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Audiopsychophonology for tinnitus treatment

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Abstract. Audiopsychoponology, developed by Alfred Tomatis, is an interdisciplinary explanatory model that binds the role of the vestibulo-cochlear system to healthy psychological functioning, and to optimal motor, emotional, language and communication development. It involves a technique for training neuropsychological and physiological systems through listening to music (essentially Mozart and Gregorian chants) modified by an "Electronic Ear". The aim of the study was to determine the effectiveness of APP in patients with tinnitus. The patients included in this study (n=30) were assessed with the Tinnitus Handicap Inventory (THI), the Self-Rating Anxiety Scale (SAS) and the APP method's own battery of tests. After an average of 46 hours of therapy, the patients recorded a median improvement of one grade on the THI questionnaire, and a median 21% decrease in the SAS score. Patients whose tinnitus had an ENT (ear-nose-throat) origin recorded a median improvement of 2 grades on the THI. Even the participants with the highest baseline score on the THI showed a median gain of 2 grades at completion of the treatment. These results, compared with known sound-based techniques for treating tinnitus, seem to offer a wider and more effective range of possibilities for addressing the tinnitus syndrome and helping patients obtain relief. These possibilities should be further investigated.

Key words: tinnitus, Audiopsychophonology, Tomatis method, sound stimulation

Audiopsicofonologia per il trattamento del tinnito

Riassunto. L'incidenza del tinnito sta aumentando in tutti i paesi occidentali e si sta estendendo sempre più alle fasce d'età giovani e giovanissime. I ricercatori stanno identificando le reti neurali diffuse ed embricate che sembrano essere responsabili della plasticità mal-adattativa che mantiene il tinnito dopo la sua comparsa. I pazienti con tinnito lamentano turbe a livello emotivo, comportamentale e dell'umore, oltre a problemi somatici; ciò configura una sindrome che può portare a disturbi psichiatrici. In questo contesto, la terapia del tinnito continua ad essere una difficile sfida. Le terapie sonore sembrano essere le più promettenti nell'aiutare le persone con tinnito. Il primo protocollo apparso è la Tinnitus Retraining Therapy di P. Jastreboff che accoppia un lavoro di consapevolezza con una stimolazione inconscia consistente in un rumore bianco. La Ultra High Frequency Vibration Therapy unisce la stimolazione acustica con quella somatosensoriale. C. Pantev ha ottenuto risultati incoraggianti con il suo Tailor-Made Notched Music Training (TMNMT) che utilizza l'inibizione laterale per ridisegnare la rappresentazione corticale della frequenza del tinnito. De Ridder e Vanneste propongono un protocollo per il trattamento del tinnito che consiste nella stimolazione acustica – priva della frequenza del tinnito - accoppiata alla stimolazione del nervo vago. Questo articolo di ricerca mostra per la prima volta il contributo dell'Audiopsicofonologia di Alfred Tomatis nel trattamento del tinnito. È una terapia sonora che agisce a vari livelli del sistema nervoso centrale e periferico modificando la percezione del tinnito e la sua penetranza nella vita quotidiana dei pazienti. La stimolazione sonora, che viene fornita attraverso l'orecchio elettronico, consente una maggiore integrazione fra i vari sistemi sensoriali ed una migliore armonia fra il sistema nervoso simpatico e parasimpatico. Comprende e integra le terapie sonore sopra citate. 30 pazienti si sono sottoposti alle sedute di Audiopsicofonologia compilando prima e dopo il periodo di terapia il Tinnitus Handicap Inventory (THI) e il Self-Rating Anxiety Scale (SAS). Vi è stato un miglioramento

mediano di un grado al THI ed un miglioramento mediano nella percezione soggettiva dell'ansia di oltre il 20%. Per verificare meglio i risultati positivi che emergono dal lavoro qui presentato, sarebbe appropriato progettare studi che impieghino valutazioni oggettive per ogni dominio di funzionamento analizzato.

Parole chiave: tinnito, audiopsicofonologia, metodo Tomatis, stimolazione sonora

Audiopsicofonologìa para el tratamiento de tinnitus

Resumen. La incidencia del tinnitus está aumentando en todos los Países occidentales, y extendiéndose más y más a los grupos de edad "jóvenes" y "muy jóvenes". Los científicos están identificando las redes neuronales difundidas y imbricadas que parecen ser responsables de la plasticidad mal-adaptiva que mantiene el tinnitus después de su aparición. Los pacientes con tinnitus lamentan trastornos a nivel emotivo, del comportamiento y del estado de animo, además de problemas somáticos; eso configura una síndrome que puede llevar a problemas psiquiátricos. En este contexto, la terapia del tinnitus sigue siendo un difícil reto. Las terapias sonoras parecen ser las mas prometedoras en ayudar las personas con tinnitus. El primer protocolo que apareció fue la "Tinnitus Retraining Therapy" de P. Jastreboff, la cual une un trabajo de concientización con una estimulación inconsciente que consiste en ruido blanco. La "Ultra High Frequency Vibration Therapy" una la estimulación acústica con aquella somato-sensorial. C. Pantev obtuvo resultados alentadores con su "Tailor-Made Notched Music Training (TMNMT), que utiliza la inhibición lateral para re-dibujar la representación cortical de la frecuencia del tinnitus. De Ridder y Vanneste proponen un protocolo para el tratamiento del tinnitus que consta de la estimulación acústica - privada de la frecuencia del tinnitus – acoplada ala estimulación del nervio vago.Este articulo de investigación muestra por primera vez la contribución de la Audiopsicofonologia de Alfred Tomatis en el tratamiento del tinnitus. Es una terapia sonora que actúa a varios niveles del sistema nervioso central y periférico, modificando la percepción del tinnitus y su penetración en la vida diaria de los pacientes. La estimulación sonora, proporcionada a través del "oído electrónico", permite una mayor integración entre los varios sistemas sensoriales y una mejor armonía entre el sistema simpático y el parasimpático. Comprende y integra las terapias sonoras antes citadas. 30 pacientes se han sometido a las sesiones de Audiopsicofonologia, llenando antes y después el periodo de terapia al "Tinnitus Handicap Inventory" (THI) y al "Self-Rating Anxiety Scale" (SAS). Hubo un mejoramiento mediano de un grado en el THI y un mejoramiento mediano en la percepción subjetiva de la ansiedad superior al 20%. Para verificar mejor los resultados positivos que se plantean en el trabajo que se presenta aquí, seria apropiado proyectar estudios que utilicen evaluaciones objetivas para cada dominio de funcionamiento analizado.

