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Comparison of two computer-automated procedures for tinnitus pitch matching

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Abstract—Clinical assessment of the perceptual characteristics of tinnitus usually includes an attempt to match the pitch of tinnitus to a pure tone. A standardized clinical protocol for tinnitus pitch matching does not yet exist, and there is a history of unsuccessful attempts to obtain such measures reliably. The present study was designed to evaluate new protocols for identifying the perceived pitch of tinnitus, with the objectives of reducing testing time and improving test-retest reliability. Two protocols ("Octave" and "Binary") were developed, each of which was patterned after the testing procedure previously developed at the Oregon Tinnitus Clinic and used to assess thousands of tinnitus patients. Both protocols use computer-automation to conduct testing; the protocols differ according to their specific testing algorithms. Twenty subjects with non-fluctuating tinnitus were each tested over two sessions. Results of testing revealed that both protocols could obtain pitch matches within 20 to 25 min. Reliability of responses was good for some subjects but not others, and the Binary protocol generally provided more reliable results.

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INTRODUCTION

Tinnitus is the perception of sound that does not have an acoustic source outside of the head. Most people have experienced tinnitus at least as a transient event. Although prevalence estimates vary, an average estimate is that 40–50 million Americans have chronic tinnitus. Of these, 10–12 million seek professional help, and 2.5 million are debilitated by their tinnitus condition.

Although there are many causes for tinnitus, the most common is noise-induced hearing loss. Tinnitus is, thus, a common complaint among veterans. According to VA Central Office, Analysis and Statistics Service, over 115,000 veterans with service-connected tinnitus receive over $110,000,000 per year in tinnitus disability compensation. Providing tinnitus management for veterans is hindered by a lack of standards for both tinnitus assessment and treatment that could otherwise be adopted for VA application. Our efforts are directed toward providing

such a standard of care for veterans who have clinically significant tinnitus.

The present study was designed to address the need for clinical methodology to quantify, accurately and reliably, the phantom sensation of tinnitus. This need was identified in 1982 by the National Academy of Sciences (1) who specified several lines of related research that were "necessary as a basis for establishing a standardized test procedure." Unfortunately, standardized test procedures have still not been universally adopted. Recently, Tyler (2) wrote, "The quantification of a symptom is fundamental to understanding its mechanisms and treatments. If we can't measure it, we cannot study it." Tyler went on to explain in detail why it is important to measure tinnitus. The interested reader is referred to Tyler, as well as other publications addressing the value of clinical tinnitus assessment (3,4).

At clinics where tinnitus measurement is conducted, there is almost universally an attempt to determine the tinnitus pitch with the use of some variation of a tone-matching procedure. Many methods for tinnitus pitch matching have been reported, but reliability of the measures has generally been poor (5). In particular, there is a lack of studies demonstrating reliable pitch matches with a technique that can be used clinically.

We recently reported a prototype system that performed computer-automated tinnitus loudness and pitch matching (6). The pitch-matching method used with the prototype system was patterned after a method used for over 20 years at the Oregon Tinnitus Clinic. The initial study with the automated system documented the feasibility of obtaining reliable tinnitus loudness and pitch matches with the use of computer automation. However, testing time ranged from 38 to 79 min to obtain a pitch match. There was, therefore, large variability in how subjects responded to the uniform testing protocol, and testing time clearly had to be shortened for this technique to attain clinical utility. The automated procedure for pitch matching was modified to shorten testing time while maintaining optimum response reliability. Two versions of the modified protocol were designed for the present study: the "Binary" and "Octave" procedures. Subjects were evaluated over repeated sessions to determine the test-retest reliability of pitch matches obtained with these protocols.

METHODS

Subjects

Twenty subjects participated in this study, including 3 females and 17 males, with a mean age of 60.1 y (range, 24–78; SD, 10.6). Subjects were selected based on having tonal, stable tinnitus, to minimize any variability in the tinnitus that might confound interpretation of the reliability analyses. Seven of the subjects had previous tinnitus-matching experience, and the remaining 13 subjects were naive to any form of tinnitus assessment. Each subject returned for a second experimental session within 2 weeks of the first.

