testing was conducted from 250 Hz to 16kHz. Thresholds were obtained using the modified Hughson-Westlake descending method (Hughson & Westlake, 1944). Tinnitus assessment and characterisation involved obtaining the pitch and loudness/sensation level of the individual's tinnitus. Tinnitus pitch match was collected by presenting two consecutive pure tones at different frequencies to the test ear. This was repeated until the most accurate pitch match was achieved. This required subjective report back from the participant, regarding whether pitch 1 or 2 was closer to their tinnitus percept. Tinnitus loudness matching was obtained by first gaining the participants threshold level at the pitch of their tinnitus in 2 dB increments. Then by presenting the tinnitus pitch in an ascending fashion, adjusting the volume in 1 dB increments, and requiring the participant to indicate when they felt the volume matched their tinnitus. The tinnitus sensation level (dB SL) was determined by subtracting the tinnitus pitch-match frequency threshold level from the matched tinnitus loudness level.

3.4 Equipment

Otoscopy was conducted using a Welch Allyn™ otoscope. Audiological testing was performed using a Grason-Stadler GSI AudioStar Pro™ Audiometer. Transducers used for air conduction thresholds were supra-aural (TDH-39P) headphones calibrated to allow for high-frequency testing. All instruments were calibrated in accordance with the NZAS guidelines and met the standards of either ANSI S3.7-1995 (R2003) or IEC 60645-1 (2001). Data pertaining to audiometric and tinnitus characterisation were gathered within an approved sound-treated booth, complying with AS ISO 8253.1 (2009).

3.5 Data Collection and Analysis

Responses were received through the RedCap software. The questionnaire software was then exported to a CSV file on a Microsoft Excel spreadsheet to be further analysed using GraphPad Prism 9.3 software. Audiological data was handwritten on a University of Auckland audiogram, then collated into a Microsoft Excel spreadsheet. Interview data was audio recorded using the researcher's password protected personal device and coded by unique participant numbers. Once transcribed, these audio recordings were erased for privacy reasons. Transcriptions were then qualitatively analysed using a general inductive approach, revealing recurrent themes. All questionnaires, results, and transcripts returned to the researcher and principal investigator were identifiable by the participant's identification code.

Statistical analysis was conducted and for all analyses, the level of statistical significance was defined as $p<0.05$. The statistical tests are reported in the Results section.

4 Results

This section will present the findings of the current research. First, sample characteristics will be explored. Secondly, a quantitative analysis of motivational messages will be reported, and finally, a qualitative thematic analysis of participant interviews around the messages will be conducted. All results focused on identifying whether motivational messages may be useful as a tool for tinnitus management for people with tinnitus and which messages may be useful. This was then analysed by group characteristics (i.e., tinnitus pitch, sensation level, and TFI scores) to see if this had an influence on how messages were rated. A total of 20 participants entered the study.

4.1 Participants

4.1.1 Demographics and sample characteristics

Data from 20 respondents were analysed. A majority of participants (n = 18, 90%) had never undergone treatment for tinnitus before. Table 4-1 describes the demographic and clinical characteristics of the participants. The majority of participants were female (n = 11, 55%), had a hearing loss (n = 19, 95%) and did not currently use hearing aids (n = 16, 80%).

Table 1

Sample Characteristics

	n	%
Gender		
Male	9	45
Female	11	55
Age (mean, range, in years)	65.95	48 - 84
Hearing loss		
Yes	19	95
No	1	5
Hearing aids		
Currently use	4	20
Do not currently use	16	80

4.2 Audiometry

Figure 1 shows the audiometric threshold data for participants' left ear and figure 2 shows the audiometric threshold data for participants' right ear. Mean thresholds are shown in bold black to demonstrate the gently sloping, high-frequency hearing losses, bilaterally, shown for the group. For the left ear, the mean audiometric thresholds show hearing loss starting at

1000 Hz, gradually increasing in severity as the frequency increases. The right ear shows a similar pattern. Higher hearing thresholds (i.e., higher on the graph) can be interpreted as a poorer hearing threshold at that frequency. The step size for testing was 5 dB. 20 participants had their air-conduction pure-tone thresholds collected, as seen in the key.

Figure 1

Left ear audiometric thresholds

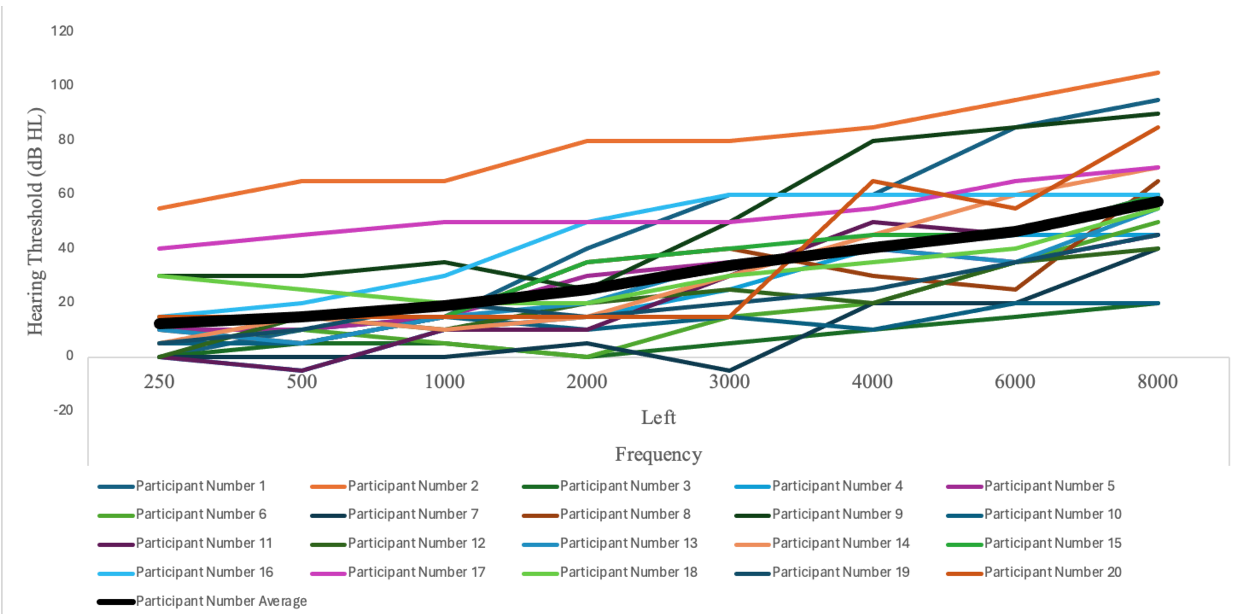
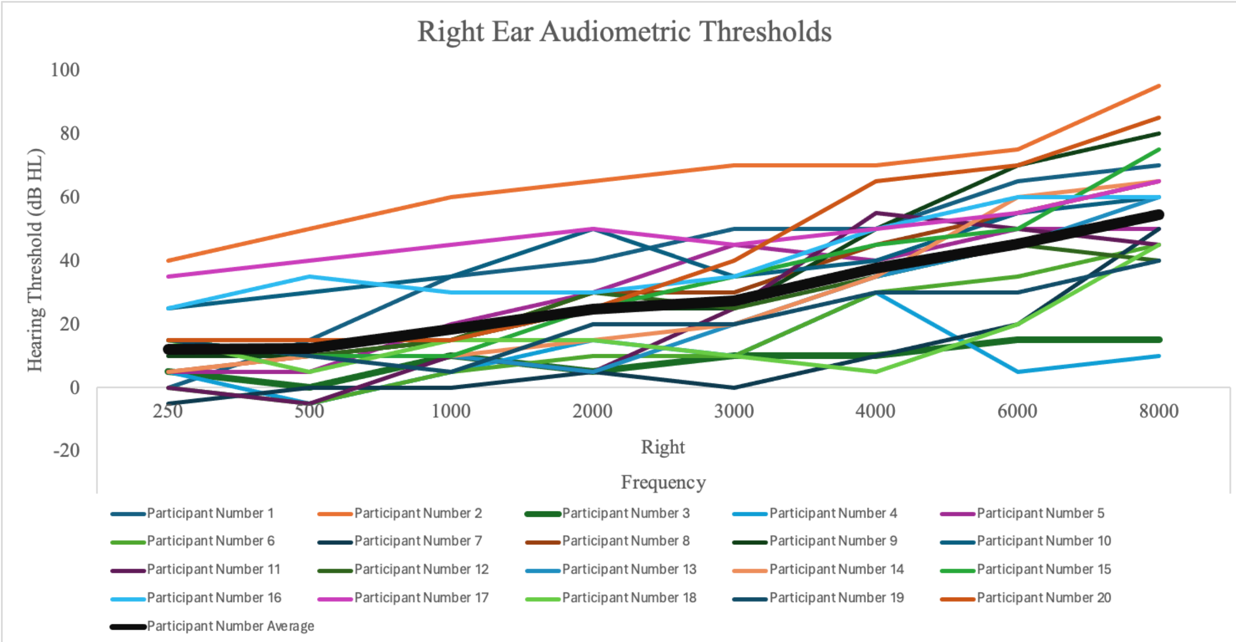


Figure 2

Right ear audiometric thresholds



4.3 Tinnitus Features

4.3.1 Tinnitus onset and duration

Participants indicated their initial onset of tinnitus. Over half the participants answered "other" (*table 4-2*). The other answers included no notable cause, scuba diving, and burst ear drums.

Table 2

Tinnitus Onset

Initial Onset of Tinnitus	Number of Participants	Percentage
Change in hearing	5	25
Head trauma	2	10

Stress	1	5
Loud blast of sound	1	5
Other	11	55

Participants also noted the duration of their tinnitus. A majority of participants had lived with their tinnitus for over 10 years (n = 11, 55%). The next largest time frame reported was 1-5 years (n = 7, 35%) and then 5 to 10 years (n = 2, 10%).

