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Intervention for restricted dynamic range and reduced sound tolerance

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Hyperacusis is the intolerance to sound levels that normally are judged acceptable to others. The presence of hyperacusis (diagnosed or undiagnosed) can be an important reason that some persons reject their hearing aids. Tinnitus Retraining Therapy (TRT), originally proposed for the treatment of persons with debilitating tinnitus, offers the significant secondary benefit of increased Loudness Discomfort Levels (LDLs) in many persons. TRT involves both counseling and the daily exposure to soft sound from bilateral noise generator devices (NGs). We implemented a randomized, double-blind, placebo-controlled clinical trial to assess the efficacy of TRT as an intervention for reduced sound tolerance in hearing-aid eligible persons with hyperacusis and/or restricted dynamic ranges. Subjects were assigned to one of four treatment groups: 1) full treatment, both counseling and NGs, 2) counseling with placebo NGs, 3) NGs without counseling, and 4) placebo NGs without counseling. They were evaluated at least monthly, typically for five months or more, on a variety of audiometric tests, including LDLs, the Contour Test for Loudness for tones and speech, word recognition measured at each session's comfortable and loud levels, and on electrophysiological measures. Results show that subjects are more likely to increase LDLs when using NGs along with counseling (full treatment), although some subjects improved when given only partial treatment. Supported by NIH R01 DC04678.

1 Introduction

Hyperacusis is an intolerance to the loudness of sounds that most individuals deem to be tolerable. Hyperacusis can occur with or without hearing loss, and is sometimes associated with tinnitus. The focus of our current research is on persons who have sound intolerance, nominally hyperacusis and hearing loss. These individuals often need amplification to compensate for their hearing loss, but find prescribed amplification of sounds via hearing aids too loud to tolerate. Consequently, they may either reject hearing aids, assume that they cannot tolerate hearing aids and never try them, or they may attempt to use amplification suboptimally. For the latter group of patients to be fitted successfully with hearing aids, they may either require large amounts of compression or inordinate decreases in the maximum output level, both of which are less-than-optimum strategies for hearing aid fittings.

Our goal is to establish whether a modification of Tinnitus Retraining Therapy (TRT), which has been used with some success to treat tinnitus and hyperacusis for almost two decades, can be helpful to hearing-impaired patients with limited sound tolerance. There have been reports that Loudness Discomfort Levels (LDLs) rise in many tinnitus patients during their TRT treatment [1,2,3]. This finding led to modifications of the TRT protocol to manage patients with hyperacusis [4]. The purpose of this project was to conduct a controlled clinical investigation of modified TRT that might ultimately be implemented as an intervention for hearing-impaired persons with sound tolerance complaints and / or limited dynamic ranges that restrict their use of amplified sound from hearing aids.

1.1 What is Hyperacusis and how is it Treated with TRT?

Hyperacusis sometimes is confused as a form of loudness recruitment. Shown in Figure 1 is a typical example of recruitment for which the growth of loudness is more rapid than normal and is greatest for sounds that are categorized as being soft (shown by the function connecting the filled triangle symbols). Judgments of louder sounds are perceived to be similar in loudness at comparable high sound levels by both recruiting ears and normal ears (shown

by the function connecting the filled circle symbols). Conversely, for a person with hyperacusis, the growth of loudness is inordinately great over a very small range of sound levels, and the uncomfortable level is dramatically lower than that observed for either normal or recruiting ears. Also in contrast to loudness recruitment, which is routinely associated with audibility threshold shifts due to sensorineural hearing loss, hyperacusis may occur with or without hearing loss and is characteristically a bilateral condition. The intervention under trial in this study is based on a modification of TRT, which has been used with considerable success for treating hyperacusis patients. Classical TRT uses directive counseling to initiate habituation of the tinnitus percept and sound therapy from ear-level noise generators to facilitate the habituation process. A modified version of TRT is used in this study to treat sound intolerance as the primary complaint, with the focus of the counseling session on the sound intolerance problem rather than on tinnitus.

