

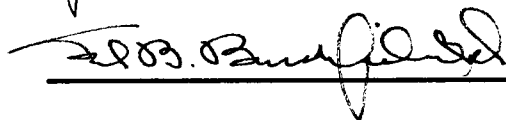
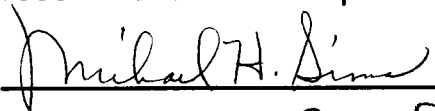
To the Graduate Council:

I am submitting herewith a thesis written by Kimberly A. Preissler entitled "A Comparison of Distortion Product Otoacoustic Emission Input/Output Function Procedures to Estimate Cochlear Sensitivity in Dogs." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Masters of Arts, with a major in Audiology.



James W. Thelin, Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:



Associate Vice Chancellor and
Dean of the Graduate School

**A COMPARISON OF THREE
DISTORTION PRODUCT OTOACOUSTIC EMISSION
INPUT/OUTPUT FUNCTION PROCEDURES
TO ESTIMATE COCHLEAR SENSITIVITY
IN DOGS**

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Kimberly A. Preissler

May, 1995

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ABSTRACT

The purpose of the present study was to determine which of three distortion product otoacoustic emission (DPOAE) input/output (I/O) procedures would elicit minimum response levels (MRLs) at the lowest primary signal levels. DPOAE I/O functions were recorded from six dogs with presumed normal hearing as determined by auditory brainstem response, otoscopy, tympanometry, ipsilateral acoustic-reflex thresholds, and DPOAEs.

The procedures (P1, P2, and P3) used to determine DPOAE MRLs at the lowest levels of the primary signals (L1 and L2) were:

P1) Equal level primary signals that were increased in level together ($L1 = L2$).

P2) Higher frequency primary signal fixed 10 dB lower in level than lower frequency primary signal and both increased together in level ($L1 = L2 + 10 \text{ dB}$).

P3) Lower frequency primary was fixed at 65 dB with the higher frequency primary signal increased in level ($L1 = 65 \text{ dB SPL}$; $L2$ varied).

A second purpose was to determine the level of correlation between DPOAE detection threshold and the slope of corresponding DPOAE I/O functions.

Statistical analysis revealed the lowest MRLs were obtained with P2. Using P1 and P3 the average MRLs were 13 dB and 3 dB higher respectively. The mean I/O function slope was 0.75 at 2000 Hz and 1.0 at 4000 Hz but they were not significantly different. Further research using P2 is proposed to correlate MRL measures with degree of cochlear hearing loss.

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1. INTRODUCTION

In veterinary clinical science and basic animal research, there is a growing demand for a procedure for estimating cochlear sensitivity. Because acquired and hereditary deafness are common in pet animals, there is an increasing need for additional objective means of evaluating auditory function. Such a procedure will not only have application to dogs and other animals, but also to humans especially those who are unable to cooperate during behavioral hearing tests (e.g., infants, comatose patients, mentally retarded persons).

Behaviorally-based hearing tests can be performed by dogs, but it is necessary to have dogs that are trained to perform certain tasks. In addition, the tests are costly and have practically no application in veterinary clinical practice. At present, researchers and/or veterinarians who evaluate auditory function in animals often rely on physiologic procedures to measure auditory function that is related to but not a direct measure of, auditory sensitivity.

Currently, an appropriate protocol for a dog audiogram has not been established. The purpose of the present study is to develop a procedure that would allow cochlear sensitivity to be measured in those subjects who are unable to cooperate during behavioral-based hearing tests, with the focus of this study being dogs.

Physiologic Measures of Auditory Functions in Current

Use. The physiologic procedures that are currently used include aural acoustic immitance measures and auditory brainstem responses. Aural acoustic immitance measures are used to perform tympanometry and acoustic reflex measures (Lilly, 1972). Tympanometry is used to provide a qualitative description of middle-ear function. Abnormal tympanometry is associated with abnormal middle-ear function which is often related to conductive hearing loss. Unfortunately, hearing sensitivity cannot be predicted from a tympanogram nor does it provide information about cochlear sensitivity.

Acoustic reflex (AR) measures depend on function of the middle ear, cochlea, neural pathways in the lower portion of the auditory brainstem, cranial nerves V and VII, and middle-ear muscles. Though AR thresholds depend on cochlear function, they are not typically used to estimate changes in cochlear sensitivity. In general, AR thresholds have been used to indicate the presence of abnormality but have not been used to estimate cochlear sensitivity. This is because there is a weak correlation between AR thresholds and thresholds of audibility. For example, moderate cochlear hearing loss may result in only minimal elevation of AR thresholds. In humans, an attempt has been made to categorize as mild to moderate, moderate to severe, and severe to profound, the degree of cochlear loss using derived measures involving differences between AR thresholds for pure tones and for noises of varying bandwidths (Jerger, Burney, Mauldin, & Crump, 1974). Results of this procedure

permit only a gross estimate of cochlear sensitivity.

Auditory brainstem response (ABR) procedures have been used for assessing auditory function in animals and humans (Marshall, 1986; Sims, 1990). Successfully recording an ABR depends on integrity of the peripheral structures including the cochlea, and central neural structures at least to the level of the inferior colliculus in the brainstem. The majority of ABR testing in humans and animals has been conducted using click stimuli that evokes hair cell activity somewhere in the frequency region from 1000 to 4000 Hz. Using click stimulation, there are many different configurations of hearing loss for which similar ABR results could be obtained. ABR data obtained near the threshold of audibility is very time consuming because it requires averaging from a large number of stimulus presentations. In humans, frequency specific stimuli have been used but the results are not as robust as those obtained with click stimuli and the data acquisition procedure is very time consuming (Kileny, 1981; Davis, Hirsh, Popelka, & Formby, 1984)

Otoacoustic Emissions. The measurement of otoacoustic emissions (OAEs) is an objective procedure that can provide information about cochlear function in response to sound stimulation. OAEs are thought to be generated by outer hair cell (OHC) movement in response to acoustic stimuli (Kemp, 1978). Energy from OHCs is transmitted in a reverse fashion through the fluids of the cochlea, through the middle ear, and into the external auditory canal where it can be measured as acoustic energy. The

normally-functioning cochlear amplifier provides the auditory system with up to 40 dB of amplification for low-level acoustic stimuli. Damage to the cochlear amplifier results in mild to moderate hearing loss and to diminution or obliteration of the OAE (Kemp, Ryan, & Bray, 1990). The majority of OAE research in humans has been conducted using two types of emissions that are generally classified according to characteristics of the stimulus used to elicit them or characteristics of the cochlear events that generate them: transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs).

Transient Otoacoustic Emissions. The most common procedure for recording TEOAE is to use a click stimulus to activate a large portion of the cochlea and to measure the emission that occurs later in time, after the cessation of the click. A frequency spectrum is computed from an averaged time waveform to determine the frequencies at which OAE energy is present. The available data from human beings and animal subjects indicate that TEOAEs are present in almost all ears that have normal cochlear function (Garrubba, Grandori, Lamoretti, and Antonelli, 1990; Leonard, Smurzynski, Jung, and Kim, 1990; Harris, Probst and Wegner, 1991; Sims, Rogers, & Thelin, 1994; Hurley and Musiek, 1994).

The value of OAEs as a measure of auditory sensitivity depends in part on their ability to differentiate between normal hearing ears, those with hearing loss, and among varying degrees of hearing loss. Several investigators have used dichotomized grouping to distinguish between normal and hearing impaired subjects. The

upper limits for cutoff for normal hearing that have been used ranged from 20 to 30 decibels hearing level (dB HL). These studies all employed click stimuli with a range of stimulus levels from 75 to 86 dB SPL (Kemp, 1978; Kemp, Ryan, and Bray, 1990; Garrubba, Grandori, Lamoretti, and Antonelli, 1990; Hurley & Musiek, 1994; Prieve, Gorga, and Neely; 1991). These results indicate that TEOAEs cannot be elicited from ears with mean pure-tone thresholds that are greater than 20 to 30 dB but report normal emissions are present at hearing levels that are below 20 dB.

Collet, Levy, Veuillet, Truy, & Morgan (1993) recorded TEOAEs from 931 ears with varying degrees of sensorineural hearing loss utilizing click stimuli of 81 dB SPL. Using 5-dB steps, they determined the percentage of responses as a function of the threshold at the *best hearing frequency* over the range from 250 to 8000 Hz (Figure 1). When the best frequency hearing level was 0 dB HL, the response rate was nearly 100 percent and there was a systematic decrease in the response rate until 45 dB HL and higher levels where no responses were obtained. An important finding of Collet, et al. was that TEOAEs may be present at frequencies for which the hearing thresholds were substantially greater than 45 dB HL. This occurred only when the hearing threshold for at least one other frequency was 40 dB HL or less. The implication of this finding is that the presence of a TEOAE at a particular frequency may not mean that there is hearing at that frequency.