Equipment

Subjects were tested in an Acoustic Systems 19701A double-walled sound booth. The testing equipment has been described in detail (7). Briefly, there were four major system components: (1) The main computer, located in the control room, controlled all parameters of testing. (2) A laptop computer (Compaq Concerto), located in the sound booth, provided the automated-testing interface between the individual being tested and the main computer. The notebook computer was enabled for Microsoft Windows for Pen, allowing the subject to use a pen-pointing device to indicate responses on a touch-sensitive video screen. (3) A custom-built, signal-conditioning module was used for signal mixing, attenuation, and earphone buffering. (4) Etymotic Research ER-4B Canal Phone™ insert earphones were used for signal transduction. Calibration procedures for this equipment have also been described previously (7).

Procedures

Initial Evaluation

At the start of the first session, standard audiometric evaluation was performed, including case history, tympanometry, and measures of hearing sensitivity at 0.25–8 kHz. Instrumentation and procedures for the initial evaluation were as described in Fausti et al. (8).

Matching tinnitus to tones in the contralateral ear is generally considered to be less challenging for the tinnitus patient than ipsilateral matching (7,9). Therefore, one ear was chosen as the "tinnitus ear" for each subject, and the contralateral ear was chosen as the "test ear." If one ear had more predominant tinnitus, that ear was chosen as the tinnitus ear. If the subject had symmetrical tinnitus, the tinnitus ear was chosen randomly.

Experimental Protocols

The entire testing protocol was under computer control, including instructions for responding, and all testing was repeated at a second session.

Instructions to Subjects

There were three interleaved response tasks for the testing protocols: threshold testing, loudness matching, and pitch matching. Instructions for responding were displayed on the patient's video screen each time the task changed. The instruction screen for threshold testing was shown previously (10), as was the instruction screen for tinnitus loudness matching (7). The instruction screen for pitch matching is shown in **Figure 1(a)**.

Test Frequencies

Available test frequencies for the pitch-matching tasks were in the range 0.5–16 kHz, each separated by one-third octave. For both pitch-matching protocols, automated hearing thresholds were obtained, followed by loudness matching, at each frequency that was used for pitch matching (not all test frequencies were used for pitch matching).

