# Continuous Versus Pulsed Tones in Audiometry

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The purpose of this study was to compare auditory thresholds obtained for continuous and pulsed tones in listeners with normal hearing. Auditory thresholds, test–retest reliability, false-positive responses, and listener preference were compared for both signals. Hearing thresholds and test–retest reliability were comparable for the 2 signals, and there were no significant differences in the number of false positives or the number of presentations required to reach threshold. Listener preference, however, indicated that pulsed tones were preferred over continuous tones by 67% of the listeners when listening to low-level or high-frequency tones. These findings, coupled with previous reports demonstrating the benefits of using automatically pulsed tones in threshold assessment for listeners with tinnitus, support the general use of pulsed tones in clinical audiometry.

**Key Words:** hearing thresholds, pure-tone audiometry, pulsed tones

Pure-tone threshold audiometry is the primary audiologic test procedure for the differential diagnosis of hearing loss and hearing disorders (Wilber, 1991; Yantis, 1994). According to a survey of audiometric practices, the majority of audiologists surveyed use a manual presentation of continuous tones (Martin & Sides, 1985). The American Speech-Language-Hearing Association (ASHA) guidelines recommend a tonal duration of 1 to 2 s (American Speech-Language-Hearing Association, 1978). These guidelines also recommend quiet intervals between tone presentations that are varied and equal to or greater than the duration of the test tone. Although the ASHA (American Speech-Language-Hearing Association, 1978) guidelines recommend use of a continuous tone, a substitution of pulsed tones is also permitted. At present, there are limited published data comparing hearing threshold measures for manually presented versus automatically pulsed tones (Dancer, Ventry, & Hill, 1976; Gardner, 1947; Hochberg & Waltzman, 1972; Mineau & Schlauch, 1997). Reliability data also seem limited to the Gardner (1947) and Mineau and Schlauch (1997) studies, although the techniques and equipment used in the Gardner (1947) study differ from current ASHA recommendations. More recent reports primarily consist of data for the two test signals in adults with sensorineural hearing loss with or without tinnitus (Dancer et al., 1976; Hochberg & Waltzman, 1972; Mineau & Schlauch, 1997).

There are selected studies that support the use of pulsed tones rather than continuous tones in manual threshold audiometry (Dancer & Conn, 1983; Dancer et al., 1976; Gardner, 1947; Hochberg & Waltzman, 1972; Hood, 1955; Mineau & Schlauch, 1997). First, relative to continuous tones, the use of pulsed tones has been shown to decrease the number of false positives in both normal-hearing listeners and listeners with sensorineural hearing loss with or without tinnitus (Dancer & Conn, 1983; Dancer et al., 1976; Mineau & Schlauch, 1997). In the case of listeners with tinnitus, automatically pulsed stimuli may be more alerting to the listener at high frequencies where their tinnitus is present (Mineau & Schlauch, 1997). That is, listeners are better able to discriminate between the test signal and random internal noise such as tinnitus. Dancer et al. (1976) reported fewer false positives for pulsed tones in hearing-impaired listeners (thresholds > 30 dB HL at 4000 Hz) when they used the pulse-counting technique described by Gardner (1947), which involved not only perceiving the pulsed signal but also correctly counting the number of pulses. This increase in necessary information required to respond correctly to the pulsed tone might predictably reduce false positives (Dancer et al., 1976). That is, "responses requiring increased information …tend to be more precise and certain" (Dancer et al., 1976, p. 322). Dancer and Conn (1983) also examined the effect of an

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ascending versus descending threshold technique using both pulsed and continuous tones in normal-hearing listeners. In this case, the pulsed method followed the more typically used clinical procedure, for which the listener simply responded as to whether he or she heard the pulses. Once again, Dancer and Conn found that the use of pulsed tones resulted in fewer false positives for both ascending and descending approaches.