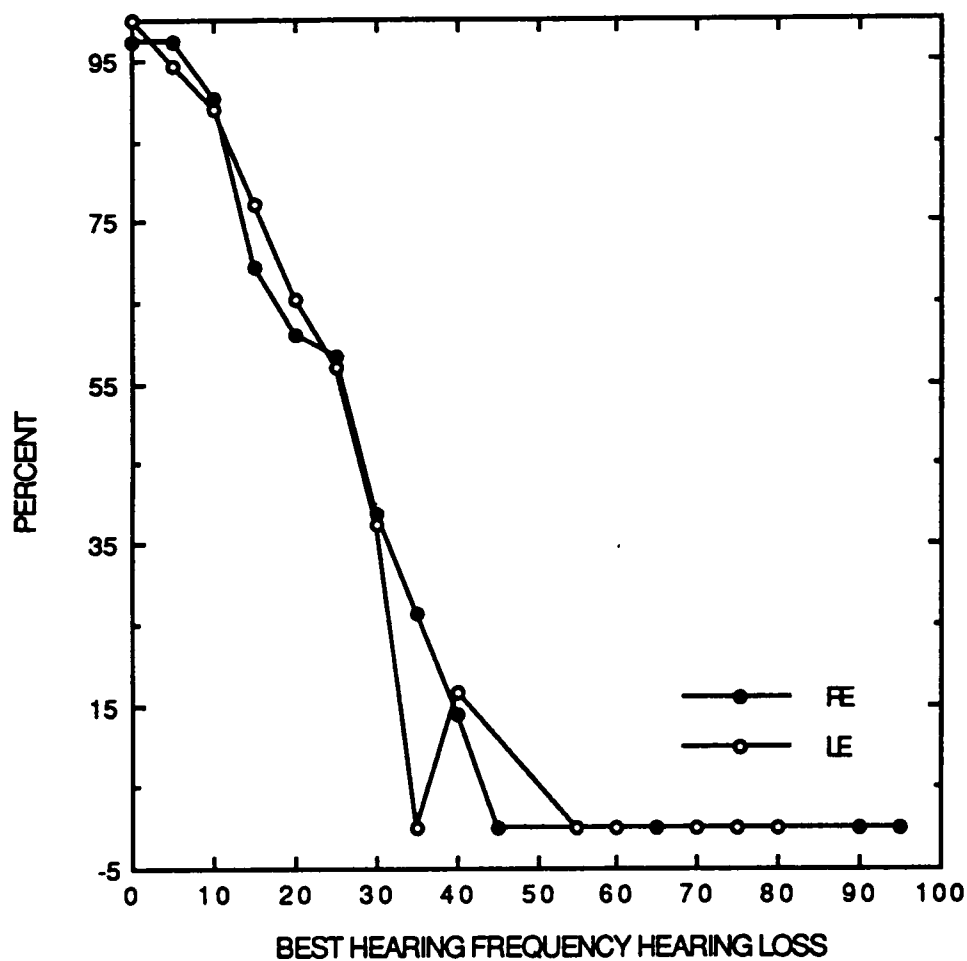


FIGURE 1. Presence of OAEs according to hearing loss on the best hearing frequency.

Distortion Product Otoacoustic Emissions. With TEOAEs, the click signal stimulates the cochlea at many frequencies and the OAE responses are measured at many frequencies. With DPOAEs, the signal simultaneously stimulates at the primary signals, two pure-tone signals (classified as L1 and L2 or F1 and F2), and DPOAEs are recorded as summation and difference tones of L1 and L2. The largest and most commonly recorded DPOAE is $2 F_1 - F_2$. The ability to record DPOAEs that depend on stimulation at different frequencies provides the opportunity to obtain a description of the sensitivity of cochlear function at those frequencies.

Distortion Product Audiograms. The DPOAE audiogram provides information about emission activity across frequencies by revealing the magnitude of the emission as a function of the geometric mean of the primary signal frequencies. Typically, the DPOAE is generated by presentation of equal-level primary signals over a frequency range from 500 to 8000 Hz. Although the DP audiogram provides information in a format similar to a typical clinical audiogram, it is crucial to realize that it does not provide a measure of pure-tone hearing thresholds.

Detectable DPOAEs have been shown to be present in 85 to 100 percent of normal and near-normal human ears (with pure-tone thresholds of 20 dB HL or less) depending on frequency between 1000 and 6000 Hz (Probst, Antonelli, and Pieren, 1990; Peterein, Karzon, Garcia, & Gates, 1992; Nelson and Kimberley, 1992; Lasky, Snodgrass and Hecox; 1994). Further, when hearing loss is present, DPOAEs are either reduced in level or absent. Harris (1990)

demonstrated that the level of the DPOAEs were reduced in ears with high frequency hearing loss. DPOAEs were absent at frequencies for which the hearing levels were greater than 50 dB. In addition, data from case studies on hearing loss caused by Meniere's disease, ototoxicity, acoustic trauma, or various other diseases found the probability of obtaining a DPOAE and the level of the DPOAE decrease as the hearing loss is increased (Martin, Lonsbury-Martin, Probst, Scheinin, & Coats, 1987; Leonard, Smurzynski, Jung & Kim, 1990; Whitehead, Lonsbury-Martin, & Martin, 1992). This agrees with information that DPOAEs are not obtained at frequencies where significant hearing loss is present in contrast to TEOAEs as demonstrated by Collet, et al. (1993).

Distortion Product Input/Output Function. Another DPOAE measure is the growth or input/output (I/O) function; it is the measurement of increase in DPOAE level with increases in the level of the primary signals. DPOAE I/O functions have been measured using frequencies from 500 to 8000 Hz with stimulus intensities typically ranging from 30 to 85 decibels sound pressure level (dB SPL). DPOAE I/O functions can be generated using equal or unequal primary signal levels. Most commonly, equal primaries that are increased together in level are used (Gaskill and Brown, 1990; Leonard et al., 1990; Harris and Probst, 1991; Bonfils and Avan, 1992; Franklin, McCoy, Martin, and Lonsbury-Martin, 1992; Nelson and Kimberley, 1992; Peterlein et al., 1992; Kimberley, Hernadi, Lee and Brown, 1994).

A second method utilizes primary signals of unequal level. One

of the primary signals is delivered at a fixed level and the other primary signal is 10 dB higher or lower. Then, both stimuli are increased in level together. Quiñónez and Crawford (1994) used this method with the level of the first primary signal 10 dB greater than the level of the second primary signal.

In a third method, one of two primaries is fixed at a relatively high level while the other primary signal is systematically raised in level. Gaskill and Brown (1990), and Rogers (1994) used this method to record I/O functions.

The investigators mentioned above used DPOAE I/O functions primarily to examine the growth of the DPOAE and also to determine the combinations of signals that gave the largest DPOAE responses. Quiñónez and Crawford (1994) examined DPOAE slope to determine the effects of hearing loss. They found a moderate correlation between increase of DPOAE slope and decrease of hearing sensitivity.

In the present study, DPOAE I/O functions were used to determine the minimum response level (MRL) that can be obtained with the three experimental I/O function procedures. Most investigators have not attempted to attain the lowest response levels because the DPOAE MRL is partially determined by the noise floor of the measurement system rather than the subject's DPOAE threshold. Additionally, there is evidence that DPOAE MRLs depend on the method of measurement. A comparison of methods by Gaskill and Brown (1990) using a paradigm with one primary signal fixed while increasing the other primary signal was compared to a

paradigm using equal level primary signals. They found that a unequal primary signal paradigm elicited DPOAE detection thresholds at lower levels than using equal level primary signals. This observation was also reported by Rogers (1994), where significant enhancement was provided by using L1 fixed at a relatively high level while L2 was systematically increased in level.

To date, investigators have not compared methods to determine which of these three I/O function procedures yields the lowest DPOAE MRLs. One purpose of the present study was to determine the DPOAE I/O function procedure that would elicit DPOAE MRLs at the lowest levels of the primary signals using three methods:

- 1) Equal level primary signals that were increased in level together.
- 2) Higher frequency primary signal fixed 10 dB lower than lower frequency primary signal and both increased together in level.
- 3) Lower frequency primary was fixed at 65 dB with the higher frequency primary signal increased in level.

A second purpose was to determine the correlation between MRL and the slope of the corresponding DPOAE I/O functions.

2. REVIEW OF LITERATURE

General Physiology. The cochlea is responsible for converting mechanical energy into neural impulses. Three rows of outer hair cells (OHCs) and one row of inner hair cells (IHCs) are the primary sensory cells of the cochlea. The Organ of Corti, which is the end organ of hearing sits on the basilar membrane. There is evidence to suggest that a positive feedback mechanism exists between the OHCs and the basilar membrane. The OHCs are thought to contribute to the active mechanical response of the basilar membrane which allows maximum displacement at the peak of the traveling wave. Therefore, the OHCs are believed to be biochemical amplifiers (Burch-Sims and Ochs, 1992).

