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MUSIC, WHEN SOFT VOICES DIE

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Music, when soft voices die,
Vibrates in the memory;
Odours, when sweet violets sicken,
Live within the sense they quicken.
Shelley

Introduction

Traditional views about the origin, aetiology and mechanism of tinnitus aurium have for centuries focused on the ear; irreversible damage caused usually by noise exposure, and the inevitability of a lifetime of suffering for the individual without any hope of effective treatment. It was against this background that the (now) Royal National Institute for Deaf People instituted a research programme in 1974 to focus directly on the problems of tinnitus and to seek an answer for its relief. This work continued to be supported by the Institute until 1998, by which time all the traditional concepts about tinnitus and decreased sound tolerance had been turned on their head, and really effective habituation based treatment became available.

This research was linked to the Royal Ear Hospital at University College Hospital, London and began the first tinnitus clinic outside the USA, in 1976 using the tinnitus masker designed by Jack Vernon.[1] A multicentric study on masking of tinnitus,[2] completed in 1985 following 472 patients through a three-year protocol of treatment, indicated that auditory masking with white noise was just as effective if used below the level at which tinnitus became inaudible (so called "partial masking"). It also showed the very important contribution of appropriate counselling. This involved considerable reassurance of the patient about the absence of serious disease, about which the patient frequently agonised, while conventional counselling commonly enhanced the patient's worst fears ("there is no treatment – some people commit suicide – you've just got to learn to live with it").

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In 1987, a chance meeting with Pawel Jastreboff (Fig. 1) resulted in a collaboration which still continues. Jastreboff had become fascinated by the complexity of tinnitus, and the total failure to find any successful treatment. As a neuroscientist working in vestibular and auditory mechanisms, he developed the neurophysiological model of tinnitus which was published in 1990[3] and has yet to receive any serious criticism. Most researchers and some clinicians now refer to this model, and many base their work upon it. It is interesting that at that time, Jastreboff was not a clinician, had never seen a tinnitus patient, and developed his model on his knowledge of brain function, a thorough review of the literature at that time, and work on an animal model of tinnitus in rats which he had perfected.[4]

Figure 1 Pawel Jastreboff at Yale 1988

In fact, the absence of clinical experience with tinnitus patients was a positive advantage for Jastreboff. The patient's perspective at that time was identical to the average practitioner's, who was convinced that the problem was in the ear. This was largely due to the subjective perception that tinnitus comes from the ear, not actually the case, but only a sensory illusion created by the auditory system (externalization of perception[5]). However it has been this powerful belief that focused all clinical activity and research, on the ear and the cochlea, looking for a pathological process responsible for the entirety of tinnitus symptomatology. This has persisted, to the extent that some otologists, ignorant of the central processes involved in persistent tinnitus, have sometimes been persuaded to cut the auditory nerve for tinnitus, usually with disastrous results. Early research at the RNID simulating tinnitus sounds with a music synthesizer,[6] graphically showed that even after acoustic nerve section tinnitus could persist either unchanged, or even worsened.

Tinnitus: source and demographics

Another issue identified by epidemiological studies from the Institute of Hearing Research in Nottingham showed that hearing loss was only loosely correlated with tinnitus.[7] In another study[8] 800 totally deaf patients waiting for cochlear implants were interviewed about their tinnitus experience. Tinnitus was totally absent in 27%. It was clear that while tinnitus was about two and a half times more common in people with hearing losses, the majority of those with hearing loss did not have problem tinnitus.

The issue of whether tinnitus was a problem or not a problem was also ignored by early researchers, although this is the only element that decides whether tinnitus is clinically relevant or not. Clearly those who experience tinnitus but were not bothered by it (about 85% of those experiencing it) were not going to affect the clinical impression of doctors and audiologists, who met uniquely with those who were in distress, and whose tinnitus had often persisted over many years, and for whom "they could do nothing".

Heller and Bergman experiment

In 1953 a unique experiment by Heller & Bergman[9] indicated how common and widespread tinnitus was, and also showed a difference between troublesome and non-troublesome tinnitus. In this experiment 80 adults with normal hearing for age and no previous experience of tinnitus were placed, one by one, in a soundproofed room for five minutes, and instructed to listen carefully. Afterwards they wrote down what they heard, 94% hearing whistling, buzzing, pulsing, rushing and other sounds, which came from inside their head, which they had never heard before, and which disappeared immediately they left the soundproofed room. A control group of 100 patients from a nearby hospital who were suffering from tinnitus went through an identical procedure. All patients described the sound of their tinnitus in the quiet room, as might be expected. When their descriptions were matched with the first group, they were found to be identical. However, on leaving the soundproofed room, tinnitus in the control group persisted unchanged, and with the same degree of annoyance as before. Although little was made of this work at that time, with the knowledge given to us by Jastreboff's model, it is obviously that anyone, or almost anyone, can hear tinnitus if instructed to listen in a silent environment, but the absence of any reaction means the tinnitus fails to persist and the experience is then forgotten. We habitually refer to tinnitus as "The Music of the Brain".

