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Customized web-based sound therapy for tinnitus

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Abstract

Introduction: Traditional masking efforts have presented broadband noises, most typically white noise. Targeted (customized) sound therapies have been introduced to overcome the limitations of traditional maskers. **Objectives:** To evaluate the efficacy of a web-based delivery of customized sound therapy in reducing tinnitus loudness and increasing the residual inhibition. **Materials and Methods:** Thirty-two subjects matched their tinnitus frequency using a web-based protocol. A customized Harmonic Sound Therapy file was produced by the web-based software and downloaded by the patient onto an MP3 player. The subjects listened to the sound file for one hour. **Results:** Tinnitus loudness mean was 6.0 ± 2.3 standard deviation (SD) which decreased to 3.3 ± 1.9 SD after one hour of sound therapy. Some reduction in loudness was seen in 81%, while 72% experienced a reduction of 25% or more. Tinnitus annoyance decreased from an average of 6.1 ± 2.6 SD to 3.1 ± 2.0 SD. Median duration of residual inhibition was 32.5 minutes, with an average of 75 minutes ± 132 SD. **Conclusion:** Customized sound therapy can be delivered via the internet. Harmonic Sound Therapy is effective in reducing the loudness and annoyance of tinnitus.

Keywords: acoustic stimulation, telemedicine, tinnitus.

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INTRODUCTION

Tinnitus is the perception of sound by the brain in the absence of an external acoustic stimulus. This perception of sound is most often caused by damage to the peripheral auditory system, specifically the cochlea. Tinnitus pathophysiology can be considered to occur with a multi-step process. First, damage or insult to a region of the cochlea increases the spontaneous firing rate in its corresponding area of the brain. This region has been termed the Lesion Projection Zone (LPZ)[1]. The second phenomenon that occurs is that the tones that border the damaged zone in the cochlea become associated with the hyperactivity occurring in the LPZ. The ringing tone that people hear when they perceive tinnitus actually corresponds to these border regions, called Lesion Edge Frequencies (LEF)[2,3]. These aspects of tinnitus pathogenesis are the basis for our approach.

Sound therapy in tinnitus management (i.e., masking) is the strategy of presenting an external sound to "cover up" one sound by another[4], distracting the attention drawn to tinnitus and reducing the loudness of tinnitus[5]. Sound therapy induces suppression of the spontaneous firing in the auditory cortex's LPZ, and hence provide tinnitus relief. Traditional (non-customized) masking efforts have presented broadband noises, most typically white noise. A disadvantage with broadband noise is that it masks the subject's hearing at all frequencies. Thus, this sets limits on the duration a subject is able to have the hyperactivity in the LPZ suppressed, and ultimately, on the rate and degree of tinnitus rehabilitation[6,7]. Additionally, there have been reports on deterioration of the intelligibility of speech with broadband noises compared with the other sound therapy signals in tinnitus treatment[7].

It is acknowledged that targeted (customized) acoustic energy at the LEF provides more effective masking than broad-based acoustic energy. In other words, the more closely the masking sound corresponds with the LEF, the more effective is the tinnitus suppression[6-11]. Unfortunately, with this approximation, the therapeutic sound might also become more noxious. There are a number of drawbacks with most of the introduced sound therapy treatments as they require multiple visits to care provider, special equipments or they are simply too expensive.

To address these issues, we have developed Harmonic Sound Therapy as a method of tinnitus treatment. Harmonic Sound Therapy is a customized masking strategy specifically designed to deliver non-noxious targeted acoustic energy to the LPZ, yet at the same time allow significant portions of the hearing spectrum to remain unmasked. This design makes it possible to have dramatically increased exposure to the therapeutic sound because the ambient acoustic space is left open.

In the current study, we evaluated the efficacy of Harmonic web-based delivery of customized sound therapy in reducing tinnitus loudness and increasing the residual inhibition (a temporary suppression of tinnitus following exposure to therapy sound).