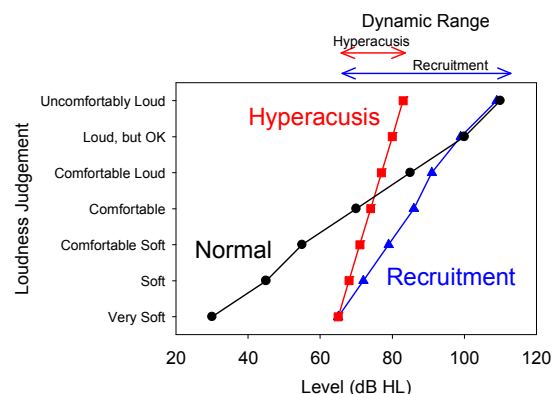


Fig.1 Comparison of growth of loudness for persons with normal hearing, hyperacusis, and recruitment. Arrows at top denote the dynamic range for person with hyperacusis (square) and person with recruitment (triangle).

2 Methods

2.1 Clinical Trial Design

Our study was designed as a randomized, placebo-controlled, clinical trial. Ten participants have been

assigned to each of four treatment groups: 1) Full treatment, which included bilateral noise generators (NGs) and counseling; 2) placebo NGs and counseling; 3) NGs alone and 4) placebo NGs alone. This design allows us to assess the effects of full treatment as well as the effects of sound therapy, provided by the NGs, separately from the effects of counseling.

2.2 Test Session

Subjects were evaluated repeatedly over intervention periods of 5 to 12 months in a series of tests, including repeated measures of air conduction thresholds, loudness discomfort levels for tones and white noise, and categorical loudness judgments for FM pulsed tones and recorded spondaic words measured per the Contour Test of Loudness [5]. Also included were repeated measures of NU-6 word recognition scores for sound levels reported as “comfortable” and “loud, but OK” for the Contour Test using speech stimuli. Electrophysiological measures of auditory brainstem (ABR) and middle latency (MLR) responses also were recorded across repeated sessions.

3 Results

3.1 Time Course of Treatment

When LDLs improved over the course of an intervention, these shifts generally were apparent within the first 4 months of the intervention. An example of LDL shifts for a 1000-Hz tone is shown over 12 months of modified TRT treatment in Figure 2. Note the initial early shift in the LDLs and the improvement in sound tolerance, which plateaus around 6 months after the onset of full treatment with counseling and use of NGs. This observation led us to modify the treatment period to finish each intervention after 6 months and, subsequently, allow participants who were not assigned to the full treatment group to cross over and receive full treatment for an additional 6 months.

Loudness Discomfort Level for 1000-Hz Tone

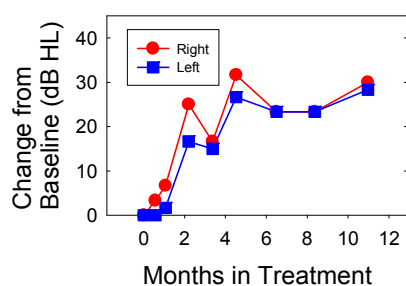


Fig.2 Change in LDL for 1000 Hz tone as a function of months in treatment.

3.2 Change in Speech Scores with Treatment

Some of the participants had comfortable levels for speech that were associated with very poor word intelligibility. In the example in Figure 3, the participant had pre-treatment, comfortable-level speech scores of 50% and 48%, which improved to 80% and 86% after 6 months of full treatment. These improved results at newly tolerable higher presentation levels are consistent with AI model predictions for a typical listener with sensorineural hearing impairment [6]. This dramatic improvement reflects substantially improved sound tolerance for comfortable speech subsequent to full treatment. This participant also was then able to use hearing aids set at a higher level of amplification that made speech more intelligible, but comfortably tolerable.