Origins of Otoacoustic Emissions. OHCs are capable of rapid changes in length when electrically stimulated. The mechanical amplification provided by the OHC electromotile response creates motion patterns within the basilar membrane that are transmitted outward from the cochlea through the middle ear. As a result of the reverse transduction process, sound can be recorded in the ear canal and is referred to as an otoacoustic emission (OAE). Sounds of this type occur either spontaneously (spontaneous OAE) or in response to acoustic stimulation (evoked OAE) (Probst, Lonsbury-Martin, & Martin, 1991).

In 1948 Gold suggested the presence of the cochlear amplifier,

which he considered to be an unstable, active process. In 1978, Kemp verified Gold's belief by measuring evoked otoacoustic emissions (OAEs). OAEs are sounds generated by the normal cochlea and can be recorded in the external ear canal using a computerized averaging system. There is evidence that otoacoustic emissions (OAEs) are a direct reflection of processes within the cochlea that are responsible for the high sensitivity, sharp tuning, and wide dynamic range of the normal auditory system (Norton, 1992).

Types of Otoacoustic Emissions. Two general classes of OAEs have been identified: spontaneous and evoked. Spontaneous OAEs (SOAEs) are pure tones of about 20 dB SPL found in the quiet ear canal with no external sound stimulation in approximately one-third of normal ears (Kemp, 1979; Kemp, 1990; Lonsbury-Martin, Harris, Stagner, Hawkins, & Martin, 1990). SOAEs have limited clinical application because they are not always present and are not necessary for normal hearing.

Evoked OAEs (EOAEs) can almost always be evoked in the healthy ear. The most common way to evoke OAEs is to provide a very short (100 μ s) but strong stimulus, repeated about every 20 ms (Kemp, 1979). Using a stimulus with rapidly fluctuating intensity, such as two beating tones, non-linear processing results in distortion products which can be separated from the stimulus by spectral analysis (Kemp, 1979). Intermodulation distortion products that are recorded in the ear canal in response to two-tone stimulation are called distortion product OAEs (DPOAEs).

Intermodulation or distortion products are added by the nonlinear mechanics of the cochlea, and they can be instantly observed utilizing a spectrum analyzer or phase locked system (Kemp, 1990). DPOAEs are thought to exist because the ear is a nonlinear processor of acoustic signals (Kemp, 1990).

DPOAEs are produced by a stimulus consisting of two simultaneous pure tones at frequencies, L1 and L2, which are called the primary signals or primaries. The frequency of the distortion product is related to the frequency of the two primary stimuli by an algebraic expression. The largest DPOAE, the cubic difference tone, is generated at the frequency described by the expression $2F_1 - F_2$ (Kemp, 1979; Lonsbury-Martin, Martin, Probst, & Coats, 1987).

DPOAEs can be obtained quickly, objectively, and test a wide range of frequencies simultaneously. DPOAEs are usually not measurable in ears with greater than 50 dB of hearing loss but are present in almost all normally hearing ears (Probst, Antonelli, and Pieren, 1990; Harris, 1990; Glatcke & Kujawa, 1991; Peterein, Karzon, Garcia, & Gates, 1992; Nelson and Kimberley, 1992; Lasky, Snodgrass and Hecox; 1994). This suggests the obvious utility of DPOAEs for assessing auditory dysfunction.

Although DPOAEs are not typically used to measure auditory threshold, the absence of DPOAE energy at any stimulated frequency component is significant for hearing loss at that frequency. The search for an objective, sensitive, and frequency-specific tool to monitor hearing loss has motivated much research. As currently used, DPOAEs confirm the presence of a mechanism needed for

normal threshold. An absent OAE is associated with hearing loss at that frequency and suggests an investigation for middle ear or cochlear pathology.

Harris (1990) demonstrated a relationship between pure tone behavioral threshold and DPOAE amplitude in two groups: normal and hearing impaired due to chronic noise exposure. Equal level primaries were presented at 65 dB and then reduced in 5-dB steps until the 2F1-F2 amplitude was less than 3 dB above the level of the noise floor for two consecutive presentations. Reduced emissions were observed at frequency regions where hearing loss occurred. Therefore, when DPOAEs were absent or reduced in amplitude, there was a high probability of a behavioral auditory threshold less than 50 dB HL. DPOAE amplitudes were comparable at low frequencies where both normal and hearing-impaired groups had normal pure tone behavioral thresholds (less than 20 dB). They concluded that when amplitudes of DPOAEs are reduced, hearing threshold at the test frequency is greater than 50 dB HL.

Probst et al. (1990) also measured DPOAEs in normal (<20 dB HL) and hearing impaired individuals. The levels of the primaries were L1=73 dB HL, L2=67 dB HL with a frequency ratio from 1.15 to 1.35 depending on the frequencies used. Emissions were considered present based on a criterion of a level that was at least 6 dB above the noise floor. Depending on frequency, 85 to 98 percent of normal subjects had emissions present. Reduced or absent emissions were measured when hearing loss was present. DPOAE amplitude above the noise floor was plotted as a function of dB HL at 1 kHz for all

subjects. As hearing threshold increased, the DPOAE amplitude decreased. These results agree with Harris (1990) who indicated a significant relationship between the level of the DPOAE and hearing threshold at the test frequency.

Peterein et al., (1992) measured DPOAE thresholds and auditory thresholds from 79 adults who were either normal hearing or had varying degrees of hearing loss. DPOAE I/O functions were elicited with an L2/L1 ratio of 1.21 from 25 to 85 dB SPL at 1000, 2000, and 4000 Hz. The levels of the primaries were equal and the criterion for an emission was >3 dB above the noise floor. The presence of DPOAE as an indicator of hearing loss was plotted. Depending on the test frequency, the 0-25 dB HL hearing loss group had emissions present 89 to 97% of the time. As hearing loss increased above 25 dB HL, the level of DPOAE amplitude decreased. When behavioral threshold was >50 dB HL, DPOAE were absent or attenuated.

Nelson and Kimberley (1992) measured auditory thresholds and DPOAE thresholds in 32 normal (<20 dB HL at all frequencies) ears and 21 ears with a moderate hearing loss at one or more test frequencies to differentiate between DPOAEs in normal and hearing-impaired ears. DPOAE I/O functions were measured at seven frequencies between 707 and 5656 Hz with an L2/L1 ratio of 1.2 and equal level primaries that were varied in 6 dB steps, from 30 dB SPL to 78 dB SPL. Normal ears produced DPOAEs that rose above the noise floor as low as 30 dB for specific frequencies and exhibited large DPOAEs at all test frequencies. The typical DPOAE I/O

function from ears with hearing loss were reduced in amplitude and only began to rise above the noise floor at higher stimulus levels.

DPOAE activity is measured using two procedures, the DPOAE audiogram and the I/O function. The DPOAE "audiogram" provides information about emission activity across frequencies by measuring the amplitude of the emission as a function of the geometric mean of the frequencies of the primary signals. The DPOAE I/O function demonstrates the growth in DPOAE level as a function of increasing the level of the primary signals. DPOAE I/O functions allow several important response parameters to be quantitatively specified: the DPOAE MRLs, maximum DPOAE level, and the slope of the growth function.

The frequency separation of the primary signals has a significant effect on DPOAEs. Recent studies have indicated that the optimal ratio between the primaries necessary to acquire the largest DPOAEs is 1.225 (Harris, Lonsbury-Martin, Stagner, Coats, and Martin, 1989; Gaskill and Brown, 1990; Rickman, Chertoff, and Hecox, 1991; Rogers, 1994).

DPOAE measurements have been used to assess and monitor auditory function in dogs. DPOAEs can be elicited and recorded consistently from dogs at frequencies between 1.00-8.01 kHz (Rogers, Thelin, Sims, and Muenchen, 1994). They found the response levels from dogs to be more robust than those normally found in human ears.

3. METHOD

Experimental Animals. Six adult dogs were used in this study. The dogs were healthy and responded normally to human voices and other sounds. All test ears were examined otoscopically and were free of excessive cerumen and debris.

Qualification Procedures.

Anesthesia. Prior to anesthesia, each dog was given atropine (atropine sulfate: AmVet Pharmaceuticals, Fort Collins, CO) (0.044 mg/kg, IM), torgugesic (butorphanol tartrate, Fort Dodge Laboratories, Fort Dodge, IA) (0.11-0.22 mg/kg, IM). Pentobarbital (Anthony Products, Arcadia, CA) (13.2 mg/kg, IV titrated to effect) was used to induce a light plane of anesthesia. Additional pentobarbital was given as needed throughout the recording session. (See Appendix B).

Tympanometry, AR threshold tests and ABR tests were performed on each dog to further establish normal auditory function. The results of these tests were required to be within normal limits for each dog to qualify for the study.

Acoustic Immitance. Acoustic immitance measures were performed with an acoustic immitance measuring system (Amplaid Model 701-702) using a 226 Hz probe frequency. The absolute value of acoustic immitance was considered within normal limits if it was > 0.3 acoustic mmhos. The tympanogram was required to be peaked rather than rounded or flat. Admittance maximum had to be

localized between ± 150 daPa (re: room pressure). Ipsilateral acoustic reflexes were measured at 500, 1000, 2000, and 4000 Hz and were required to be 110 dB or less. Acoustic immittance data for subject qualification are shown in Appendix B.