Palabras clave: tinnitus, Audiopsicofonologia, método Tomatis, terapia sonora

Introduction

Tinnitus is a phantom auditory sensation (1). In the first study on the prevalence of tinnitus in the general Italian adult population, Gallus et al. indicate that it affects more than 3 million adults and is felt to be a major problem by more than 600,000 Italians, mostly aged 45 years or over (2).

More generally, approximately 15-20% of the general population in Western industrialised countries experience unremitting tinnitus to the extent that they seek assistance from health professionals (3). Some studies have reported that as many as 80% of adults experience tinnitus at some point in their life (4).

Children complain of tinnitus far less frequently (5), whereas its prevalence is increasing in young adults (6). Loud environmental noise is thought to be the cause of this increase (7).

A large number of patients describe tinnitus as a steady tonal sound or hissing percept, but some report

more complex sounds, likened to those made by insect, chimes, running water, or multiple different sounds. Tinnitus varies in its time course (continuous or intermittent), in its spatial attributes (whether it is experienced in one or both ears or perceived to be 'inside' the head), in its degree of intrusiveness, and also according to whether or not it is accompanied by hyperacusis (8).

Tinnitus is a symptom, not a disease. Numerous dysfunctions within the peripheral and central components of the auditory system, and of other parts of the central nervous system (CNS), may result in tinnitus. It is, therefore, a disorder of perception and should not be understood as perception of signals originating from a single, localised generator (9).

Tinnitus can be a symptom of cochlear pathologies associated with hearing loss, such as noise-induced damage, Ménière syndrome or acoustic neuroma (10). It can have central causes such as stroke, demyelinating lesions and ateriovenous malformations (11).

In addition, autoimmune disorders and neck or head trauma can cause tinnitus, and the symptom may be both triggered by and treated with antidepressants (12). Last but not least, most of the ototoxic drugs can lead to tinnitus (13,14).

About one third of patients can change the loudness and pitch of their tinnitus through somatic manoeuvres such as jaw clenching or tensing of the neck muscles. Therefore, the neural connections between the auditory and somatosensory systems, such as the auditory connections in the dorsal column and trigeminal system, are also implicated in tinnitus (15–17), and in these cases it is defined as somatic.

Anxiety, sleeplessness and depression are common comorbidities particularly soon after tinnitus onset (3,18). Minen et al. go further, stating that the presence of non-auditory symptoms (cognitive, behavioural and affective) shapes a "tinnitus syndrome" which should therefore be considered a neuropsychiatric disturbance (19).

Sound-based therapies seem to be very promising in helping people with tinnitus. The first such protocol to appear was Jastreboff's "Tinnitus Retraining Therapy" (9) which couples conscious work with unconscious stimulation consisting of a white noise. "Ultra-high Frequency Vibration Therapy" (20) combines acoustic stimulation with somatosensory stimulation. C. Pantev et al. have achieved encouraging results with their "Tailor-Made Notched Music Training" (TMNMT) (21) which uses lateral inhibition to redraw the cortical representation of the tinnitus frequency. Finally, the protocol proposed by De Ridder and Vanneste consists of acoustic stimulation - without the tinnitus frequency - coupled with stimulation of the vagus nerve (22).

The aim of the present research is to start a discussion and stimulate further investigations on the use of the APP approach, a complex and complete sound-based therapy, in the treatment of tinnitus.

Materials and methods

Audiopsychophonology and the "Electronic Ear"

Audiopsychophonology (APP) is the cross-disciplinary field that Alfred Tomatis developed in parallel with his sound stimulation technology and method of sound stimulation (23). APP is based on the neurophysiology of sensory processing and its influence on human sensory-motor and psycholinguistic abilities, as well as behaviour and learning. Tomatis' APP is an interdisciplinary explanatory model that binds the role of the vestibulo-cochlear system to healthy psychological functioning, and to optimal motor, language and communication development (24). In the last 60 years, it has been used to treat many neurological and psychological impairments (25–27).

Essentially, the APP approach involves the use of high-definition recordings of the music of Mozart and Gregorian chants (in the past Revox tape recorders or DAT recorders were used; now these have been replaced by DVDs or aiff files). The sonic source is sent to the «Electronic Ear» (over time what initially was an electronic device has now been replaced by software that performs the same operations on music), where it is immediately separated into two channels. One serves the auricular output of the headphone; the other serves a bone vibrator which is placed on the top of the headphone resting on the skull (28). In this way the music is directly transmitted to the cochlea through the vibration of the cranial theca, bypassing the middle ear. It should be noted that air transmission

is delayed in comparison with bone transmission by a variable time.