Table 3

Duration of tinnitus

Duration of tinnitus	n	%
1–5 years	7	35
5 to 10 years	2	10
> 10 years	11	55

4.3.2 Tinnitus Pitch Matching

Pitch matching for tinnitus was conducted with participants, covering frequencies ranging from 250 Hz to 16 Hz for each ear independently. 4 kHz was most commonly chosen as the most accurate tonal match to their tinnitus perception of participants in the right ear. The left ear was more spread.

Figure 3

Pitch-matched frequency left vs. right

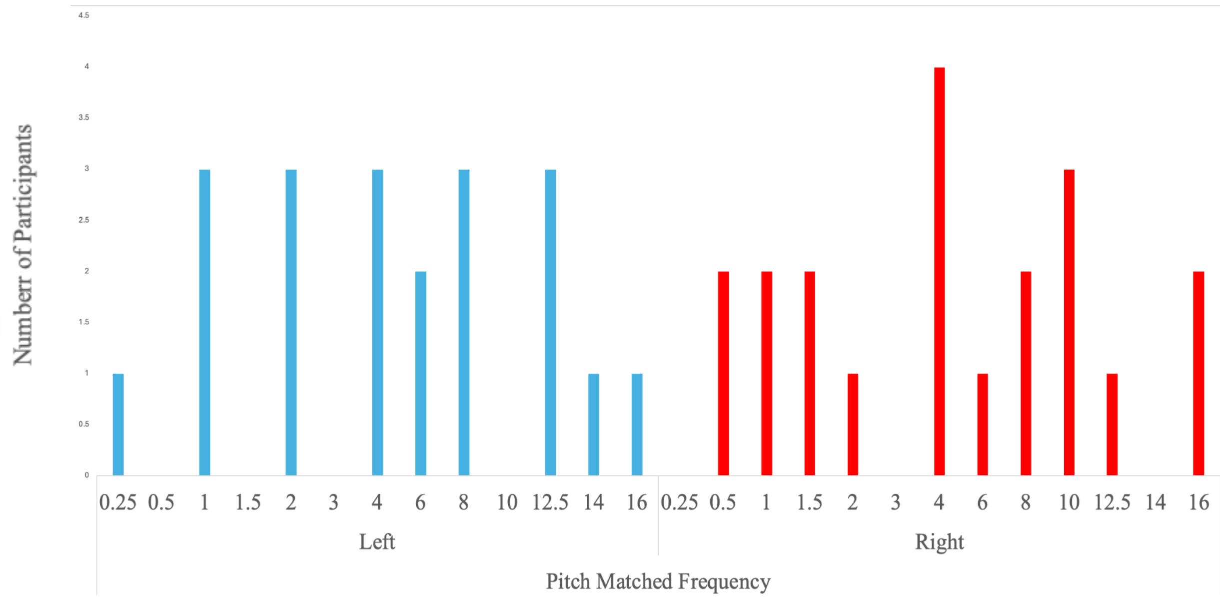
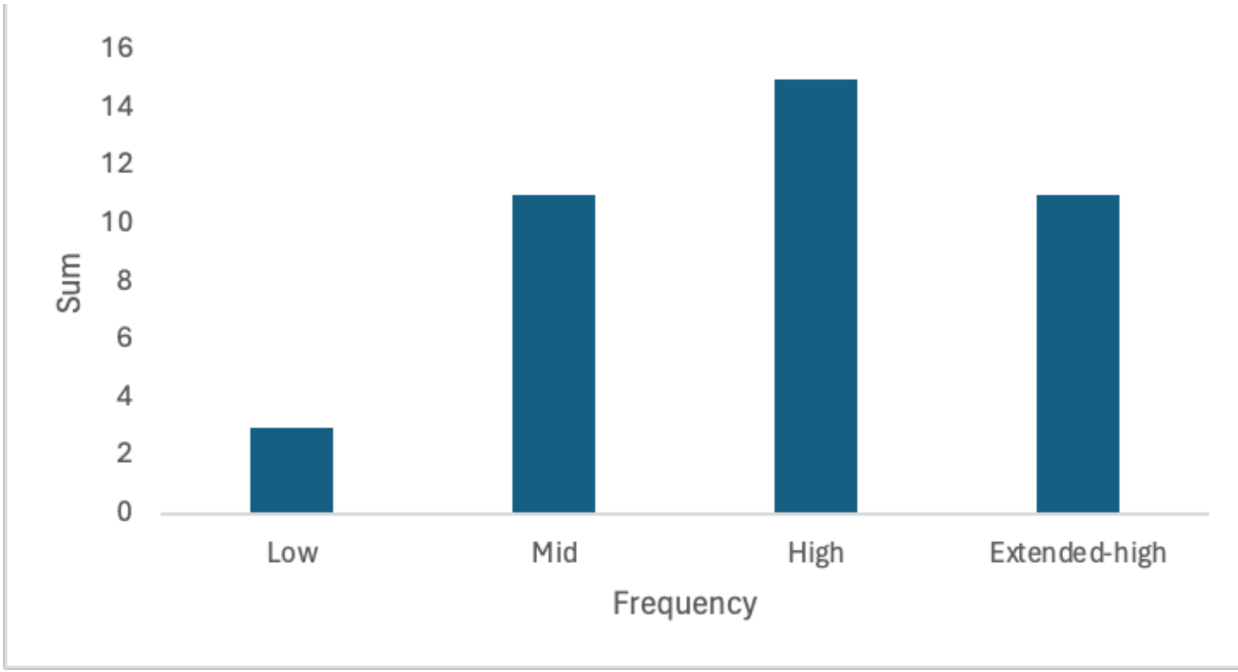


Figure 4 shows the pitch matched frequency irrespective of ear. Frequency ranges were determined as 0 to 750 Hz for low frequencies; 751 to 3,000 Hz for mid frequencies; 3,001 to 8,000 Hz for high frequencies; and 8,001 to 16,000 Hz for extended high frequencies. Most participants' tinnitus pitch frequency fell in the high frequency range, where there were 15/40 responses (37.5%). The most infrequent response was for the low frequency range, with 3/40 responses (0.075%).

Figure 4

Tinnitus pitch-match by frequency group



4.3.3 Tinnitus Loudness Matching

As shown in Figure 5, sensation levels varied across participants. For the left ear however, the mean sensation level was 7 dB SL and the mean sensation level for the right ear was 9 dB SL.

Figure 5

Tinnitus sensation level in dB SL left vs. right

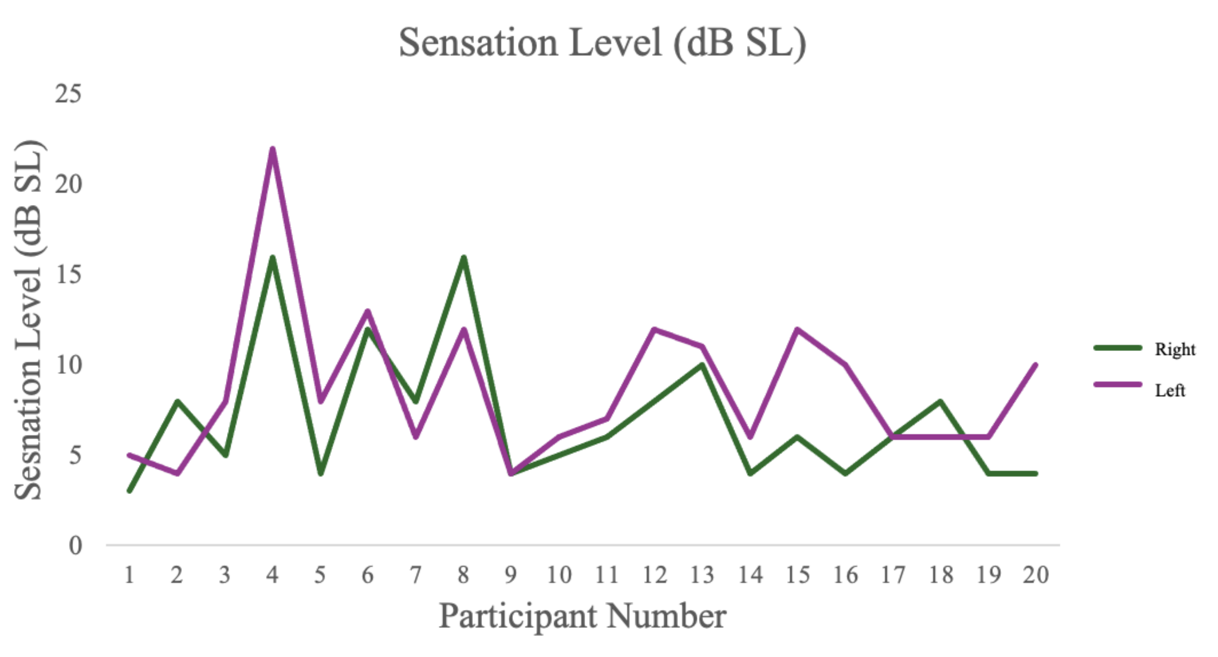


Table 4-4 provides an overview on the sample as a whole. We can see 4 kHz was the most common pitch-match for the left ear and 6 kHz was the most common pitch match for the right ear.

