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Acoustic Reflex Threshold Tenth Percentiles and Functional Hearing Impairment

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Abstract

This study addressed the issue of whether functional impairments can be identified or confirmed using tonal acoustic reflex thresholds (ARTs). Tonal ARTs from 74 ears with functional impairments were compared to 10th percentiles of the ARTs for normal and cochlear-impaired ears at 500 to 2000 Hz (Gelfand, Schwander, and Silman, 1990). Only one ear (5.3%) was correctly identified among the 19 ears in which all of the voluntary thresholds at 500 to 2000 Hz were ≤ 55 dB HL. Acoustic reflex thresholds correctly identified functional losses in 70.9 percent, 78.6 percent, and 85.7 percent of the ears with voluntary thresholds ≥ 60 dB HL at one, two, or three of these frequencies, respectively. The false positive rate was only 5 to 7 percent for a control group of 50 ears with genuine sensorineural hearing losses. The results indicate that tonal ARTs are an effective nonbehavioral tool for identifying or substantiating the presence of functional losses when thresholds are ≥ 60 dB HL; however, ARTs cannot identify functional components when thresholds are ≤ 55 dB HL.

Key Words: Acoustic reflex, acoustic reflex threshold (ART), exaggerated hearing loss (impairment), functional hearing loss (impairment), 10th percentiles

Functional hearing impairments can be revealed by an assortment of behavioral and physiologic tests (Chaiklin and Ventry, 1963; Hopkinson, 1973; Rintelmann and Schwan, 1991). The principal methods involve use of the patient's behavioral responses and are able to demonstrate the presence of most functional losses. These methods usually involve the audiologist's interpretation of responses obtained during routine evaluation procedures, and they can be generalized into such categories as discrepancies between measures, lack of reliability, and inconsistencies between the patient's behavior and test results. The specific tests of functional hearing loss, per se, are for the most part also behavioral measures and are usually employed to verify exaggeration after it is already suspected.

Physiologic measures can strengthen the process of identifying or confirming functional impairments because they do not rely upon responses that are volunteered by the patient. Virtually every physiologic method for assessing hearing has been tried or at least mentioned with respect to functional hearing loss (for current reviews, see Rintelmann and Schwan, 1991; Silman and Silverman, 1991). The acoustic reflex, however, is the only one of these that is routinely employed in the initial evaluation of almost every patient.

Audiologists have been using the acoustic reflex as a nonbehavioral test for functional hearing loss since the 1960s (Feldman, 1963; Lamb and Peterson, 1967; Alberti, 1970) and continue to do so. Functional hearing loss is suspected if the acoustic reflex threshold (ART) occurs below a patient's behavioral thresholds or above auditory threshold but at lower than expected sensation levels. The application of ARTs as a test of functional loss, however, presupposes knowing how ARTs are related to auditory thresholds as a function of hearing level in general and how the "lower end" of the ART distribution is related to hearing threshold in particular. Thus, the ART has been employed in functional loss assessment for 30

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years without the benefit of normative values or a clear understanding of the limitations of this application.

This information is now available in the form of 10th percentiles for the distribution of ARTs as a function of hearing level in normal and cochlear-impaired ears (Gelfand and Piper, 1984; Gelfand et al, 1990). Reflex thresholds below the 10th percentile are expected to occur in less than 10 percent of normal or cochlear-impaired ears and can thus be viewed as occurring at a lower than expected level.

Another ART-based approach that has been used with functional losses is the modified bivariate method, which distinguishes normal from impaired ears for individuals ≤ 44 years of age (Silman et al, 1984a). Using subjects ≤ 44 years old, Silman (1988) found that the modified bivariate procedure effectively identified ears with functional losses that were actually normal, as opposed to those with some degree of underlying organic impairment. Thus, functional losses can be identified by the bivariate method, provided that the ear is actually normal and that the patient is ≤ 44 years of age. This is expected, because the bivariate method depends on the broadband noise (BBN) ART, which is sensitive to even small amounts of sensorineural hearing loss (see, e.g., Gelfand, 1984; Silman and Silverman, 1991). These limitations are clinically significant because many patients are ≥ 45 years old, and most adults with functional impairments actually have underlying organic hearing losses (Chaiklin and Ventry, 1963; Coles and Mason, 1984; Gelfand and Silman, 1985, 1993).