Second, listeners with normal hearing and those with sensorineural hearing loss and tinnitus prefer pulsed tones over continuous tones as a listening task (Gardner, 1947; Hochberg & Waltzman, 1972). Although the specific reason for these results is unknown, pulsed tones once again may be more alerting for listeners. While listener preference is important, it should not mandate a specific signal at the expense of accurate hearing thresholds. The data available, however, are equivocal regarding comparability in hearing thresholds for continuous and pulsed tones (Dancer et al., 1976; Hirsh, 1952; Hochberg & Waltzman, 1972; Hood, 1955; Mineau & Schlauch, 1997; Rosenblith & Miller, 1949). Hirsh (1952) reported that relative to thresholds for continuous tones, hearing thresholds at 4000 Hz were approximately 15 dB better for slowly interrupted tones (Hirsh, 1952; Rosenblith & Miller, 1949). Hood (1955) also found lower hearing thresholds for pulsed tones than for continuous tones in listeners suffering from Ménière's disease. More recent studies using modern audiometric test equipment, however, suggest that threshold differences between pulsed and continuous tones do not exceed the typical 5 dB clinical step size (Dancer et al., 1976; Hochberg & Waltzman, 1972; Mineau & Schlauch, 1997).

The use of pulsed tones in Bekesy audiometry and in ultra-high-frequency audiometry also relates to issues in the current study. In threshold applications of Bekesy audiometry, pulsed tones are typically presented to minimize any effects of auditory adaptation to a continuous tone (Hallpike & Hood, 1951; Jerger, 1960; Reger, 1970; Silman & Silverman, 1991; Sorensen, 1962). McCommons and Hodge (1969) compared thresholds obtained with Bekesy audiometry for pulsed tones of various periods and duty cycles and a continuous tone in normal-hearing listeners. They found that a pulsed tone provides more feedback or a series of cues by which the listener can make a decision regarding the presence of the signal. These increased cues offered by pulsed tones for Bekesy audiometry might also carry over to manual audiometry.

Pulsed tones are also typically used when measuring ultra-high-frequency thresholds (Hamill & Haas, 1986). The reasoning is much the same as described previously for listeners with tinnitus. That is, pulsed tones can help the listener extract the test signal from internal background noises. Hamill and Haas (1986) found that pulsed tones provided comparable threshold measures relative to continuous tones in normal-hearing listeners for the 10 kHz to 16 kHz frequency range.

To date, threshold data comparisons for pulsed tones and continuous tones in normal-hearing listeners using the manual pure-tone technique recommended by ASHA (American Speech-Language-Hearing Association, 1978) are lacking. Accordingly, the purpose of this study was to compare threshold responses for manually presented 1–2-s continuous tones and short, automatically pulsed tones, using the threshold search procedure recommended by ASHA (American Speech-Language-Hearing Association, 1978). This study addressed the following: In comparing automatically pulsed tones with manually presented 1–2-s continuous tones, were there significant differences in (a) the reliability in measured thresholds within and across sessions, (b) the measured thresholds across frequencies, (c) the number of presentations required to reach threshold, (d) the number of false positives, or (e) participant preference for the two tones used?

## Method

### *Participants*

Twenty-four women between the ages of 19 and 44 years (mean age = 23 years) participated in this study. Participants were volunteers recruited from undergraduate courses in communicative disorders at the University of Wisconsin—Madison. Each participant had normal otoscopic findings and pure-tone thresholds ≤ 15 dB HL for octave test frequencies of 250 to 8000 Hz. All participants had normal tympanometric measures based on 90th percentile values published by Roup, Wiley, and Stoppenbach (1998) for compensated acoustic admittance (Peak $Y_{tm}$) and equivalent ear canal volume ($V_{ec}$). Ipsilateral acoustic reflexes were present for all participants at 1000 Hz (≤105 dB HL).

### *Instrumentation*

Acoustic immittance measures were obtained using a calibrated (American National Standards Institute, 1987) tympanometer (Virtual Corporation, Model M310 V4.9 HF). Hearing thresholds were obtained using a console audiometer (Grason-Stadler, Model GSI 16) calibrated in accordance with American National Standards Institute (1996) specifications. All threshold testing took place under earphones (Telephonics TDH-50P earphones in MX-41/AR cushions) in a double-walled sound-treated room (Industrial Acoustics Company, Inc., Model 1202) that met or exceeded ANSI guidelines for permissible ambient noise (American National Standards Institute, 1999).

