

FROM THE JASTREBOFF MODEL

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How we hear

The conscious awareness of sound takes place near the surface of the brain, when a pattern of electrical activity traveling up the nerve of hearing from the ear reaches the auditory cortex. (Figure 1) The hearing nerve has about 30,000 fibres, and patterns of electrical activity in these fibres are matched with other patterns, which are held in the auditory, or hearing memory. The cochlea, or inner ear, which changes sound waves into these electrical patterns, is a surprisingly noisy place, where continuous mechanical and electrical activity in 17,000 hair cells can now be monitored with sensitive, computer enhanced, listening devices (otoacoustic emissions). Most of what we hear is a sequence of different sounds, like speech or music. In infancy, new sound experiences are stored in an information hungry, but relatively empty auditory cortex. Later on there is a continuous process of matching familiar memory patterns with those coming from the ear. Each time a pattern from the ears is matched with a pattern in the auditory memory we have the experience of hearing and recognizing a sound. Putting together these matched patterns starts a process of evaluation. Another part of the brain close to this initial hearing centre is involved in the meaning of what we hear, and in interpreting the language. If it's a foreign language we can hear the sound but may not understand the meaning.

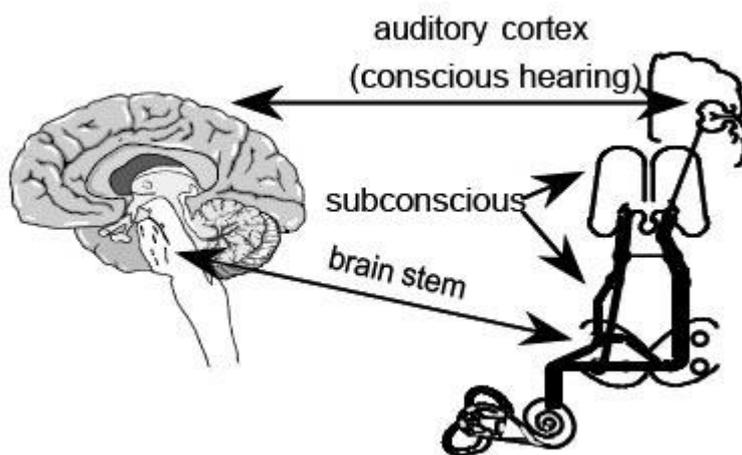


Figure 1, nothing heard until sound patterns, generated in the cochlea, reach the cortex of the brain

The meaning of sound

Sound is of enormous importance in monitoring our environment. Hearing in animals (who are constantly in fear of their lives because of attacks from predators) has to be very sensitive and specific. The ability of animals to develop extremely acute hearing, by which they could detect the very small sounds of an attacker a long

way off, contributes to the survival of that species. These warning signals produce acute anxiety, prompting appropriate action to avoid attack, the so-called survival reflex. We respond in the same way to the sound of a motorcar horn, by automatically putting our foot back on the pavement or sidewalk. Some sounds can be identified as warning signals, while others can evoke a feeling of security or pleasure. We have this experience every day with sounds that alarm us, or sounds that soothe us such as music, or the sounds of nature. Many sounds naturally evoke strong emotions of one sort or another.

Conditioned responses

When a sound has special or critical meaning, like the baby waking at night, or the creaking of a floorboard, or the sound of our first name, we respond to it in an automatic manner, even if the volume is very soft. This happens after a short learning period, but the responses can remain as strong as ever throughout life. During sleep, the conscious part of the brain is 'shut down' so we don't hear, see or feel anything. However the mother still wakes to the baby stirring even though she has just slept through a thunderstorm. (Maybe that's what woke the baby!). This shows that weak patterns of sound, if of great significance, can be detected by subconscious filters, (Figure 2) in the hearing pathways, between ear and brain. The conditioned response also triggers activity outside the auditory system where there are large numbers of connections with the limbic system (Figure 3) which is concerned with emotion and learning. Also

activated is the autonomic nervous system, which activates the body, to prepare for any eventuality. In situations of danger, or perceived threat the familiar 'fight or flight' response is triggered. This involves high levels of autonomic function; tense muscles, raised heart and breathing rates, sweating, and are the complete opposite to the state of relaxation. They rightly preclude sleep, or concentration on other, less important tasks.