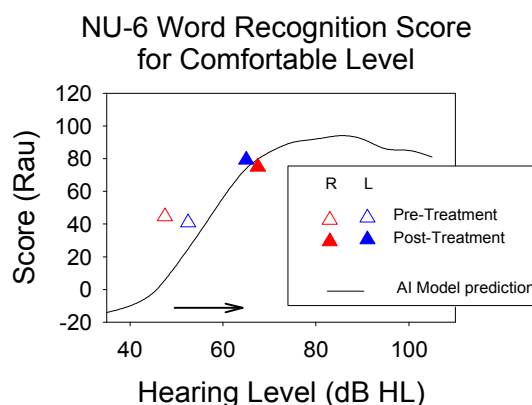


Fig.3 Speech scores for comfortable level pre-treatment (open triangles) and post-treatment (filled triangles) for the right (R) and left (L) ear of one participant.

3.3 Loudness Discomfort Change with Treatment

The LDL for 1000 Hz (hatched bars) and the average level for “Uncomfortably Loud” reported on the Contour Test for 500 and 2000 Hz (open bars) are plotted in Figure 4 for each participant in their treatment group. Initial results measured at baseline before the start of each treatment (shown with unfilled bars) are shown alongside the result measured after 6 months of treatment (shown with filled bars). The participants’ results are marked with a large asterisk if the change with treatment for either the LDL or the Contour 7 judgment increased by more than 10 dB. The treatment success rate with treatment was 83% for the full treatment group, 29% for the placebo NG + counseling group, 29% for the NG alone group, and 50% for the placebo NG alone group. Albeit we are still collecting data for each treatment group, and cannot now draw definitive conclusions, full treatment appears at this time to be more effective than any of the partial treatments. However, technical difficulties were associated with some of the placebo NG devices and the defects caused them to behave as conventional NG devices over some portion of the treatment period. These failures are marked with a small asterisk on the participant number shown along the x-axis label of Figure 4. If we regroup these participants to

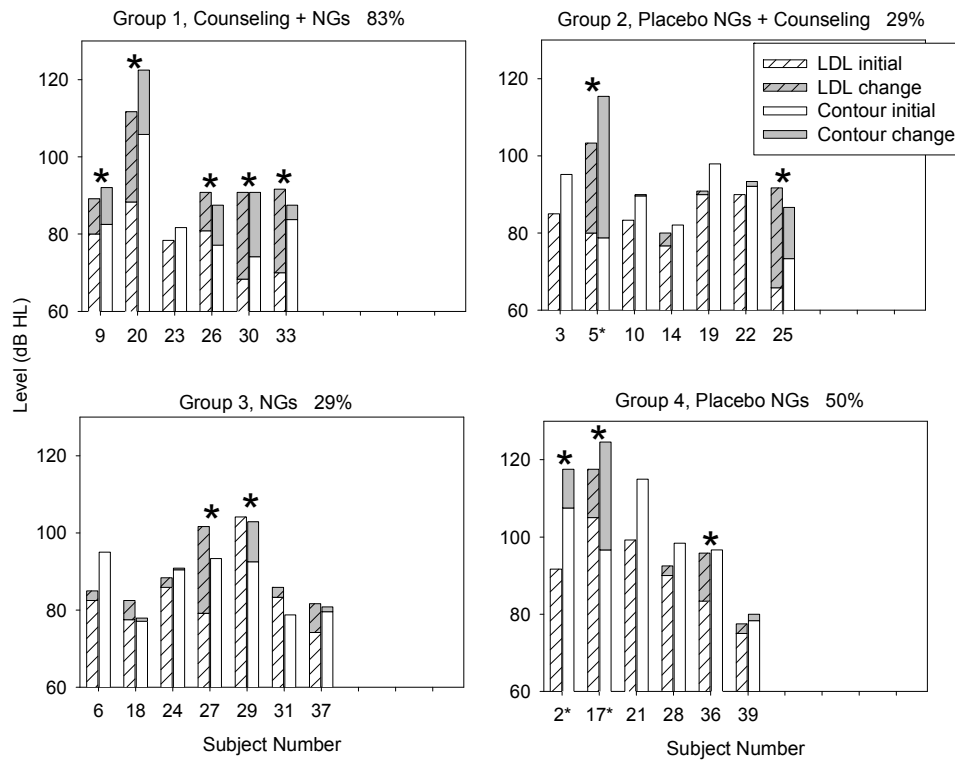


Fig.4 Change in LDL and Contour Test for individual subjects over the course of each treatment. Large asterisks denote a change of more than 10 dB. Small asterisks denote a malfunction with the placebo device for the participant during treatment.

consider them as receiving conventional NG treatment instead of their assigned (defective) placebo NG treatment, then the success rates for both the full treatment (NG + counseling) group and for the NG alone treatment group increases, while the success rates for the placebo NG + counseling group and the placebo NG alone group decreases.