### *Procedure*

Otoscopy and acoustic immittance measures were administered before audiometric testing. Participants were instructed according to the ASHA guidelines for manual pure-tone audiometry (American Speech-Language-Hearing Association, 1978). Participants took part in two testing sessions. The signal conditions were either a manually presented continuous tone for 1 to 2 s or three short pulses (rise–fall time of 35 ms with a duration of 200 ms onset to offset) automatically generated by the audiometer. Session 1 contained two trials for each signal condition. For each trial, thresholds were measured at octave

**Table 1. Pure-tone thresholds (dB HL) for 24 participants averaged across three trials.**

| | Frequency (Hz) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 250 | | 500 | | 1000 | | 2000 | | 4000 | | 8000 | |
| No. presentations | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Pulsed tones | 5.6 | 5.6 | 1.4 | 6.1 | –1.3 | 5.0 | –4.0 | 4.7 | –0.5 | 6.5 | 5.1 | 6.0 |
| Continuous tones | 4.2 | 6.2 | –0.1 | 6.2 | –1.9 | 5.5 | –4.7 | 4.4 | –2.1 | 6.0 | 4.8 | 5.9 |

frequencies from 250 to 8000 Hz in the participant's right ear, yielding two sets of thresholds for pulsed and continuous tones at the end of Session 1. The first signal (either automatically pulsed or a continuous tone) was randomly chosen and followed alternately by the other signal. The participants were given a rest period during which the headphones were removed after two trials. Thresholds in dB HL (re: American National Standards Institute, 1996) were obtained from three ascending runs following the ASHA guidelines for manual pure-tone audiometry (American Speech-Language-Hearing Association, 1978). All changes in signal level were accomplished with the signal off. The total number of presentations to reach threshold at each frequency, total number of false positives, and the threshold measures across trials were examined to evaluate threshold reliability for both signals. False positives were identified by the examiner based on a general impression that the participant's response occurred more than 1 s after stimulus presentation or during a silent interval between presentations.

Participants returned 3–7 days later for Session 2, in which one trial was repeated for each signal condition. At the completion of each session, participants were asked to complete a questionnaire related to the ease of the listening task for each signal presentation method (see the Appendix). The questionnaire was administered twice to help counterbalance the different starting procedure for each session.

The examiner in this project was a master's level graduate student in audiology who had completed 300 supervised clinical hours, including some testing experience. A graduate student was chosen to eliminate any procedural biases from many years of testing. This examiner was fully knowledgeable regarding the ASHA (1978) method and was instructed to present three pulses at each presentation level when using the automatic pulsing feature on the audiometer.

## Results

The following data were gathered for each participant during each trial: (a) threshold at each test frequency, (b) the number of false positives for each frequency, and (c) the total number of presentations per frequency. The questionnaire on the ease of the task was administered at the completion of each testing session. A general linear model repeated measures analysis (SPSS, Version 11.5) was used to examine hearing thresholds, number of presentations, and number of false positives as a function of signal type, trial, and test frequency. Post hoc paired-sample *t* tests with a Bonferroni adjustment for multiple comparisons were computed as needed.

Thresholds averaged across the three trials for both stimuli are shown in Table 1. The main effect of signal type was significant (see Table 2). The continuous tone threshold was 1.0 dB lower than that for the pulsed tone. The main effect of trial and that of frequency also were significant. Post hoc analysis showed the average threshold for Trial 2 was lower than that for Trial 1, $t(287) = 5.2$, $p < .05$; however, this difference was only 1.3 dB. There were no other significant differences between trials. Differences in thresholds at each test frequency (averaged across signal and trial) ranged from 0.04 dB between 250 and 8000 Hz to 9.3 dB between 2000 and 8000 Hz. Post hoc analysis of auditory threshold as a function of frequency showed that thresholds at the test frequency extremes (250 Hz and 8000 Hz) were generally higher than thresholds from 500 Hz to 4000 Hz (see Table 3). These differences between frequencies averaged across signal type, however, were not of

**Table 2. Within-subjects repeated measures analysis of variance data for the dependent variables of threshold, number of presentations to reach threshold, and number of false positives.**