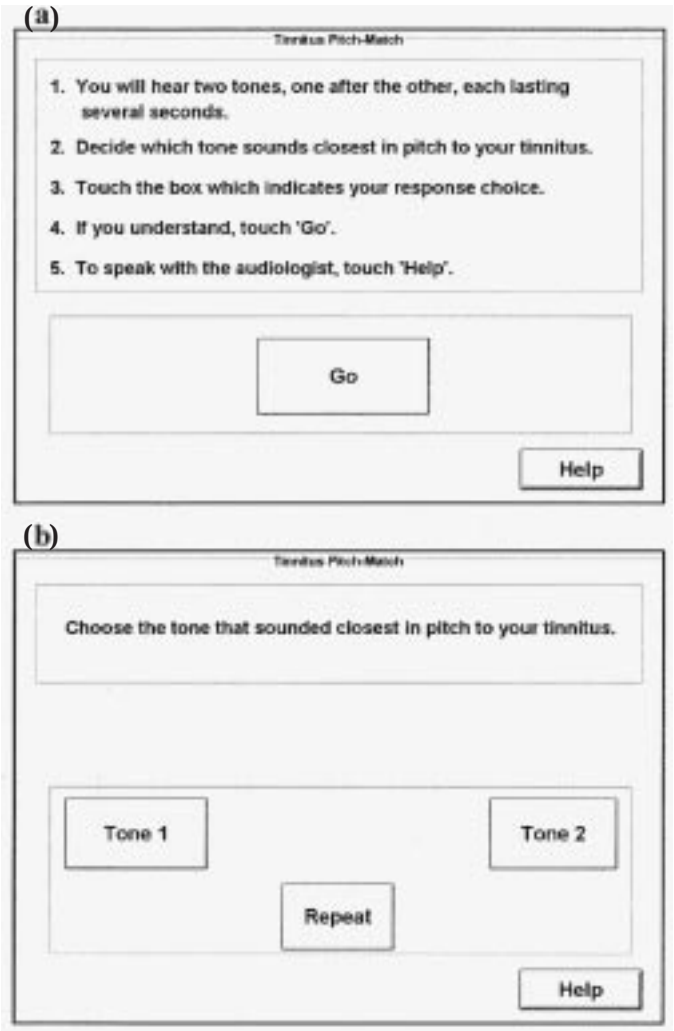
Common Procedures for Pitch Matching

The basic testing algorithm was designed to replicate closely the clinical testing protocol for tinnitus pitch matching as described by Vernon (11). Hearing threshold evaluation, tinnitus loudness matching and tinnitus pitch matching were sequenced to ensure that pitch-matching tones were presented only at levels that were previously matched to the tinnitus loudness. For each of the two pitch-match protocols, an adaptive two-alternative forced choice (2AFC) procedure was used to determine the frequency of a pure tone that subjects identified as closest to their perceived tinnitus pitch (11,12). For each tone pair, tones were presented consecutively for 4 s each with an intertone interval of 1 s.

The automated program sequenced through the test frequencies in order of increasing or decreasing frequency, dependent upon the responses of the subject. Pitch matching did not occur until thresholds and loudness matches had been obtained at the first two test frequencies. At that time, pitch-matching instructions appeared on the screen (**Figure 1(a)**) and the subject selected "Go" when the instructions were read and understood. The computer screen then showed that tones were being presented during pitch matching, i.e., "Tone 1" appeared on the screen during the presentation of the first tone and "Tone 2" during the presentation of the second tone. Following termination of Tone 2, response buttons appeared (**Figure 1(b)**). Subjects were thus required to listen to both tones before making a response choice.

For the pitch-matching task, the lower frequency tone was presented first, followed by the higher frequency tone and the subject was instructed to choose the tone that was closest to his/her tinnitus pitch. In general, if the higher frequency tone was chosen, the program moved to a higher test frequency, while selection of the lower frequency tone moved the program to a lower frequency.

When the final pitch match had been selected, the computer program entered a special loop to test for "octave confusion," a common mistake that tinnitus



Figures 1.
Screen displays (on notebook computer of subject) for tinnitus pitch matching; **(a)**) instructions; **(b)**) response screen.

patients make during pitch matching, described by Vernon and Fenwick (12). Octave confusion was checked at the frequency one octave higher than the final pitch-matched frequency, then at the frequency one octave lower (only if these test frequencies were available). When the program switched to these octave frequencies, the threshold and loudness match were obtained (if they had not been already), and pitch matching occurred with the use of the two frequencies separated by one octave.

Pretesting Evaluation to Determine Subjects' Understanding of Pitch and Loudness

Before testing with the automated system, subjects received pretesting to confirm their understanding of the concepts of pitch and loudness, and training regarding these concepts if there was confusion. The pretesting protocol is shown in the Appendix.

"Octave" Procedure

The computer algorithms for obtaining sequenced thresholds and loudness matches have been described previously (7). For the Octave procedure, thresholds and loudness matches were first obtained at 1 kHz, then at 1.26 kHz. Pitch matching, with the use of the 2AFC procedure, was then done with the loudness-matched tones from each of the first two test frequencies. If the higher frequency tone was chosen as closest in pitch to the subject's tinnitus, the computer then obtained a threshold and loudness match at the next higher octave (2 kHz) and at 2.52 kHz. With each 2AFC selection of the higher of two test frequencies, the computer went to the next higher octave frequency and repeated this procedure. The 2AFC selection of the lower frequency of a tone pair indicated that the pitch match had been bracketed to within the octave below the pair. At that point, the computer conducted the same protocol through the bracketed frequency range, from lower to higher frequencies, to determine a pitch match to the closest one-third octave frequency. This was followed by octave-confusion testing.

