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EVIDENCE SUPPORTING THE USE OF ZEN AS A TOOL FOR TINNITUS AND RELAXATION

BACKGROUND:

The vast majority of individuals suffering from tinnitus also have hearing loss [1]. When a peripheral hearing deficit exists, a cascade of reorganizational and physical changes occur leading to increased neural activity in the central auditory pathways[2]. Moreover, stress is a significant exacerbating factor for tinnitus[3]. The physical consequences of stress are manifested in responses from the limbic system which are either due to a malfunctioning inhibitory gating system[4-6] or are based on negative emotional reaction, rendering natural habituation to this benign, but annoying auditory perception very difficult. The use of acoustic signals to mask, mix with, or ease the distress associated with tinnitus has been clinically employed for decades. Given the evidence that many forms of tinnitus are associated with decreased peripheral stimulation and increased limbic system activity (stress), popular current management procedures for tinnitus sufferers[7-9] use an educational counseling approach combined with sound therapy (noise, music, or amplification) to help reduce the brain's tendency to seek the acoustic stimulation that it is missing. While each of these approaches has been shown to be beneficial for certain patients, none are universally effective. Potential shortcomings are that the incoming acoustic stimuli may lack inherent stress-reducing and relaxation abilities, that they only provide stimulation during the limited time they are employed each day, and that they don't provide amplification of external stimuli to compensate for hearing impairment.

The use of music for setting and altering moods, arousing, and relaxing, is certainly not new. Music has been actively, and increasingly, employed as a therapeutic treatment for a number of physical and psychological ailments[10], in part because certain rules and preferences are well established. For example, patterns of musical elements, such as slower tempo, lower pitch, degree of repetition, and lack of emotional content have been established as having a calming, rather than alerting effect[11, 12]. Active listening tends to arouse, passive listening tends to soothe. In addition, research has also shown that the use of previously recorded music may have restrictions on stress reduction because familiar music can evoke memories and potentially negative emotions[13] and create unwanted distraction. Active listening tends to distract, passive listening may allow for increased relaxation and cognitive function. Thus, it can be argued that the use of music for subconscious relaxation and reduction of stress, as may be present in tinnitus, should not be actively distracting.

An alternative approach that incorporates the benefits and rules of music but avoids these potential limitations is the use of fractal tones. Auditory fractal tones utilize harmonic, but not predictable relationships, and are generated by a recursive process where an algorithm is applied multiple times to process its previous output[14,15]. The tones (which sound somewhat like wind chimes) are pleasant, but are not associated with music that the listener may hold in memory. Kuk, et al, 2008[16]

reported on the relationship between fractal tones (Zen) and relaxation. It seems natural, therefore, to establish whether fractal tones can be applied to the tinnitus population.

An experiment was conducted in 2009 at the University of California, San Francisco (UCSF) to determine the effectiveness of fractal tones, and in particular the Zen option contained within Widex hearing aids, with tinnitus patients. The hypothesis was that fractal tones corrected for hearing loss are effective in relaxing the tinnitus sufferer, as well as reducing the annoyance of tinnitus. The results of this experiment, which were detailed in a 2010 JAAA article[17], are summarized and discussed in this issue of WidexPress.

Experimental Conditions

Fourteen adults, ranging in age from 34-72 years, with mild to moderately severe hearing loss, and primary complaints of subjective tinnitus, were fit with Widex mind440 experimental hearing aids and were asked to rate the signals in terms of their effect on relaxation and tinnitus annoyance. Prior to the experiment, only 4 of the subjects were hearing aid users. The subjects subsequently wore the hearing aids for six months and completed tinnitus handicap and reaction scales. Data were collected at the initial visit, one week, one month, three months, and six months. Non-parametric statistics included Wilcoxon matched pairs signed-rank, Chi square, and repeated measures ANOVA. Subjective tinnitus severity was assessed using two standardized outcome measures, the Tinnitus Handicap Inventory[18] (THI) and the Tinnitus Reaction Questionnaire[19] (TRQ) .The majority of the participants in the current study were considered "difficult" tinnitus cases in that they presented with THI scores that were higher than average for the UCSF tinnitus clinic, and most had THI scores that were unchanged following counseling. All participants signed an informed consent approved by the IRB prior to their participation.