Table 4

Mean, median, range and mode sensation levels, left vs. right

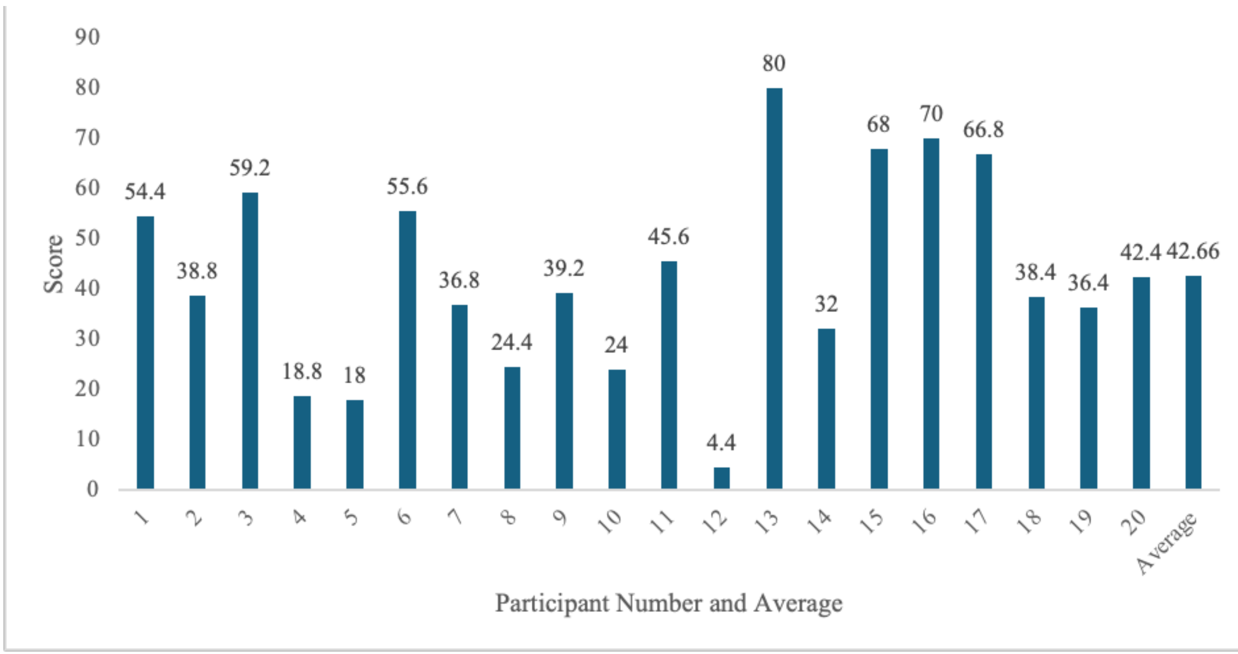
	Left dB SL	Right dB SL
Mean	7.05	8.7
Median	6	7.5
Range	13 (3 - 16)	18 (4 - 22)
Mode	4 (appeared 6 times)	6 (appeared 6 times)

4.4 Tinnitus Functional Index

The TFI categorises severity based on scores: 0 to 18 indicating low severity, 18 to 42 indicating lower moderate severity, 42 to 65 indicating upper moderate severity, and scores above 65 indicating high severity justifying a need for intervention. To participate, individuals ideally needed a score above 18, however due to time constraints this criterion was not met in all cases. The TFI scores for each participant are displayed in Figure 6 below.

Figure 6

Tinnitus functional index scores



4.5 Quantitative analysis of message ratings and group differences

Table 5

4.5.1 Average message rating by category

Group	Average Rating (Out of 5)	Standard Deviation
Strategies for managing tinnitus	2.93	1.20
Masking noise	3.02	1.14
Training reminders	3.01	1.11

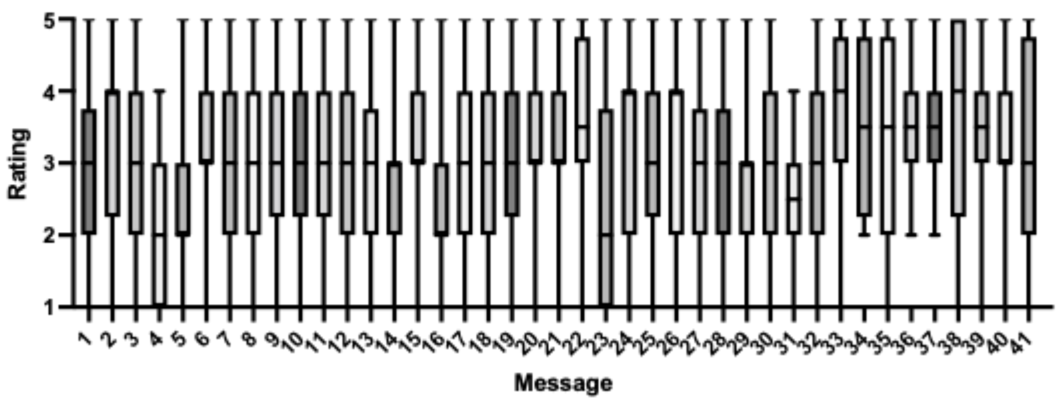
Stress management	3.12	1.18
Time-of-day reminders	3.04	1.17
Motivational support messages	3.48	1.11
Education around tinnitus	3.44	1.20

The highest mean ratings for motivational messages for tinnitus management by category were motivational support messages and education around tinnitus. The lowest mean rating by category was for strategies for managing tinnitus.

4.5.2 Difference in overall ratings

Figure 7

Difference in overall ratings for messages



An analysis exploring the difference in ratings was conducted. Results showed an f distribution and p-value of (40, 779) = 1.77, P = 0.0025, where 40 is the degrees of freedom of the numerator relating to the number of groups or samples and 779 is the degrees of freedom of the denominator, which relates to the total number of observations. The F statistic of 1.777 represents the ratio of the variability between groups to the variability within groups in the data. The p-value of 0.0025 represents the probability of observing an F statistic as extreme as, or more extreme than, the one obtained from the data, assuming the null hypothesis (that there is no difference between groups) is true. The p-value of 0.0025 allows us to make a decision about whether or not to reject the null hypothesis. Because the p-value is 0.0025 (i.e., less than 0.05), we can reject the null hypothesis, indicating there is enough evidence to conclude that there are significant differences between the groups compared. In this instance, this indicates that participants were rating the messages differently because of a content difference or preference as opposed to random differences. The study was not powered to identify differences in individual messages. A full list of motivational messages is listed in Appendix A.

4.5.3 Difference in Ratings by Gender

Figure 8

Female motivational message ratings

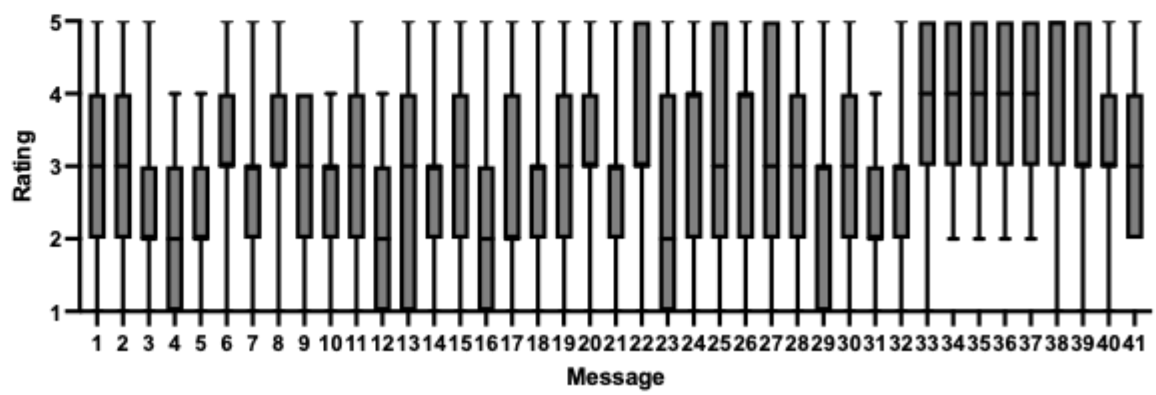
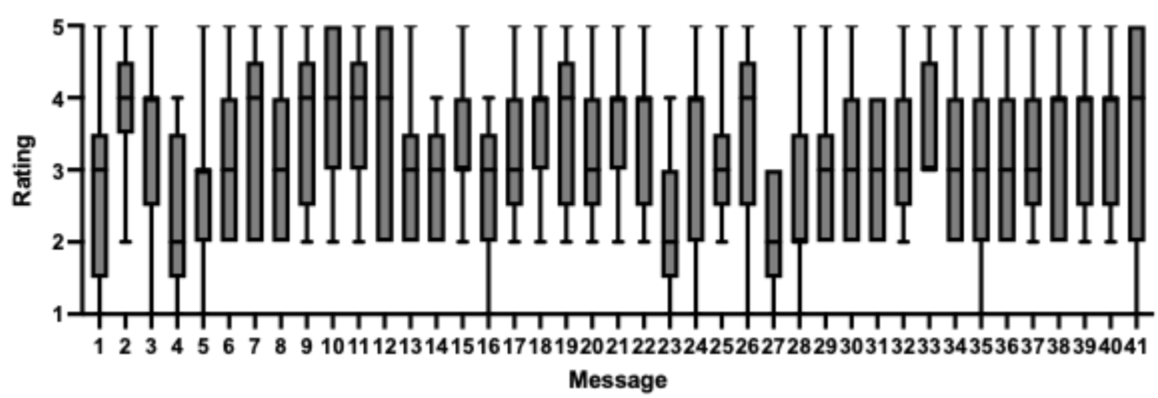


Figure 9

Male motivational message ratings



When comparing males vs. females in regard to how highly they rated the motivational messages, results found that on average, males rated the messages higher than females, with a statistical significance of $p = 0.0159$. However, there is not enough data to establish if that is true for any individual message. Again, the study was not powered to identify differences in individual messages.