Tonal ARTs may still be used to reveal or confirm functionality because: (1) tonal ARTs are not age dependent (Handler and Margolis, 1977; Silman, 1979; Gelfand and Piper, 1981; Silverman et al, 1983; Gelfand, 1984); and (2) the relationship between tonal hearing levels and ARTs is well defined (Silman and Gelfand, 1981b; Gelfand et al, 1983, 1990; Gelfand and Piper, 1984). It has been proposed that functional impairments may be identified or verified when tonal ARTs fall below the 10th percentiles of the functions relating ARTs to hearing levels (Gelfand and Piper, 1984; Gelfand et al, 1990; Silman and Silverman, 1991). Although tonal ARTs increase with hearing thresholds above about 50 to 60 dB HL, however, they are essentially independent of hearing levels below about 50 to 60 dB HL (Popelka, 1981; Silman and Gelfand, 1981b; Gelfand et al, 1983, 1990; Gelfand and Piper, 1984). Thus, the use of the 10th percentiles to confirm functional impairment is expected to be limited to exaggerated thresholds exceeding about 50 to 60 dB HL.

It is not suggested that ARTs can supplant other approaches to functional loss identification, of which the pure-tone average (PTA) - speech reception threshold (SRT) discrepancy is probably the most efficient (Chaiklin and Ventry, 1963, 1965). Rather, tonal ARTs can provide a cost-effective confirmation of such findings using routinely obtained immittance results. Moreover, there are times when PTA-SRT criteria are ambiguous, especially in cases of sloping audiograms (Gelfand and Silman, 1985, 1993). Tonal ARTs can provide the audiologist with insights into the possibility of functionality in situations such as these.

This study addressed the suggestion that functional hearing losses can be verified by tonal ARTs, principally using the 10th percentiles described by Gelfand et al (1990). The goal was to provide information about the application of ARTs to functional loss assessment, including the limitations of this approach.

METHOD

The functional group included 74 ears of 43 male subjects with exaggerated losses, whose thresholds were later resolved to their actual hearing levels. The data were accumulated prospectively using the criteria described below, rather than by a retrospective analysis of clinical records. The subjects ranged in age from 22 to 72 (mean 50.3) years old. Fifteen (35%) were ≤ 44 years of age. Functional losses were present bilaterally in 31 (72%) of the subjects and in one ear for 12 (28%) subjects. The means and standard deviations for their functional and resolved hearing losses and ARTs are shown in Table 1.

A control group consisted of 50 ears of 29 subjects with sensorineural hearing losses with a variety of audiometric configurations and no signs of functional impairment. There were 19 males and 10 females ranging in age from 15 to 81 (mean 50.9) years old. Table 2 shows the means and standard deviations for their hearing levels and ARTs. As will be described, the findings for the functional subjects indicated that the 10th percentiles are most applicable when thresholds are ≥ 60 dB HL at 500, 1000, and/or 2000 Hz. The control ears, therefore, were selected to include a majority of ears with

Table 1 Means and Standard Deviations (SD) for Functional and Resolved Hearing Levels and Acoustic Reflex Thresholds for 74 Ears with Functional Hearing Losses

Frequency (Hz)	*250*	*500*	*1000*	*2000*	*4000*	*8000*
Functional Hearing Levels						
Mean	60.47	63.24	63.24	69.66	82.36	80.34
SD	20.57	22.65	23.49	23.77	22.17	21.25
Resolved Hearing Levels						
Mean	22.16	23.38	24.05	32.43	57.84	58.65
SD	10.78	11.03	12.46	18.55	22.53	26.51
Acoustic Reflex Thresholds						
Mean		90.07	89.93	94.46		
SD		9.71	8.64	12.07		

Data is given in dB HL (ANSI, 1969).

losses in this range. The thresholds were≥ 60 dB HL in 22 (44%) of the ears at 500 Hz, 33 (66%) at 1000 Hz, and 39 (78%) at 2000 Hz.

For the purpose of this paper, a hearing loss was considered as functional only if there was a discrepancy ≥ 15 dB between the SRT and the PTA. Other characteristics commonly associated with functional loss were also encountered, but an SRT–tonal discrepancy had to be found to avoid misclassifying a loss as exaggerated. For the same reason, the SRT was compared to the best frequency in cases with considerably sloping audiograms (Gelfand and Silman, 1985, 1993). All subjects had peak compensated static acoustic immittance and tympanometric peak pressure values within the normal range (Wiley et al, 1987; Wiley, 1989).

A functional hearing loss was considered to be resolved if the retest results included both good tonal–SRT agreement and good reliability for at least two successive retest sessions. This involved two criteria: (1) test–retest agreement within 5 dB at 1000 Hz within each retest session; and (2) agreement within 10 dB at each frequency from 500 to 4000 Hz between two retest sessions. In addition, there could be no other clinical manifestations suggestive of functionality (e.g., Rintelmann and Schwan, 1991) during these retest sessions.