"Binary" Procedure

With the Binary procedure, the computer started testing at 3.18 kHz. A threshold and loudness match was obtained at 3.18 kHz, followed by a threshold and loudness match at 4 kHz. Pitch matching, with the use of the 2AFC procedure, was then done, and the frequency choice determined whether further testing would occur below 3.18 kHz or above 4 kHz. Thus, the initial frequency choice resulted in binary bracketing, either to the lower or to the upper frequency range. Movement to new frequencies was then in octave steps, and the computer further bracketed the pitch match to within an octave. When this had been done, testing proceeded as with the Octave protocol, i.e., through the bracketed-frequency range to determine the pitch match with a resolution of one-third octave, followed by octave-confusion testing.

RESULTS

For each of the two procedures, one pitch match was obtained during each of two sessions. All pitch matches are shown in **Table 1**, with the across-subjects means of the pitch matches displayed in the bottom row of the table. Paired t-tests were calculated to evaluate if there were significant differences across sessions between the mean pitch matches for each procedure. The t-tests revealed that the means of the Binary procedure did not differ significantly ($p=0.2952$), while the means of the Octave procedure were significantly different ($p=0.0198$). Thus, for the group of subjects, the mean pitch matches between Sessions 1 and 2 were significantly different only for the Octave procedure.

To evaluate within-subject reliability of responses, we calculated differences between individual Session 1 and Session 2 pitch matches for each procedure (**Table 2**). For the Binary procedure, the Session 1 pitch match was subtracted from the Session 2 pitch match, and the mean of these differences was 742 Hz. When the same calculations were made for the Octave procedure, the mean of the differences was 2394 Hz. Thus, for both procedures, there appeared to be a trend for pitch matches to be higher in frequency during the second session.

The directionality of the individual differences, however, was random between subjects; thus, the trend was not significant. To determine the magnitude of these differences, disregarding directionality, the absolute values of the differences were calculated (**Table 3**). The means of the absolute values of the differences were 2246 Hz for the Binary procedure, and 3247 Hz for the Octave procedure. Thus, the magnitude of the differences was, on average, larger for the Octave procedure, but the difference between the two means was not significant (paired t-test, $p=0.3282$).

Pearson product-moment correlation coefficients were calculated between the Session 1 and Session 2 pitch matches for each procedure. The Pearson r was

Table 1.
Tinnitus pitch matches for each subject.

	Pitch Match (Hz)			
	Binary Procedure		Octave Procedure	
Subject	Session 1	Session 2	Session 1	Session 2
1	620	3,180	1,000	2,520
2	5,040	6,340	4,000	6,340
3	1,580	2,520	1,580	620
4	2,000	800	2,000	500
5	3,180	3,180	3,180	6,340
6	2,520	5,040	2,520	5,040
7	5,040	6,340	8,000	3,180
8	8,000	10,080	6,340	10,080
9	12,700	16,000	10,080	16,000
10	5,040	8,000	6,340	8,000
11	6,340	500	500	500
12	4,000	12,700	1,000	4,000
13	16,000	16,000	16,000	16,000
14	10,080	5,040	10,080	10,080
15	5,040	5,040	3,180	4,000
16	12,700	12,700	2,000	12,700
17	6,340	5,040	1,260	12,700
18	6,340	8,000	8,000	8,000
19	8,000	6,340	2,520	1,260
20	620	3,180	500	10,080
Mean	**6,059**	**6,801**	**4,504**	**6,898**

Table 2.
Individual differences in pitch matches between sessions.

	Pitch Match Difference (Hz), Session 2 minus Session 1	
Subject	Binary	Octave
1	2,560	1,520
2	1,300	2,340
3	940	–960
4	–1,200	–1,500
5	0	3,160
6	2,520	2,520
7	1,300	–4,820
8	2,080	3,740
9	3,300	5,920
10	2,960	1,660
11	–5,840	0
12	8,700	3,000
13	0	0
14	–5,040	0
15	0	820
16	0	10,700
17	–1,300	11,440
18	1,660	0
19	–1,660	–1,260
20	2,560	9,580
Mean	**742**	**2,394**

0.757 ($p \geq 0.0001$) for the Binary procedure, and 0.589 ($p = 0.0053$) for the Octave procedure.