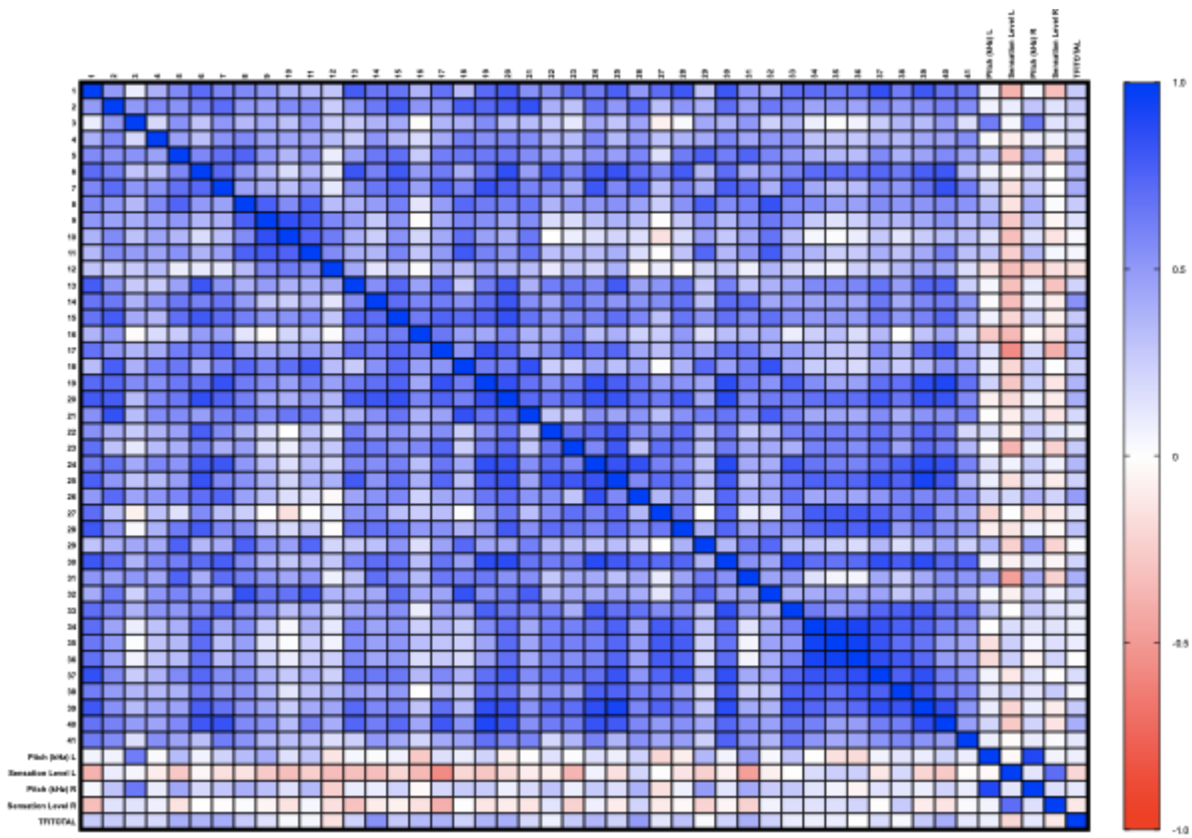
Further statistical analysis explored the rankings of the messages across different groups i.e. TFI scores, sensation level (left and right) and pitch (left and right) to determine whether there was a significant difference ($p<0.05$) between how different groups prioritised these options. Messages from 1 to 41 are listed in appendix A.

4.5.4 Tinnitus Functional Index, Pitch and Sensation Level Group Differences

Figure 10 shows Pearson r correlations regarding message rating, TFI scores, sensation levels and pitch-matched frequencies. Where data have a higher correlation, correlation scores are closer to 1.

Figure 10

Pearson r correlation investigating TFI, pitch-match and sensation level



From the results, certain differences in how different groups prioritised the messages are shown. Table 4-6 shows where the p-values, highlighted in bold, are less than 0.05, we see statistically significant differences in how these groups prioritise the messages. For example, for message three, pitch in the left ear may have an influence on how the messages were rated, and for messages 14 and 26, TFI scores may have an influence on how these messages were rated.

Table 6

Significant p-values from pearson r correlation

Message Number	Pitch (kHz) L	Sensation Level L	Pitch (kHz) R	Sensation Level R	TFI TOTAL
1	0.813	0.094	0.862	0.166	0.276

2	0.785	0.701	0.207	0.548	0.277
3	**0.003**	0.856	**0.002**	0.548	0.405
4	0.914	0.673	0.678	0.745	0.419
5	0.144	0.232	0.053	0.552	0.082
6	0.789	0.855	0.408	0.992	0.113
7	0.335	0.505	0.226	0.960	0.076
8	0.146	0.551	0.086	0.938	0.259
9	0.077	0.256	0.175	0.816	0.517
10	0.514	0.163	0.518	0.546	0.900
11	0.221	0.295	0.134	0.861	0.847
12	0.566	0.150	0.316	0.500	0.520
13	0.857	0.172	0.674	0.195	0.349
14	0.943	0.166	0.702	0.687	**0.016**
15	0.769	0.381	0.349	0.764	0.251
16	0.255	0.128	0.870	0.524	0.139
17	0.499	**0.008**	0.406	0.083	0.101
18	0.722	0.384	0.276	0.977	0.336
19	0.336	0.224	0.277	0.592	0.109
20	0.745	0.448	0.755	0.687	0.084
21	0.985	0.683	0.455	0.592	0.402
22	0.540	0.718	0.209	0.570	0.756
23	0.971	0.109	0.724	0.330	0.270
24	0.508	0.785	0.263	0.747	0.120
25	0.739	0.509	0.485	0.691	0.337
26	0.327	0.385	0.091	0.354	**0.030**
27	0.388	0.971	0.509	0.649	0.584
28	0.707	0.578	0.762	0.869	0.190
29	0.119	0.310	**0.031**	0.357	0.922
30	0.810	0.755	0.578	0.838	0.349
31	**0.034**	**0.035**	0.067	0.330	0.083
32	0.890	0.741	0.286	0.793	0.337

33	0.216	0.987	0.247	0.493	0.703
34	0.988	0.466	0.582	0.554	0.738
35	0.501	0.302	0.790	0.501	0.697
36	0.428	0.306	0.793	0.369	0.988
37	0.804	0.603	0.534	0.961	0.461
38	0.589	0.418	0.606	0.267	0.873
39	0.696	0.378	0.708	0.673	0.267
40	0.384	0.255	0.355	0.563	0.079
41	0.722	0.922	0.689	0.914	0.628

4.6 Thematic Analysis of Interviews

Semi-structured interviews were conducted with each participant, including the following questions as a guideline:

1. *What do you think about receiving messages to help your tinnitus?*
2. *Do you think receiving these types of messages would keep you motivated to work on improving your tinnitus?*
3. *Is there anything different you'd like to see in these messages?*
4. *How frequently would you like to receive these motivational messages?*
5. *What kind of content or themes did you find most helpful and motivating in the messages?*
6. *Can you describe any specific challenges or difficulties you face due to your tinnitus that you think these messages could help address?*
7. *Are there any concerns or reservations you have about receiving messages for your tinnitus? If so, what are they?*

Because the interviews were semi-structured, these questions were not all directly asked. The semi-structured approach provided a more flexible and open-ended approach to data collection. The questions were asked where possible, however, and overall interviews were successful in reaching answers to these questions even if they were not strictly asked.

Interviews were recorded and transcribed, allowing for thematic analysis through Excel. Excel was used to organise, code, and analyse the data. Themes were determined by pulling quotes from each participant's interview to match each of the questions. From here, quotes were coded to reveal common themes and labelled as such.

Table 7

Thematic analysis: overarching & sub-themes

Overarching theme	Benefit	Frequency	Personalisation	Apprehension
Sub themes	Willingness to try, seeking relief, community, and motivation	Control, randomness, and rating scale	Opportunity for feedback, tailored messages, and content preferences	Accessibility, effectiveness, intrusiveness, and fear of reminders

Theme 1: Benefit

Participants identified many ways in which they thought receiving motivational messages for their tinnitus may be beneficial. Within the theme of benefit came sub-themes including willingness to try, seeking relief, coping mechanisms, community, and motivation.

20: "If there's something out there that could give me a boost when I need it, I'm all for it."

9: "Oh, definitely, yeah. An in- app message is good. You know, you get a message on your phone and also, yeah, you can look back, yeah, through the messages. It'd be motivating."

10: "Absolutely. Having access to motivational messages when I feel like I need them would definitely keep me motivated."

14: "I'm definitely interested in trying them out."

12: "I think it's a pretty cool idea, honestly. Tinnitus can be a real pain sometimes, so if there are messages out there that could offer some tips or support, I'm willing to give it a go."

Theme 2: Frequency

The frequency at which participants would like to receive these messages showed many personal differences. While some participants would prefer to receive messages randomly throughout the day or once daily, others would like more control over when they would receive messages. One idea that came up among a few different participants was the ability to be able to receive a message on an as-you-need-it basis. Ideas also included entering a rating from 1 to 10 on how severe the tinnitus was at a given moment and receiving a message dependent on that rating.

4: "I mean, you could try sending something which says rate your tinnitus from one to ten and flick back a message depending on the score. Yeah, you could immediately then follow it up with a message, rather than just bombarding with random things."

20: "The ability to choose when I receive them. Like, if I'm having a particularly rough day with my tinnitus, it would be great to be able to get a message right when I need that extra bit of motivation."

3: "I wouldn't mind daily, like maybe at the set time, like say noontime."

14: "Maybe once or twice a week would strike a good balance."

9: "Daily would be good."

17: "To have control over when that happened. Maybe instead of something randomly popping up."

Theme 3: Personalisation

Personalisation was a key theme that came up across the majority of participants. Participants wanted the opportunity for feedback, tailored messages, and a preference for particular content within the messages given.

1: "Each message, I mean, there's obviously some that don't suit particular people."

3: "I'd like to be able to give feedback on the messages as they come to choose what suits me best though."

9: "I want to be able to reuse them, I wouldn't want them to disappear."

12: "I'd just want to make sure they are suited to me."

13: "I liked the messages that were more focused on educational tips about tinnitus."

14: "My concern is that they could be too generic, I'd prefer them to be personalised."

"Having more tailored advice"

15: "It would be helpful if the messages were personalised".

Theme 4: Apprehension

There was some apprehension from participants, specifically around accessibility, effectiveness, intrusiveness, and the fear of being reminded about the condition. Some struggled to see how it would help but were still interested in the overall idea of managing their tinnitus and were willing to try any method.