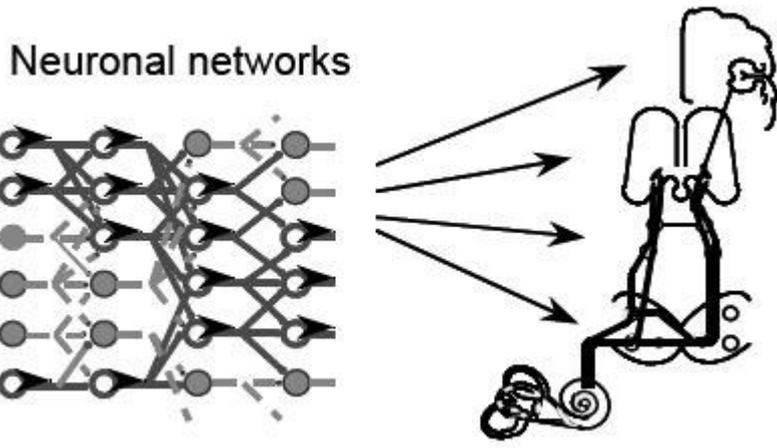


Figure 2. Between ear and brain there are 2M nerve cells forming a neuronal network, capable of sophisticated pattern recognition, enhancement and suppression of auditory signals.

Most of our day-to-day activity consists of a series of conditioned or learned responses, executed to order, like reading, writing, playing an instrument or driving the car. Other examples of conditioned responses include the famous Pavlov dog experiment. So, each and every

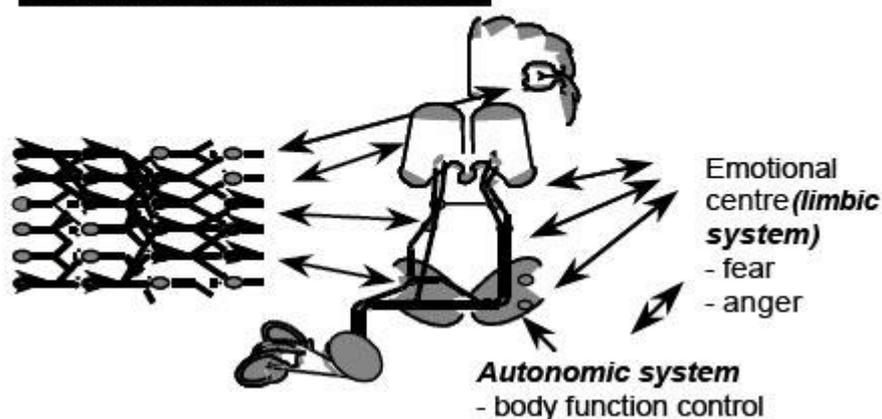
sound that we hear and learn the meaning of, has an 'emotional label' attached to it, which may change from time to time according to how we feel in ourselves and the context in which we hear it. For example the sound of a neighbour's television set may be acceptable, or unpleasant and intrusive, depending on whether it belongs to a well-loved friend or relation, or somebody else who for various reasons we dislike or distrust.

Figure 3. Neuronal networks between ear and brain detect threatening sounds and activate a reflex response involving fear/annoyance, and increase of body functions, to prepare for danger – the conditioned aversive response

The meaning of tinnitus sounds

In 1953 Heller and Bergman performed a simple and classic experiment. They placed 80 tinnitus free individuals, university members, in a sound proofed room, each for 5 minutes, asking them to report on any sounds that might be heard.

Extra auditory processing: conditioned response



The subjects thought they might be undergoing a hearing test, but actually experienced 5 minutes of total silence. 93% reported hearing buzzing, pulsing, whistling sounds in the head or ears identical to those reported by tinnitus sufferers. This simple experiment shows almost anyone can detect background electrical activity present

in every living nerve cell in the hearing pathways as a sound. Although some areas of the auditory system may be more active than others, every neurone will contribute to some extent to the final perception of tinnitus. These electrical signals are not evidence of damage, but compensatory activity that occurs all the time in the auditory system of each