Moreover, the sound is submitted to a gating system that increases or decreases the higher and the lower frequency content of the sound source (music or voice). This stimulates the muscles of the middle ear (stapedius and tensor tympani).

After this step, the sonic source can be filtered with either high pass or bandpass filters, or both, as well as with filters tailored to every specific tinnitus frequency.

In addition, it is possible to differentiate the volume of the output directed respectively to the left and right ear.

One of the consequences of this modification of the incoming music is prevention of the full preconfigured tension of the muscles of the middle ear due to mal-perceptive conditioning. The vestibulo-cochlear sensation, i.e. a change in the physical environment (energy) picked up in a selective and differentiated manner by the sensory system, is therefore brought to conscience through a way with highly reduced mal-perceptive conditioning (29).

Population of the study

This analysis concerns a population of 30 patients (12 females and 18 males) with an average age of 55 years (SD = 13) who have attended my centre specifically to treat their tinnitus.

All the participants signed an informed consent form to the therapy. They were asked to give explicit consent to participate in the study.

The population showed a very wide range of time since tinnitus onset: from 2 months to 43 years (516 months). It is interesting that the majority of the patients with long-lasting tinnitus (>36 months) were men (10 males and 2 females), while there was a prevalence of women in the acute group (≤6 months – 3 males and 6 females) and substantial parity (5 males and 4 females) in the early chronic group (7 to 36 months).

The subjects perceived the tinnitus in only one ear (R = right, n=7; L = left, n=8), in both ears (R+L, n=10), or inside the head (n=5).

Hypoacusis was associated in nine cases, while the other 21 patients had a listening test showing a normal acoustic threshold.

With regard to the aetiology, the patients were divided into three main groups: in 18 cases (9 males and 9 females) it had been possible to identify an ENT impairment as the primum movens of the tinnitus. In four of the patients in this group, the onset of the tinnitus had followed a sudden onset of deafness (ipsilateral), in two cases it was among the accompanying symptoms of Ménière syndrome; in two cases it appeared in the context of otosclerosis. In a further two cases the severe tinnitus was a consequence of iatrogenic damage (aminoglycosides), and in one patient, the tinnitus appeared after surgical resection of the VIII cranial nerve to treat serious vertigo. In one other case the tinnitus was definitely somatic.

Acoustic trauma was the origin of tinnitus in five cases (3 males and 2 females), while in seven (6 males and 1 females), the phantom percept emerged in a readily identifiable stressful life moment: for instance, a serious illness of a relative, a divorce, a bankruptcy, etc.

Some of the patients (7 cases) had already been treated with psychotropic medications, mainly antidepressants and anxiolytics prior to beginning their listening therapy. The anamnestic data are summarised in Table 1.

Audiopsychophonology sessions

The "Bilan Audiopsychophonologique" (BAPP) is the initial assessment during which, after anamnestic data collection, the clinical evaluation and the listening test together with a test of lateralisation are performed. In addition, the participant completes a modified version of "The Baum Test" (or "Koch Test"). Originally developed by Charles Koch, this is a projective test used to analyse an individual's personality and his underlying emotional history.

The listening test evaluates the listening thresholds for air and bone conduction; these data are represented in two separate diagrams, one for each ear. Moreover, it evaluates listening selectivity, which is the ability to discriminate between tones, and auditory lateralisation, namely the preferred ear for the incoming sounds. The listening test is interpreted from an

Table 1. Anamnestic characteristics of the population studied

Patient	Gender	Age	Schooling	Time (months)	Lateralisation	Hypoacusis	Psychotropic drugs	Cycles	Aetiology	Aetiological ENT subtypes
1	M	70	H	6	head	no	yes	2	stress	
2	F	42	D	4	R	yes	no	2	ENT	sudden deafness
3	M	69	M	612	L>R	yes	no	2	ENT	iatrogenic
4	F	45	D	6	L>R	no	yes	3	ENT	
5	M	70	H	12	R	yes	yes	2	stress	
6	F	47	H	12	L	no	no	2	ENT	sudden deafness
7	F	62	H	4	L>R	yes	no	2	ENT	
8	F	51	M	2	head	yes	no	2	ENT	sudden deafness
9	F	78	M	516	R+L	yes	no	2	trauma	
10	M	58	D	240	L	yes	no	2	ENT	surgery VIII c.n.
11	M	46	D	12	L	yes	yes	2	ENT	Ménière
12	M	67	H	108	R	yes	no	2	ENT	sudden deafness
13	F	25	D	24	R	yes	no	2	ENT	otosclerosis
14	M	57	D	36	R+L	yes	no	3	trauma	
15	M	58	H	3	R>L	no	no	3	stress	
16	M	44	H	264	R	yes	no	4	ENT	iatrogenic
17	M	60	D	240	R>L	yes	no	5	trauma	
18	F	54	H	180	L	yes	yes	2	ENT	Ménière
19	M	36	D	24	R	no	yes	2	stress	
20	F	61	H	36	head	yes	yes	2	ENT	
21	M	77	H	264	L	yes	no	3	trauma	
22	F	56	D	6	R+L	yes	no	3	stress	
23	M	37	D	228	L	yes	no	2	ENT	
24	M	71	M	60	L>R	yes	no	2	ENT	
25	F	40	H	12	R+L	yes	no	3	ENT	otosclerosis
26	F	54	D	4	L	no	no	3	trauma	
27	M	57	D	48	L	yes	no	2	ENT	
28	M	35	H	24	head	no	no	2	stress	
29	M	50	D	3	R	no	no	2	stress	
30	M	71	D	240	head	no	no	4	ENT	

Gender: M = male; F = female - Schooling: M = middle school; H = high school; D = degree – Lateralisation: R = right ear; L = left ear; R+L = both ears; head = tinnitus percept in the head – Aetiology: ENT = ear-nose-throat pathologies; stress = a stressful event identifiable as a cause of tinnitus; trauma = acoustic trauma.

audiological and behavioural point of view according to Alfred Tomatis' guidelines (30). The programme for the listening sessions is then planned taking into consideration all the aspects mentioned above, and it is specifically tailored for each patient.

