Rating the Annoyance of Synthesized Tinnitus

M. J. Penner, Ph.D.

Psychology Department, University of Maryland at College Park, College Park, Maryland, USA

Abstract: Ten tinnitus sufferers mimicked the sensation caused by their tinnitus with a complex sound pattern consisting of the sum of sine waves. The annoyance of these ten sounds was then rated on a scale from 1 (not annoying) to 10 (very annoying) by some of the tinnitus sufferers and by 50 normal-hearing subjects. For the normal-hearing subjects, the number assigned to rate the annoyance of each sound varied widely from subject to subject, while the rank ordering of the ratings was in rough agreement. Because rankings have less inter-subject variability than ratings, ranking are likely preferable as a dependent variable in the clinical assessment of tinnitus. The correlation between the ratings of the ten stimuli by the subjects with normal hearing and the subjects with tinnitus averaged 0.90, indicating that the tinnitus sufferers and the normal-hearing subjects tended to judge the annoyance of the sounds in a similar fashion. Further, the rating of the subject's own tinnitus lay near the regression line, indicating that the subject judged his own tinnitus imitation no differently than he judged the annoyance of other sounds.

INTRODUCTION

The efficacy of a treatment for tinnitus must be assessed by comparing some aspect of the tinnitus before and after the treatment. Two of the most obvious psychophysical measures of tinnitus have not constituted successful candidates for the comparison. The first candidate, the frequency of a tone matching the tinnitus pitch, is too evanescent.[1,2] The second candidate, the level of a tone matching the tinnitus loudness, is contraindicated because the level of a tinnitus masker often exceeds the measured tinnitus level and yet is still preferred to the itself.[3] Because of these difficulties, most comparisons have involved subjective reports of the annoyance caused by the tinnitus,[4] or the results of a questionnaire evaluating the annoyance the tinnitus,[4] or the results of a questionnaire evaluating the annoyance of tinnitus.[5-7]

Recently, it has been demonstrated that a pure-tone complex provides a better imitation of the tinnitus than does a single pure tone.[8] In the Penner[8] portrayal of tinnitus, a copy of the tinnitus spectrum was constructed from the sum of sine waves. The synthesized tinnitus was judged as more similar to the tinnitus than was a single pure tone. This suggests that another way to contrast the efficacy of tinnitus treatments is to compare the tinnitus synthesized before and after treatment.

Tinnitus imitations may serve as a basis for evaluating a treatment because such stimuli may differ simultaneously in loudness, in pitch, and in "quality". That is, tinnitus imitations do not vary from one another solely in one dimension. Thus, to judge improvement in tinnitus, the subject might merely be asked to rate the annoyance of a series of sounds, and one sound among these would be the pre-treatment tinnitus imitation and another the post-treatment imitation. In this way, if the treatment had a palliative effect, the rating of the two imitations should be different.

This suggestion does not run counter to extant beliefs about tinnitus severity. Tinnitus severity is thought to relate to both the psychological state of its owner[9-11] and, in some as yet unknown way, to the stimulus itself. If some of the factors causing the severity of a sound reside in the stimulus parameters, then normal-hearing subjects should judge synthesized tinnitus similarly. To the extent that the severity of tinnitus resides in the stimulus, synthesized tinnitus that is less bothersome to its owner, should be less bothersome to others as well. It is this hypothesis which is explored here.

METHODS

Subjects

Fifty normal-hearing subjects (22 females and 28 males) were recruited from an introductory psychology course.

Reprint requests: M. J. Penner, Ph.D., Psychology Department, University of Maryland at College Park, Maryland 20742, USA

Audiograms (threshold as a function of frequency) for a 500-msec pure tone signal at the audiometric frequencies were determined in a two-interval forced-choice adaptive procedure. Only subjects whose pure-tone audiograms were within 10 dB of normal[12] were employed in this experiment.

Ten subjects with tinnitus matched their tinnitus to a pure tone complex. A detailed description of this procedure is found in Penner.[8] These ten subjects are referred to with numbers (i.e., Subject 1). The audiograms of these subjects have been published previously but are presented again in Table 1. The spectrum of each of the ten synthesized tinnitus complexes is presented in Table 2.