To provide an overall perspective of response reliability for both procedures, distributions of the between-sessions pitch-match differences are shown in **Figure 2**. For this analysis, the test frequencies, in Hz, were converted to their *frequency position* in ascending order so that differences between frequencies would be spaced logarithmically, roughly equivalent to their relative spacing on the basilar membrane. The shapes of the distributions can be described by their coefficients of skewness and kurtosis. Skewness was −0.807 and 0.597, and kurtosis was 2.267 and 0.161 for the Binary and Octave procedures, respectively. Thus, the distribution of the differences with the Binary procedure was negatively skewed, indicating that the negative differences (reflecting pitch matches becoming higher in frequency during Session 2) were greater than the positive differences (pitch matches becoming lower in frequency).

In contrast, the distribution for the Octave procedure was positively skewed. The kurtosis values are scaled so that a value of zero indicates a normal distribution. The distribution for the Binary differences was more positively peaked than normal (indicating more data in the central part of the distribution), while the Octave differences were more normally distributed.

Reliability of the responses can also be depicted as confidence intervals. **Table 4** shows confidence intervals with the percentages of the numbers of differences falling within each specified interval. For example, 30 percent of the intersession differences were within (plus or minus) one-third octave for the Binary procedure (20 percent for the Octave procedure). Seventy percent of the differences were within one octave for the Binary procedure (50 percent for Octave).

Testing time was recorded for each procedure. The Octave procedure required an average of 24 min and 20 min for Sessions 1 and 2, respectively. The Binary procedure required an average of 24 min and 25 min, respectively.

DISCUSSION

This study follows a previous investigation that demonstrated repeatable tinnitus pitch matches with the use of our computer-automated system (6). The previous

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Table 3.
Absolute values of individual differences in pitch matches between sessions.

	Absolute Value of Pitch Match Difference (Hz), Session 2 minus Session 1	
Subject	**Binary**	**Octave**
1	2,560	1,520
2	1,300	2,340
3	940	960
4	1,200	1,500
5	0	3,160
6	2,520	2,520
7	1,300	4,820
8	2,080	3,740
9	3,300	5,920
10	2,960	1,660
11	5,840	0
12	8,700	3,000
13	0	0
14	5,040	0
15	0	820
16	0	10,700
17	1,300	11,440
18	1,660	0
19	1,660	1,260
20	2,560	9,580
Mean	**2,246**	**3,247**