| Variable | *df* | *F* | *p* |
|---|---|---|---|
| Threshold | | | |
| Signal (S) | 1, 23 | 32.08 | .00* |
| Trial (T) | 2, 46 | 5.06 | .01* |
| Frequency (F) | 5, 115 | 18.03 | .00* |
| S × T | 2, 46 | 1.79 | .18 |
| S × F | 5, 115 | 2.22 | .06 |
| T × F | 10, 230 | 0.97 | .47 |
| S × T × F | 10, 230 | 0.72 | .71 |
| No. presentations | | | |
| Signal (S) | 1, 23 | 3.96 | .06 |
| Trial (T) | 2, 46 | 2.03 | .14 |
| Frequency (F) | 5, 115 | 3.47 | .01* |
| S × T | 2, 46 | 2.08 | .14 |
| S × F | 5, 115 | 1.21 | .31 |
| T × F | 10, 230 | 1.84 | .06 |
| S × T × F | 10, 230 | 0.59 | .82 |
| No. false positives | | | |
| Signal (S) | 1, 23 | 0.02 | .88 |
| Trial (T) | 2, 46 | 0.77 | .47 |
| Frequency (F) | 5, 115 | 1.96 | .09 |
| S × T | 2, 46 | 0.22 | .80 |
| S × F | 5, 115 | 1.63 | .16 |
| T × F | 10, 230 | 0.58 | .83 |
| S × T × F | 10, 230 | 1.24 | .27 |

*Significant at the .05 level.

**Table 3. Post hoc analysis of hearing thresholds as a function of test frequency.**

| Frequency (Hz) (A) | Frequency (Hz) (B) | Mean diff. (dB) (A – B) | *SE* | *p* |
|---|---|---|---|---|
| 250 | 500 | 4.27 | 0.71 | .000* |
| | 1000 | 6.46 | 0.84 | .000* |
| | 2000 | 9.24 | 1.14 | .000* |
| | 4000 | 6.18 | 1.50 | .006* |
| | 8000 | –0.04 | 1.34 | 1.000 |
| 500 | 1000 | 2.19 | 0.95 | .454 |
| | 2000 | 4.97 | 1.21 | .006* |
| | 4000 | 1.91 | 1.56 | 1.000 |
| | 8000 | –4.31 | 1.47 | .112 |
| 1000 | 2000 | 2.78 | 0.95 | .111 |
| | 4000 | –0.28 | 1.39 | 1.000 |
| | 8000 | –6.49 | 1.28 | .001* |
| 2000 | 4000 | –3.06 | 1.31 | .423 |
| | 8000 | –9.27 | 1.39 | .000* |
| 4000 | 8000 | –6.22 | 1.29 | .001* |

*Note.* Adjustment for multiple comparisons: Bonferroni.

*Mean difference is significant at the .05 level.

**Table 4. Test–retest correlations (*r* values) for 24 participants among each of three trials.**

| Tone | Frequency (Hz) 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|---|---|---|---|---|---|---|
| Pulsed | | | | | | |
| Trial 1–Trial 2 | .73** | .85** | .76** | .82** | .82** | .57** |
| Trial 1–Trial 3 | .62** | .66** | .60** | .65** | .69** | .41* |
| Trial 2–Trial 3 | .65** | .70** | .43* | .58** | .67** | .77** |
| *M* | .67 | .73 | .60 | .68 | .73 | .59 |
| Continuous | | | | | | |
| Trial 1–Trial 2 | .77** | .70** | .80** | .73** | .63** | .77** |
| Trial 1–Trial 3 | .53** | .70** | .75** | .53** | .64** | .62** |
| Trial 2–Trial 3 | .50* | .77** | .82** | .67** | .63** | .70** |
| *M* | .60 | .72 | .79 | .64 | .64 | .69 |

*Note.* Trial 1–Trial 2 are within the same test session; Trial 1–Trial 3 and Trial 2–Trial 3 are across sessions.

*$p < .05$. **$p < .01$.

primary interest. The Signal × Trial, Signal × Frequency, and the Signal × Trial × Frequency interactions were not significant.

Test–retest correlations for thresholds at each frequency were calculated for the two signals among all three trials. This enabled both within-session and across-session measures of reliability. All test–retest correlations were significant at the .05 level (see Table 4). The grand mean correlation at each frequency is an average of the correlations for all three trials. The test–retest reliability at each test frequency was quite similar for both stimuli, as indicated by the mean Pearson product–moment correlation coefficients, which ranged from .59 to .79. In general, test–retest correlations were higher between trials within the same session as compared with across-session measures. The maximum mean threshold difference across the three trials was 1.5 dB for the pulsed tones (at 250 and 2000 Hz) and 3.3 dB for the continuous tones at 250 Hz. Threshold standard deviations (group mean across trials) were quite similar for both presentation methods, ranging from 4.3 to 7.4 dB for the pulsed tones and 3.8 to 6.9 dB for the continuous tones.