Table 1. Pure-tone air conduction thresholds (dB SPL) for the 10 subjects with tinnitus using a 500-msec signal in a two alternative forced-choice adaptive procedure with 10 reversals per point. A dash is entered whenever the signal level exceeded 90 dB SPL. The subject number and the ear in which the tinnitus imitation was produced appear in the first and second columns of the table.

Subject,	Right Ear Frequency (kHz)					Left Ear Frequency (kHZ)				
Ear	0.5	1	2	4	8	0.5	1	2	4	8
1, L	-2	-1	4	9	13	2	-6	8	2	31
2, L	31	22	32	46	-	25	15	23	60	75
3, L	21	16	66	63	-	22	4	49	58	-
4, L	49	51	40	90	-	50	39	35	90	-
5, L	12	0	49	3	8	42	4	0	52	77
6, L	36	30	37	53	82	34	30	32	32	-
7, L	25	29	47	74	90	21	16	39	54	73
8, R	8	3	14	15	26	10	-2	6	10	18
9, R	53	9	-1	5	27	45	-2	12	-2	36
10, L	-10	-9	-10	-5	20	3	4	7	2	14

Table 2. The spectra of the imitation tinnitus. Frequencies are rounded to the nearest 100 Hz

Stimulus	Frequency (kHz)	Level (dB SPL)
1	4.1, 5.1, 7.5, 7.3	28, 76, 62, 62
2	5.1, 5.5, 5.5	34, 46, 62
3	1.5, 4.6	48, 58
4	2.1, 2.7, 3.4, 3.8, 3.9	24, 38, 60, 82, 84
5	9.9, 8.7, 5.8, 7.6, 4.2	90, 66, 12, 56, 12
6	six components within 100 Hz centered at 7.2	52, 54, 52, 74, 72, 50
7	4.5, 5.4, 5.7, 6.0	82, 68, 74, 76
8	1.7, 2.1, 2.5, 3.3, 3.8, 5.4	29, 32, 37, 25, 22, 21
9	1.9	87
10	1.2, 2.6, 2.7, 2.7 3.6, 4.5, 5.3, 7.9	38, 30, 48, 30 20, 40, 42, 38

Apparatus

The timing and presentation of the stimuli were controlled by a computer that was interfaced to a Tucker Davis Technologies psychoacoustic system. The stimuli were presented in ER-2 headsets. The second harmonic of all the computer generated tones was at least 90 dB below that of the primary. The remaining harmonics were at least 70 dB below the primary throughout the frequency and amplitude range tested.

Protocol

All subjects were seated in a double-walled sound proof booth which contained a video display terminal (VDT). Instructions to the subject appeared on the screen at all times. To initiate the experiment, the subject pressed the space bar. One of the ten imitation tinnitus sounds was presented after the space bar was depressed. If the space bar was depressed a second time, the stimulus was repeated. After each presentation, the subject could rate the annoyance of the stimulus. Pressing the escape key, signified readiness to rate the stimulus annoyance. The rating scale appeared on the VDT with 1 being defined as a sound which was not annoying and 10 being defined as a very annoying sound. Each imitation tinnitus was judged ten times. The order of presentation of the stimuli was random.

Unfortunately, not all the tinnitus subjects could participate in the rating experiment. In particular, only data from Subjects 1, 8 and 9 could be used. Subjects 2, 3, 4, 6, and 7 heard less than four of the tinnitus imitations. Subjects 5 and 10 had graduated from the University, moved out of state, and so were not available for testing.

Data Analysis

The ratings were considered in two ways. First, the ratings themselves were analyzed. Second, the ten ratings were rank ordered and then analyzed. In the first analysis, the absolute judgment of the imitation was considered. In the second analysis, the relative judgement was considered.

RESULTS

The mean of the ten ratings made by each of the normal-hearing subjects in response to a selection of the tinnitus imitations is presented in Figure 1. The subjects' mean ratings do not tend to cluster at a single value. Thus, subjects do not tend to assign exactly the same rating to a stimulus. On the other hand, some trend is apparent. For example, stimulus 1 tended to be rated as more annoying than stimulus 8.