The experimental hearing aids had the option to include amplification, fractal tones and broadband noise. Each of these options could be used together or independently (giving 7 different options all together). There were five different default fractal styles or patterns that the participants could select. Four of the styles (designated as green, aqua, coral and lavender) were tonal in nature (fractal) while the fifth included a broadband noise. The fractal styles differed by their combination of major/minor notes as well as their tempo and pitch combinations. Table 1 provides a general description of each of the four tonal fractal styles. Within each style, the clinician and the wearer could also adjust the intensity, pitch, and tempo of the tones so the signal may be the most desirable for the wearer. See Table 1.

At the initial fitting visit, only the "Master" program (amplification only, no fractals or noise) was activated. Subjects returned for the second visit after at least one week of hearing aid use and the additional listening programs (three programs of the fractal tones or noise) were added. With the hearing aids connected, the subjects listened to the fractal styles at the default settings in a counterbalanced order, and rated the perceived relaxing qualities of each signal. The style that was rated the highest was further fine-tuned to adjust tempo and pitch in an attempt to make it more relaxing. Then, the subjects again rated the adjusted fractal program to assess tinnitus annoyance while listening to different stimuli while in the lab setting. For each listening program the gain or level setting of the fractal and/or noise stimuli was adjusted to a soft-level that was audible to the participant, but not so loud as to interfere with comfortable listening or speech intelligibility.

	DEFAULT PITCH				TONALITY		DYNAMIC RANGE		DEFAULT TEMPO		
FRACTAL STYLES	Low	Medium Low	Medium High	High & Reverberant	Major	Minor	Restricted	Broad	Slow	Medium	Fast
Aqua	■				■		■		■		
Coral			■			■		■	■		
Lavender			■		■			■			■
Green				■	■		■			■	

Table 1. Acoustic characteristics of the four fractal (Zen) styles available in the mind440.

RESULTS

Results are summarized below with respect to the effects on relaxation, fractal quality preferences, tinnitus annoyance, tinnitus handicap and reaction.

Relaxation ratings:

Following introduction of the fractal tones, subjects assigned a relaxation rating on a 1-5 point scale with 1 being very relaxing and 5 being very tensing. Figure 1 depicts the results. Lavender was rated approximately neutral while the other three fractal programs were rated "somewhat relaxing." Lavender was significantly less relaxing than the other three fractal programs (p<0.05), and three of the four fractal signals were rated significantly more relaxing than neutral (p<0.05). As a comparison, a small group of non-tinnitus participants (N=6) were also asked to rate the fractal settings based on relaxation. These participants similarly found the green (N=4) and the aqua (N=2) fractal settings to be most relaxing, there was no difference between the non-tinnitus and tinnitus groups' preferred fractal settings (p>0.05).

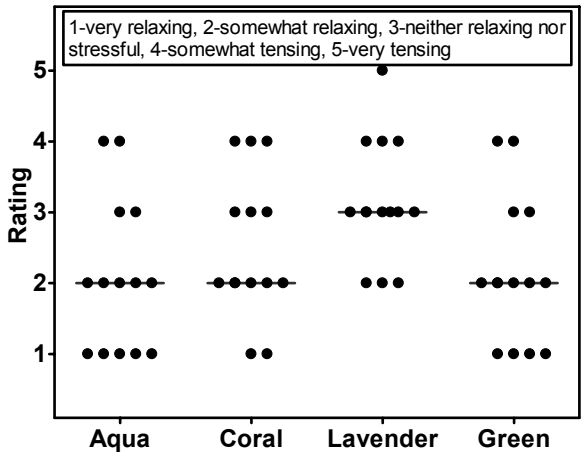

Figure 1: Relaxation ratings for the four default fractal settings. Lower numbers indicate the participant perceived the fractals as being more relaxing. The horizontal bars reflect the median rating.