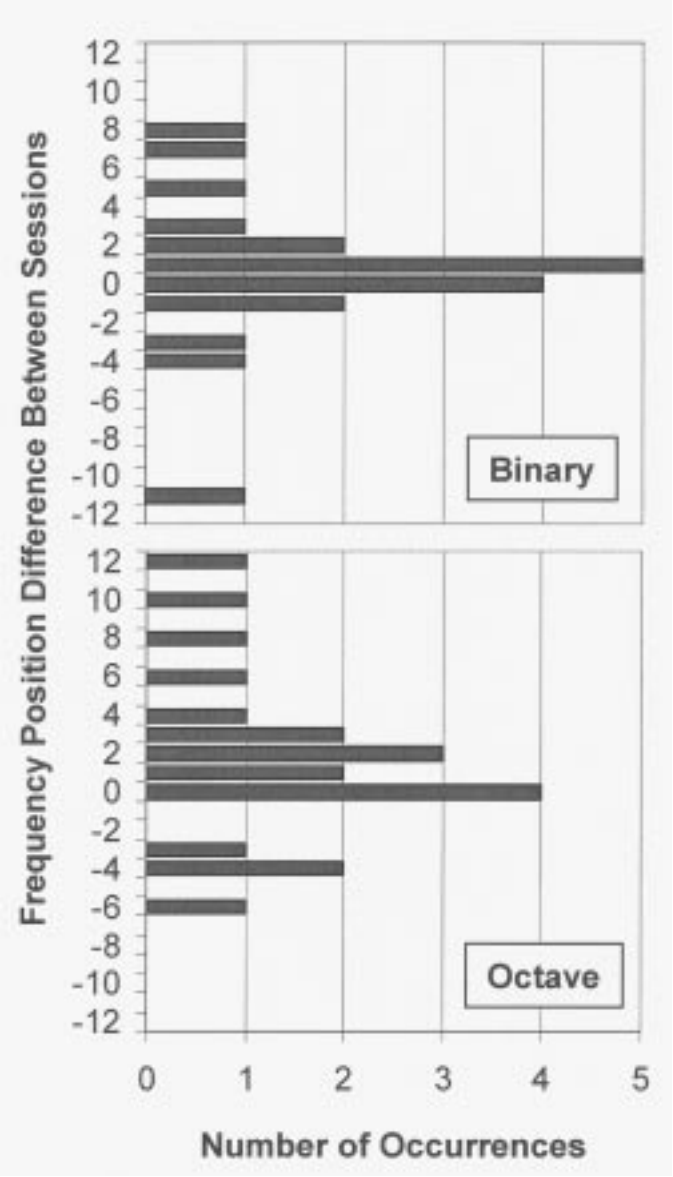

Figure 2.
Distributions of differences in pitch matches between sessions. For this analysis, each test frequency was coded as a "frequency position," i.e., position 1 represents 500 Hz, position 2 represents 820 Hz, etc.

and present investigations each used adaptations of the manual tinnitus-matching procedure that has received extensive use at the Oregon Tinnitus Clinic (13,14). In the previous study, the computer-automated protocol was designed to replicate the testing procedure used with the manual method. The starting test frequency was 1 kHz, and testing proceeded in ascending 1-kHz frequency steps to approach gradually the frequency of a tone that most closely matched the perceived tinnitus frequency of the patient. Such a procedure can be tedious to arrive at a pitch match that most often occurs in the 4–8 kHz frequency range (15–17). Testing in the previous study required up to 79 min, which would not be too unexpected for a slow responder with a very high tinnitus frequency.

To increase the speed of arriving at a pitch match, we evaluated two new pitch-match procedures in the present study. With the "Octave" procedure, matching tones started at 1 kHz, but then progressed in octave intervals to bracket the tinnitus pitch. The "Binary" procedure started at a middle audiometric frequency (3.18 kHz), and the order of frequencies was designed to bracket the tinnitus pitch to within a quartile of the test-frequency range. Results of this study revealed that the Binary procedure generally provided more reliable between-session pitch matches than the Octave procedure. Collapsing across both sessions, the overall average time to obtain a pitch match with the Octave procedure was 25 min, and 22 min for the Binary procedure. Clinically, this time difference would not be considered significant.

Table 4.
Confidence intervals for between-sessions differences in tinnitus pitch matches.

Interval (re: frequency position) in Which Between-Sessions Pitch-Match Differences Occurred			Percent of Differences*	
From	**To**	**Frequency range**	**Binary protocol**	**Octave protocol**
–1	1	± 1/3 octave	30	20
–2	2	± 2/3 octave	55	30
–3	3	± 1 octave	70	50
–4	4	± 1 1/3 octave	80	70
–5	5	± 1 2/3 octave	80	75
–10	10	± 3 1/3 octave	95	95
–15	15	± 5 octave	100	100

* Each 5% represents one subject.

Individual Differences in Pitch-Matching Ability

Matching the pitch of tinnitus might appear to be a straightforward task that should be accomplished easily. Studies that have obtained repeated pitch matches, however, have shown that it is extremely difficult to obtain good reliability of responses (5). In general, pitch matches for tinnitus are not as reliable as loudness matches, and individuals vary greatly in their ability to match their tinnitus pitch. There can be large differences between "musical" *versus* "nonmusical" subjects in their initial ability to make frequency discriminations (18). Thus, individuals with musical training or who work in acoustics generally have more natural pitch-matching ability, while naive listeners can have difficulty differentiating the higher pitched of two tones (19). For those who are untrained, however, their inability can improve with practice, and even supposedly "tone deaf" individuals can perform good frequency discrimination with enough practice.