Animal experiments indicate an increase in activity in subcortical auditory neurones in a similar situation, and it is clear that the source of such tinnitus is a compensatory activity of normal auditory neurones in response to silence. In addition, emergence of tinnitus, while extremely common, relatively rarely results in persistence of tinnitus. In the wild, silence is a warning signal, precedes predation, and results in increased sensory awareness (as well as enhanced autonomic activity).

Tinnitus emergence may occur in response to silence, or relative silence (in hearing loss), or any changes in the auditory system and its connections which might result in compensatory activity.

Another common everyday experience of tinnitus is that following noise exposure after discos or rock concerts. About 80% of those attending will experience some degree of tinnitus after the exposure if the music is loud enough. However, this tinnitus invariably disappears by the morning. Disco tinnitus is also a rare cause of persistent tinnitus in clinical practice (the majority of patients being over 50). It is deemed by disco aficionados to be "party tinnitus", commonly experienced, and not something that is associated with disease or damage to the ear.

The Jastreboff model; anatomical considerations

The outer and middle ear are concerned with collecting all sounds in the environment and presenting it as a combined signal of many different frequencies to the cochlea. Here the individual frequencies are extracted by hair cells and passed as a neural impulse to one of the 30,000 fibres in the auditory nerve, each of which has a characteristic frequency. Thus, there are patterns of electrical activity passing up the auditory nerve, constantly changing every moment in time, but at each moment are a representation of

all frequencies present in the environment. Organised perception of this information can only occur at a cortical level, but the first awareness of sound is of a completely reconstructed auditory environment with each sound source clearly identified as a separate entity. Even someone with hearing in only one ear achieves this. Anatomical examination of the subcortical pathways connecting with the auditory nerve in the brainstem shows them to consist of complex neuronal networks rather than simple cables. It is these networks which perform extremely rapid tasks of pattern recognition, based on a continuous, ongoing, learning process. They also prioritize the patterns of sound according to their importance. That is why the sound of your own name in a nearby conversation may be amplified some 500 times, while the sound of the refrigerator in your kitchen some weeks after delivery, becomes almost inaudible. The process by which sounds are habituated or blocked is an everyday experience for everyone.

Warning signals.

The process of blocking any sensory signal (habituation) is essential to allow our attentional focus to concentrate on the most important element at hand. In the auditory system perhaps 95% of all sound collected by the ear never reaches our consciousness. However there are certain rules associated with the process of habituation which have been known to psychologists for nearly a century. That is, that signals relating to food, sexual activity, or threats to life and health, are never habituated, and could not be so without compromising essential survival strategies. The sound of creaking floorboards at night, a footstep behind us on a dark night in a strange city, or the practically inaudible sound of an advancing predator in the wild, is always strongly amplified, even in the presence of considerable background sound. This requires not only the development of very sensitive auditory sense organs, but also sophisticated sub-awareness neuronal networks which are capable of identifying the sound of the predator from ordinary sounds of nature.

Survival reflexes and aversive reactions

The ability to detect warning signals in our environment is not enough. What is needed is an automatic, irrepressible, rapid response mechanism to get us out of danger as fast as possible. In the case of an animal responding to predation, this requires an immediate subconscious response from both limbic and autonomic nervous systems, initiating extreme fear and a rapid activation of all bodies systems to enable fight or flight.

In other situation where the danger signal is not of such immediate importance, for instance in the case of territorial intrusion (think about tinnitus, or your neighbour's television set!), the response may be less strong, but still involves activation of the autonomic and limbic system. We might refer to this as an aversive reaction, something that most of us experience on a daily basis to some extent in work or social situations. Phobic reactions are also extremely common, and indicate a highly developed survival system, often inappropriately trained on previous experiences, perhaps in childhood. In those people who experience persistent phobic responses the lesson or trigger becomes forgotten or very unimportant, but the aversive reaction remains consistent and uncontrollable. Of course habituation can occur, and fortunately often does, but this requires a change in attitude or belief on the part of the phobic individual, as well as ongoing intermittent exposure to the phobic stimulus, without flooding, or reacting strongly.