The total number of presentations to reach threshold was very similar for both stimuli, with the total number differing between signals by at most one presentation (see Table 5). As shown in Table 5, it took approximately 13 to 16 stimulus presentations to measure threshold at each frequency. The main effect of frequency was significant. Post hoc analysis showed 2.4 more presentations were needed to obtain threshold at 250 Hz than at 2000 Hz, $t(143) = 5.9$, $p < .05$. There were no other significant differences between frequencies. The main effects of signal and trial and the Signal × Trial, Signal × Frequency, and Signal × Frequency × Trial interactions were not significant (see Table 2).

As can be seen in Figure 1, there were very few false positives regardless of the signal used. For example, at 500 Hz, the continuous tone required 15 presentations on average to reach threshold. Across 24 participants and three trials, representing approximately 1,080 presentations, there were only 11 false positives. Although the number of false positives increased with higher test frequencies, so did the total number of presentations needed to reach threshold, keeping overall percentages at a low 0.3%–1.4%. In general, most participants had 2 or fewer false positives within a trial. The greatest number of false positives overall occurred at 8000 Hz for the pulsed tone; even at this frequency, there were only 16 false positives across all participants. There were no significant differences in the number of false positives for the two test signals (see Table 2).

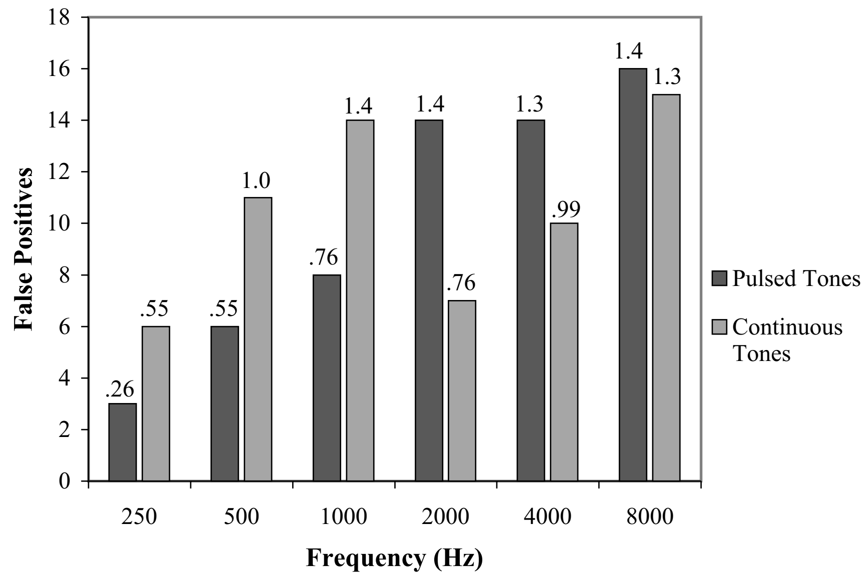
The percentage of participants finding each signal easier based on the five different questions during both trials is displayed in Table 6. A chi-square analysis was used to compare the data from Session 1 to Session 2 and to

**Table 5. No. presentations to reach threshold for 24 participants averaged across three trials.**

| Tone | 250 *M* | 250 *SD* | 500 *M* | 500 *SD* | 1000 *M* | 1000 *SD* | 2000 *M* | 2000 *SD* | 4000 *M* | 4000 *SD* | 8000 *M* | 8000 *SD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pulsed | 15.9 | 3.6 | 15.1 | 3.6 | 14.7 | 4.1 | 13.5 | 4.1 | 14.5 | 4.6 | 15.6 | 3.8 |
| Continuous | 15.1 | 3.2 | 15.0 | 3.5 | 13.7 | 3.9 | 12.8 | 3.9 | 14.0 | 4.4 | 16.0 | 3.2 |

Note. Column headers are Frequency (Hz).