METHODS

Subjects

Thirty-two participants were enrolled in the study through the Otolaryngology clinic at our institution or through patients who found the study via the web. The inclusion criteria were being aged 18 years or older, presence of tinnitus for 6 months or more and constant tinnitus. The exclusion criteria were: active illicit drug use or alcohol dependence, active ear infections, treatable cause of tinnitus, history of psychosis, abnormalities of the ear canal, subjects on medications known to cause tinnitus (aspirin, ibuprofen, naproxen, etc) which could not be stopped, and currently under another sound or masking therapy for tinnitus. The study protocol was approved by the local Institutional Review Board.

Introductory session

The study protocol only included one introductory session with each participant to ensure the eligibility criteria and process of written informed consent. After signing the informed consent form, each participant was introduced to the website created for the study with minimal further instructions. The website contained general information on the tinnitus, aim and procedure of the study, and instructions on every step of the web-based protocol. To unify the delivery method, each participant was provided with a unique username and password. Furthermore, they were given a 2 GB Sansa Clip MP3 player (San Disk, Milpitas, CA) and an AirDrives Interactive Stereo Earphone (Mad Catz Inc, San Diego, CA). The innovative design of these headphones, where the speaker sits outside of the ear and transmits sound via the tragal cartilage, prevented the participant from being acoustically isolated (Figure 1). The speakers in these headphones do not sit in the ear canal, and therefore, the environment sound could pass into the ear canal and reach the users' ear. During this session, the participants were asked to run the MP3 player and headphone once to ensure they know how they work.

Web-based procedure

The online protocol included four steps. The first step was to determine the participants' tinnitus type. Participants were asked whether their tinnitus is a tonal/ringing or hissing/buzzing sound. Then they were given a series of choices of different sound frequencies (pure tones for tonal/ringing tinnitus, narrow band noise for hissing/buzzing tinnitus). The participants were given

Figure 1. AirDrives Interactive Stereo earphones: the speaker sits outside of the ear and transmits sound via the tragal cartilage.

the option of using a scrolling slider, to select the closest sound to their tinnitus if the multiple choices did not closely approximate their tinnitus.

In the second step, the participants were asked to rematch their tinnitus with a choice of the tinnitus frequency and one octave above and below the tinnitus frequency. This allowed the elimination of octave confusion, which can occur when selecting the tinnitus frequency[12]. In the third step, they had to select if the tinnitus was unilateral or bilateral. In bilateral cases, they were instructed to adjust the balance on a scroll bar to hear the pitch-matched sound equally in both ears, to allow for asymmetry in tinnitus and hearing loss (Figure 2). The website would then implement participants' selections of frequency, loudness and inter-aural characteristics to construct a customized Harmonic Sound Therapy file (Figure 3). The Harmonic Sound Therapy file is composed of a series of narrow-band noise peaks centered on the tinnitus frequency and the first and fifth sub-harmonics. The width of these bands is one-half octave of the center frequency. The result was a file that sounded similar to generic white noise, but the amount of required acoustic energy was dramatically reduced and centered on the frequencies where therapy is needed.

The last step was to download the customized Harmonic Sound Therapy file, generated by the website, onto the MP3 player. Then, participants were instructed to place both headphones around the ear in a way that the speaker sits in front of the ear canal and then listens to the therapy file for an hour at a level equal to tinnitus loudness (mixing-point). The subjects were instructed to have the level of the sound therapy file such that the tinnitus can still barely be heard.

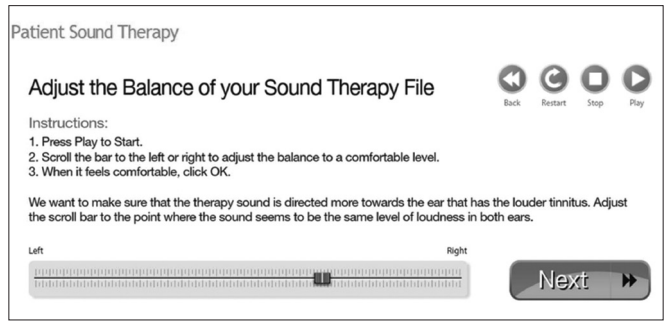

Figure 2. Third step in web-based protocol of Harmonic Sound Therapy for tinnitus treatment: balance adjustment on a scroll bar to compensate for asymmetry in tinnitus and hearing loss.