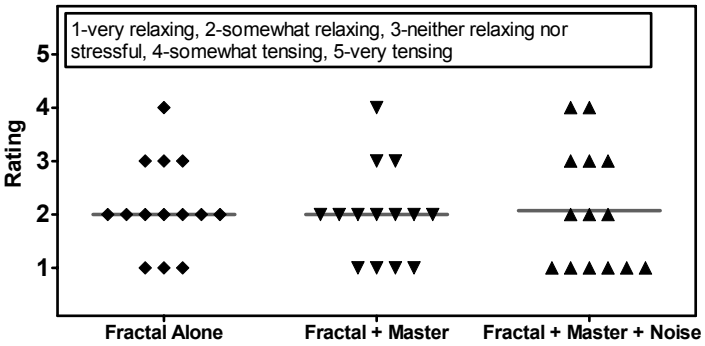

Figure 2. Relaxation ratings for three conditions following tuning to preference. Lower numbers indicate the participant perceived the fractals as being more relaxing. The horizontal bars reflect the median rating.

Figure 2 shows the relaxation ratings for fractal alone versus master + fractal versus master + fractal + noise when the preferred fractal program had been self adjusted to preference. There were no significant difference among these three conditions. However, all three acoustic programs were found to be significantly more relaxing than neutral.

Tinnitus Annoyance Scale

Subjects were asked to use a 7 point Tinnitus Annoyance Scale (0 = least annoying, 6 = most annoying) to rate their tinnitus annoyance for 7 conditions (the four fractal settings, noise only, amplification "master" only, and no hearing aid). Annoyance was operationally defined as "any negative emotional reaction such as anxiety, irritation, frustration, anger, or displeasure". These decisions were made during brief listening trials with each setting in the lab, and do not reflect the six months of actual wearing time.

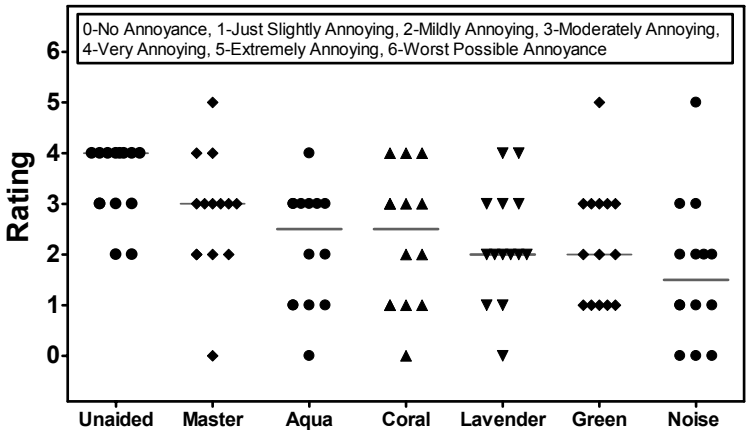

Figure 3. Tinnitus annoyance scale as ranked during the initial listening trial in the lab. Worst annoyance from tinnitus is at the top of the scale, least annoyance is at the bottom. Horizontal bars reflect the median rating.

The data shown in Figure 3 reflect differences among the ratings on 7 acoustic conditions (unaided, master, aqua, coral, lavender, green, and noise only). The unaided condition has the highest median tinnitus annoyance rating and noise only has the lowest median tinnitus annoying rating. The four fractal settings had similar median annoyance ratings. The unaided condition had significantly more annoyance than the four fractal programs or the noise only program ($p<0.05$) but not different from master ($p>0.05$). When noise alone was compared with the fractal programs, no significant difference was found ($p>0.05$). Previous hearing aid experience was not significant in determining the annoyance rating for each acoustic condition ($p>0.05$).

Although there were no significant differences in tinnitus annoyance among the four fractal settings, participants did show a preference for certain settings. Specifically, seven of the fourteen participants preferred green, five preferred aqua, and lavender and coral were each preferred by one participant.

Tinnitus annoyance scale rating at self-adjusted (preferred) setting

Participants were asked to select a preferred fractal program as well as make tempo and pitch fine tuning adjustments for both the lab surveys and field trials. On average, subjects tended to slow the tempo from the default setting, and to a lesser degree tended to lower the pitch from their preferred default setting. Slowing the tempo agrees with the literature suggesting that slower beats tend to be more relaxing. Pitch selection seemed to be determined by personal preference and in some cases by audiometric configuration, and was bimodal in distribution.