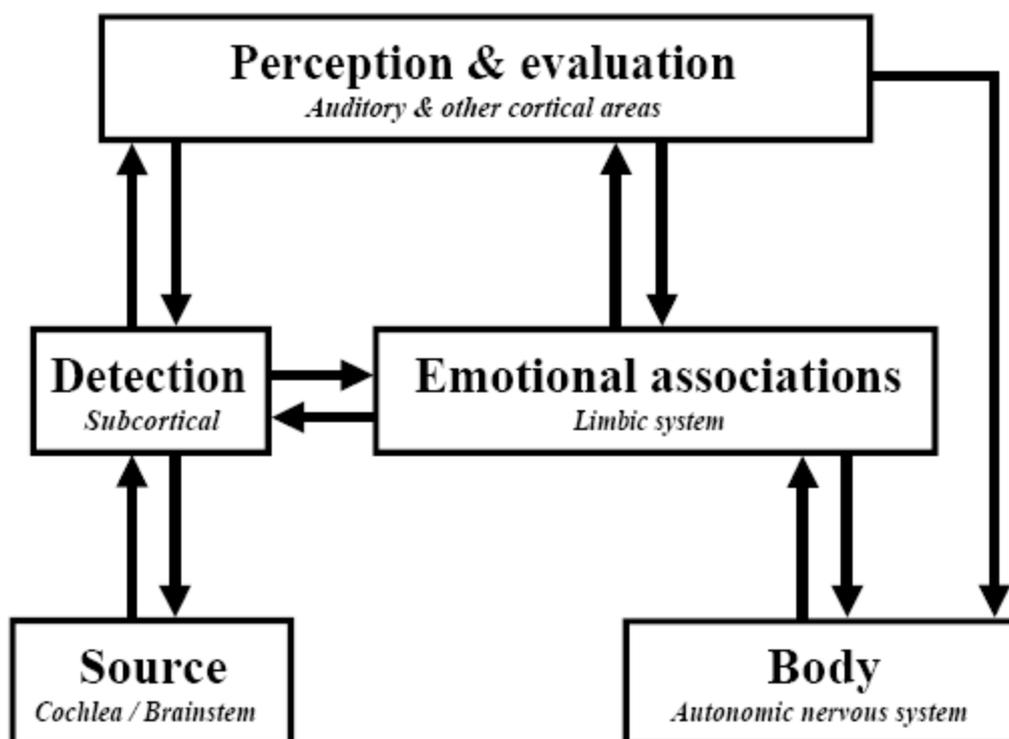
one of us. This compensatory activity can occur as a response to changes in our sound environment (e.g. silence), to hearing loss, which may be a natural part of ageing, or to exposure to sudden noise. It is good to think of the sounds produced by this compensatory activity as 'the music of the brain'. Of those who DO experience persistent tinnitus, population studies have shown that about 85% do not find it intrusive, disturbing or anxiety provoking (something tinnitus sufferers find very hard to believe!). The reason for this is not so much because the quality or loudness of the tinnitus is different; in fact we have found that tinnitus is of a very similar type of sound in those who are bothered by it and those who are not.

The main difference is that those who find tinnitus troublesome, evaluate and perceive it as a threat, or an annoyance, rather than something of little or no consequence. It may also emerge for the first time when something else unpleasant or frightening is happening to us. In these situations, tinnitus is classified as a warning signal, relating either to a bad experience (classical Pavlovian conditioning) or to negative thoughts about its meaning or outcome. Just as the animal alerted to danger by the sound of a predator focuses solely on that sound in order to survive, so those who consider that tinnitus is a threat or warning signal are unable to do anything but listen to it. It is part of the mechanism that all animals have developed for self-preservation, although clearly in this situation it is not working to our advantage! Many people complain of the loss of silence, something they previously greatly treasured and enjoyed, before tinnitus became persistent. Tinnitus becomes part of a bereavement for the loss.

Persistent tinnitus depends on a conditioned response

What happens, even in mild cases of persistent tinnitus, is that a conditioned response (reaction) is set up to the tinnitus sound. As the conditioned response is part of the subconscious brain, and automatic, what you may be thinking about tinnitus at any time, (or even if you're not thinking about it), is irrelevant to the reaction produced. Moreover, it is the reaction to tinnitus, which is creating distress, not the tinnitus itself (another difficult concept for some). The degree to which unpleasant feelings about it (from the limbic system) and increased tension (from autonomic system stimulation) are experienced, dictates the severity of the tinnitus. The loudness and quality of the sound heard is irrelevant. This mechanism is best illustrated by the Jastreboff model in a graphical format (Figure 4).

Figure 4 Graphic representation of the Jastreboff Neurophysiological Model of Tinnitus 1990



Tinnitus as a new experience

When tinnitus first emerges it is a new signal, there are no memory patterns, and no means of categorizing it. Any new experience produces an 'orienting response' where we are forced to pay attention, until the signal is classified and understood. Until proper evaluation has been undertaken of what tinnitus means, it will be regarded with understandable suspicion. Many 'sufferers' only experience mild annoyance from tinnitus as a result of this mechanism, but it may be sufficient to promote the need to seek help. A typical anxiety is 'will it get worse?' or 'what happens if it goes on for ever?'