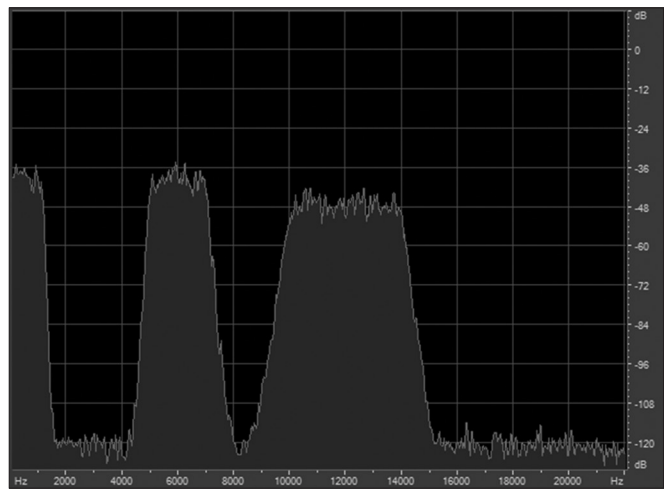

Figure 3. A sample spectral plot of a Harmonic Sound Therapy File with the center frequency around 12000 Hz and first (6000 Hz) and fifth (375 Hz) sub-harmonics.

Outcome measurements

Tinnitus loudness and annoyance were measured by visual analog scales (VAS) before and after treatment. After downloading the Harmonic Sound Therapy file and before starting to listen, participants were asked to score the loudness and annoyance of their tinnitus on separate scale lines numbered from 0 to 10. After one hour of listening to the file, they were asked to score the loudness and annoyance again. A 25% or more reduction in loudness or annoyance was considered as significant. If the loudness was reduced then the participants were instructed to report the duration that the tinnitus suppression lasted, in minutes. This was recorded as residual inhibition.

Tinnitus loudness, annoyance and residual inhibition were defined as dependent variables and age, gender, tinnitus frequency, type (tonal/ringing or hissing/buzzing), and ear side (right, left or both ears) were defined as independent variables.

Statistical analysis

Means, standard deviation (SD) and range of values were calculated for loudness and annoyance before and after treatment. Non-parametric tests were used to compare the reduction in each participant's loudness and annoyance, and to evaluate the difference in reductions and residual inhibitions between different levels of independent variables. A *p*-value of less than 0.05 was considered as significant.

RESULTS

The sample population consisted of 10 females and 22 males. Mean age of participants was 49 years old (SD ± 9.4; range 32 to 67). Participants' tinnitus pitch had an average of 6438 (SD ± 3004; range 2000-12000). Nineteen (59.4%) described their tinnitus as tonal or ringing and 13 (41%) as hissing or buzzing. In 53% (17/32), tinnitus was present in both ears, in 28% (9/32) in right ear and in 19% (6/32) in left ear.

Tinnitus loudness and annoyance were both significantly reduced after Harmonic Sound Therapy ($p < 0.001$) as shown in Table 1. Reduction in loudness was detected in 81% (26/32); while 16% (5/32) had no change in loudness and 3% (1/32) had increase in loudness. Reduction in annoyance was detected in 84% (27/32); while 16% (5/32) had no change in annoyance. Further information is provided in Table 1.

There was a significant difference in loudness reduction between tonal/ringing (57.9%) and hissing/buzzing (92.3%) tinnitus ($p = 0.03$). However, the annoyance reduction difference was statistically insignificant ($p = 0.40$). There were no associations between reduction in loudness or annoyance and other independent factors (age, gender, ear side and tinnitus pitch).

The median duration of residual inhibition was 33 minutes, with an average of 75 minutes (SD ± 132; range, 0-720). There was no inhibition in 19% (6/32), while 41% (13/32) had a residual inhibition of 60 minutes or more. Among those with a 25% or more reduction in tinnitus loudness, median residual inhibition was 60 minutes (mean 99 ± 148 SD). There was no association between residual inhibition and other independent factors (age, gender, ear side and tinnitus frequency and type).