Figure 1. **Total number of false positives at each frequency for all 24 participants summed across three trials. The overall percentage of false positives relative to the average number of presentations needed to reach threshold is shown above each bar.**




identify significant differences between the two stimuli within a session. There was no significant difference on the five questions between Session 1 and Session 2 at the .05 level; therefore, the data from both sessions were combined for subsequent analyses. As shown in Table 6, significantly more participants preferred the pulsed tones over the continuous tones when they were listening to high-frequency signals, $\chi^2(1, N = 48) = 5.3$, $p < .05$, and when they listened to very low level tones, $\chi^2(1, N = 48) = 5.3$, $p < .05$. When the tones were either at a high level, $\chi^2(1, N = 48) = 0.8$, $p > .05$, or lower in frequency, $\chi^2(1, N = 48) = 0.8$, $p > .05$, there was no significant difference in preference between the two stimuli.

The questionnaire was followed with a space for the participants to comment as to why they chose one signal over the other for all situations. On the basis of review of the comments, all participant statements were arbitrarily assigned to one of three categories: (a) “the tone was more alerting or easier to hear,” (b) “the tone was more distinguishable from noise,” and (c) “there was a temporal pattern.” Although participants were not required to write a comment, 92% chose to write a response at the end of both sessions. One participant did not comment at the end of a session, thereby leaving 47 assignable comments, accounting for those participants who gave more than one reason for their preference. Of those comments, 62% were by those who preferred the pulsed tones, with the remaining 38% of the comments from those participants who preferred the continuous tones. The most common response for those participants preferring the pulsed tone was that the signal was easier to hear.

## Discussion

As can be seen in Table 1, the differences in thresholds for the two stimuli were relatively small. Although the 1–2-s continuous-tone threshold (averaged across frequencies and trials) was significantly lower than that for an automatically pulsed tone, the difference was only 1.0 dB. While statistically significant, this small difference is not important in clinical applications for which 5-dB steps are typically used. The continuous tones produced slightly lower thresholds at all the test frequencies. The mean differences ranged from only 0.3 to 1.6 dB. Overall, these differences

**Table 6. Percentage of participants preferring each method averaged across both sessions.**

| | Question 1 Easier when listening to high pitches | Question 2 Easier when listening to low pitches | Question 3 Easier when listening to very soft tones | Question 4 Easier when listening to louder tones | Question 5 If only one could be chosen for all situations, which would it be? |
|---|---|---|---|---|---|
| Pulsed tones | 66.7* | 52.1 | 66.7* | 47.9 | 58.3 |
| Continuous tones | 33.3 | 47.9 | 33.3 | 52.1 | 41.7 |

*$p < .05$.

are similar to previously reported findings for listeners with tinnitus and sensorineural hearing loss (Henry & Meikle, 1999; Hochberg & Waltzman, 1972; Mineau & Schlauch, 1997).

Both signals showed significant test–retest correlations among the three trials for all test frequencies. The mean threshold differences across trials were also quite small, with similar standard deviations at each test frequency for both methods. The maximum mean threshold difference across trials of 1.5 dB for the pulsed tones and 3.3 dB for the continuous tones was very close to the 1.5 dB and 2.7 dB reported by Mineau and Schlauch (1997). The observed standard deviations were also similar to those reported by Carhart and Jerger (1959; which ranged from 4.0 to 7.2 dB) for thresholds obtained using an ascending continuous tone. These small differences in thresholds and standard deviations obtained across trials for both methods reinforce the equality of the two procedures. The overall differences present would not be sufficient to recommend one signal over the other.

Although there was no clear test–retest reliability benefit for either signal condition when only one tester was used, this may not be the case across multiple testers. Using multiple testers could affect the reliability and consistency of the presented test signal across repeated tests and across clinics. That is, for manual presentation of a continuous tone, the examiner's prior experience and procedural biases could have an effect on the test outcome. There are numerous ways in which the tone and interval between the tones can be presented that fall within the allowable ASHA criteria. The clinician's experience might predictably influence his or her decisions regarding the duration of signals and the spacing between the presented tones. Using a specific number of automatically pulsed tones would provide identical signal presentation across test sessions and across clinics, potentially providing more reliable retest measures.

The differences in the average number of presentations needed to reach threshold across all frequencies for each signal were extremely small. Mineau and Schlauch (1997), however, found significantly fewer presentations were needed to achieve threshold for a pulsed tone at 4000 Hz than a continuous tone; however, they found no other significant differences.