Auditory Brainstem Response. ABR measures were recorded for the experiment at each ear using a commercial auditory evoked potential measurement system (Nicolet Compact Four). The signals were 100 μ s clicks (alternating polarity) presented at a rate of 31.4 clicks/second. A subcutaneous needle electrode (+) was placed at the vertex and a similar reference electrode (-) was situated just rostral to the tragus on each side. The ABR latencies for peaks I - VI and the maximum response amplitude were required to be within normal ranges as specified by Sims (1990). ABR MRL data for subject qualification are shown in Appendix B.

Experimental Procedures.

Experimental Equipment. The dogs were placed on a padded surface in a sound attenuating booth designed for small animals (Industrial Acoustics Corporations) to minimize background noise from external sources. Each dog's mouth was open with the tongue projected to minimize respiratory noise. Background noise levels without the dog in the chamber were below the levels permissible for audiometric testing by ANSI standard S3.1-1977.

The DPOAE signals were generated and the DPOAE responses were measured using an otoacoustic emission test instrument (Virtual Corporation, Model 330 with software version 6.5) operated

by a computer (MacIntosh, Model IICX). Data analysis was accomplished using a custom-made frequency spectrum videoscreen display (Virtual Corporation) that permits frequency analysis of signals and responses from 0 to 20 kHz in 10-Hz wide bands.

Experimental Signals. Each DPOAE was measured using two pure tone signals (the primary signals) levels specified in dB SPL (re: 20 μ pa) The calibration of these tones is provided in Appendix A. Each pair of primary signals was specified using the geometric mean of the two primary frequencies: the frequency ratio of the primary signals was 1.21 for each of the three experimental procedures. The levels of the primary signals were required to be within 2.5 dB SPL of their nominal levels. With the computer driven signal presentation sequences, time did not permit a determination of signal levels until after the completion of the trial. For seven of the seventy-two DPOAE I/O function recordings (3 procedures X 2 frequencies X 6 subjects X 2 trials), the actual signal levels of the primary signals were not appropriate. These data were eliminated from the analysis and compensation for the lost data was made by the statistical analysis program (JMP 3.1). In these instances, the data (Appendix E) is identified by **.

Experimental Procedures. There were three different I/O functions procedures used in this study:

Procedure 1: $L1 = L2$. I/O functions were measured as equal level stimuli were covaried from 30 dB to 75 dB SPL.

Procedure 2: $L1 = L2 + 10$ dB. The level of L2 was 10 dB less than L1. L1 was incremented from 30 dB to 75 dB while L2 was

incremented from 20 dB to 65 dB.

Procedure 3: L1 = 65 dB SPL; L2 varied. One of the tones, L1 was held constant in level at 65 dB SPL while the other primary signal (L2) was increased from 20 to 65 dB SPL.

The levels of the signals (L1 and L2) for each procedure is shown in Table 1. For each procedure, the primary signals were incremented in an ascending order to minimize adaptation or fatigue (Nelson & Kimberley, 1992).

DPOAEs were recorded from one ear of each dog. DPOAE time waveforms were averaged over 32 signal presentations to reduce the effects of the noise floor before a Fourier analysis was performed to obtain a frequency spectrum of the data. For each trial, four frequency spectra were obtained. Averaging the frequency spectra did not reduce the noise floor but it did produce a more stable estimate of the level of the DPOAE which can fluctuate over time.

Responses. The data record for each trial was a single frequency spectrum that included the averaged sound levels of the primary signals, the DPOAEs, and the ambient noise in the ear canal. An example of a response frequency spectrum displayed on the vide screen is shown in Figure 2 in which the level of L1 and L2 were equal at 65 dB SPL. The levels of the primaries were verified from the response frequency spectrum.

Determination of MRL. In Figure 2, the DPOAE at 2 F1- F2 can be seen. The measurements of the level of the DPOAE were also obtained from the response frequency spectrum. When the level of

Table 1. Sound pressure levels (L1 and L2) in dB re: μPa of primary signals L1 and L2 for the three experimental procedures used to obtain DPOAE I/O functions.

L1 = L2		L1 = L2 + 10 dB		L1 = 65 dB SPL; L2 varied	
L1	L2	L1	L2	L1	L2
30	30	30	20	65	20
35	35	35	25	65	25
40	40	40	30	65	30
45	45	45	35	65	35
50	50	50	40	65	40
55	55	55	45	65	45
60	60	60	50	65	50
65	65	65	55	65	55
70	70	70	60	65	60
75	75	75	65	65	65

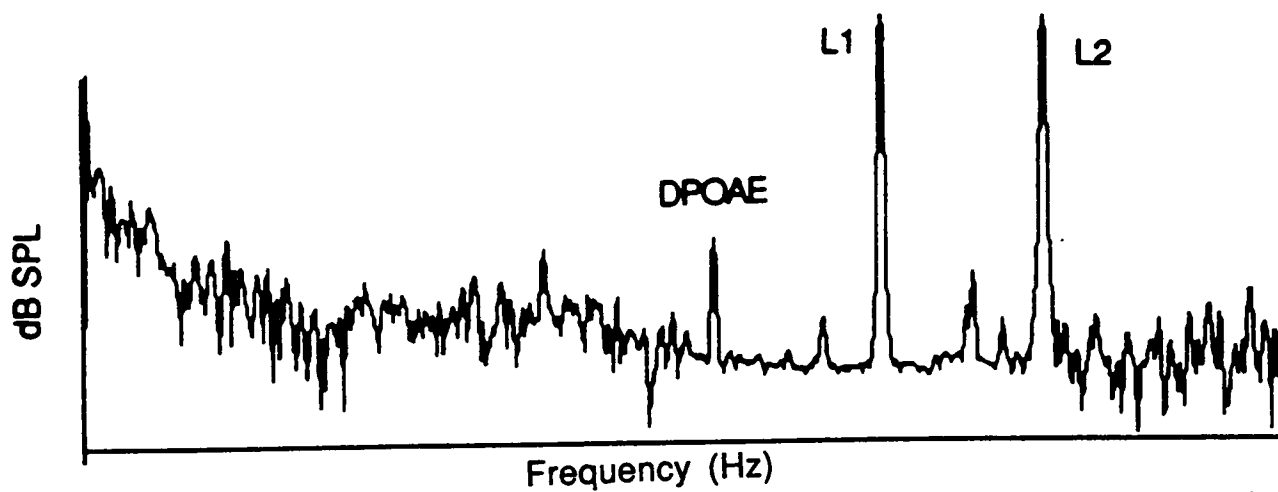


Figure 2. Response frequency spectrum showing the primary signals, L1 and L2, and DPOAE at $2 F_1 - F_2$.

the DPOAE was near the level of the noise, decisions regarding the validity of the DPOAE were made with using the two 10-Hz bands that surround the DPOAE on both sides. A DPOAE was considered to be valid when the level of the DPOAE was at least 3 dB greater than the average level of noise in the two 10-Hz bands above and below the DPOAE. If this criterion was not met, the DPOAE was considered to be absent. In these cases, the data (Appendix E) is identified with the letter "N" for no response.

Computation of DPOAE I/O Function Slope. For each I/O function, the slope was calculated using a regression equation with points 5, 10, and 15 dB above the MRL. Using this method, information was obtained about slope close to the MRL. This method of calculating slope is similar to the method used by Gaskill and Brown (1990), Nelson and Kimberley (1992) and Quiñónez and Crawford (1994) who computed slope by using all points above the noise floor below the saturation point of the function. In the present study, the MRL datum point was not used because it could have been elevated in level because of noise. Data points at high stimulus levels were not used due to nonmonotonicity of many of the I/O functions. This method provided information regarding measurement of slope closest to MRL without the influence of noise.

Procedures.

Session One. There were two experimental sessions for each subject. During the first session (one hour per dog), subject qualification required a light anesthesia of atropine (.02 mg/lb), torgugesic (.05 mg/lb), and glycopyrrolat (.005 mg/lb) was

administered. Then, the otoscopic and ABR qualification described in the method section was conducted.

Session Two. The second session, the experimental session, was conducted at least one week after the first session. At the beginning, a light plane of anesthesia (as described in the Methods session) was administered followed by pentobarbital administered according to the weight of the dog and as necessary. The amounts of drug administered and times of administration are listed in Appendix B. Once the subject was anesthetized, the tympanometric, AR, and ABR data were collected. The subject was placed in a sound treated booth on a "MuttMats®" blanket. These qualification procedures were followed by the two experimental trials. In each trial, a DP audiogram was recorded and I/O functions were obtained at 1000, 2000, and 4000 Hz for P1, P2, and P3. The order of presentation was randomized within each trial. Session 2 lasted from two to four hours. Raw data for all experimental conditions for all subjects are shown in Appendix E.

Data Analysis.