Tinnitus as a threat

For many sufferers, tinnitus is quite threatening. Some people fear that tinnitus means they have some kind of serious illness. Others are convinced that the experience of 'disco tinnitus' means permanent damage to the ear, rather than temporary protective 'shut down'. There are patients who worry about the possibility that it heralds a brain tumour, blood clot, or some serious mental illness ('it will drive me mad!'). Many people fear that tinnitus will get louder, continue forever, and cannot be cured. Even the concept that tinnitus is invading one's 'right to silence' constitutes a threat, very similar to the territorial invasions that all animals experience. It is often feared that tinnitus will continue to spoil peace and quiet, interfere with concentration at work, quiet recreational activity and the ability to sleep at night.

Unfortunately, these fears may be enhanced by professional advice, or reports from others of their own, phobic reaction to tinnitus. Many doctors and other professionals still advise patients that there is nothing that can be done about tinnitus and that it will go on forever. Other people fear that tinnitus may mean that their hearing is becoming impaired. Tinnitus may be the consequence of a mild hearing impairment rather than the other way around, but is still only twice as common with hearing impairment to normal hearing. In any event the threatening qualities of the tinnitus are enhanced by beliefs and negative ideas about tinnitus, not any physical changes that may or may not have occurred. Finally many tinnitus sufferers are angry about the treatment, or lack of treatment, or inappropriate advice that they have received. They may feel guilty for having submitted to treatment, which they think, is the cause of their tinnitus.

Fear, anger and guilt are very powerful emotions, which are intended to enhance, survival-style, conditioned reflex activity, and consequently greatly increase attention on the tinnitus. In our experience, tinnitus improves when the patient overcomes these feelings and stops dwelling on thoughts of injustice.

Tinnitus as a phobic state

In some patients extreme fear of tinnitus results in a phobic state developing, very similar to that of the fear of spiders, frogs, small spaces, flying etc. Many tinnitus sufferers also have these phobias, suggesting common mechanisms at work. In any phobic state a slow process of 'desensitization' has to be used, confronting the feared object, learning first to tolerate it, and then to accept it as a normal phenomenon that does not in any way threaten. Many aspects of tinnitus retraining are common to these techniques.

In other people the response to tinnitus is milder, though still negative in its meaning. Annoyance or ill ease exists, and although strong emotions may not be evoked, the limbic and autonomic systems are still being stimulated to produce aversive and intrusive emotions which reduce life quality, but most importantly to insure that tinnitus persists rather than habituates naturally. These qualities of tinnitus, which make people seek help, are created outside the hearing mechanism, and therefore cannot be helped by a purely audiological or ear-related approach. This is the reason for the failure of tinnitus treatments before TRT.

Tinnitus Retraining Therapy (TRT)

Successful tinnitus management in our clinics is a result of retraining and relearning. Once the tinnitus loses its sinister meaning, however loud it has been or however unpleasant it may seem, it DOES begin to diminish, and in many cases may not be heard for long periods of time. In some cases firmly held beliefs are hard to alter, particularly where there is a conviction that tinnitus is only related to ear damage which cannot be fixed (NEVER the case).

Retraining the subconscious auditory system to accept tinnitus as something that occurs naturally, does not spell a lifetime of torture and despair, and is not a threat or a warning signal, can take months and occasionally even years. Retraining should be guided by professionals with experience in this field, forming part of a multi-disciplinary team. However many people can be helped by understanding the Jastreboff model and applying the principles of retraining as described on our website. For people who also have co-existing or pre-existing anxiety or depression, it can take longer to change their feelings about their tinnitus.

How retraining works

When we talk about TRT, this is not simply an abstract learning exercise. In the subconscious part of the brain concerned with hearing, beyond the inner ear, but before the act of conscious perception of sound takes place, subconscious filters, networks of nerve cells (neuronal networks) are programmed to pick up signals on a 'need to hear' basis. Think again of the way we invariably detect the sound of our own name, or a distant car horn, or a new baby stirring in sleep, whereas we may be unaware of the sound of rain pounding on the roof or surf beating on a seashore. Retraining therapy involves reprogramming or resetting these networks which are selectively picking up 'the sound of life / music of the brain' in the auditory system. Tinnitus retraining first involves learning about what is actually causing the tinnitus. As a result of this and other therapy including sound therapy, the strength of the REACTION against tinnitus gradually reduces. This reaction controls the disposition of subconscious filters, which are constantly looking for threats. With strong reactions the filters are constantly monitoring the tinnitus, without a reaction habituation occurs, as it does to every meaningless sound that is constantly present. Firstly the disappearance of the reaction means that sufferers no longer feel bad, or distracted, and normal life activities can be resumed – sleep, recreation and work, as before. Secondly as the auditory filters are no longer monitoring the tinnitus it is heard less often and less loud. As a result it can become a friend instead of an enemy. Think now how much of this treatment depends on being able to believe that tinnitus results from normal compensatory changes in the hearing mechanism.