For the purpose of this work, the Italian version of the Tinnitus Handicap Inventory (THI) (31) was administered to the patients during the BAPP and 30 days after the end of the therapy.

In accordance with the theories of Alfred Tomatis, who first postulated a direct link between the ear and the limbic system (27), each patient filled in the Self-Rating Anxiety Scale (SAS) (32,33) prior to beginning and also at the end of the therapy.

The therapy is organised into intensive cycles of listening to modified music: the first consisting of 15 days of daily therapy, four sessions per day, each session lasting 30 minutes. After a break, which varies in length from 3 to 6 weeks, the patients undergo another intensive cycle this time lasting 8 days, but again involving two hours of listening (four 30-minute sessions) per day. Twenty patients completed only two cycles. Seven patients required a further 8-day cycle. This cycle took place 3 to 6 months after the second one. Two patients needed a fourth cycle (of 8 days) and one did a total of five cycles of listening therapy. Hence, 2/3 of the patients obtained satisfying results in less than three months.

During the therapy (both the cycles and the break periods) the listening test was repeated to check for improvements; the results of these tests, together with the clinical information, are essential to orient the subsequent planning of the treatment.

Results and discussion

The initial THI average score of the population studied (n=30) corresponded to grade 3 (median 3), while the final THI average score was grade 2 (median 2).

From the THI grade-difference perspective, 10 cases did not show any change in their THI grade. Although eight of these 10 cases showed an improvement on this scale, it was not sufficient to change their grade. One case had a very slight worsening and one did not achieve any change. In three cases the tinnitus disappeared completely. Figure 1 shows the differences between the initial and the final THI scores, while Table S1 summarises data from the single cases.

The SAS gives a score ranging from a minimum of 20 to a maximum of 80 points. The SAS mean score at baseline was 51 points (median 54), while the final SAS mean score was 35 points (median 34). The average difference was 16 points (median 17). This corresponds to an average decrease of 19% (median 21%). Figure 2 shows the differences between the initial and the final SAS scores, while Table S1 summarises the data from the single cases.