The number of false positives in this study also was quite low (i.e., only 124 false positives out of 12,665 presentations (0.98%). There were slightly more false positives for continuous tones at lower frequencies (250–1000 Hz) and slightly more false positives for pulsed tones at higher frequencies (see Figure 1). As stated previously, there were no significant effects, and the overall numbers were very low and within acceptable clinical criteria. These findings were in contrast to the findings of Mineau and Schlauch (1997) in listeners with sensorineural hearing loss and tinnitus. Mineau and Schlauch (1997) reported that "60% of patients in the continuous-tone group presented one or more false-positive responses" (p. 55), whereas in the pulsed-tone group this number was only 30%. Dancer et al. (1976) also reported more false positives when listening to continuous tones. However, half of their participants made no false positives regardless of signal type. In listeners with either hearing impairment or hearing impairment accompanied by tinnitus, then, the use of pulsed tones produced fewer false positives (Dancer et al., 1976; Mineau & Schlauch, 1997). As noted in the project rationale, this result may be related to the alerting character of the pulsed tones against a background of sustained tonal tinnitus.

A consistent finding in the present study was a listener preference for pulsed tones under more difficult listening conditions. It may be the case that when the presented signal was perceived as easier (e.g., a loud tone), the task was easily accomplished regardless of the signal used, as indicated by the almost equal split in preference for high-level or low-frequency tones. However, when the conditions became more difficult, there was a clear preference for pulsed tones. Although more participants preferred pulsed tones, the posttest comments across signal type were very similar. The most common issue for those participants who preferred the pulsed tones was the more apparent alerting character of the signal ("easier to hear"). Several responses from the group who preferred the continuous tone referred to having a longer time to respond, although the total presentation time was similar for both signals. This issue could have been clarified by more specific participant instructions regarding when and how to respond to a pulsed signal. The numbers for overall preference were very close to those observed by Hochberg and Waltzman (1972). For their control group of normal-hearing participants, 60% preferred pulsed tones, whereas 72% of their hearing-impaired participants preferred pulsed tones.

Finally, the results of the present study were limited to threshold audiometry in women with normal hearing. However, the observed benefits of pulsed tones in audiometry for these listeners and similar reported advantages for hearing-impaired listeners with tinnitus may hold promise for other clinical populations. Specifically, the alerting character of pulsed tones and associated reports of improved task simplicity may be particularly useful in threshold audiometry for young children and older adults.

## Conclusion

The use of pulsed tones for audiometric threshold measures in normal-hearing listeners had no clinically significant effect on obtained hearing thresholds, test time, false positives, or test–retest reliability for the pulsed and continuous tones. Pulsed tones, however, clearly showed an advantage in terms of presenting what is perceived as an easier task without adversely affecting the test's outcome. The slight but significant preference for pulsed tones in normal-hearing listeners, coupled with previous reports demonstrating the benefits of using pulsed tones in threshold assessment for listeners with sensorineural hearing loss and tinnitus (Hochberg &Waltzman, 1972; Mineau & Schlauch, 1997), supports the general use of pulsed tones in audiometry.

## Acknowledgments

This work is based in part on Matthew H. Burk's thesis, completed for the master of science degree in communicative disorders at the University of Wisconsin–Madison. This research was supported in part by U.S. Department of Education Grant H029D 940085. We wish to thank Kip Kelly for his assistance with data collection and Dan Stoppenbach and Larry Humes for their comments and suggestions on the manuscript.

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Received October 9, 2003
Accepted December 16, 2003
DOI: 10.1044/1059-0889(2004/008)

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## Appendix

Participant Questionnaire

The following questions all refer to the two different types of tones that you listened to during the testing sessions. There was a pulsed tone, which always consisted of three short pulses in succession, or a continuous tone, which lasted one to two seconds in length, for each presentation. Please circle your responses.

1. Which type of tone did you find easier when listening to high pitches?

   Pulsed tones     1–2-second continuous tone

2. Which type of tone did you find easier when listening to low pitches?

   Pulsed tones     1–2-second continuous tone

3. Which type of tone did you find easier when listening to very soft tones?

   Pulsed tones     1–2-second continuous tone

4. Which type of tone did you find easier when listening to louder tones?

   Pulsed tones     1–2-second continuous tone

5. If you were forced to choose one of the two different types of tones for all testing conditions, regardless of level, pitch, or any other background noises, which would it be and why?

   Pulsed tones     1–2-second continuous tone

Why: