



NEW DEVELOPMENTS IN THE TREATMENT OF TINNITUS - THE AUREX-3 FOR TINNITUS

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Tinnitus is a very common and often distressing condition affecting 10% of the UK adult population. Some people with tinnitus will be able to habituate to the noise and attention has been placed to date on treatments that aid this process. However, many sufferers are constantly aware of tinnitus with little or no relief possible. Increasing awareness of the prevalence and plight associated with tinnitus together with the significant progress in neurological research in recent years is leading to a number of new treatment strategies for tinnitus. The current status of these strategies is presented and in particular the modality and application of a new device for managing tinnitus is described.

Introduction

Tinnitus is the perception of sound when no external sound is present. Subjective tinnitus is only heard by the affected person. The 'head noises' can originate anywhere from the cochlea to the auditory cortex of the brain where sound reaches a conscious level. The causes for tinnitus are many and varied including pathological, physiological and psychological derivatives, or very often combinations of these. The symptoms can vary from mildly irritating to maddening and debilitating with over ½ million people in the UK afflicted to a point where their lifestyles are affected. Despite its recognition as a medical condition since the 19th century there is still today little medical consensus on the actual causes, mechanisms and hence potential treatments for tinnitus. In this paper we present a combined physiological and psychophysical approach to the causes of tinnitus allowing us to assess the effects of potential new treatments in tackling the causes of tinnitus.

Tinnitus in the UK Population

Figures based on the most recent National Study of Hearing carried out by the Medical Research Councils Institute of Hearing reveals that 10% of adults have at some time experienced Prolonged Spontaneous Tinnitus. 7% of adults have sought medical advice from their doctor for tinnitus.

Furthermore,

- 5% of adults (2m) have tinnitus causing moderate or severe annoyance
- 5% of adults (2m) have tinnitus causing sleep disturbance
- 1% of adults (0.4m) have tinnitus severely affecting their quality of life
- 0.5% Of adults (0.2m) have tinnitus severely affecting their ability to lead a normal life.

Given the demographic range of tinnitus it is not unusual to come across people who have been affected continuously by tinnitus for over thirty years. Beyond these figures there is a growing number of young people reporting tinnitus.

Hearing or Listening?

In the late 1950's Berard and Tomatis, French ENT specialists, argued that the ear performs a much greater role than simply allowing us to hear. In particular Tomatis differentiated the concept of

listening, absorbing information, from the sensory response of hearing. He observed a close relationship between how a person hears and their behaviour, learning abilities, sociability, emotional health and general well being. The success of the subsequently developed Listening Therapy in treating a number of behavioural difficulties attests to the important link between hearing physiology and psychology. In so doing the highly stimulating perceptive response to ordered classical music is used to train to listen properly. Thus, the organ of hearing takes on a far greater role and importance. Perhaps it is no evolutionary surprise that in the highest form of living being the Organ of Corti, the “peripheral seat of hearing”, is enclosed in the cochlea which itself is deeply embedded in the temporal bone, the hardest in the body.

To understand tinnitus we need to understand how we hear, how we listen and how we perceive sound.

For convenience this may be broken down into three descriptive stages ;

1. Auditory stimulation : sound reception and treatment
2. Auditory transmission : sound conversion and nerve transmission
3. Auditory perception : sound storage and identification

In order to develop an alternative non-invasive approach to tinnitus management it is useful to consider the functions of these in terms of the physics of sound.

1. Mechanics of the Ear

Vibrating airwaves (sound) enter the outer ear canal and create a resonating column of air with length about 2.5cm and average diameter 0.8mm. The open end of the ear canal is surrounded by the pinna that provides spatial focussing. The resonance inside the ear canal amplifies the variations of air pressure that make up sound waves, placing a peak pressure directly at the closed, eardrum, end of the canal. For frequencies between approximately 2KHz and 5.5KHz, the sound pressure level at the eardrum is approximately 10 times the pressure of the sound at entry. Air pressure waves set up sympathetic vibrations in the taut component of the eardrum that are then passed on to the solid components of the middle ear. The three bones of the middle ear form a system of levers that are linked together and driven by the eardrum. Working together as a lever and columnar system, the bones may amplify the force of the sound vibrations to up to three times the force of the vibrations at the eardrum. The muscles of the middle ear modify the performance of this lever system as an amplifying unit. They act to protect the ear against excessively loud noises. The vibrations from the middle ear are passed to the oval window covering an opening in the bony case of the cochlea. This oval window is 15 to 30 times smaller than the eardrum producing the critical amplification needed to match the impedance between sound waves in the air and in the cochlear fluid. The incoming vibrations of sound are amplified a further 30 times by this concentration of force. By this combination of mechanisms relatively weak vibrations in air are amplified by more than 800 times so that they can establish pressure waves in the liquid of the inner ear. The pressure waves in the cochlea exert energy along a route that begins at the oval window and ends at the membrane covered round window, where the pressure is dissipated. Complying with the principles of hydraulics, the pressure applied at the oval window is transmitted to all parts of the cochlea. Hydraulic pressure waves in the cochlea induce a wave like ripple in the basilar membrane which travel from the taut end adjacent to the oval window to the loose end at the other. High frequency sounds vibrate the basilar membrane at the base of the cochlea whilst lower frequency sounds vibrate it at the apex. Frequencies in between have their maximum effects at points like the notes on a piano keyboard The positions of these crests determines which nerve fibres send signals to the brain.

2. Neurophysiology of Hearing

It is in the area of the neurophysiology and associated electrochemistry of sound conversion and nerve

transmission that the greatest strides in knowledge have led to new development opportunities for tinnitus treatment. Work over the last 20 years by Hudspeth (USA), Crawford (UK), Osborne (UK) and Hackney (UK) has created a greater understanding of the processes occurring.

Spiralling around within the cochlea is the organ of Corti, a gelatinous mass about 4 cm long that contains a mass of cells almost touching the branch endings of the auditory nerve. From these cells fine 'hairs', stereocilia, rise in four orderly rows, three outer and one inner. These 23,500 stereocilia are about 2microns in length and can be likened to transducers. Movements of the inner hairs acts immediately to generate electrical signals which stimulate the auditory nerve, a bundle of about 30,000 individual fibres. Adjacent sensory hairs are linked together by fine filaments called tip links that are like mechanical gates. When there is no sound at that hair cells frequency, the hair stands upright with the tip links 'gate valve' closed. When sound of the appropriate frequency deflects the hair cell, the gate opens and an electrochemical flow is initiated. Recent work has shown that movement of the stereocilia leads to gate opening by tiny levers. The tip links are important limiting devices, preventing excessive movements and/or returning to the upright position after deflection. This is likened to spring and switch nanotechnology of molecular dimensions. The flow of charged ions from the hair cell causes glutamate, a neurotransmitter, to be released which stimulates the nerve fibre causing an eletrochemical message to rush along the nerve towards the brain.

The tip link 'limit switches' can become damaged by exposure to loud noise such that this flow continues or is disrupted when no sound is present, leading to tinnitus.

Another area of interest follows from the knowledge that over release of Glutamate in other nerve pathways can cause nerve damage by over excitation. Interruption of oxygen supply to the nerve can cause over release of glutamate, leading to tinnitus.

Both of these areas are being researched as possible treatment opportunities for tinnitus.

3. Sound Perception

Emerging from the organ of Corti to form the auditory nerve, the 30000 nerve fibres transmit sound signals to the brain. Nerve fibres lead to different parts of the auditory cortex depending on the frequencies they carry. Descending nerve fibres from the brain carry instructions back to the inner ear to filter out some signals that the brain determines are of no importance or significance, and concentrate on others. Sound recognition and response occurs at the auditory cortex that may be likened to the hard disk of a computer. Files of data are maintained as memory functions for each frequency of sound. Long term sound memory functions are an example of neuronal plasticity relying on a rewiring of brain connections. A tinnitus response may thus be imprinted requiring time to redress the balance. Other parts of the brain can significantly effect the importance that is given to a tinnitus sound. In particular the Limbic system is an important control Centre of the brain comprising the hippocampus involved with incoming sensory information, the hypothalamus which is the emotional and functional barometer/ control unit of the brain and the amygdala which is thought to be more directly involved in emotion. So any history or underlying Psychosis is likely to affect the rate and extent of progress towards rewiring to accommodate the tinnitus sound – habituation. Jastreboff (USA) and Hazell (UK) have developed methods based on psychological treatments to speed up this habituation.

Tinnitus Treatment Strategies

Current strategies involve tinnitus retraining therapy that enhances the process of habituation using psychological methods combining directive counselling with noise therapy. Counselling generally is often used to reassure the tinnitus sufferer in coming to terms with their tinnitus and so aid the

habituation process. Another technique used in accommodating the effects of tinnitus is masking by noise generators of various types. Although the development of methods for enhancing habituation offers relief to a number of tinnitus sufferers this approach does not suit everyone. Hyperbaric oxygen treatment and blood oxygenation treatments are popular in Germany for tinnitus. A number of alternative medical treatments are available for tinnitus including homeopathy, acupuncture and hypnosis.