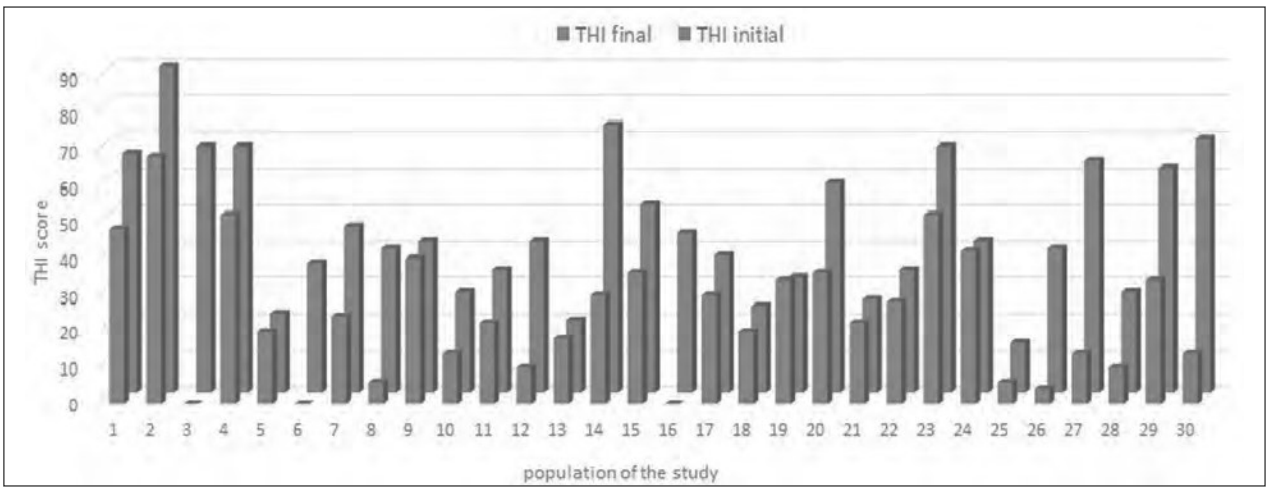

Figure 1. Differences between the initial and final THI grades

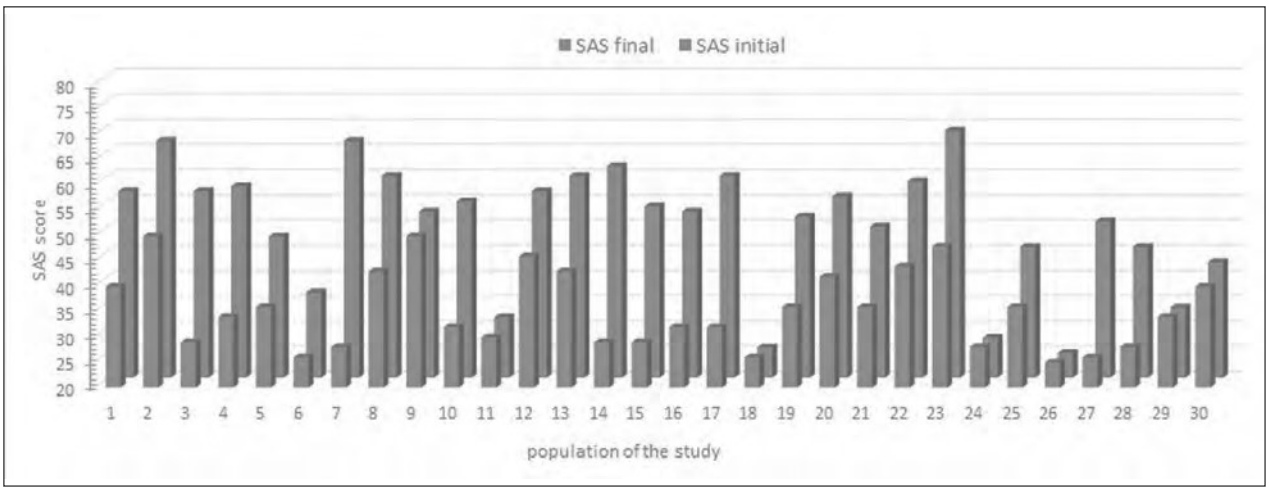

Figure 2. Differences between the initial and final SAS scores

Hence, 87% of the patients experienced a decrease in their level of anxiety. Even the case that showed a slightly worse THI score recorded a 31% improvement on the SAS. Detailed scores are shown in Table S1.

The data were analysed considering the variables that could have influenced the results (Table 2).

The results were found to differ appreciably according to the initial THI grade: the patients who originally had a THI grade 1 or 2 (n=11) did not show substantial changes (average and median 0), while those initially recording THI grade 3 (n=9) achieved a median improvement of one grade; those with an ini-

Table 2 Analysis of the data considering the variables that could have influenced the results

Aetiology			**Time since onset (months)**		
ENT (n=18)	Δ THI grade	%Δ SAS	**≤6 (n=9)**	Δ THI grade	%Δ SAS
average	1.6	23	average	0.9	23
median	1.5	22	median	1.0	21
stress (n=7)	Δ THI grade	%Δ SAS	**7 ÷ 36 (n=9)**	Δ THI grade	%Δ SAS
average	0.4	21	average	1.4	24
median	0.0	21	median	1.0	29
trauma (n=5)	Δ THI grade	%Δ SAS	**>36 (n=12)**	Δ THI grade	%Δ SAS
average	0.8	4	average	1.3	14
median	0.0	0	median	1.5	13
Lateralisation			**Gender**		
R (n=7)	Δ THI grade	%Δ SAS	**female (n=12)**	Δ THI grade	%Δ SAS
average	1.4	31	average	1.8	23
median	1.0	30	median	2.0	24
L (n=8)	Δ THI grade	%Δ SAS	**male (n=18)**	Δ THI grade	%Δ SAS
average	1.1	18	average	0.8	17
median	0.5	19	median	1.0	16
R + L (n=10)	Δ THI grade	%Δ SAS	**Number of listening cycles**		
average	1.1	13	**2 (n=20)**	Δ THI grade	%Δ SAS
median	1.0	11	average	1.5	23
head (n=5)	Δ THI grade	%Δ SAS	median	1.0	21
average	1.2	19	**more (n=10)**	Δ THI grade	%Δ SAS
median	1.0	15	average	0.6	12
			median	0.0	13
Initial THI grade			**Schooling**		
1 and 2 (n=11)	Δ THI grade	%Δ SAS	**middle (n=4)**	Δ THI grade	%Δ SAS
average	0.4	15	average	2.3	14
median	0.0	15	median	2.5	13
3 (n=9)	Δ THI grade	%Δ SAS	**high (n=12)**	Δ THI grade	%Δ SAS
average	1.3	20	average	1.3	21
median	1.0	21	median	1.0	21
4 and 5 (n=10)	Δ THI grade	%Δ SAS	**degree (n=14)**	Δ THI grade	%Δ SAS
average	2.0	23	average	0.9	19
median	2.0	24	median	0.5	19
Hearing threshold			**Psychotropic drugs**		
normal (n=9)	Δ THI grade	%Δ SAS	**yes (n=7)**	Δ THI grade	%Δ SAS
average	0.8	21	average	1.3	26
median	0.0	21	median	1.0	26
hypoacusis (n=21)	Δ THI grade	%Δ SAS	**no (n=23)**	Δ THI grade	%Δ SAS
average	1.4	19	average	1.2	17
median	1.0	20	median	1.0	18

tial grade 4 or 5 (n=10) improved by a median of two grades. The SAS results improved by an average and median of 15% in the grade 1 and 2 groups; an average of 20% (median 21%) in the grade 3 group, and an average of 23% (median 24%) in the grade 4 and 5 groups. This seems to be coherent with the reported relief from tinnitus.

Considering the aetiology of tinnitus, the ENT group (n=18) obtained 1.5 grades of improvement on the THI (average 2 – median 2), and an average 23% decrease in their subjective perception of anxiety (median 22%). The same gain at the SAS test was identifiable in the stress group (n=7; average 21%, median 21%). However, there were no differences in THI grade in this group. In patients suffering from tinnitus arising from an acoustic trauma there was almost no change either in the THI grade (average 0.8% – median 0%) or in their level of anxiety (average 4% – median 0%).