The ART-based criteria for identifying functional hearing loss were: (1) ARTs falling below the 90th percentiles; and (2) for hearing losses ≥ 90 dB HL, ARTs failing to exceed the voluntary thresholds by more than 5 dB. Absent reflexes were always considered misses.

The second criterion reflects the fact that there is only one 10th-percentile value for all hearing levels ≥ 90 dB HL at each frequency (see Gelfand et al, 1990). This pooling creates an anomaly when using the 10th percentiles for hearing levels ≥ 90 dB. Here, certain cases would be missed by strict adherence to the cutoff line even though the ART is obviously too low for the apparent hearing loss. For HLs < 90 dB, all ARTs 5 dB above the hearing loss fall below the 10th percentile.

The procedures, instrumentation, calibration procedures, and test environments were the same as has been reported previously (e.g., Silman and Gelfand, 1981b; Gelfand et al, 1990). All tests were done by audiologists with extensive experience in the evaluation of patients

Table 2 Means and Standard Deviations (SD) for the Hearing Levels and Acoustic Reflex Thresholds of 50 Ears with Sensorineural Loss

Frequency (Hz)	*250*	*500*	*1000*	*2000*	*4000*	*8000*
Hearing Levels						
Mean	45.3	52.7	60.9	66.7	71.4	76.3
SD	22.9	20.0	15.2	19.6	21.8	29.9
Acoustic Reflex Thresholds						
Mean		97.3	100.9	104.7		
SD		14.9	14.3	14.8		

Data is given in dB HL (ANSI, 1969).

with functional impairments. The ARTs at 500, 1000, and 2000 Hz were obtained using a bracketing technique with visual monitoring and 5-dB steps.

RESULTS

Sixty-seven (90.5%) of the ears actually had sensorineural hearing losses once their functional components were resolved, when normal is defined as thresholds ≤ 25 dB HL at all frequencies from 250 to 8000 Hz. Only 6 (8.1%) of the ears would be considered normal using the criteria of the modified bivariate plotting procedure (thresholds ≤ 20 dB HL from 250–4000 Hz and ≤ 30 dB HL at 4000 Hz [Silman et al, 1984b]), and only 3 of them were from subjects ≤ 44 years old. Consequently, the modified bivariate method would have been applicable in only 3 (4.1%) of the 74 ears in this sample of adults with functional hearing losses.

The functional subjects' ARTs are compared to the 10th percentile cut-off values at 500, 1000, and 2000 Hz in Figures 1–3, respectively. The numbers and percentages of ears with functional hearing loss identified and missed at each frequency are summarized in Table 3. Table 3 and Figures 1–3 reveal that functional losses ≤ 55 dB HL are not identified by tonal ARTs. On the other hand, functional losses ≥ 60 dB HL are correctly identified 57 to 68 percent of the time on a frequency-by-frequency basis.

In order to identify an ear with functional impairment in clinical practice, it would be necessary for at least one of the three ARTs to meet the functional criteria. This would require an ear to have a threshold of ≥ 60 dB for at least one frequency in the 500 to 2000 Hz range. Table 4 shows the sensitivity and false negative rates for tonal ARTs as a test of functional loss for the 74 ears in this study, broken down according to the number of frequencies (500–2000 Hz) with thresholds ≥ 60 dB HL. Sensitivity ranged from 70.9 percent when only one reflex test frequency had a threshold ≥ 60 dB HL to 85.7 percent when all three thresholds were ≥ 60 dB HL. As expected, only one ear (5.3%) was correctly identified among the 19 ears in which all three thresholds were ≤ 55 dB HL.

Reflex thresholds were at or below the voluntary hearing threshold in two cases each at 500 and 1000 Hz and once at 2000 Hz. There were also five cases (three at 500 Hz and one each at 1000 and 2000 Hz) where the ART was 5 dB above the voluntary hearing level. Only one ear was identified solely on the basis of the ARTs being 5 dB above the voluntary thresholds, in which case the criterion was met at two frequencies.

Figures 1–3 also show the ARTs of the 50 ears with real sensorineural losses. Only 3 of the 50 ears with sensorineural losses had ARTs under the 10th percentiles, which is an overall false positive rate of 6 percent in this sample. Table 4 shows the specificity and false positive rates according to the number of thresholds ≥ 60 dB HL in the 500- to 2000-Hz range.