New patients are also likely to be unfamiliar with tinnitus evaluation techniques and terminology, which could cause them to respond inappropriately, especially during the initial phases of the automated program. In particular, if patients confuse the terms "loudness" and "pitch," they will not be capable of performing tinnitus loudness and pitch matching (14). Because of the practice effect for some individuals and the potential confusion regarding testing terminology, it is critical to provide tinnitus patients with tone discrimination practice before conducting tinnitus matching.

For this concern to be addressed, a pretesting procedure, shown in the Appendix, was developed and implemented for this investigation. The protocol tested the ability of a subject to differentiate between "louder" and "softer" tones, and between "higher" and "lower pitched" tones. If the subject had difficulty making these discriminations, the protocol also provided a minimum of training.

The pretesting protocol was conducted just before each subject's first evaluation with the automated system. Every subject was able to respond correctly to the pretesting tasks, and most subjects responded correctly the first time each task was presented. Only a few had difficulty, and upon reinstruction, they were able to perform the tasks with accuracy. The pretesting protocol confirmed that patients understood the difference between pitch and loudness and that they could differentiate higher pitched tones from lower pitched tones, and louder tones from softer tones. This is important when performing tinnitus matching because accurate responding requires an understanding of these concepts. We are currently developing the pretesting as an automated program that will be presented by computer before testing with the automated technique.

There is the further concern of patients with significant hearing loss who may have reduced frequency-resolving ability. Clearly, such individuals may be limited in their ability to make reliable frequency judgments about their tinnitus pitch, even with training. Anecdotally, we have encountered patients for whom all frequencies above a certain value (e.g., 3 kHz) sound similar. It will therefore be necessary in the future to devise a means of determining at which frequencies a patient can make frequency discriminations, and to limit testing to those frequencies.

Tinnitus Pitch-Match Reliability

Obtaining reliable tinnitus pitch matches has been a vexing problem for decades (5). The majority of these studies have reported between-sessions pitch matches that were highly variable, and only one study has documented reliable pitch matches within sessions (20). These historically consistent findings raise the concern that if studies report tinnitus pitch matches without repeated measurements, the accuracy of the single measurements must be questioned.

According to questionnaire responses from a large population of tinnitus patients, the sound quality of tinnitus varied for about one-third of the patients (21). Variations over time, concerning pitch, timbre, or loudness of tinnitus, thus present additional sources of unreliability. Some patients describe multiple tinnitus sounds of which one of the sounds must be identified as the predominant sound for tone matching. Such individuals may have difficulty "remembering" their predominant tinnitus sound for repeated tone matching.

Patients with tinnitus that varies or that has multiple components will present the greatest challenges in obtaining reliable matches. If the tone matches show variability, that variability must reflect a true change in the patient's perception of their tinnitus. A tool that could actually reflect such perceptual changes would be invaluable for a range of clinical and research purposes (2). However, current methods of tinnitus assessment have not reached the level of achieving reliable pitch matches, even when the patient's tinnitus does not fluctuate. Therefore, the first step in developing a reliable pitch match procedure will require documentation of reliability with patients who have stable tinnitus. The technique could then be used to measure actual tinnitus fluctuations.

CONCLUSION

A tinnitus pitch match is an important clinical measurement for quantifying a patient's tinnitus perception, specifying a therapeutic masking noise that is centered around the tinnitus frequency, and enabling detection of changes that may occur during treatment (2,5,6,22). Obtaining accurate pitch matches is also important for clinical research purposes. If the pitch match is not repeatable, then the measurement is not valid for any of these applications. Therefore, the pitch-match experiments in the present study were directed at developing a standardized clinical method for obtaining such measurements reliably.