From the perspective of the time since tinnitus onset: the group of patients who had had tinnitus for more than 36 months prior to the beginning of intervention exhibited a decrease of two grades on the THI, while in the other two groups (tinnitus lasting less than 6 months and from 7 to 36 months) the decrease was of one grade. No appreciable differences were identifiable in the SAS score, only a small decrease in perceived anxiety recorded in the acute group (≤6 months: average 23% – median 21%; from 7 to 36 months: average 14% – median 13%; >36 months: average 13% – median 14%).

From the gender perspective, it was found that the 12 females had a median THI improvement of two grades, while the 18 males gained one grade. The level of anxiety decreased by an average of 23 points (median 24) in the females, as opposed to an average of 17 points (median 16) in the males.

From the perspective of lateralisation of the tinnitus, all the groups (R, L, R+L, head) recorded an average THI reduction of around one grade. The subjective evaluation of anxiety showed a different pattern, with a much greater improvement in anxiety emerging in the R group (average 31% – median 30%) compared with the R+L (average 13% – median 11%), head (average 19% – median 15%) and L (average 18% – median 19%) groups.

With regard to hearing test performance, no score differences were found between the group with normal hearing and the subjects with hearing loss, and the self-evaluated anxiety level decreased by an average of 20% in these two groups (normal hearing: average 21% – median 21%; hearing loss: average 19% median 20%).

Psychotropic drugs seem to have no impact on these results, with both the treated and the untreated groups recording a decrease of one grade on the THI, and drug-treated patients showing a SAS improvement very close to (only a little higher than) the average improvement seen in the whole population (psychotropic drugs group: average 26% - median 26%; no drugs group: average 17% – median 18%).

Other sound-based stimulation techniques

There are various research groups that use sound stimulation with the aim of treating tinnitus.

Pawel Jastreboff points out the maladaptive associations that patients often develop, first of all because they are afraid that their tinnitus could be the alarm bell of a severe illness such as a brain cancer, and second because the first advice that a tinnitus patient gets from doctors is usually that “there is nothing to be done about it, and that he has to learn to live with it, forever”. Jastreboff’s “Tinnitus Retraining Therapy” entails two types of work: conscious work, to separate the negative emotional associations formed in the early stages following the appearance of tinnitus, and unconscious, to favour plastic changes, that is, to allow habituation with the aid of a white noise. The therapy has to last from 12 to 18 months to give results (9,34).

Martin Lenhardt and Barbara Goldstein investigated the role of the parabrachial nucleus in the final common pathway in severe tinnitus (35). The parabrachial nucleus, even though it is not part of the auditory pathways, contributes to transforming an aberrant auditory stimulus into an emotionally relevant one. It helps to transfer aberrant audiological signals from the amygdala to the insula where they become emotional percepts. They invented the Ultra Quiet Device to obtain tinnitus improvement with “Ultra High Frequency Vibration Therapy” (20,36). The best results that they achieved were in patients with high auditory thresholds at high frequencies (≥8000Hz).

Their method involves the use of stimulation from 6 to 20KHz through headphones and a bone transducer on the mastoid bone. They called it multisensory vibration stimulation as it combines acoustic stimulation with somatosensory stimulation which is delivered through the bone vibrator. Their protocol consists of 16 sessions (2 per week for 8 weeks) of one hour each.

Christo Pantev considered that music-induced cortical plasticity, specifically at the level of the auditory cortex, might be a basis for tonal tinnitus treatment. Lateral inhibition is due to lateral connections and it is an active mechanism that causes a softening of the evoked auditory response. On the contrary, habituation is a neural mechanism that supresses the neural activity of neurons that are repeatedly activated. Habituation plays an important role both in inhibiting irrelevant neural activity and in increasing neural activity triggered by irregular sensory stimuli (21). The research group led by Pantev explored both of these possibilities and found that lateral inhibition gave more positive results. After 15 years of study of the effects of lateral inhibition on the auditory cortex they developed a treatment strategy for tonal tinnitus called "Tailor-Made Notched Music Training" (TMNMT). In a first long-term controlled study that lasted one year, they obtained a significant reduction in subjective tinnitus loudness and annoyance. The training was more effective when the tinnitus frequency was ≤8000Hz (37).

De Ridder and Vanneste suggest that tinnitus should be seen as an emerging property of multiple parallel subnetworks that change dynamically and are partially overlapped. Their protocol for tinnitus treatment consists of acoustic stimulation paired with vagus nerve stimulation (22,38). They implant electrodes on the vagus nerve. The patient hears tones – except for the tinnitus matched frequency – paired with brief electrical stimulation of the vagus nerve.

The role of APP in tinnitus treatment

APP seems to promote myelination of the auditory pathways (24) which improves the processing speed of auditory signals. In addition the auditory stimulation results in better integration between the different sensory systems and a more harmonious balance between the sympathetic and parasympathetic nervous systems (23).

Listening therapy seems to offer a wide range of possibilities for modifying the history and wellbeing of tinnitus patients. It stimulates the middle ear (via the gating system) and specific portions of the cochlea and the whole acoustic pathway (via the filters); moreover it reaches sub-cortical levels (via the gating system, bone conduction, delays). The whole CNS receives harmonious signals that open the possibility of reconsidering the significance of tinnitus, thus activating neural plasticity.

Researchers have identified neural changes related to tinnitus that commence at the cochlear nucleus and extend to the auditory cortex and brain regions beyond. Maladaptive neural plasticity appears to underlie these neural changes, as it results in increased spontaneous firing rates and synchrony among neurons in central auditory structures that may generate the phantom percept (39).