Minimum Response Level. A repeated measures analysis of variance with confidence level of .05 was performed to determine if there were differences among the three experimental procedures and between the two test frequencies. A personal computer statistical analysis program (JMP 3.1) was used. It was necessary to perform a logarithmic transformation on the MRL data before performing the analysis of variance because the MRL data were not normally

distributed. As a result, the analysis of variance of MRLs was performed using the logarithm of the actual data.

Slope. For each function, slope was calculated with a regression equation using points 5, 10, and 15 dB above the MRL. Using this method, information was obtained about the slope of the I/O function close to MRL rather than at higher signal levels. The units for each slope of the I/O functions were amount of growth of DPOAE in dB SPL divided by the amount of the increase in the level of F2 in dB SPL.

A repeated measures analysis of variance with a confidence level of .05 was performed with the personal computer statistical analysis program (JMP 3.1) to evaluate the dependence of slope on experimental procedure and on frequency.

4. RESULTS

Individual Subject Data. Distortion product I/O functions were obtained from all dogs in this experiment. Figure 3 shows an example of the results for one subject during one trial at a frequency of 4000 Hz. In this instance, MRLs were obtained at lowest levels at 20 dB SPL with both P2 and P3, whereas the MRL for P1 was obtained at 30 dB SPL. In this example, the steepest slope was observed for P2 -- 1.25. The shallowest slope -- 0.79 -- was obtained with P3.

Appendix E shows DPOAE I/O function data at 2000 and 4000 Hz. All attempts to record DPOAE data at 1000 Hz failed because no records revealed activity above the noise floor. Therefore, no data are presented for 1000 Hz.

Group data for MRL. Mean DPOAE MRLs for the six experimental subjects for the two trials at frequencies of 2000 and 4000 Hz are presented in Figure 4 and also in Table 2. The ordinate of Figure 4 is the level of the DPOAE at $2 F_1 - F_2$ in dB SPL. The abscissa is the test frequency in Hz. Each datum point represents the mean MRL for each frequency for one of the experimental procedures. The MRLs were lower at 4000 Hz than at 2000 Hz. The highest MRLs were obtained with P1 ($L_1 = L_2$) while the lowest level MRLs were obtained using P2 ($L_1 = L_2 + 10$ dB). At 4000 Hz, the true MRL may actually be lower than the obtained MRL because in thirteen of the thirty-six cases, the MRL was obtained at the lowest signal levels

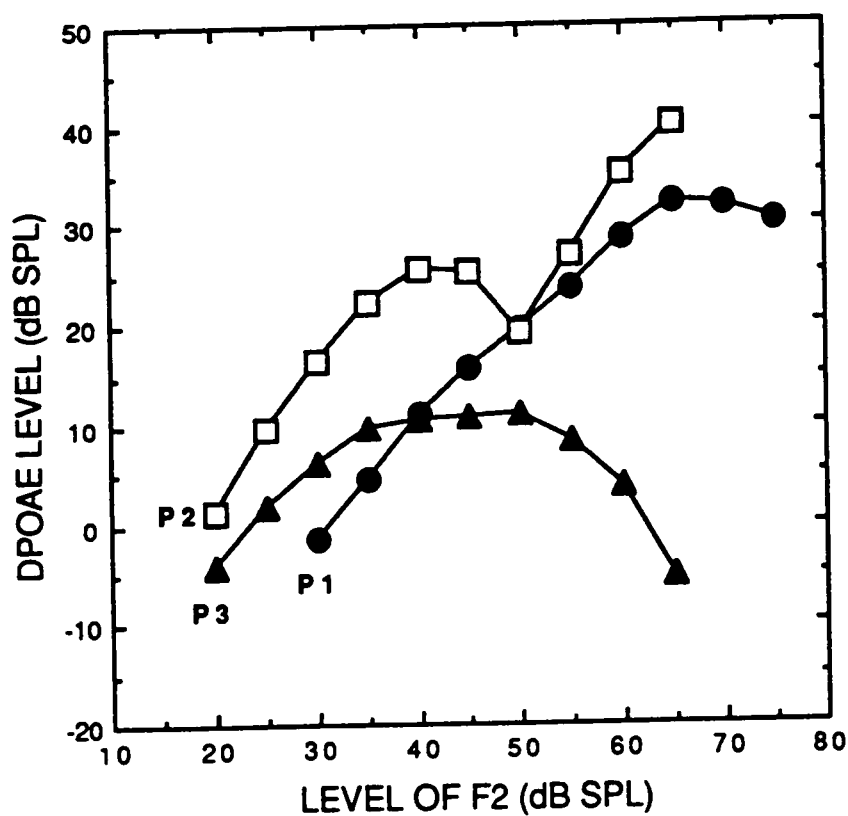


Figure 3. Example of DPOAE I/O functions for three experimental procedures. Test frequency is 4000 Hz.

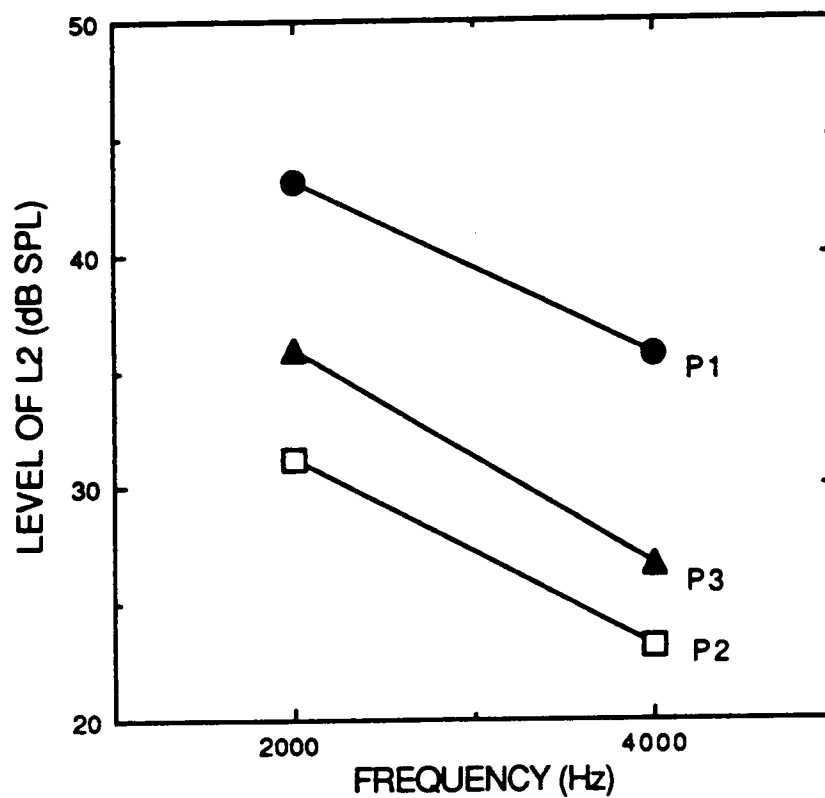


Figure 4. Mean DPOAE MRLs for all subjects for the three experimental procedures for 2000 and 4000 Hz.

Table 2. Mean MRL for L2 and mean I/O function slopes for six subjects for the three experimental procedures.

	P1	P2	P3
MRL			
2000 HZ	43.1	31.2	35.9
4000 HZ	35.6	23.2	26.7
SLOPE			
2000 HZ	0.7	0.7	0.9
4000 HZ	1.1	1.0	0.9

used.

The results of the analysis, which are shown in Table 3, indicate that there was a significant effect due to procedure ($p=.0001$) and to frequency ($p=.0064$). Contrasts were performed to examine differences among the three procedures. The results for P3 were significantly lower than for P1 ($t(5) = 7.24$, $p = .00017$) and the results for P2 were significantly lower than for P3 ($t(5) = 2.57$, $p = .0260$).

There was also a significant interaction of procedure, frequency, and subject ($p= .0064$). The meaning of this interaction is unclear and is possibly be due to the small sample size. All other effects were not significant.

The average levels of the primary signals used to obtain MRLs for the three experimental procedures are shown in Figure 5. The results for 2000 and 4000 Hz were averaged. For P1, the average level of L1 and L2 were 39 dB SPL. For P2, the average level of L2 was 26 dB which is 13 dB below L2 for P1, while the level of L1 (36 dB SPL) was also 3 dB lower than L1 for P1. With P2, the levels of both signals required to obtain MRL are lower than for P1. Comparing P2 and P3, L1 for P3 was 29 dB higher than P2 and L2 (31 dB SPL) was 5 dB higher than L2 for P2. Thus, the MRLs for P2 were systematically lower than either P1 or P3.

Group data for slope. The mean DPOAE I/O function slopes for the six experimental subjects for the two trials at 2000 and 4000 Hz are presented in Figure 6 and in Table 2. In Figure 6, I/O function

Table 3. Analysis of variance for MRL.