DISCUSSION

Audiologists have been using ARTs to identify or at least confirm functional loss for many years, although this has been done without the benefits of an explicit ART criterion for exaggeration or knowing the delimitations of the approach. This study has shown that tonal ARTs 10th percentiles are useful for identifying and/or confirming functional impairments, providing the voluntary thresholds are ≥ 60 dB HL at one or more of the reflex-activator frequencies. Equally important, tonal ARTs cannot

Table 3 Correct Identifications (Hits) and Misidentifications (Misses) of Functional Hearing Loss at Each Frequency

Functional Loss	*Frequency (Hz)*	*N (Total)*	*Hits*		*Misses*	
			Number	*Percentage*	*Number*	*Percentage*
≤ 55 dB HL	500	31	1	3.2	30	96.8
	1000	36	2	5.6	34	94.4
	2000	23	0	0	23	100.0
≥ 60 dB HL	500	43	25	58.1	18	41.9
	1000	38	26	68.4	12	31.6
	2000	51	29	56.9	22	43.1

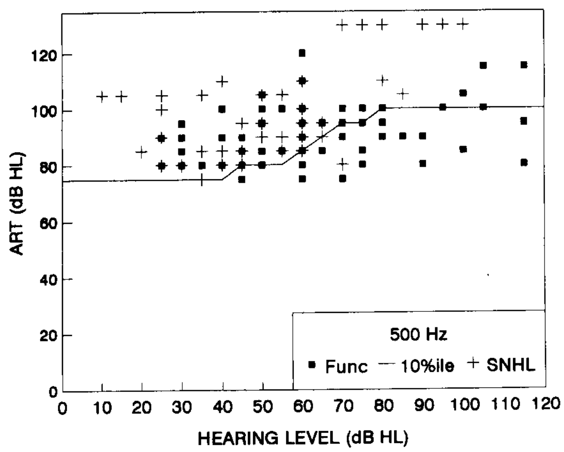

Figure 1 Acoustic reflex thresholds (ARTs) and 10th percentile cut-off values as a function of hearing level for functional thresholds (boxes) and sensorineural losses (crosses) at 500 Hz.

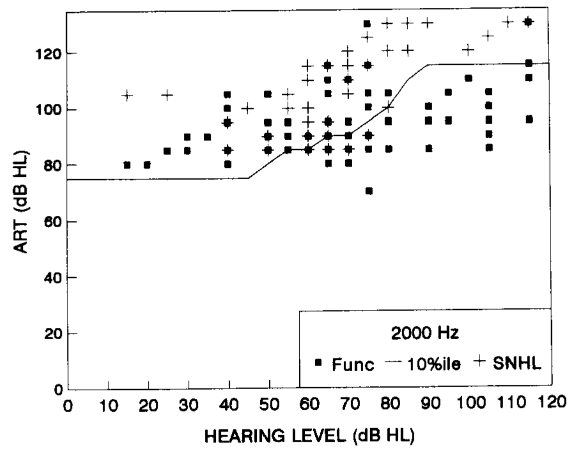

Figure 3 Acoustic reflex thresholds (ARTs) and 10th percentile cut-off values as a function of hearing level for functional thresholds (boxes) and sensorineural losses (crosses) at 2000 Hz.

indicate functionality when the voluntary thresholds are less than 60 dB HL at all of the reflex-activator frequencies. These findings are consistent with the relationship between ARTs and the magnitude of hearing loss (Silman and Gelfand, 1981b; Gelfand et al, 1983, 1990; Gelfand and Piper, 1984) and extend the clinical applications of the ART to the lower as well as the upper ends of its distribution.

Tonal ARTs can identify/confirm functional loss with a sensitivity of 71 to 86 percent depending on how many behavioral thresholds are ≥ 60 dB HL in the 500- to 2000-Hz range. These values compare very favorably to the sensitivity of the PTA-SRT discrepancy, which is about 62 to 70 percent for comparable adult

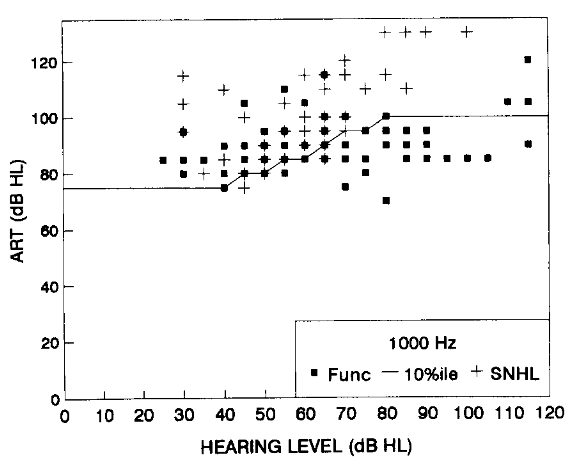

Figure 2 Acoustic reflex thresholds (ARTs) and 10th percentile cut-off values as a function of hearing level for functional thresholds (boxes) and sensorineural losses (crosses) at 1000 Hz.

samples (Chaiklin and Ventry, 1965; Alberti, Morgan, and Czuba, 1978). The hit rates in these studies may reflect the effects of sloping losses, for which specific criteria for the PTA-SRT discrepancy lose robustness. If one uses the modified bivariate method in addition to the 10th percentiles, then the hit rate should increase to an extent reflecting the functional ears that are actually normal in patients who are ≤ 44 years old, regardless of their functional thresholds.