The average performance changes for the LDL and Contour 7 judgments at the end of each treatment are shown in Figure 5 for each of the treatment groups. The groups are the same as those shown in Figure 4 (assigned treatment groups). In addition, we show the group results corrected for the placebo NG malfunctions mentioned above (corrected groups). Regardless of correction, the full treatment group benefitted appreciably more from their treatment than did the groups receiving partial treatment.

3.4 Effect of Crossover Treatment

Some of the participants, who were initially assigned to a partial treatment, elected to receive an additional 6 months of the full treatment and were crossed over to receive NGs + counseling. The example in Figure 6 is that of a participant who was initially assigned to the placebo NG + counseling treatment group. This participant improved with the partial treatment over 6 months. At the conclusion of her initial treatment assignment, the placebo NG devices were verified to have been working properly throughout the treatment. The placebo function was then disabled to achieve conventional NG operation for the crossover phase during which she received full treatment. Note the further increases in the LDL over the subsequent few months of

full treatment. Similar increases also were measured for the Contour 7 judgment (not shown here).

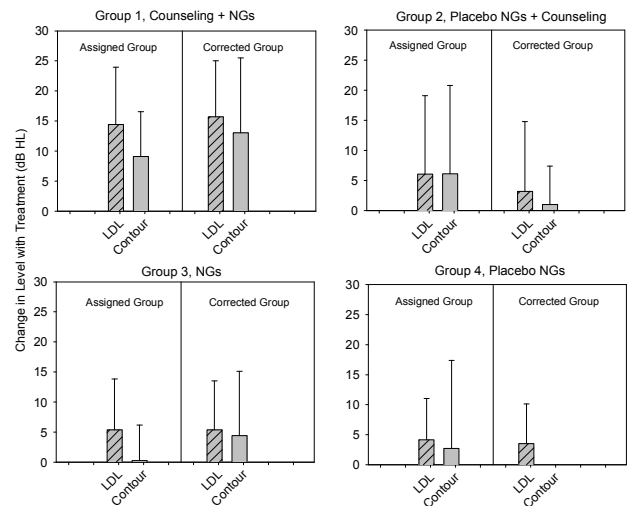


Fig.5 Average change and corresponding standard deviation for the LDL (hatched bars) and Contour 7 judgement (open bars) for the assigned (shown in Fig. 4) and corrected (described above) groups at the end of treatment.

Loudness Discomfort Level for 1000-Hz Tone

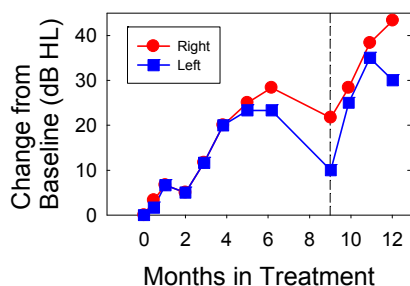


Fig.6 Change in LDL for 1000-Hz tone as a function of months in treatment in initial group and after cross-over to full treatment (vertical dashed line).

4 Conclusions

A modification of TRT can be used to help some persons with sound tolerance complaints improve their conditions prior to being fitted with hearing aids. Furthermore, it appears that full treatment (i.e., NGs + counseling) achieves better results than any of the partial treatments considered in this study. Changes in sound tolerance occur generally within the first 2-4 months of full treatment, with stable results usually by 6 months. Ultimately, the goal of this research is to enable patients to tolerate amplified sounds from their hearing aids so that aided speech and environmental sound can be heard optimally with minimal need for compression, which distorts the fidelity of the amplified signal. Future research will extend the principles and theory applied in the current study to practical applications in hearing aids to minimize the need for compression and enhance the dynamic range for aided sound.

Acknowledgments

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