Source	Numerator		Denominator		F	p
	df	ms	df	ms		
P	2	.1290	11.274	.00481	26.815	.0001*
F	1	.1616	5.674	.00530	30.508	.0018*
T	1	.0097	5.251	.00605	1.595	.2598
S	5	.0191	.255	.00265	7.186	.6196
PxT	2	.0025	18	.00302	.831	.4516
PxF	2	.0032	10.376	.01103	.292	.7528
PxS	10	.0050	10.059	.01151	.434	.8980
FxS	5	.0056	10.327	.01110	.502	.7689
SxT	5	.0062	18	.00302	2.053	.1193
FxT	1	.0113	18	.00302	3.750	.0687
PxFxS	10	.0116	18	.00302	3.8403	.0064*

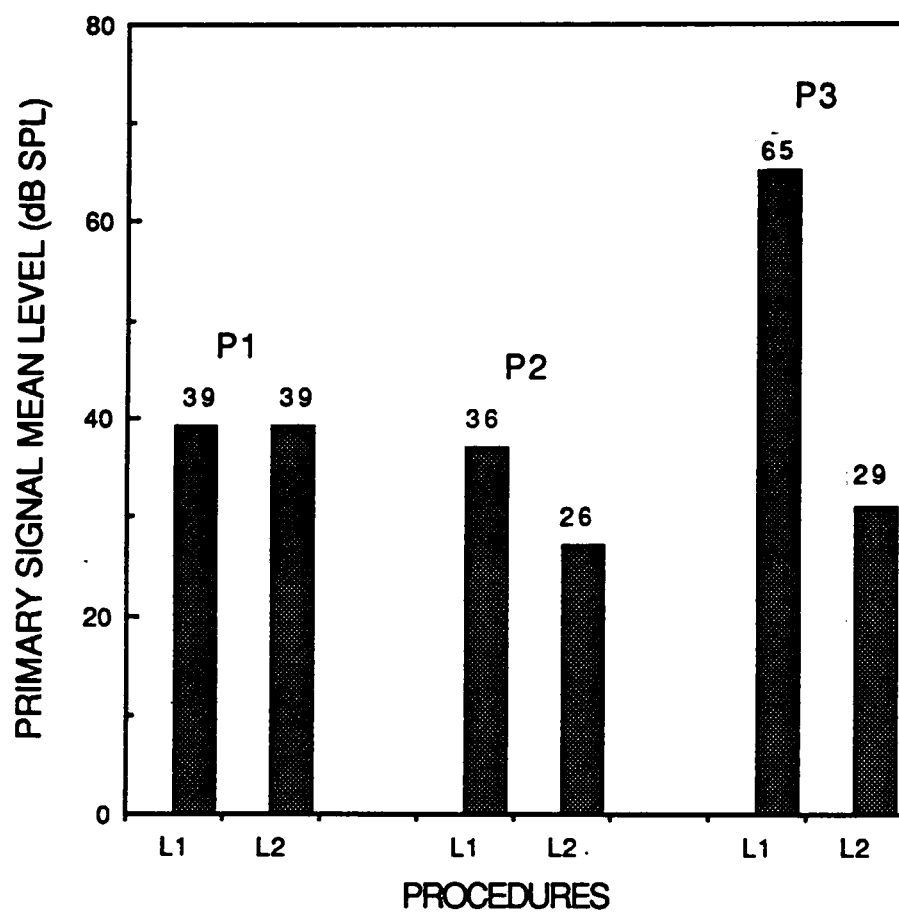


Figure 5. Average levels of the primary signals used to obtain MRLs with the three experimental procedures. Data are averaged across frequency.

slopes are plotted as a function of test frequency. The slopes appear greater at 4000 Hz with an average slope of 1.0. The mean slope at 2000 Hz appears more shallow with an average of 0.75.

The results of the analysis which are shown in Table 4 indicate that I/O function slope does not depend on procedure or frequency.

There was a significant effect shown by the interaction of procedure, frequency, and subject ($p = .000639$). The significance of this interaction is unknown. All other effects were not significant.

Nelson and Kimberley (1992) classified DPOAE I/O functions into seven shape categories. Examples of six of the seven shapes are shown in Figure 7 using data from the present study (The seventh category was absence of DPOAE responses). The I/O functions for the two trials in the present study were classified into Nelson and Kimberley's seven categories (Table 5). Slightly over 80% of the I/O functions for all experimental procedures can be characterized as single-segment, diphasic, or nonmonotonic. For P3, the most common shape was the single-segment while the diphasic shape was most common for P1 and P2.

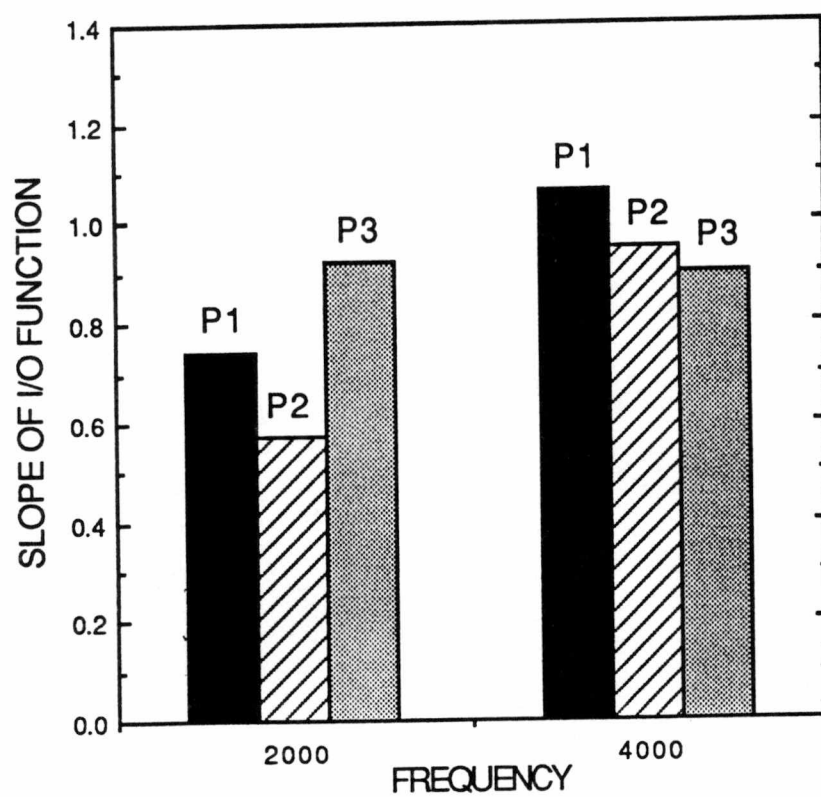


Figure 6. Mean I/O function slopes for six subjects for the three experimental procedures at 2000 and 4000 Hz.

Table 4. Analysis of variance for slope of DPOAE I/O functions.

Source	Numerator		Denominator		F	p
	df	ms	df	ms		
P	2	.0274	11.502	.09097	.301	.7456
F	1	.4942	5.531	.13049	3.788	.1037
T	1	.0245	8.048	.01674	1.463	.2608
S	5	.3186	.061	.02039	15.625	.8347
PxT	2	.0631	17	.06852	.921	.4172
PxF	2	.1593	10.559	.15156	1.051	.3834
PxS	10	.0932	10.099	.15585	.598	.7849
FxS	5	.1370	10.427	.15274	.897	.5177
SxT	5	.0138	17	.06852	.201	.9576
FxT	1	.0417	17	.06852	.609	.4461
PxFxS	10	.1568	17	.06852	2.289	.00639*