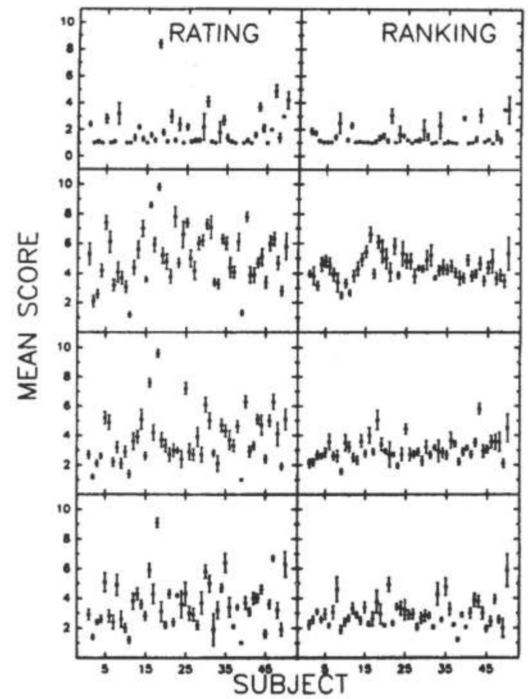

Figure 1. Ratings (left side) and rankings (right side) of selected stimuli by the normal hearing subjects. Note that the ratings exhibit larger inter-subject variability than do the rankings. The error bars represent the standard error of the mean for the ten judgments. From top to bottom, the tinnitus imitations were those of Subjects 8, 1, 3, and 10.

The mean rankings of the tinnitus imitations by the normal-hearing subjects are also presented in Figure 1. The mean rankings displayed more clustering than do the ratings, and, across subjects, the SD of the average rankings is significantly less than the SD of the average ratings ($t = 2.446$, 9 df, $p < .01$). Thus, inter-subject reliability is better for the ranking of stimuli than for the rating of them.

Figure 2 displays the ratings for the three available tinnitus subjects who heard nine or more of the tinnitus imitations and those of the normal-hearing observers. Each point represents the mean rating by one tinnitus sufferer and the mean rating of all the normal-hearing subjects. If the tinnitus sufferers and the normal-hearing subjects rated the stimuli identically, then the data would all lie on the solid line which has a slope of one. The slope of the line through the tinnitus sufferer's data appears visually steeper than for the normal-hearing subjects, although the difference is not statistically significant: the 95% confidence intervals for the slopes of the three tinnitus sufferer's regression lines are [0.93-1.92], [0.50-1.76], [0.93-1.6] respectively.