DISCUSSION

Our findings support two hypotheses: 1. Harmonic Sound Therapy is effective in temporarily reducing the intensity and loudness of tinnitus in a significant group of patients; 2. Customized sound therapy can be delivered via the web. We found 25%, 50% and 100% temporary reduction in tinnitus loudness after one hour of Harmonic Sound Therapy usage in 72%, 34% and 13% of patients respectively. We believe that customized web-based sound therapy for tinnitus could be an effective and promising alternative to current methods of tinnitus treatment. The Harmonic Sound Therapy could be used as a complement to routine tinnitus management or as a replacement for patients who are unable to have frequent visits to their care provider or live in remote locations. The web-based protocol allows patients to change their sound therapy file with changes in their tinnitus frequency. In general, the patients had no difficulty performing the web-based procedures and downloading the sound file onto an MP3 player. Some of the older patients, who had not used an MP3 player in the past, required some assistance.

In the current study, participants were only seen once to be introduced to the study, sign the consent form and to be provided with the research equipment (MP3 player and headphones). They were given minimal instructions on the web-based protocol before using it, though a research staff was present by their side as the procedures were completed. However, after they followed the online protocol, their tinnitus loudness and annoyance scores were significantly reduced temporarily. About 72% of the participants experienced a 25% or more reduction in loudness and annoyance that on average lasted for a median of approximately 60 minutes. Those who had hissing/buzzing tinnitus showed higher reduction in tinnitus loudness (92.3%) compared to those with tonal/ringing tinnitus (57.9%). This could be explained by the nature of the Harmonic Sound Therapy files that are composed of a series of narrow-band noise peaks centered on the tinnitus frequency and the first and fifth sub-harmonics. Therefore, they provide partial coverage one quarter-octave below and above the tinnitus frequency and are more likely to resemble the participants' tinnitus spectra[11].

Table 1. Tinnitus loudness and annoyance on visual analog scale, before and after one-hour Harmonic Sound Therapy with web-based protocol (n = 32).

	Before		After		*p*-value	Reduction ≥ 25%	Reduction ≥ 50%	100% Reduction
	(mean ± SD)	Range	(mean ± SD)	Range				
Tinnitus Loudness	6.0 ± 2.3	2-10	3.3 ± 1.9	0-6	< 0.001	72%	34%	13%
Tinnitus Annoyance	6.1 ± 2.6	1-10	3.1 ± 2.0	0-8	< 0.001	72%	56%	9%

There is controversy about the exact region of damage that leads to the perception of a specific tinnitus frequency. Although some authors have suggested that tinnitus frequency corresponds to the region of maximal hearing loss[12,13] or some opposed the LEF theory[15], many studies have supported it[2,3,11,16]. Harmonic Sound Therapy files are centered on the patient's tinnitus frequency and not only stimulate the LEF but its neighboring octave frequencies as well and theoretically will decrease the hyperactivity in the LPZ. By doing so, concentrated delivery of therapeutic sound is achieved, while at the same time the noxious quality, which might result by stimulation of the tinnitus frequency alone, is avoided. Furthermore, because Harmonic Sound Therapy only targets the regions of the hearing spectrum that involve the tinnitus frequency and its sub-harmonics, the remaining portions of the hearing spectrum are spared and allowed to pass through to the ear. This innovative approach is further exploited by the use of Air Drives Interactive Stereo Earphones. These headphones transmit sound via the tragus, and thus do not occlude the external ear canal. This allows the patient to listen to their therapeutic sound files during the course of their everyday activities.

Recent studies have demonstrated the advantage of customized sound therapies over traditional sound therapies (i.e. maskers)[8,17]. In the current study, we sought to test the feasibility of providing customized sound therapy over the internet. Although web-based treatments of tinnitus have been introduced using other approaches such as cognitive behavioral therapy[18], this is the first study to evaluate customized sound therapy as a possible telemedicine application through automated web-delivery of sound files.

There are a number of limitations to this study. Findings of the current study should be interpreted with caution due to the small sample size and lack of a control group. However, the results highlight the feasibility of a potentially cost-effective, customized treatment of tinnitus over the web.

CONCLUSION

Web-based delivery of customized sound therapy for tinnitus is a practical and potential solution for the treatment of tinnitus. This study has shown that Harmonic Sound Therapy is effective in at least temporary reduction of tinnitus in a large number of subjects. This will illuminate the path towards future studies and applications of internet-delivered customized Harmonic Sound Therapy in larger populations and controlled trials.

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