The specificity of tonal ARTs using 10th percentiles as a test for functionality is expected to be about 10 percent by definition. This expectation was confirmed for a control group of 50 ears with true sensorineural losses, in which the false positive rate was 5 to 7 percent depending on the number of thresholds ≥ 60 dB HL at 500 to 2000 Hz.

Combining the current findings for tonal ARTs and those reported by Silman (1988) for the modified bivariate method, it appears that the acoustic reflex can assist in the diagnosis of functional impairment as follows (presuming a hearing loss): (1) modified bivariate results falling into the "normal region" of the bivariate graph suggest the presence of functionality and a strong likelihood of normal organic hearing thresholds; (2) tonal ARTs falling below the 10th percentile (and/or no more than 5 dB above an auditory threshold that is ≥ 90 dB HL) suggest the presence of a functional component.

Several limitations, however, must be kept in mind when using ARTs to reveal or confirm functional impairments. Results falling into the "impaired region" on the modified bivariate

Table 4 Sensitivity, Specificity, and False Negative and False Positive Rates (in Percent) according to the Number of Frequencies (500–2000 Hz) with Thresholds ³ 60 dB HL

Number of Thresholds ≥ 60 dB HL	*Sensitivity*	*Specificity*	*False Negative*	*False Positive*
All 3	85.7	94.7	14.3	5.3
≥ 2	78.6	93.5	21.4	6.5
≥ 1	70.9	29.1	29.1	6.8
0*	5.3	100.0	94.7	0

*All thresholds ≤ 55 dB at 500–2000 Hz.

plot do not rule out functional hearing loss because of age effects and the fact that most patients with functional impairments have underlying organic hearing losses. Tonal reflex threshold 10th percentiles cannot be used to identify/confirm functional impairments when thresholds are less than 60 dB HL because ARTs are not systematically dependent upon hearing sensitivity within this range of hearing loss. These limitations agree with the manner in which both BBN and tonal ARTs are related to the magnitude of organic hearing impairment (see, e.g., Gelfand, 1984; Silman and Silverman, 1991).

Most conservatively, tonal ARTs below the 10th percentile for losses ≥ 60 dB HL provide physiologic support for the suspicion of a functional loss that is based on a PTA-SRT discrepancy. Using both the PTA-SRT discrepancy and ART 10th percentiles should improve the identification of functionality, because both methods have limitations (the former becomes ambiguous with sloping losses and the latter requires thresholds ≥ 60 dB HL), although data are needed to verify this expectation. Other procedures can then be applied to confirm one's suspicions.

The purpose of this study was to identify the usefulness and limitations of tonal ARTs in the diagnosis of functional loss, rather than to compare this method to other physiologic approaches. Part of the desirability of using ARTs in functional loss assessment, however, comes from their routine nature, compared to factors that limit the daily use of other physiologic methods. For example, cortical evoked potentials (Coles and Mason, 1984) and galvanic skin responses (Chaiklin and Ventry, 1963) can address a wider range of losses than tonal ARTs, and they can also yield physiologic results that closely approximate true behavioral thresholds. These two procedures, however, have well-established practical limitations and are rarely used. Otoacoustic emissions (OAEs) are obliterated by many sensorineural losses and auditory brainstem responses (ABRs) are substantially affected by hearing losses in the high frequencies, yet most functional patients actually have such organic losses (Chaiklin and Ventry, 1963; Coles and Mason, 1984; Gelfand and Silman, 1985, 1993). Moreover, the ABR lacks frequency specificity. These issues limit ABRs and OAEs as tests to authenticate functional losses, at least as a matter of routine. In contrast, almost every patient's initial evaluation routinely includes acoustic reflexes, so that their application to functional loss comes virtually without cost.

In conclusion, this study supports the suggestion that tonal ARTs falling below the 10th percentiles of the normal/cochlear distribution can be used to identify or confirm functional impairments, although their usefulness is limited to cases in which voluntary thresholds are at least 60 dB HL.

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