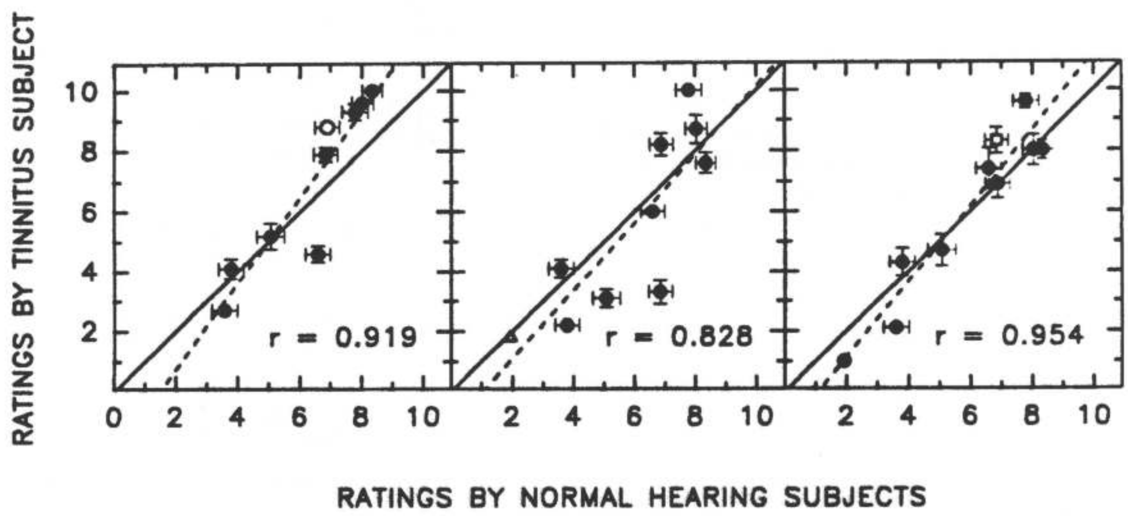

Figure 2. A comparison of the average ratings of a subject with tinnitus and the average rating of all the normal-hearing subjects. The solid line is the 45 degree line and the dashed line is the best-fitting regression line. The standard error of the mean is graphed with the data point whenever it exceeded the width of the data point. From left to right, the data are those of Subjects 1, 8, and 9. The unfilled symbols represent the subject's own tinnitus imitation.

There is one interesting aspect seen in Figure 2. Note that Subjects 1 and 9 rate their own imitation tinnitus (the unfilled symbols in Figure 2) as somewhat more severe than the normal's ratings of that imitation. Subject 8, on the other hand, does rate her tinnitus as the normals do.

DISCUSSION

On the one hand, many different sounds may be considered extremely annoying. On the other hand, a subject may be able to discriminate between annoying sounds and even rank them in terms of their annoyance. This observation raises the issue of whether tinnitus treatments should be evaluated in terms of the subject's absolute (rating) or relative (ranking) judgment.

In this article, we have presented data showing that normal-hearing subjects rate the same sound quite differently, whereas the same subjects rank order sounds somewhat more consistently (Figure 1). This suggests that comparative judgements (rankings) are more reliable and less susceptible to personal bias than are absolute judgments (ratings).

In terms of assessing the effectiveness of a therapy for tinnitus, asking subjects to consider their tinnitus on an absolute scale will likely produce decisions which are individualistic and only marginally related to stimulus parameters. On the other hand, if tinnitus is considered within the context of other sounds, the relative annoyance of the sounds may be somewhat less susceptible to personal idiosyncracies.

The fact that tinnitus sufferers do not unduly minimize or maximize the annoyance of their own tinnitus imitation (Figure 2) has one important consequence: tinnitus sufferers may be able to ignore psychological factors in assessing sounds. It follows that treatments which alter the physical composition of tinnitus may be evaluated in the context of comparative judgments.

REFERENCES

1. Penner MJ. Variability of matches to subjective tinnitus. *Journal of Speech and Hearing Research* 30:147-152, 1983.

2. Burns EM. A comparison of the variability of among measures of subjective tinnitus and objective stimuli. *Audiology* 23:426-440, 1984.

3. Vernon J, Griest S, Press L. Attributes of tinnitus and the acceptance of masking. *American Journal of Otolaryngology* 11:44-50, 1990.

4. Jakes SC, Halam RS, Chambers CC, Hinchcliffe R. The effects of reassurance, relaxation training and distraction on chronic tinnitus sufferers. *Behavioral Therapy Research* 24:497-507, 1986.

5. Hiller W, Goeble G. A psychometric study of complaints in chronic tinnitus. *Journal of Psychosomatic Research* 36:337-348, 1992.

6. Kuk FK, Tyler RS, Russell D, Jordan H. The psychometric properties of a tinnitus handicap questionnaire. *Ear and Hearing* 11:434-445, 1990.

7. Wilson PH, Henry J, Bowen M, Haralambous G. Tinnitus reaction questionnaire: Psychometric properties of a measure of distress associated with tinnitus. *Journal of Speech and Hearing Research* 34:197-201, 1991.

8. Penner MJ. Synthesizing tinnitus from sine waves. *Journal of Speech and Hearing Research* 36:1300-1305, 1993.

9. Harrop-Griffiths J, Katon W, Dobie R, et al. J. Chronic Tinnitus: Association with psychiatric disorders. *Journal of Psychosomatic Research* 31:613-621, 1987.

10. Kirsch CA, Blanchard E, Parnes S. Psychological characteristics of individuals high and low in their ability to cope with tinnitus. *Psychosomatic Medicine* 51:209-217, 1989.

11. Scott B, Lindberg P, Lyttkens L, Melin L. Psychological treatment of tinnitus. *Scandinavian Journal of Audiology* 14:223-230, 1985.

12. American National Standards Institute. Specifications for audiometers (ANSI S3.6), New York, 1969.

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