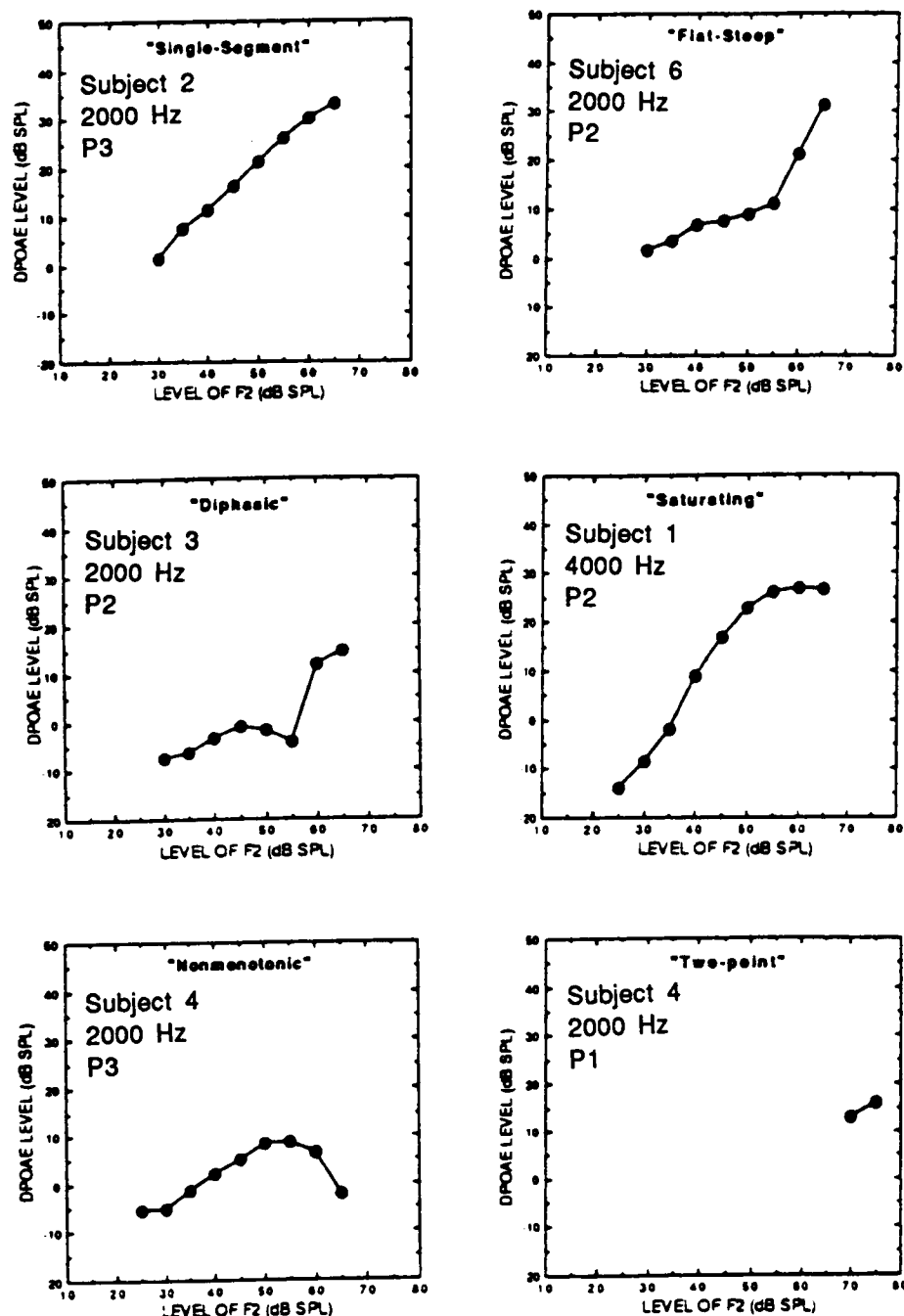


Figure 7. Examples of the different types of DPOAE I/O functions that were observed in the present study as labeled by Nelson and Kimberley (1992).

Table 5. Frequency of occurrence of different types of DPOAE I/O functions observed in the present study.

	2000 Hz			4000 Hz		
	<i>P1</i>	<i>P2</i>	<i>P3</i>	<i>P1</i>	<i>P2</i>	<i>P3</i>
Single Segment	1	2	5	1	0	6
Flat-steep	0	2	0	0	1	0
Diphasic	5	4	0	3	8	2
Saturating	1	0	0	5	2	0
Nonmonotonic	3	2	5	2	1	3
Two-point	1	0	0	0	0	0
No DPOAEs due to equipment error	1	2	2	1	0	1

5. DISCUSSION

Minimum Response Level. The purpose of the present study was to determine the DPOAE I/O function procedure that would obtain MRLs at the lowest levels of the primary signals. To date, several other researchers have compared DPOAE I/O function procedures and studied MRL but none have attempted to attain MRLs at low levels as a means of estimating threshold of hearing.

In previous studies, researchers have used primary signals at high levels (65 - 75 dB HL) and examined the amplitude of the DPOAE above the noise floor (Probst et al., 1990; Harris, 1990; Bonfils and Avan, 1992; Peterein et al., 1992; Gorga, Neely, Bergman, Beauchaine, Kaminski, & Lui, 1994). They found, in general, that DPOAE level increases as signal level is increased. When hearing impaired subjects were also used (Leonard et al., 1990; Probst et al., 1990; Nelson and Kimberley, 1992; Peterein et al., 1992; Lasky et al., 1994; Harris, 1990) to determine the efficacy of DPOAEs in determining hearing loss, relatively high level primary signals (65 - 75 dB HL) were used. Findings indicated that when hearing loss increased, the amplitude of the DPOAE decreased. They were able to differentiate between those with normal hearing (≤ 20 dB SPL) and those with hearing loss.

Nelson and Kimberley (1992) used procedure P1 with normal hearing (< 20 dB HL) and hearing impaired subjects. They computed a detection threshold by interpolating the intersection of the I/O

function with the mean level of the noise floor. There are two notable aspects of their data: 1) interpolated detection thresholds were as low as 0 dB SPL which is significantly lower than the minimum levels at which signals were presented, and 2) for normal hearing subjects, detection thresholds ranged from 0 - 60 dB SPL and were poorly correlated with threshold of audibility. In addition, with hearing impaired subjects, detection thresholds were greater than 60 dB or absent in the vast majority of cases.

In the present study, some of the MRLs were as high as those reported by Nelson and Kimberly by many of their detection thresholds were much lower than those obtained due to their method of determining detection threshold. With their method of interpolation, the slopes of their I/O functions were much more shallow than those obtained in the present study.

Gorga et al., (1994) utilized procedure P2 to measure I/O functions using L2 levels of 20 - 75 dB in normal hearing subjects ($\leq$ 15 dB HL). They calculated DPOAE thresholds as the lowest levels of the primary signals in which the standard deviation of distortion product $2F_1 - F_2$ and the noise floor did not overlap. Using this method, they obtained average DPOAE thresholds of 25 dB at 2000 Hz and 20 dB at 4000 Hz. These values obtained on humans are quite similar to values in the present study of 31 dB at 2000 Hz and 23 dB at 4000 Hz in dogs. However, in an examination of their individual data at 2000 Hz (Figure 3), their method for determining DPOAE threshold does not take into account nonmonotonicity in the I/O functions. From their raw data, only two of the twenty subjects

were judged to have 25 dB MRL using the method from the present study. Thus, the method of Gorga et al. for computing DPOAE threshold appears to be less stringent than the method used for computing MRL in the present study.

Slope. In the present study, slope was computed in order to provide values as normative data to be compared with slopes when hearing loss is present. Researchers have previously examined the relationship between slope and hearing sensitivity (Gaskill and Brown, 1990; Bonfils and Avan, 1992; Nelson and Kimberley, 1992; Gorga et al., 1994; Lasky et al., 1994; Quiñónez and Crawford, 1994). Regardless of the method of slope calculation, they found that I/O function slope increases in steepness with frequency. This was confirmed in the present study with an average slope at 4000 Hz (1.0) that was steeper than at 2000 Hz (0.8).

Quiñónez and Crawford (1994) utilized DPOAE I/O slope data to make predictions of hearing loss. They suggested that there is a moderate correlation between hearing threshold and slope of the I/O function. This correlation must be verified because in contrast, previous studies (Bonfils and Avan, 1992; Nelson and Kimberley, 1992) that used normal and hearing-impaired subjects found no consistent differences in slopes in normal and hearing-impaired subjects.

Conclusions and Considerations for Future Research. If appropriate stimulus parameters are selected, DPOAE I/O MRL could provide an objective measure of auditory function near threshold when middle-ear function is normal. Difficulties associated with subjective measures of auditory sensitivity would be eliminated and the time required to obtain equivalent thresholds would be reduced. This procedure could also be utilized to monitor changes in hearing sensitivity related to ototoxicity and noise exposure.

With the knowledge from previous research and the present study, further investigation of procedure P2 with lower level primary signals and several configurations of hearing loss must be examined. The extent of correspondence of DPOAE MRL with normal hearing and impaired ears needs to be examined in future research.

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APPENDICES

APPENDIX A

CALIBRATION OF LEVELS OF PRIMARY SIGNALS

Sound levels were measured using a calibration cavity provided by the manufacturer and a 1/2 inch condenser microphone (Bruel and Kjaer, Type 4134) with a sound level meter (Bruel and Kjaer, Type 2209). Sound levels were measured and adjusted at the outset of the study for all frequencies in the range from 200 to 10250 Hz. The accuracy of the levels were verified at the completion of the study; levels changed by no more than 2 dB at each frequency.