Emergence and persistence of tinnitus

The experience of tinnitus approaches 100% in the general population. However, if it does not persist the experience is commonly forgotten and individuals often say they

have never experienced tinnitus. Transient tonal tinnitus, lasting perhaps a few seconds and sometimes associated with a feeling of ear blockage is one manifestation of this type of tinnitus. If, however, emergence of tinnitus is associated with some negative experience, particularly with a strong aversive reaction, then a Pavlovian style conditioned reflex can be established in which, whenever the tinnitus is heard, various elevations of autonomic and limbic activity invariably occur. This creates the symptoms which are associated with distressing persistent tinnitus.[10] It must be stressed that it is this reaction which causes the symptoms, and the patient's complaint. The auditory characteristic of the tinnitus have no statistical relationship with tinnitus distress.[2]

Jastreboff's model is illustrated in Fig. 2 and shows the relationship between the emergence of tinnitus, the establishment of the aversive reaction and a feedback mechanism which enhances detection of the tinnitus by subcortical filters and ensures its persistence. The extra-auditory connections are supremely important in the generation of tinnitus complaint.

Another mechanism which is very powerful in increasing tinnitus or ensuring its persistence is the association of negative beliefs about the meaning of tinnitus. These commonly included the belief that tinnitus would go on forever, could not be cured, might be associated with the brain tumour, might cause patients to become mad or commit suicide, and would severely reduced life quality and the ability to work and socially interact. Many patients who did not initially have this belief, often acquire them rapidly after inappropriate counselling from their general practitioner or otolaryngologist. The classical counselling approach was to tell patients the worst-case scenario, and this information was based on a highly skewed distribution of patients in the specialist's repertoire; those patients who were extremely phobic or distressed by their tinnitus and in whom it had persisted for many years and whom the practitioner had failed to help. A self-fulfilling prophecy indeed, with medicine doing it is very worst, establishing a persistent distressing condition which would have disappeared or habituated naturally had the negative counselling not been given.

Decreased sound tolerance

About 40% of patients with tinnitus have a decrease tolerance to external sound. Another very large number, (as yet the epidemiology is unknown), experience sensitivity to external sounds without tinnitus. In hyperacusis there is a general increase in loudness perception to all sounds due to an increased gain or amplification in the auditory system. In misophonia (a dislike of external sounds) or phonophobia (a fear of external sounds – particularly that they may damage the hearing) the auditory system is functioning normally, but there is an abnormal reaction produced by increased limbic and autonomic activity. In practice most patients have a mixture of hyperacusis, plus either misophonia or phonophobia, and treatment has to be directed to all of these elements.

In all cases where there is an aversive reaction to sound, whether generated internally or externally, the mechanism is the same, and simply and clearly illustrated by the Jastreboff model.

Global Hypersensitivity

Many of our patients exhibit increased sensitivity in other sensory modalities. They often complain of increased awareness and size of floaters, despite any visual pathology. Pain, touch and smell may often be heightened (see the title of this paper), and associated with aversive responses. Phobic reactions are also very common, especially insects, animals, and claustrophobia with fear of flying. It is usual for these reactions to predate the onset of tinnitus or hyperacusis, perhaps setting the scene for aversive or