While it is important to have a proper examination by an ear specialist, those professionals who themselves believe that tinnitus is an 'ear phenomenon' cannot help. We are in a difficult situation where the classical training of tinnitus being due to inner ear damage is still very dominant, rather than an understanding based on the Jastreboff neurophysiological model (Jastreboff P.J. 1990). With appropriate directive counselling (or 'retraining') from TRT trained professionals, we can change even strongly held views, that tinnitus is a threatening and unpleasant experience that cannot be altered.

Habituation of reaction and perception

The presence of any continuous stimulus usually results in a process called habituation, whereby the individual responds less and less to the stimulus as long as it does not have any special negative meaning. Think of moving to live by a busy road from the quiet of the country. The final stage in this process is when the signal is no longer detected, and cortical neurones are unresponsive. With tinnitus this means that it is no longer heard, even if it is listened for. However maintaining this habituation is easier if tinnitus IS heard from time to time, after successful TRT. This enables the renewal of beliefs that tinnitus is 'a friend', and guards against relapse. Even where people do develop new negative reactions to tinnitus (which may have gone away from some years, treatment with TRT is always quicker the second time. Any learned skill is easier to practice when all you need is revision. Sadly some people think because tinnitus can return after TRT that 'the treatment has failed'. As the goal is to get rid of tinnitus reaction – NOT tinnitus perception – provided you have achieved this, then TRT is always successful, and permanent.

It is important to distinguish between the role of the ear in the EMERGENCE of tinnitus (e.g. disco tinnitus) and the role of central processing in the brain, outside the auditory system, in the PERSISTENCE of tinnitus and our emotional response to it. Despite the importance of hearing change (temporary or permanent) in triggering an emergence of tinnitus, a recent study of our tinnitus clinic patients showed there was no significant difference in hearing between the tinnitus group and normal population statistics.

Wearable sound generators (WSGs)

Wearable sound generators (which look similar to 'maskers' and hearing aids), have an important role to play. Tinnitus masking was at one time thought to be useful in that it simply made tinnitus inaudible. In fact this proved to be counter-productive, as tinnitus, the object of the habituation exercise, must be audible for habituation to occur. Habituation to any signal cannot occur in the absence of its perception. Imagine trying to habituate your response to spiders, which you hate, simply by avoiding them. Much better long-term results can be obtained if wide band noise is used at low intensities while the tinnitus can be heard at the same time. WSGs contain many frequencies, and therefore gently stimulate all the nerve cells in the auditory pathways allowing them to be more easily programmed, (increasing plasticity). They must be fitted and instruction given by a trained professional. Wrong use, including one-sided use, can make sufferers worse.

Silence is not golden

Emergence of tinnitus is often dependent on silence. Most tinnitus is first heard at night in a well-soundproofed bedroom, or a quiet living room (Heller and Bergman 1953). Persistence of tinnitus depends not only on the meaning attached to it, but also to the contrast it creates with the auditory environment. Contrast contributes greatly to the intensity of any perception. Thus a small candle in the corner of a large darkened room seems dazzlingly bright until floodlights are switched on making it virtually invisible. Everyone, especially tinnitus patients should avoid extreme silence, and retraining programmes will always use sound enrichment. Make sure there is always a pleasant, non-intrusive background sound (like a large slow fan, or an open window, and purchase a device for generating nature sounds). Choosing what is right for you may take some time. Nature sounds are always the best, as they are already habituated, and usually produce feeling of relaxation, calm and well-being. Avoid masking tinnitus, but have some sound present during day and night. Remember filters are working 24 hours a day, and so should sound enrichment. Many tinnitus patients have decreased sound tolerance and for this reason often seek very quiet environments. They

are their own worst enemy! In all cases, sound enrichment should be practiced, using unobtrusive sound sources, to break the silence.

At the present moment TRT is available in relatively few centres, but the techniques are spreading and gradually being learned and used in an increasing number of ENT and audiology departments around the world. In 2002, 800 professionals had attended TRT training courses around the world.

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