The tinnitus paradigm described above is coherent with the results found. The APP sessions were found to be more effective when the tinnitus had a major impact on normal daily activities (THI grades 4 and 5), when it was the consequence of a previous malfunctioning of the peripheral or central auditory pathways (ENT aetiology), and when it became chronic, that is a new maladaptive normality. In this regard, given that those whose tinnitus has lasted longer or has a greater impact experience the suffering as a daily devastation, the effect of their intrinsic desire for relief, or tension towards freeing themselves from the symptom, should probably be considered as a possible contributory motivating factor.

Speculating on why there was a greater improvement in the group of patients perceiving tinnitus in their right ear, the reason may be linked to the "directive nature" of the right ear. In spite of the ongoing debate about the hemispheric lateralisation (40), and according to Alfred Tomatis' theories, the sounds conveyed by the right auditory pathways seem to be better controlled and managed by the CNS. Moreover, there is a lighter emotional load associated with sound picked up by the right ear (23).

The music of Mozart and the gating system of Tomatis' Electronic Ear allow natural stimulation of

the vagus nerve (41); moreover, the administration, through both bone and delayed air conduction, of music tailored to the frequency of the tinnitus stimulates the auditory cortical areas and the sub-cortical circuits involved in the final common pathway for tinnitus (42) inducing lateral inhibition. APP raises the possibility that the phantom percept may be declassified to its natural role: that of an annoying sound that does not deserve to be considered.

Another interesting fact that seems to emerge is that considerable and sufficient improvement (corresponding to an average THI improvement of 1.5 grades – median 1) takes place in the first two listening cycles. This result should be further investigated, as the patients who continued with the listening cycles beyond the second were the ones who had not achieved satisfactory results in the first two. And these results did not change in the following cycles either (average THI grade 0.6 – median 0).

The study data as a whole seemed to show that the women obtained greater improvements than the men, both in THI and SAS scores. APP is based on the work of the "Electronic Ear" and on the support provided through interviews that helps patients to manage the emerging listening possibilities, paving the way for change. According to Eugenio Borgna (43), who considers listening a crucial foundation for getting close to mental distress, women have a natural predisposition for listening, and they are generally more prone to introspection and more willing to ask for help.

Figure 3 and 4 show a graphic representation of what has been discussed above.

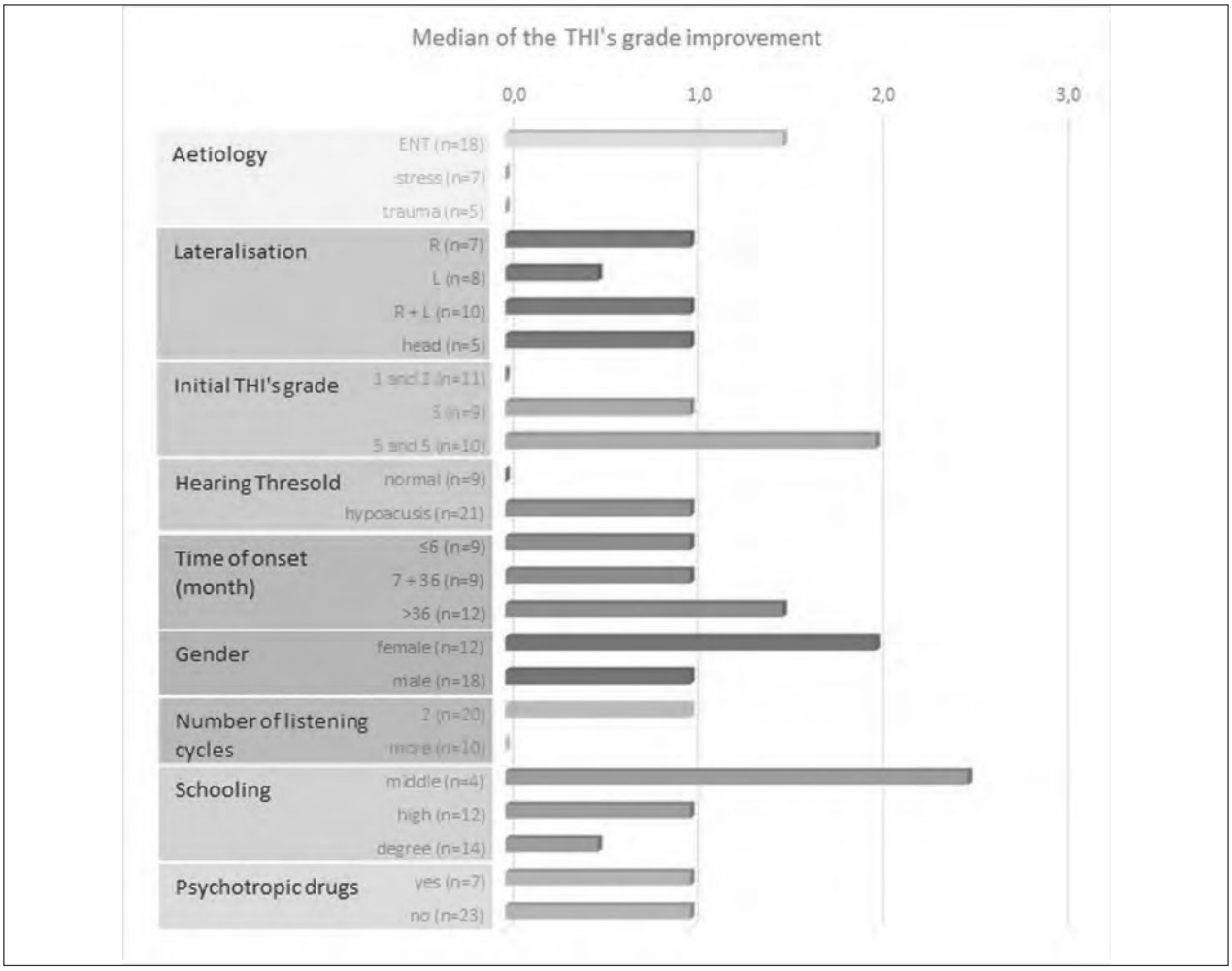

Figure 3. Graphic representation of THI grade improvement in relation to the variables considered