From the above description it remains that tinnitus is caused by damage or a weakness in the hearing pathway. New research is aimed at cognitive therapies using anti-phase noise devices or drug therapies to tackle the underlying causes of tinnitus.

Drugs which can be used to modify the ion channels in the cochlear hair cells or those that can control neurotransmitter activity are showing great potential for tinnitus. However, the side effects of such drugs render them impractical in general treatment at this time.

Much interest is being shown in the technique of using devices to tune into a person's tinnitus using anti-phase noise to eliminate tinnitus perception. Sounds of opposite phase will cancel each other out. Current research into the area of objective tinnitus measurement raises the potential of anti-phase noise devices.

Aurex-3

In 1995 acclaimed US inventor Dr Alfonso Di Mino was the recipient of the Marconi award in recognition of his work on short wave radio transmissions used in military communications. This completed a lifetime of novel inventions following early pioneering work in the development of ultrasound technologies for medical applications. In 1999 Di Mino was voted the New Jersey inventor of the year for his Aurex-3 device for treating tinnitus. Four years earlier he had applied his extensive experience of sound energy to develop an effective treatment for his own severe tinnitus “.. like trying to sleep next to a jet engine!”.

In developing the Aurex-3 Dr Di Mino considered hearing as a repetitive memory function. Dr Di Mino chose to consider tinnitus as resulting from the brain memory repetitive functions. In particular he focussed on the effect of damaged cochlear cilia ‘imprinting’ sounds in the brain through memory repetition. Based on this the first Aurex-3 was developed for his own use only and employed a central vibratory and audio frequency excitation tuned to a broad band surrounding his tinnitus. Through frequent use of the device long term masking may be achieved. By stimulating the damaged nerve endings in a broad band surrounding the tinnitus sound, the brains repetitive memory attribute will deviate to repeat the sound injected. Eventual inability to reproduce the original tinnitus sound will alleviate the intensity.

Using these principles the Aurex-3 was developed as a non-invasive device for applying user tuned frequency spectra through low intensity vibratory and audio excitations. The Aurex-3 generates a complex range of frequency spectra from the interactions of three fundamental frequencies (hence ‘Aurex-3’) together with sideband frequencies. The resulting harmonic frequencies span the audible range from 200 to 15,200 Hz (for reference middle C on a piano has a frequency of 256 Hz, human speech tends to be around 300 – 1,000 Hz, sounds above 5,000 Hz are high pitched squeals or screeches). These frequency spectra are tuned to complement the users tinnitus and applied via a handheld applicator to the mastoid bone behind the ear, and then transmitted by bone conduction to the inner ear.

In order to provide user adjustable setting of the device Di Mino employed extremely innovative application of harmonic beat theory to derive consonant frequencies between the sound delivered and the tinnitus sound.

To use the Aurex-3 a pencil like probe is placed in the small indent behind the ear pressing backwards onto the mastoid bone. Mechanical vibrations are generated by the control unit and transmitted through the applicator probe into the mastoid bone. By positioning the probe correctly these vibrations develop as a deep feeling within the head. The user then alters the frequency and amplitude settings to obtain a complimentary, often masking, sensation to their tinnitus. A fine tuning is then introduced whereby complex harmonic frequencies are introduced to create a comforting or soporific feeling. When this point is reached the tinnitus may be fully masked or if it is heard, it may not be uncomfortable. User patterns will vary but typically will involve treatments of 5 minutes duration, 3 times a day for the first two weeks. As benefits are seen the number of treatments may be reduced and the intervals increased. Aurex-3 will not suit all tinnitus sufferers. It requires initial determination when often there appears to be no improvement. The device is difficult to use needing patience, practice and a little encouragement. However, experience from using the Aurex-3 is showing some remarkable results and on the basis of subjective evidence amassed from around the world is being regarded as a major new development in the treatment of tinnitus.

Future Developments

Inspired by these early successes clinical research studies are now underway at Leicester Royal Infirmary to understand further the relationship between a person's tinnitus, the Aurex-3 settings and customised user patterns. These studies will eventually involve objective tinnitus measurements and experimental recording of cochlear activity to measure the changes occurring during treatment.

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