2: "It's hard because I mean I'm pretty good at ignoring it for the most part because I've been doing it for a long, long time. But for me, the most times when it's irritating is when I'm trying to go to sleep. Yeah, which is not when you'll be wanting to receive messages about it, necessarily."

6: "Because it's just actually probably that will make it worse rather than helping. I'm really apprehensive that someone sending me messages to say do your exercises or yeah because I've just managed to tune out and now, I'm aware, yeah."

18: "I like the structure of my day. I don't know I want to change it."

2: "I think that for a lot of people, they would be very helpful, but not necessarily for me, cause I know, I know this stuff. I mean, you know, I'm old. I'm figuring it out OK."

8: "Probably not. Yeah. At the moment, probably just a reminder that yes, you've got it. I wouldn't want to get bombarded."

20: "...as long as they don't become intrusive".

Other generally useful and interesting interview answers included emphasis on gamification, the ability to ignore tinnitus and the option to add tips from personal user experiences.

1: "Yeah, I think the educational stuff would be the best, as opposed to motivational stuff. But yeah, science stuff is good. The actual education stuff. And I was also thinking if there's a way to gamify things where you know, you get a chocolate fish, you know, a visual chocolate fish for getting it right, then that might be a way of. Encouraging people. Keeping people engaged."

2: "It's hard because I mean I'm pretty good at ignoring it for the most part because I've been doing it for a long, long time. But for me, the most times when it's irritating is when I'm trying to go to sleep. Yeah, which is not when you'll be wanting to receive messages about it, necessarily."

19: "Maybe even people being able to add their own tips, maybe that people can look at as well? Making a community around it."

5 Discussion

5.1 Main findings

This research aimed to identify whether motivational messages were a viable management method for tinnitus, and what kind of messages would work best. The primary issue to concentrate, discuss, and elaborate on is the effectiveness and preferred content of motivational messages within a mobile therapeutic framework for tinnitus management. Understanding the impact of motivational messaging on tinnitus sufferers' motivation and coping mechanisms is crucial, as well as exploring potential challenges associated with its implementation. The research findings presented show an exploration of various aspects related to tinnitus management and the potential utility of motivational messages in this context. Initially, the sample characteristics were examined, revealing that the majority of participants had never undergone treatment for tinnitus before, with most being female, having a hearing loss and not currently using hearing aids.

Quantitative analysis of motivational messages highlighted varying perceptions among participants, with motivational support messages and education around tinnitus receiving the highest mean ratings. Interestingly, differences in message ratings were observed between genders, with males generally rating the messages higher than females ($p = 0.0159$). Additionally, the study delved into group differences based on tinnitus pitch, sensation level and TFI score, uncovering significant variations in how different groups prioritised the messages.

Furthermore, thematic analysis of participant interviews shed light on several key themes. Participants expressed a willingness to try motivational messages for tinnitus management, highlighting potential benefits such as seeking relief, coping mechanisms, community support, and motivation. However, apprehensions were also noted, particularly regarding the effectiveness, intrusiveness, and fear of reminders associated with receiving such messages. Additionally, preferences for message personalisation and control over message frequency emerged as important considerations for participants.

Across both qualitative and quantitative analyses, motivational support messages and education around tinnitus emerged as the top scoring categories. These findings suggest that individuals with tinnitus perceive motivational support and educational content as particularly beneficial for their management of the condition. The qualitative insights from participant interviews reinforce this, with many expressing enthusiasms for receiving messages that provide emotional support and educational resources to help them better understand and cope with their tinnitus.

On the other hand, strategies for managing tinnitus received lower scores in both the qualitative and quantitative analyses. This indicates that participants may not find generic strategies for managing tinnitus as helpful or motivating compared to other message categories. The interviews shed light on why this might be the case, with some participants expressing concerns about the practicality and relevance of generic management strategies to their specific tinnitus experiences. They may prefer messages that offer more personalised advice or coping techniques tailored to their individual needs and challenges. This was another result that emerged across both qualitative and quantitative analyses. This preference for personalization was evident in both the quantitative ratings, where generic strategies for managing tinnitus scored lower, and in the qualitative interviews, where participants expressed a desire for messages that are relevant to their specific experiences and needs. Furthermore, the quantitative analysis revealed differences in message ratings based on demographic factors such as gender. While males tended to rate the messages higher on average, individual preferences varied, highlighting the importance of considering diverse perspectives when designing motivational messaging interventions. The qualitative insights provided additional context to these findings, with some participants expressing preferences for certain types of messages based on their gender or other demographic characteristics. These findings emphasise the importance of tailoring motivational messaging interventions to address the unique preferences and needs of individuals with tinnitus. By focusing on delivering content that resonates with participants and provides practical support and education, such interventions are more likely to be perceived as valuable tools for tinnitus management.

One notable point that came up in the interviews was a participant's suggestion to incorporate gamification elements, such as rewarding correct responses with visual incentives, reflecting a desire to make the intervention more engaging and interactive. While this idea was not explicitly captured in the quantitative ratings, it shows the importance of considering innovative approaches to enhance user engagement and motivation. Furthermore, the participant's emphasis on gamification aligns with the qualitative finding that individuals seek ways to stay motivated and engaged with the intervention. By integrating gamification elements into the educational content, such as quizzes or challenges with visual rewards, the intervention can potentially increase user involvement and adherence. This highlights the potential synergy between quantitative ratings and qualitative insights, as participants' suggestions for gamification provide valuable input for enhancing the effectiveness of the intervention beyond traditional messaging approaches. Incorporating educational content and gamification elements into the intervention can address both the preference for informational material and the need for engagement and motivation expressed by participants. By integrating these features based on both quantitative ratings and qualitative feedback, the intervention can offer a comprehensive and tailored approach to tinnitus management that resonates with users and maximises its impact. This also supports the theme around personalisation, where some people may prefer this as a feature, while others may not.

Another suggestion emerged from participant interviews, that individuals should have the ability to contribute their own tips and insights to the tinnitus management platform, fostering a sense of community and shared knowledge. This supports the sub-theme of community. This recommendation aligns with the growing emphasis on patient-centred care and collaborative approaches in healthcare interventions. By allowing users to share their experiences and strategies for coping with tinnitus, the platform could evolve into a dynamic resource that reflects the diverse perspectives and needs of its community members. Moreover, fostering a sense of belonging and mutual support among individuals with tinnitus could contribute to enhanced engagement and adherence to tinnitus management strategies over time.

The findings of this research hold significant implications for both clinical practice and future research endeavours in the field of tinnitus management. Firstly, the identification of motivational messages as a viable management method shows the importance of incorporating psychosocial interventions alongside traditional medical treatments for tinnitus. Healthcare providers can integrate motivational messaging interventions into their treatment plans, offering a holistic approach that addresses both the physical symptoms and the psychological impact of tinnitus.

Overall, the research findings underscore the potential value of motivational messages as a tool for tinnitus management, while also highlighting the need for personalisation, non-intrusive approaches that align with individual preferences and experiences. Our study contributes to the solution of this question by providing valuable insights into the potential benefits and challenges of motivational messaging for tinnitus management. By identifying effective message categories and highlighting the importance of personalisation, this research lays the groundwork for future studies to develop more tailored and targeted interventions. Ultimately, this contributes to improving tinnitus management strategies and enhancing the quality of life for individuals affected by the condition. Further exploration into these areas could offer valuable insights into optimising motivational messaging interventions for individuals with tinnitus.

5. 2 Study Limitations

Several limitations of the study should be considered when interpreting the findings.

5.2.1 Sample size limitations

The sample consisted of only 20 participants, which may limit the generalisability of the results to a broader population. The study was not powered to identify differences in individual messages. Additionally, the majority of participants were female and had a hearing loss, potentially skewing the findings and limiting their applicability to other demographic groups.

5.2.2 Self-report data limitations

The study also relied on self-reported data from participants, including responses to interview questions and ratings of motivational messages. This introduces the possibility of response bias, where participants may provide socially desirable or inaccurate responses. The Likert-scale responses, where participants were asked to rate the questions from 1 (not very helpful) to 5 (very helpful), had 41 motivational messages to rate. Revising this, it would be advisable to state how many ratings were required. As participants were unaware, they may have lost interest throughout scoring, without an end in sight. This could mean a neutral response bias, where respondents tend to choose the neutral or middle option. Mean ratings ranged from 2.93 to 3.48. From the results, we can see that mean ratings were placed around a 3, being a neutral response. This should be taken into consideration when looking at results.

5.2.3 Operational aspect confusion

Some participants expressed confusion regarding the operational aspects of the motivational messaging intervention. Despite efforts to clarify the functioning of the messaging system during interviews, some participants still demonstrated uncertainty or confusion about how the messaging would operate. This lack of clarity could have influenced participants' perceptions and responses to the intervention, potentially affecting their engagement and adherence. Additionally, unclear understanding of the intervention may have introduced variability in participant experiences and interpretations of the messages, making it challenging to assess the intervention's effectiveness accurately.

5.2.4 Insufficient tinnitus severity

A notable limitation observed in the study is the possibility that participants, in general, may have been able to ignore their tinnitus on a day-to-day basis. This phenomenon could potentially influence the effectiveness of the motivational messaging intervention, as individuals who are less bothered by their tinnitus may perceive less benefit from such interventions compared to those who experience more distress or impairment due to their symptoms. The ability to ignore tinnitus varies greatly among individuals and can be influenced by factors such as the perceived loudness of the tinnitus, coping strategies, and overall psychological well-being. In this study, a significant proportion of participants reported minimal bother or interference from their tinnitus in their daily lives, which could have implications for the relevance and impact of the motivational messages suggested for intervention. This limitation shows the importance of considering the heterogeneity of tinnitus experiences within the study population. While some individuals may benefit greatly from motivational messaging interventions to enhance their coping strategies and motivation for tinnitus management, others who perceive their tinnitus as less bothersome may not find such interventions as relevant or beneficial.