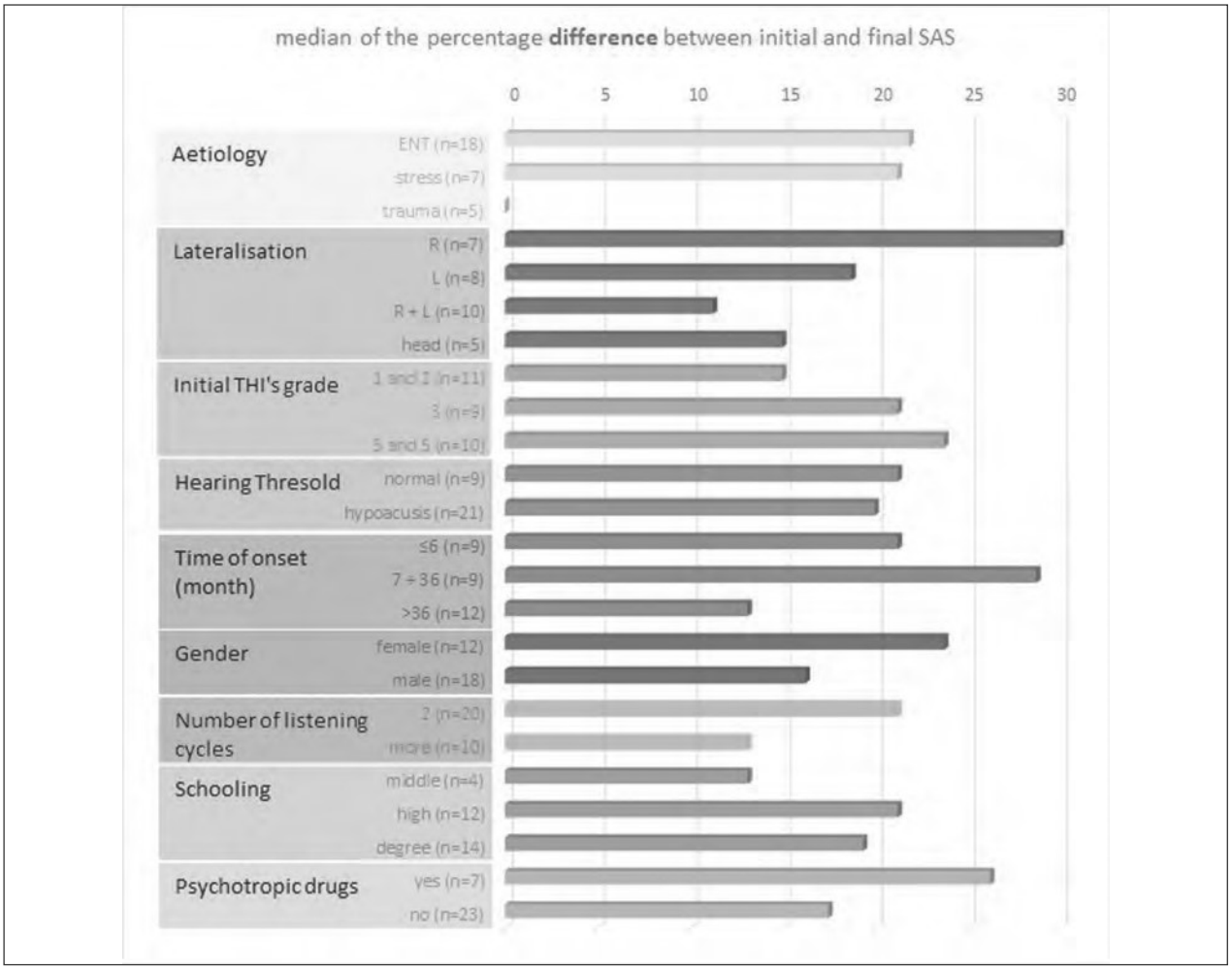

Figure 4. Graphic representation of the mean percentage of improvement on the SAS test

Conclusions

Although this is an open study with a small and inhomogeneous population, its findings strongly suggest that Alfred Tomatis' listening therapy deserves to be investigated as a possible viable tinnitus treatment. It is non-invasive and has no side effects. It seems to be effective and efficient in providing relief from the intrusiveness of tinnitus in patients' daily lives, while at the same time reducing their anxiety levels. The APP approach seems to be more than just the synthesis of current sound therapies for tinnitus: it also evokes lateral inhibition, uses music (a complex stimulus, effective, even in itself, in the induction of CNS plasticity), deploys bone stimulation and vagal stimulation, and works on emotions related to tinnitus. It would be appropriate to plan studies using objective assessments for each domain of functioning that might better verify the positive findings emerging from the data presented here.

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Supporting information

S1 table. **Summary of all data**. Legend. Gender: M = male; F = female - Schooling: M = middle school; H = high school; D = degree – Lateralisation: R = right ear; L = left ear; R+L = both ears; head = tinnitus percept in the head – Aetiology: ENT = ear-nose-throat pathologies; stress = a stressful event identifiable as a cause of tinnitus; trauma = acoustic trauma.