Tinnitus Handicap Inventory and Tinnitus Reaction Questionnaire scores were obtained at four visits (initial, 1 month, 3 months, and 6 months). Figure 4 reflects the progressive improvement in THI and TRQ scores over time. The mean THI score significantly decreased (improved) from 58.7 to 42.0 after 6 months. The mean TRQ score also significantly decreased (improved) from 52.6 to 40.9 after 6 months.

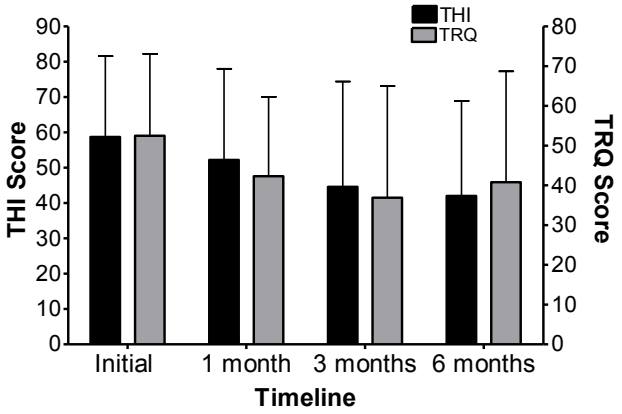

Figure 4. Mean THI and TRQ scores as a function of visit. Black bars represent THI, gray bars represent TRQ.

However, not every individual participant showed significant improvements. Because of the diverse reaction to tinnitus management approaches, we further examined individual responses which are shown in the Figure 5 scatter plot. Each square represents a single participant's performance. Filled squares reflect THI measures, open squares reflect TRQ scores. Symbols plotted below the dashed line represent improvement over time. Using a 20 point difference as indicating clinical significance, 6 of the 14 subjects obtained clinically significant improvements on the THI during the course of the study. Using a 40% criterion for the TRQ, 7 subjects showed significant improvements at some visit during the study.

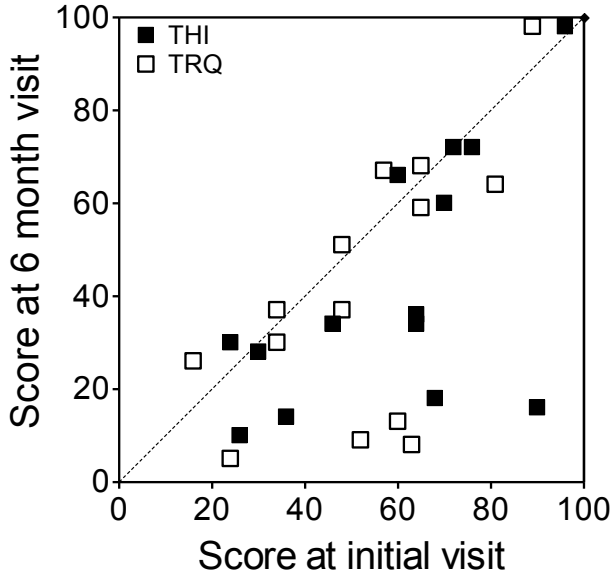

Figure 5. Individual THI and TRQ scores from baseline and end of experiment. Each square represents a single participant's performance. Filled squares reflect THI measures, open squares reflect TRQ scores.

DISCUSSION:

Numerous studies have already confirmed the positive effect hearing aids have on tinnitus perception[20-22]. The main objective of this investigation was to determine if tinnitus sufferers could benefit from the effects of fractal tones delivered through a wearable hearing aid. Lab obtained data indicate that there was a range of preferences observed for fractal settings. The most preferred fractal programs were those that had a slow or medium tempo, and a restricted dynamic range. This finding was also observed in a small group of non-tinnitus hearing impaired patients who were asked to rate the relaxation level of the fractal tones in the same manner as the tinnitus group. Thus, the preference trends for fractal settings do not appear to be specific to patients with tinnitus. Regardless of the sound qualities of the preferred fractal setting, most participants found the fractal settings to be relaxing.