To address this limitation, future research could consider stricter regimens around participants' perceived tinnitus severity or bother levels. By examining the effectiveness of motivational messaging interventions within subgroups of individuals with varying degrees of tinnitus severity, researchers can better understand how to tailor interventions to meet the specific needs of different patient populations. Additionally, qualitative exploration of participants' experiences with tinnitus management strategies, including their perceptions of the relevance and usefulness of motivational messaging, can provide valuable insights into the factors that contribute to treatment engagement and effectiveness. This approach can help researchers identify potential barriers and facilitators to intervention uptake and inform the development of more targeted and personalised interventions for individuals with tinnitus.

5.2.5 Language constraints

The surveys were also constrained to English, potentially excluding those whose primary language was different. Limited resources and time constraints prevented the development of translations for this study. Future motivational messaging studies should consider incorporating various languages in both study design and content to ensure broader accessibility for those affected by tinnitus.

5.3 Future Directions

Several potential future directions emerge from the findings and limitations of the current study. Conducting longitudinal studies with larger sample sizes would allow for a more robust assessment of the long-term effects of motivational messaging interventions for tinnitus management. Tracking participants over extended periods would provide insights into the sustainability of behaviour change and symptom reduction. Randomised controlled trials (RCTs) with control groups could also enable researchers to establish the causal efficacy of motivational messaging interventions for tinnitus. By comparing outcomes between intervention and control groups, researchers can better understand the specific effects of motivational messages on tinnitus severity and quality of life. Ecological momentary assessments and ambulatory monitoring techniques could also be explored to capture a more comprehensive understanding of participants' experiences.

As results emphasised, participants had a preference for the ability to personalise their messages to suit their individual needs and preferences. Investigating the effectiveness of personalised messaging approaches tailored to individual characteristics and preferences could enhance intervention outcomes. Utilising machine learning algorithms or adaptive systems to customise message content and delivery timing based on participant responses and feedback may optimise engagement and effectiveness.

Considering health equity considerations, such as accessibility for individuals with diverse socioeconomic backgrounds, cultural sensitivities, and linguistic preferences, could be useful in developing inclusive and effective interventions for tinnitus management. This study did not look at the effects of culture or socio-economic background, which could have provided an interesting insight. Addressing health equity considerations is important for ensuring that motivational messaging interventions are accessible and effective for everyone, regardless of socioeconomic background or cultural sensitivities. Future research should prioritise the development of interventions that are culturally responsive, considering the diverse needs and preferences of tinnitus sufferers from different cultural backgrounds. This might involve translating motivational messages into multiple languages, incorporating culturally relevant content and imagery, and ensuring that intervention platforms are accessible to persons with disabilities or limited digital literacy.

A further study looking at the development of training programs for healthcare providers, including audiologists and primary care physicians, on the integration of motivational messaging interventions for tinnitus into clinical practice may facilitate the adoption and implementation of these approaches in real-world settings. However, time-constraints are a significant factor among healthcare workers.

As mentioned previously, there was some confusion regarding the operational aspects of the motivational messaging intervention. Future studies should prioritise enhancing the clarity of intervention protocols and instructions to mitigate participant confusion and ensure consistent understanding and implementation across participants.

By investigating these future directions, there is the potential for researchers to advance our understanding of the role of motivational messaging in tinnitus management. Further investigation could help contribute to the development of evidence-based interventions that improve outcomes for individuals living with tinnitus.

6 Conclusion

The objective of this study was to determine if, and which, motivational messages individuals with tinnitus may consider beneficial within a mobile therapeutic framework designed for tinnitus management. Based on the findings presented in this study, it is evident that motivational messages hold promise as a valuable tool for tinnitus management. The quantitative analysis revealed varying degrees of effectiveness across different message categories, with motivational support messages and education around tinnitus receiving the highest ratings. Moreover, the nuanced differences in message ratings across demographic factors, such as gender, underscore the necessity of personalised and tailored messaging strategies to cater to individual preferences and characteristics.

The thematic analysis of participant interviews provided valuable insights into the perceived benefits and challenges associated with receiving motivational messages for tinnitus management. While many participants expressed enthusiasm for the concept and highlighted potential benefits such as increased motivation and coping mechanisms, some also voiced concerns regarding the potential intrusiveness and effectiveness of such messages. Interestingly, participants also suggested the incorporation of gamification elements, such as rewarding correct responses with visual incentives as a means of enhancing engagement and motivation.

In addition to the insights gained from quantitative and qualitative analyses, participant suggestions for user-generated content and community engagement represent a valuable avenue for enhancing the effectiveness and sustainability of motivational messaging interventions for tinnitus management. By incorporating features that enable users to contribute their own tips and experiences, the platform can foster a sense of community and empowerment among individuals living with tinnitus. Moving forward, it will be essential to explore strategies for implementing and moderating user-generated content in a way that maintains relevance, accuracy, and inclusivity. Through collaborative efforts and innovative approaches, motivational messaging interventions have the potential to not only improve tinnitus management outcomes but also cultivate a supportive ecosystem that empowers individuals to take an active role in their healthcare journey.

Overall, these findings emphasise the importance of adopting personalised and targeted approaches in the development and implementation of motivational messaging interventions for tinnitus management. Further research in this area, focusing on refining message content and delivery methods based on individual needs and preferences, is warranted. By addressing these considerations, motivational messaging has the potential to significantly enhance tinnitus management strategies and improve the quality of life for those grappling with tinnitus.

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Appendices

Appendix A: Motivational Messages

Message Number	Message
Strategies for managing tinnitus	
1	Relaxation techniques: Stress and anxiety can worsen tinnitus. Practice relaxation techniques such as deep breathing, meditation, yoga, or progressive muscle relaxation to help manage stress levels.
2	Sound therapy: Background noise can help to mask or distract from your tinnitus sound.
3	Avoid loud noises: Exposure to loud noises can exacerbate tinnitus. Protect your ears by wearing ear plugs or earmuffs in noisy environments and avoid activities that involve prolonged exposure to loud sounds.

4. Manage your hearing: If you have hearing loss in addition to tinnitus, using hearing aids or other hearing devices may help alleviate symptoms. Amplifying external sounds can reduce the perception of tinnitus.

5. Avoid stimulants: Certain substances like caffeine, nicotine, and alcohol can intensify tinnitus symptoms. Limit or avoid consumption of these stimulants to see if there is an improvement.

6. Relaxation exercises: Incorporate relaxation exercises into your daily routine, such as progressive muscle relaxation, deep breathing, or mindfulness meditation. These techniques can help reduce stress and promote overall well-being.

7. Healthy lifestyle: Maintain a healthy lifestyle by engaging in regular exercise, getting enough sleep, eating a balanced diet, and managing stress. Taking care of your overall health can positively impact your tinnitus symptoms.

Masking noise

8. Tinnitus can become bothersome, especially when trying to sleep. One effective method is using masking noise, to create a soothing background sound that helps distract from the tinnitus.

9. Consider using your smartphone app for tinnitus relief. You can listen to nature sounds, gentle music, or static noise, which can help distract from the ringing in your ears.

10. Experiment with different types of masking noise to find what works best for you. Some people prefer low-pitched sounds like the rain, or ocean sounds, while others find high-pitched white noise more effective. Find the sound that provides the most relief for tinnitus.

11. Ensure that the masking noise you are using is at a comfortable volume and not too loud. It should be just loud enough to cover the tinnitus without causing any discomfort or preventing you from falling asleep.

12. Consider using headphones or earbuds if you find it difficult to sleep with external noise. There are specialised sleep headphones available that are designed to be comfortable for sleeping while providing masking sounds directly to your ears.

13 In addition to masking noise, you can also try incorporating relaxation techniques into your bedtime routine. Techniques such as deep breathing or meditation that can help you relax and promote better sleep.

14 Creating a sleep-friendly environment can contribute to better sleep with tinnitus. Keep your bedroom quiet, dark, and cool. Using blackout curtains, earplugs, or an eye mask can further enhance your sleep environment.

Training reminders

15 Remember to practise your tinnitus exercises today!

16 Spend a few minutes today to journal about your tinnitus experiences and any changes you've noticed. Reflect on your progress.

17 Practising mindfulness exercises today can promote a positive mindset and reduce tinnitus distress.

18 Engaging in sound therapy today can help reduce the perception of tinnitus. Use your masking sounds or listen to soothing sounds.

19 Remember to take some time to relax today. This can help manage your tinnitus.

Stress management

20 Practise deep breathing exercises, progressive muscle relaxation or meditation to help relax your body and mind. This can alleviate stress and reduce the impact of tinnitus.

21 You can create a calming environment by using background noise to help mask the ringing or buzzing sounds and provide relief. If you’re struggling today, try this!

22 Try to engage in activities that you find enjoyable and relaxing. Find what works best for you to manage your stress effectively. Activities could include hobbies, getting outside or exercising.

23 Sharing what you’re going through with others can provide emotional support and help to develop coping strategies.

24 Our ability to manage stress is influenced by our lifestyle habits. Getting regular exercise, eating a balanced diet, and getting enough sleep can all help reduce stress and tinnitus perception.

Time of day reminders

25 The morning is a great time to start your day with relaxation exercises or mindfulness techniques, to set a positive tone for the day.

26 Avoid loud noise exposure in the morning to give your ears a rest and to minimise discomfort.

27 Consider some yoga or stretching this morning to improve blood circulation and reduce stress levels. This can help start the day off well and reduce tinnitus symptoms.

28 Take some breaks throughout the day to practise deep breathing to alleviate tinnitus related stress.

29 Create a calm environment by reducing noise distractions, or utilising sound therapy if they help to mask your tinnitus.

30 Now is a good time to relax. Establishing a relaxing bedtime routine to promote better sleep is important, as fatigue can make tinnitus symptoms worse.

31 Avoid stimulating substances like caffeine or nicotine before bed, as they may interfere with your sleep quality and contribute to tinnitus discomfort.