Most previous tinnitus pitch-match protocols have relied on an upward progression of test frequencies to approach the tinnitus frequency gradually. This can be a tedious process, and thus far, reliability of pitch matches obtained with such methodology has not been demonstrated. The present experiment was designed to shorten testing time by using larger steps to bracket initially the tinnitus frequency to a specific range. We then used smaller frequency steps within the identified range to determine the more precise tinnitus frequency. Results of this testing provided further validation that computer automation can be an efficient means of performing tinnitus matching.

Although this methodology has shortened testing time considerably from our previous investigation (6), further work is needed to design protocols that can be conducted even more rapidly. Also, there is need for further improvement in pitch-match reliability for this technique to offer utility for routine clinical application. **Table 4** shows confidence intervals for the intersession differences with each method. For the Binary and Octave procedures, respectively, 70 percent and 50 percent of the intersession differences in pitch matches occurred within one octave. A reasonable goal would be to achieve approximately 95 percent of intersession differences within one octave. Refinement efforts will, therefore, target shorter testing time and improve reliability of responses. Accomplishment of these goals could result in standardization of tinnitus evaluation techniques that would ultimately improve hearing health-care services.

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APPENDIX

PRETESTING EVALUATION TO DETERMINE PATIENTS' UNDERSTANDING OF "LOUDNESS" AND "PITCH"

Hearing Thresholds

1. Instruct subject for threshold testing: *You will hear soft beeping tones. Raise your hand when you hear a tone.*
2. Obtain hearing thresholds at 1000, 1260, and 4000 Hz (to closest 5 dB).

Loudness

3. Instruct subject to choose the louder of each pair of tones: *You will hear two tones, one followed by the other. After you hear both tones, tell me which tone was the louder of the two.*
4. Present 1000-Hz tone at 10 dB SL, followed by 1000-Hz tone at 20 dB SL. Log choice of the subject.
5. Instruct subject: *Listen to two tones again, and choose the louder of the two.*
6. Repeat Step 3, except reverse the order of presentation, i.e., 20 dB SL followed by 10 dB SL. Log choice of the subject.
7. If subject chose correctly for each of the two tone pairs, log subject as "understands loudness."
8. If subject choses incorrectly for at least one of the first two presentations, ask the subject: *Is it clear to you how to tell whether one sound is louder than another?*
   a. If the subject responds that it is clear, retest as for Steps 4–6.
   b. If subject reports that he or she doesn't understand "loudness," instruct: *A louder tone pushes harder on your eardrum than a softer tone. For example, a jet engine is louder than a whisper. Think about making your radio louder by turning up the volume.* Then retest as for Steps 4–6.
9. If subject does not respond correctly for three total presentations (i.e., three times Steps 4–6), subject is logged as "doesn't understand loudness."

Pitch

10. Instruct subject to choose the "higher pitched" tone of each pair of tones: *You will hear two tones, one followed by the other. After you hear both tones, tell me which tone was the higher in pitch of the two.*
11. Present 1000 Hz tone at 10 dB SL, followed by 4000 Hz tone at 10 dB SL. Log choice of the subject.
12. Instruct subject: *Listen to two tones again, and choose the higher pitched of the two.*
13. Repeat Step 11, except reverse the order of presentation, i.e., 4000 Hz followed by 1000 Hz. Log choice of the subject.
14. If subject chose correctly for each of the two tone pairs, repeat Steps 11–13, except use 1260 Hz instead of 4000 Hz.
15. If subject chose correctly for all presentations, log subject as "understands pitch."
16. If subject chose incorrectly for any presentations, ask the subject: *Is it clear to you how to tell whether one sound is higher in pitch than anothe*r?
    a. If the subject responds that it is clear, retest as necessary for Steps 11–14.
    b. If subject reports that he/she doesn't understand "pitch," instruct: *The pitch of a sound refers to whether it is a low sound (such as a man's voice) or a high sound (such as a woman's voice).* Then retest as necessary for Steps 11–14.
17. If subject does not respond correctly for three total presentations (i.e., 3 times Steps 11–14), subject is logged as "doesn't understand pitch."

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