The importance of allowing the participants to choose among various acoustic signals was apparent. While the anticipated expected musical preferences (that is, most selected fractals with slower tempos) were chosen, the fact that there was no single preference among tinnitus participants underscores the benefit of providing the individual listener with choices. Although seven participants in the current investigation rated the noise only condition as providing the least tinnitus annoyance (and noise alone produced the lowest mean tinnitus annoyance rating) in the lab, only two of the participants opted to have the noise only as a program during the 6 month wearing of the hearing aids, and none of them selected the noise only condition as their preferred setting. Furthermore, while all four of the experienced hearing aid users selected noise as producing the least annoying tinnitus in the lab, only one selected it for the field wear. Thus, it is possible that noise was associated with the lowest tinnitus annoyance in the time limited laboratory condition because of its masking effect (thus the reduction in tinnitus annoyance), but this acoustic signal was not deemed desirable or viable in the real world. It was also interesting to note that participants were more likely to select noise as a program when it was embedded in the fractal plus master setting.

Similarly, though the lavender setting was rated the least relaxing, it, along with the green, and the noise only condition, created the least tinnitus annoyance. Again, this may be related to the possibility that it produced the most masking (likely because the tempo was fast and the duration between tones was thus shorter), however, for either the short term or long term, participants did not find this fast tempo signal relaxing and therefore did not choose to listen to it during the six month trial.

Only 3 (15%) of the subjects preferred the fastest tempo, with 11 participants preferring the slowest tempo (60%). These findings also agree with the literature on general musical preferences showing slower tempos were most relaxing and preferred. Thus, notwithstanding the fact that fractal music differs from conventional music in terms of its familiarity, similar preferences appear to apply. Pitch seemed to be less important (or more subject to personal preference) in that the most preferred green setting had a higher pitch with reverberation, while the second most preferred aqua setting had the lowest default pitch. The other common feature of the two preferred fractal settings was tonality. Both the green and aqua settings utilize major keys. Lavender, the least preferred fractal setting, also used a major key, however, the fact that it has the fastest tempo may have been the overriding factor accounting for its lack of preference.

Subjects were assessed before, during, and at the conclusion of a 6 month trial with hearing aids containing fractal tones and noise as program options that have become commercially available since the end of this study. Thirteen of fourteen participants reported that their tinnitus annoyance was reduced for at least one of the amplified conditions, (with or without fractal tones or noise), relative to unaided. In addition, nine subjects assigned a lower tinnitus annoyance rating when listening to fractals tones alone versus the amplification alone condition. THI or TRQ scores obtained during and after a field trial were significantly reduced in about

half of the tinnitus participants. For most, amplification alone provided a reduction in tinnitus annoyance. When asked at the final visit if having additional sounds increased their overall satisfaction with amplification, eleven of the fourteen (78%) replied positively. However, for long term usage, as demonstrated by the datalog over the course of the 6 month study, participants chose to use amplification alone (the master program) on average 60% of the time, while amplification plus a combination of fractal and/or noise was worn 30% of the time, and fractal alone was used 10% of the time. The implication is that while minimizing annoyance of tinnitus is important, the ability to hear better is deemed at least as important. This is an interesting find considering the fact that prior to the study, only 4 of the 14 tinnitus participants wore hearing aids.

When asked about the effect of each of the programs containing fractals, 70% of the responses judged the programs as being relaxing or slightly relaxing while 20% judged them as neutral and only 10% deemed them slightly tensing. There was an approximate even spread among fractal alone versus fractal plus master plus noise versus fractal plus master. Again, however, participants had definite opinions and preferences for certain programs and for certain fractal characteristics. The vast majority (86%) of the participants indicated it was easier for them to relax while listening to the fractal signals.

CONCLUSIONS

These results are in good agreement with a recent publication[23] and suggest that use of fractal tones, delivered through high quality hearing aids can provide amplification while allowing for relief for many tinnitus sufferers. It is important to recognize, however, that tinnitus management procedures need to be supplemented with appropriate counseling.

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