	32	Consider using sound therapy devices to create a relaxing environment while you sleep.
	33	Remember to keep hydrated today! This can help manage your tinnitus.
Motivational support messages		
	34	Your tinnitus may feel overwhelming at times, but remember you are not alone. With the right strategies and support, you can control and minimise the impacts of tinnitus on your health and life.
	35	Take one step at a time, and don't be discouraged if progress seems slow. Small victories add up overtime, and each step you take towards managing your tinnitus brings you closer to a better quality of life.
	36	Remember to explore various options to help your tinnitus. Your tinnitus can be controlled. Stay open-minded and willing to try different approaches until you find what works best for you.
	37	Be patient and kind to yourself in this process. It is important to remember you have the strength to persevere and improve your tinnitus.
Education around tinnitus		

38	Remember tinnitus is the perception of an internal sound when there is no external sound source. Tinnitus is your brain filling the gaps.
39	Your hearing system interacts with other areas in your brain that direct your emotional reactions, stress response or your behaviour. These interactions can mean that you will perceive a louder tinnitus sound when you are distressed.
40	Different factors such as your emotional state, stress and lack of sleep can amplify the perception of your tinnitus.
41	You cannot remove all stressors from your life, and sometimes stressful events cannot be avoided, but by reducing daily stressors like negative self-talk can be worked on to improve overall tinnitus perception.

Appendix B: P-values for Pearson r Correlations

Message Number	Pitch (kHz) L	Sensation Level L	Pitch (kHz) R	Sensation Level R	TFI TOTAL
1	0.813	0.094	0.862	0.166	0.276
2	0.785	0.701	0.207	0.548	0.277
3	**0.003**	0.856	**0.002**	0.548	0.405
4	0.914	0.673	0.678	0.745	0.419
5	0.144	0.232	0.053	0.552	0.082

6	0.789	0.855	0.408	0.992	0.113
7	0.335	0.505	0.226	0.960	0.076
8	0.146	0.551	0.086	0.938	0.259
9	0.077	0.256	0.175	0.816	0.517
10	0.514	0.163	0.518	0.546	0.900
11	0.221	0.295	0.134	0.861	0.847
12	0.566	0.150	0.316	0.500	0.520
13	0.857	0.172	0.674	0.195	0.349
14	0.943	0.166	0.702	0.687	**0.016**
15	0.769	0.381	0.349	0.764	0.251
16	0.255	0.128	0.870	0.524	0.139
17	0.499	**0.008**	0.406	0.083	0.101
18	0.722	0.384	0.276	0.977	0.336
19	0.336	0.224	0.277	0.592	0.109
20	0.745	0.448	0.755	0.687	0.084
21	0.985	0.683	0.455	0.592	0.402
22	0.540	0.718	0.209	0.570	0.756
23	0.971	0.109	0.724	0.330	0.270
24	0.508	0.785	0.263	0.747	0.120
25	0.739	0.509	0.485	0.691	0.337
26	0.327	0.385	0.091	0.354	**0.030**
27	0.388	0.971	0.509	0.649	0.584
28	0.707	0.578	0.762	0.869	0.190
29	0.119	0.310	**0.031**	0.357	0.922
30	0.810	0.755	0.578	0.838	0.349
31	**0.034**	**0.035**	0.067	0.330	0.083
32	0.890	0.741	0.286	0.793	0.337
33	0.216	0.987	0.247	0.493	0.703
34	0.988	0.466	0.582	0.554	0.738
35	0.501	0.302	0.790	0.501	0.697
36	0.428	0.306	0.793	0.369	0.988

37	0.804	0.603	0.534	0.961	0.461
38	0.589	0.418	0.606	0.267	0.873
39	0.696	0.378	0.708	0.673	0.267
40	0.384	0.255	0.355	0.563	0.079
41	0.722	0.922	0.689	0.914	0.628

Appendix C: Persons with Tinnitus Participant Information Sheet

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Auckland 1142

New Zealand

PARTICIPANT INFORMATION SHEET

Messages for Tinnitus Management

Research team:
Professor Grant Searchfield (Principal Investigator/Supervisor)
Lauren Dodd (Researcher/Masters student)

Purpose of the study: We wish to invite people who are experiencing bothersome tinnitus to participate in this research. The aim of this study is to explore the effect of text messages on participation in tinnitus counselling. The overall aim is to improve outcomes in tinnitus intervention.

If you agree to take part in this study, you will be asked to sign the Consent Form on the last page of this document. You will be given a copy of both the Participant Information Sheet and the Consent Form to keep.

It is important that you read this document carefully so that you can make an informed decision about whether you would like to participate.

Eligibility: **The eligibility to participate are as follows:**

1. Age 18 years and over and living in New Zealand.
2. Have internet and email access, and the ability to use these.
3. Bothered with tinnitus for a minimum period of 6 months.
4. Have tinnitus which is sufficiently severe as determined (using a tinnitus impact of life score calculation).
5. Have tinnitus which **does not**:
    - Fluctuate (i.e., is constant)

What will my participation in the study involve?

This research will involve a hearing and tinnitus assessment as well as a set of questionnaires regarding tinnitus history and impact on life, and text messages to assist in tinnitus management. Sessions will be held in one of the clinic rooms of the Audiology Teaching Clinic, University of Auckland, Grafton Campus.

Participants will receive the assessment and questionnaires.

Prior to the appointment: Questionnaires (15 minutes)

Before the hearing and tinnitus assessment, you will be asked to fill in these questionnaires. The questionnaires will take approximately 15 minutes to complete. You will receive access to these questionnaires through email. This will allow you to complete the questionnaires at a time that is convenient for you.

We may then discuss thoughts around the text messages when you come in for your hearing and tinnitus assessment. *This may be recorded* to allow for transcription. This is optional and even if you agree to being recorded, you may choose to have the recorder turned off at any time. You will be able to edit your transcription up to two weeks after the receipt of the transcript. If a third party is used to transcribe these recordings, they will be made to sign a confidentiality agreement.

You will be asked to complete questionnaires measuring tinnitus history and impact on life (Tinnitus Case History Questionnaire, Tinnitus Functional Index) and about text messages and how encouraging you find these.

On the day: Hearing and tinnitus assessment

A. **Case history follow-up (10 minutes):** Relevant information gathered relating to your tinnitus and hearing.
B. **Otoscopy (5 minutes):** We will look into your ear canal using a light (otoscope) to see if the ear canal is free of wax and check the status of the ear canal and ear drum.

C. **Pure tone audiometry and tinnitus assessment (60 minutes):** You will be played a variety of sounds through a pair of headphones. These sounds will be short beeps at different pitches and volumes. You will be asked to respond by pressing a button when you hear a beep. Sounds will also be played over the headphones where you will be asked if they match your tinnitus.
D. **Messages for tinnitus management questionnaire follow-up (15 minutes):** Discussion around how effective the messages were.

Benefits

A $20 Westfield voucher will be provided as a token of gratitude for participating in the study, you may keep this even if you withdraw from the study. Funding is supplied by School of Population Health Graduate research funding. If any additional management of tinnitus is required, then an Audiologist will appropriately counsel you. You will not incur any costs in taking part in this research. Participation may also provide an opportunity in improving methods to reduce tinnitus distress in the population.

Risks and Discomforts

The procedures outlined in this protocol are non-invasive. They do not involve greater than minimal risk, harm, or discomfort than may be encountered in daily life.

Data Storage

All data (questionnaires and hearing and tinnitus assessment) will be stored in electronic format by the researcher. Data will be stored on a password-protected computer and backed up by a server. The access to these files will be restricted to the researcher and the supervisor only.

Confidentiality

All personal information will remain strictly confidential and no material that could personally identify you will be used in any report on this study. The information and data collected from you will be stored securely, in locked cabinets and on secure computer networks. Only the investigators will have access to this information, and your data will be made confidential by assigning a unique code to it. After completion of the study, all confidential data will be kept for a minimum period of six years to allow for publication and analysis, after which time it will be securely and confidentially disposed of. Research publications and presentations from the study will not contain any information that could personally identify you.

Rights to Access Your Information

You have the right to request access to your information held by the research team. You also have the right to request that any information you disagree with is corrected.

Results

You can request a summary of the study's results, which we can send to you once the project is complete. As it takes some time to analyse the results of studies, it may be more than a year after your participation that you receive this information.

Your rights as a participant

- Your participation is entirely voluntary.
- You may with the project at any time without stating a reason and without any negative consequence.
- You may have your data withdrawn from the study within two months of your participation.
- You may obtain results regarding the outcome of the project from the experimenters upon completion of the study.
- Your identity will not be anonymous but will be kept strictly confidential throughout the study. Your identity will be kept confidential in any publications that may arise from the study.
- After six years, your data will be deleted, and your consent form and all related paperwork put through a shredder.

- You are encouraged to consult with your whanau/family, hapu or iwi regarding participation in this project.
- For some people discussing their tinnitus may be distressing. Support is available through the University of Auckland clinics.

We appreciate the time you have taken to read this invitation. If you have any further questions, concerns, or complaints about the study ar any stage, please contact:

Lauren Dodd (Researcher)
Master of Audiology student
Faculty of Medical and Health Sciences
The University of Auckland
Private Bag 92019
Auckland 1142
Email: ldod131@aucklanduni.ac.nz

Alternative contacts:

Professor Grant Searchfield (Supervisor)
Head of Audiology
Faculty of Medical and Health Sciences
The University of Auckland
Private Bag 92019
Auckland 1142
Email: g.searchfield@auckland.ac.nz
Phone: +64 9 923 6316

Ethical Concerns

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 x 83711, or at Auckland Health Research Ethics Committee, The University of Auckland, Private Bag 92019, Auckland 1142.

Approved by the Auckland Health Research Ethics Committee on 14/09/2023 for three years. Reference number AH26156.