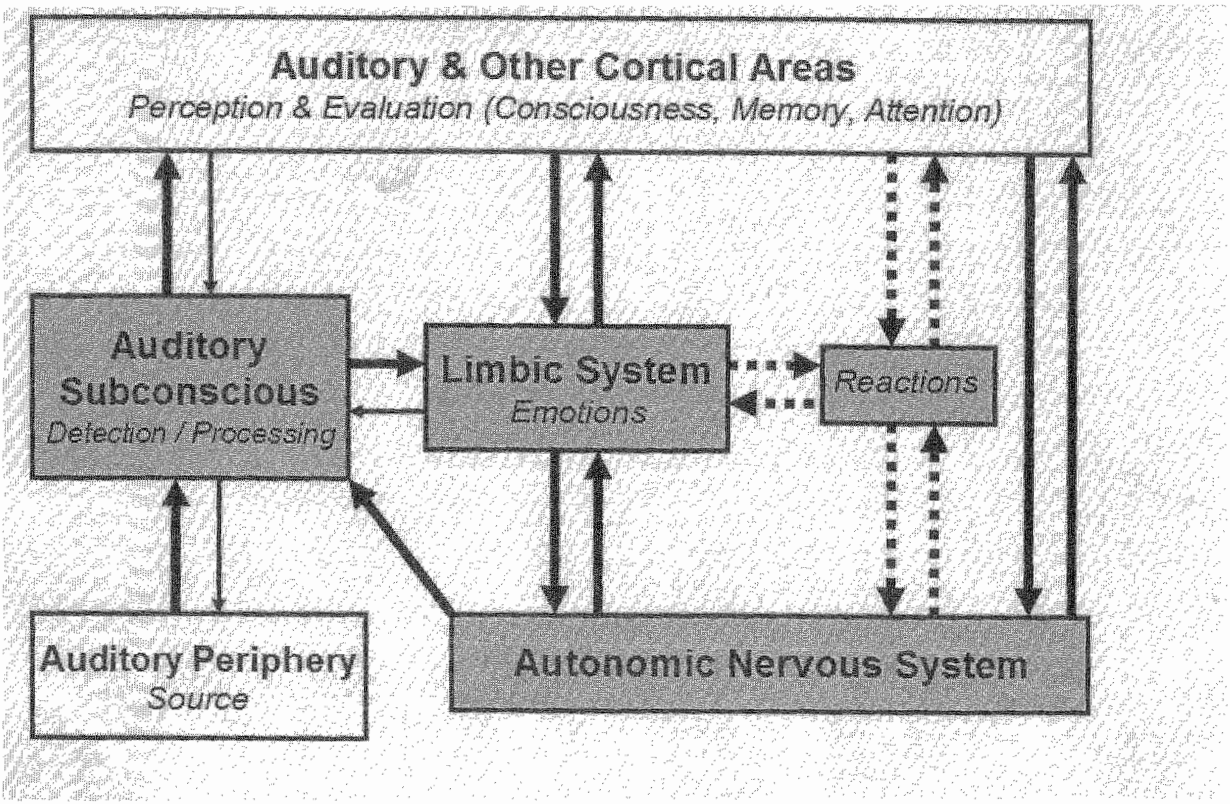

Figure 2 Jastreboff model from Jastreboff 1995. The shaded areas indicate how subconscious detection of a threatening sound activates an aversive reaction. Note that the reaction feeds back to enhance signal detection, and consequent perception of tinnitus (or external sound in hyperacusis or phonophobia). Once the aversive reaction is set, it has to be habituated (retrained) to permanently relieve symptoms.

phobic reactions towards sound, in the future. Hyperacusis can also be a symptom of attention deficit hyperactivity disorder, William's syndrome and Lyme's disease Tinnitus Retraining Treatment TRT can be very helpful in dealing with the auditory symptoms of these disorders.

Tinnitus retraining therapy

This approach evolved rapidly, logically and to some extent spontaneously from an understanding of the Jastreboff model and was first applied in London by the author. Clearly if the problem is an aversive reaction to some stimulus, then the answer is to get rid of this reaction. Once the reaction disappears, then the activity of subcortical neuronal networks or filters which are picking up this normal compensatory activity within the auditory system, will cease to do so, and habituation of perception (passive extinction) will later occur. The neural connections responsible are illustrated in Fig. 2. In hyperacusis there is an increased gain in the auditory system which needs to be reversed. For this, silence must be avoided at all costs, and sound enrichment used continuously. The auditory system responds to quite low levels of environmental noise by reducing its gain. Therapeutically we use nature sounds produced by widely available electronic devices, and also wide band noise generators fitted to the ears, looking somewhat like hearing aids, but used according to a very specific protocol.[11] Sound enrichment is needed in tinnitus too, with all but simple cases needing instruments as well.

The avoidance of negative counselling and negative thinking about tinnitus is paramount, and we have discovered that substituting this wrong information with the Jastreboff model itself, which stresses the universality, and normality of the sounds to which the individual has created such a dislike, is highly effective in bringing about habituation of the reaction. The model also answers all the puzzles of tinnitus, whereas previously the patient was met with the retort; "We just don't know". According to the rules of habituation it is important for the individual to be exposed to the aversive stimulus, not avoid it by masking or distraction, but to do this in a low state of arousal. This leads to a behavioural desensitisation exercise which is powerful in removing the aversive reaction to tinnitus or external sound.[12] The common solution, particularly in dealing with people who have decreased sound tolerance (hyperacusis, misophonia or phonophobia), is to recommend earplugs, which simply results in an avoidance strategy making patients very much worse, and also results in increasing gain within the auditory system.

Further information; results of treatment

It is beyond the scope of this short paper to teach the whole process of tinnitus retraining therapy, but information is readily available to patients and practitioners alike. A website *www.tinnitus.org* contains an account of the Jastreboff model and TRT, together with help for decreased sound tolerance, in a simple manner that can be understood by patients (and doctors), and on its own can be enough to help those with low levels of aversive reaction. Information about three-day training courses for professionals is also available on the site, and these courses run by Hazell & Jastreboff on a worldwide basis have now resulted in a large number of trained personnel who are successfully carrying out TRT according to the Jastreboff model.

In addition a textbook has been written with patient friendly margin notes to assist those without technical knowledge.[13]

Results of TRT from centres around the world show a high consistency of good results. Approximately 80% of patients going through full TRT achieve habituation of reaction, requiring no further treatment, within one year. The further 20% of patients

also experience improvement, but over a longer period of time. The website, and that of Jastreboff's, contains a list of alumni from these courses so that trained personnel can be easily identified.

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