Appendix D: Consent Form

UNIVERSITY OF AUCKLAND Waipapa Taumata Rau NEW ZEALAND | MEDICAL AND HEALTH SCIENCES

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audiology@auckland.ac.nz
The University of Auckland
Private Bag 92019
Auckland 1142
New Zealand

CONSENT FORM

THIS FORM WILL BE HELD FOR A PERIOD OF 6 YEARS

Messages for Tinnitus Management
Principle Investigator: Prof. Grant Searchfield, **Student Researcher:** Lauren Dodd

I have read or have had read to me in my first language, the Participant Information Sheet. I have been given sufficient time to consider whether to participate in this study and to ask questions and was offered support from whānau/family or a friend to help me understand what the study involves. I am satisfied with the answers given to me, I understand the nature of the research and why I have been invited to participate.

- I agree to take part in this research.
- I understand my participation is voluntary.
- I understand that I am free to withdraw my participation at any time.
- I understand that data will be kept for six years and separate from the consent forms, after which they will be destroyed.
- I understand that my participation in this study is confidential and that no material which could identify me personally will be used in any reports on this study.
- I understand that filling in the questionnaires implies consent to having information shared available for research purposes.
- I **agree** / **do not agree** to be audio recorded **(please circle one)**.
- I **wish** / **do not wish** to receive a transcript of my interview for editing **(please circle one)**.
- I understand that a third party who has signed a confidentiality agreement may transcribe the recordings.
- I consent to the research staff collecting and processing my information, including information about my health.
- I know who to contact if I have any questions about the study in general.
- I wish / do not wish to receive the summary of findings **(please circle one)**.

Email/postal address: ___________________________________

Name: ______________________

Signature: ______________________ Date: ___________

Approved by the University of Auckland Human Participants Ethics Committee on 14/09/2023 for three years. Reference Number AH26156

Appendix E: Tinnitus Functional Index

Page 1

Tinnitus Functional Index

Please read each question below carefully. To answer a question, select ONE of the numbers that is listed for that question.

TFI

1) Date of Birth

____
(DD-MM-YYYY)

2) Sex

◯ Male
◯ Female

Over the PAST WEEK:

3) What percentage (%) of your time awake were you consciously AWARE OF your tinnitus?
(0% = Never aware; 100% = Always aware)

◯ 0 ◯ 10 ◯ 20 ◯ 30 ◯ 40 ◯ 50 ◯ 60 ◯ 70 ◯ 80 ◯ 90 ◯ 100

4) How STRONG or LOUD was your tinnitus?
(0 = Not at all strong/loud; 10 = Extremely strong/loud)

◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10

5) What percentage (%) of your time awake were you ANNOYED by your tinnitus?
(0% = None of the time; 100% = All of the time)

◯ 0 ◯ 10 ◯ 20 ◯ 30 ◯ 40 ◯ 50 ◯ 60 ◯ 70 ◯ 80 ◯ 90 ◯ 100

Over the PAST WEEK:

6) Did you feel IN CONTROL in regard to your tinnitus?
(0 = Very much in control; 10 = Never in control; NB: A HIGHER NUMBER indicates that you felt LESS in control)

◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10

7) How difficult was it for you to COPE with your tinnitus?
(0 = Very easy to cope; 10 = Impossible to cope)

◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10

8) How difficult was it for you to IGNORE your tinnitus?
(0 = Very easy to ignore; 10 = Impossible to ignore)

◯ 0 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10

Over the PAST WEEK how much did your tinnitus interfere with:

9) Your ability to CONCENTRATE?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

10) Your ability to THINK CLEARLY?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

11) Your ability to FOCUS ATTENTION on other things besides your tinnitus?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Over the PAST WEEK:

12) How often did your tinnitus make it difficult to FALL ASLEEP or STAY ASLEEP?
(0 = Never had difficulty; 10 = Always had difficulty)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

13) How often did your tinnitus cause you difficulty in getting AS MUCH SLEEP as you needed?
(0 = Never had difficulty; 10 = Always had difficulty)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

14) How much of the time did your tinnitus keep you from SLEEPING as DEEPLY or as PEACEFULLY as you would have liked?
(0 = None of the time; 10 = All of the time)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Over the PAST WEEK how much did your tinnitus interfere with:

15) Your ability to HEAR CLEARLY?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

16) Your ability to UNDERSTAND PEOPLE who are talking?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

17) Your ability to FOLLOW CONVERSATIONS in a group or at meetings?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Over the PAST WEEK how much did your tinnitus interfere with:

18) Your QUIET RESTING ACTIVITIES?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

19) Your ability to RELAX?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

20) Your ability to enjoy "PEACE AND QUIET?"
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Over the PAST WEEK how much did your tinnitus interfere with:

21) Your enjoyment of SOCIAL ACTIVITIES?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

22) Your ENJOYMENT OF LIFE?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

23) Your RELATIONSHIPS with family, friends and other people?
(0 = Did not interfere; 10 = Completely interfered)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

24) How often did your tinnitus cause you to have difficulty performing your WORK OR OTHER TASKS, such as home maintenance, school work, or caring for children or others?
(0 = Never had difficulty; 10 = Always had difficulty)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Over the PAST WEEK:

25) How ANXIOUS or WORRIED has your tinnitus made you feel?
(0 = Not at all anxious or worried; 10 = Extremely anxious or worried)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

26) How BOTHERED or UPSET have you been because of your tinnitus?
(0 = Not at all bothered or upset; 10 = Extremely bothered or upset)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

27) How DEPRESSED were you because of your tinnitus?
(0 = Not at all depressed; 10 = Extremely depressed)

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Appendix F: Tinnitus Sample Case History Questionnaire

Tinnitus Sample Case History Questionnaire

Please complete the survey below.

Thank you!

TSCHQ

Age

____
((years))

Handedness

◯ Right ◯ Left ◯ Both sides

Family history of tinnitus complaints

◯ Yes ◯ No

If yes, who?

☐ Parents ☐ Siblings ☐ Children

Initial Onset: When did you first experience your tinnitus? (approximately)

____
(DD-MM-YYYY)

How did you perceive the beginning?

◯ Gradual ◯ Abrupt

Was the initial onset of your tinnitus related to:

◯ Loud blast of sound
◯ Whiplash
◯ Change in hearing
◯ Stress
◯ Head Trauma
◯ Other

If "other" please explain

Does your tinnitus seem to PULSATE?

◯ YES with heart beat ◯ YES different from heart beat ◯ NO

Where do you perceive your tinnitus?

◯ Left ear
◯ Right ear
◯ Both ears, worse in left
◯ Both ears, worse in right
◯ Both ears equally
◯ Inside the head

How does your tinnitus manifest over time?

◯ Intermittent ◯ Constant

Does the LOUDNESS of the tinnitus vary from day to day?

◯ Yes ◯ No

Describe the LOUDNESS of your tinnitus using the slider scale from 1 (very faint) - 100 (very loud)

Very faint Very loud

(Place a mark on the scale above)

Please describe in your own words what your tinnitus usually sounds like*:
(*The following list gives examples of some possible sensations, feel free to use other terms as well: hissing, ringing, pulsing, buzzing, clicking, cracking, tonal (like a dial tone or other kinds of tones), humming, popping, roaring, rushing, typewriter, whistling, whooshing.)

Does your tinnitus sound more like a tone or more like noise?

◯ Tone ◯ Noise ◯ Crickets ◯ Other

Please describe the PITCH of your tinnitus:

◯ Very high frequency ◯ High frequency ◯ Medium frequency ◯ Low frequency

---

What percent (%) of your total awake time, OVER THE LAST MONTH, have you been aware of your tinnitus? For example, 100% would indicate that you were aware of your tinnitus all the time, and 25% would indicate that you were aware of your tinnitus ¼ of the time.

____
(Please write a single number between 1 and 100)

What percent (%) of your total awake time, OVER THE LAST MONTH, have you been annoyed, distressed or irritated by your tinnitus?

____
(Please write a single number between 1 and 100)

How many different treatments have you undergone because of your tinnitus?

◯ None ◯ One ◯ Several ◯ Many

Is your tinnitus reduced by music or by certain types of environmental sounds such as the noise of a waterfall or the noise of running water when you are standing in the shower?

◯ Yes ◯ No ◯ I don't know

Does the presence of loud noise make your tinnitus worse?

◯ Yes ◯ No ◯ I don't know

Does any head and neck movement (e.g. moving the jaw forward or clenching the teeth), or having your arms/hands or head touched, affect your tinnitus?

◯ Yes ◯ No

Does taking a nap during the day affect your tinnitus?

◯ Worsens my tinnitus ◯ Reduces my tinnitus ◯ Has no effect

Is there any relationship between sleep at night and your tinnitus during the day?

◯ Yes ◯ No ◯ I don't know

Does stress influence your tinnitus?

◯ Worsens my tinnitus ◯ Reduces my tinnitus ◯ Has no effect

Does medication have an effect on your tinnitus?

◯ Yes ◯ No

Please name the medication(s) and describe its effect(s) on your tinnitus
(Please specify medication(s) and details of the effect(s))

Do you think you have a hearing problem?

◯ Yes ◯ No

Do you wear hearing aids?

◯ Left ◯ Right ◯ Both ◯ No

Do you have a problem tolerating sounds because they often seem much too loud? That is, do you often find sounds too loud or hurtful which other people around you find quite comfortable?

◯ Never ◯ Rarely ◯ Sometimes ◯ Usually ◯ Always

Do sounds cause you pain or physical discomfort?

◯ Yes ◯ No ◯ I don't know

Do you suffer from headaches?

◯ Yes ◯ No

Do you suffer from vertigo or dizziness?

◯ Yes ◯ No

Do you suffer from any temporomandibular disorders?
(Temporomandibular disorders are disorders of the jaw muscles, temporomandibular joints, and the nerves associated with chronic facial pain.)

◯ Yes ◯ No

Do you suffer from neck pain?

◯ Yes ◯ No

Do you suffer from other pain syndromes?

◯ Yes ◯ No

Are you currently under treatment for psychiatric problems?

◯ Yes ◯ No