FREQUENCY (Hz)	PRE-DATA (dB SPL)	POST-DATA (dB SPL)
200	75.7	75.5
300	75	74.5
400	75	75.2
500	74.7	75
600	74.9	75.2
700	74.8	75.1
900	75.2	76
1000	75	75.5
1250	75.5	76.9
1500	75	75.5
1650	75.5	75.9
1750	75	75.1
2000	74.9	75.1
2250	75	75.9
2500	75	75.9
2750	75	75.9
3000	75.7	76
3150	74.9	75.5
3250	75.2	76
3500	75.1	76
3750	75	76.8
4000	75.5	77
4250	75	76
4500	74.9	75.5
4750	74.5	75.1
5000	75.6	76.9
5250	75	76.9
5500	75.5	77
5750	75	76.1
6000	74.9	75.8
6250	74.8	74.8
6300	75.5	76
6500	74.8	75.5
6750	75.5	76.9
7000	75	76.7
7250	75	76.8
7500	74.8	76
7750	75.1	76.3
8000	75.1	76.5
8250	74.9	76
8500	74.5	75.5
8750	75.2	76.5
9000	75.8	76.8
9250	75.5	76
9500	75.1	74.8
9750	75.1	74
10000	75.2	74.5
10250	74.8	75

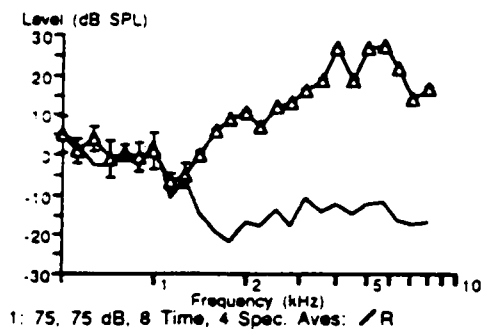
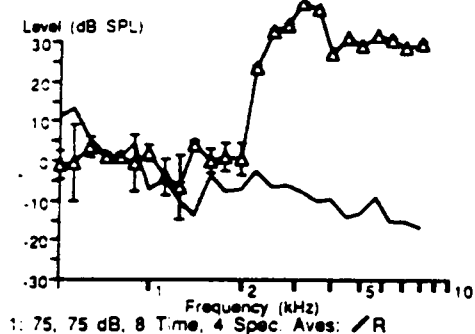
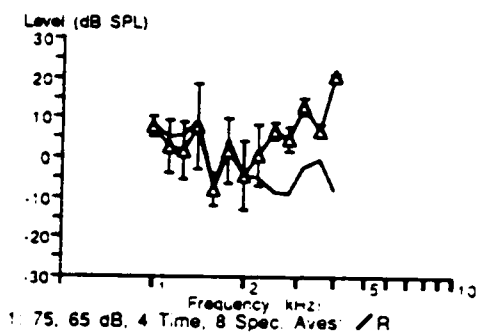
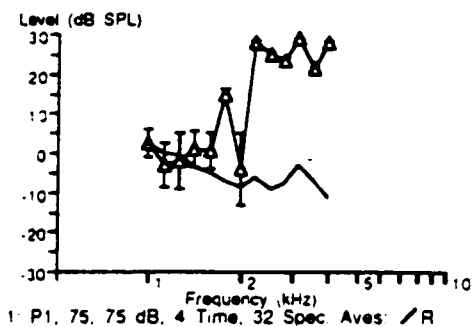
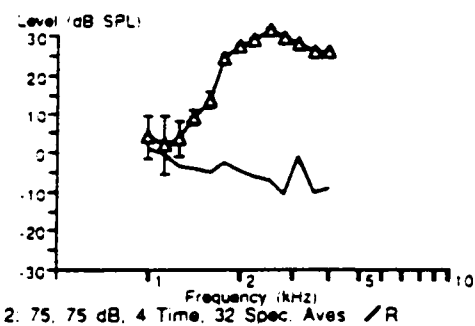
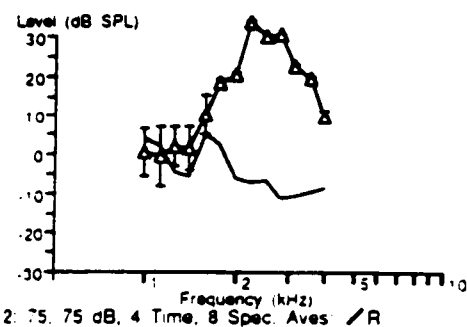
APPENDIX B
SUBJECT QUALIFICATION DATA

	SUBJECT					
	1	2	3	4	5	6
Qualification Session Date	1/30/95	1/30/95	1/30/95	2/1/95	2/1/95	2/1/95
Weight (lbs)	26	26	31.5	35	28	29
Test Ear	L	L	R	R	L	R
ABR MRL (dB nHL)	30	30	40	30	40	40
Experimental Session Date	2/8/95	2/10/95	2/13/95	2/15/95	2/22/95	2/27/95
Weight (lbs)	25	24.5	29.5	35.5	28	29
Tympanometry (226 Hz; Ya)						
200	0.7	0.7	0.7		0.09	0.8
100		0.8	0.8	1.1	1.05	1
0	1	1.05	1	1.2	1.1	1.05
-100		0.8	1.1	1.1	0.9	1
-200	0.3	0.7	1	1	0.8	0.9
-300			0.8		0.9	
Uncrossed Acoustic-Reflex						
Thresholds (dB HL)						
500 Hz			85		95	75
1000 Hz			95		95	95
2000 Hz	85	80	95	85	95	95
4000 Hz	75	85	85	95	100	100
Probe Color	blue	blue	blue	blue	blue	blue
MRL for Click ABR (dB HL)	40	20	40	30	20	40
Anesthesia (ml) : Dose / Time	1.5 @ 0925	1.5 @ 0850	1.0 @ 0875	2.0 @ 0900	1.5 @ 0900	1.0 @ 0925
	1.0 @ 1050	1.0 @ 1000	1.0 @ 0910	.5 @ 0983	1.0 @ 1042	.5 @ 0937
			.5 @ 1050		.5 @ 1108	.5 @ 1073
			.5 @ 1060			.3 @ 1118
						.3 @ 1138

APPENDIX C

SUBJECT QUALIFICATION:

DISTORTION PRODUCT AUDIOGRAMS

SUBJECT 1**SUBJECT 2****SUBJECT 3****SUBJECT 4****SUBJECT 5****SUBJECT 6**

APPENDIX D
RAW DATA FOR INDIVIDUAL SUBJECTS

SUBJECT 1/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	28.7	N	30	30	30	29
N	35	34.3	35	33.7	-1.1	35	35	35	34
N	40	39.3	40	38.7	0	40	40	40	39
-11.7	45	44.3	45	43.7	<u>16.1</u>	45	45	45	44
<u>-3.4</u>	50	49.3	50	48.7	<u>22.8</u>	50	50	50	49
<u>4.2</u>	55	54.3	55	54.2	27	55	55	55	54
<u>9.6</u>	60	59.3	60	59.7	28	60	60	60	59
12.6	65	64.3	65	64.7	28	65	65	65	64
13.1	70	70.3	70	69.7	26.9	70	70	70	69.4
10.4	75	75.3	75	75	26.8	75	75	75	74.6
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.1	20	19.1	N	30	30	20	18
N	35	34.3	25	23.7	-3.2	35	35	25	23.6
N	40	39.3	30	28.7	<u>6.4</u>	40	39.8	30	28.9
N	45	44.3	35	33.5	<u>13.4</u>	45	44.4	35	34
-9.7	50	49.3	40	38.7	<u>17.2</u>	50	49.2	40	39
<u>-0.9</u>	55	54.3	45	43.7	18.8	55	54.1	45	44
<u>2.3</u>	60	59.3	50	48.7	19	60	59.2	50	49
<u>4.1</u>	65	64.3	55	53.7	18.3	65	64.2	55	54
3	70	69.3	60	59.5	17.5	70	69.5	60	59
0.6	75	75.3	65	64.7	16.3	75	75	65	64.1
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	64.7	20	19.5	N	65	65	20	18
N	65	65	25	23.9	-6	65	65	25	23.9
N	65	65.2	30	28.7	<u>-6.6</u>	65	65	30	29
N	65	65.3	35	33.7	<u>-0.6</u>	65	65	35	34
-10.7	65	65.3	40	38.7	<u>4</u>	65	65	40	39
<u>-5.9</u>	65	65.3	45	43.7	8.9	65	65	45	44
<u>-1.4</u>	65	65.3	50	49.7	13.7	65	65	50	49
<u>3.9</u>	65	65.3	55	54.7	18.5	65	65	55	54
8.8	65	65.3	60	59.7	23.1	65	65	60	59
12.8	65	65.3	65	64.7	27.9	65	65	65	64

SUBJECT 1/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	28.3	30	28.7	N	30	30	30	29.1
N	35	33.3	35	33.7	N	35	35	35	34
N	40	38.3	40	38.7	N	40	40	40	39.1
N	45	43.3	45	44.7	N	45	45	45	44
-5.2	50	49.3	50	49.7	1.5	50	50	50	49.6
<u>1.4</u>	55	54.3	55	54.2	<u>9.8</u>	55	55	55	54.4
<u>6.8</u>	60	59.3	60	59.7	<u>17.2</u>	60	60	60	59.5
<u>10.6</u>	65	64.3	65	64.7	<u>23</u>	65	65	65	65
11.4	70	69.3	70	69.7	27	70	70	70	70
9.4	75	74.3	75	75.7	28.8	75	75	75	75
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29	20	19.4	N	30	30	20	18.9
N	35	34.3	25	24.1	-14	35	35	25	24.1
N	40	39.3	30	28.8	<u>-8.6</u>	40	40	30	29
N	45	44.3	35	33.7	<u>-2</u>	45	45	35	34
-9.5	50	49.3	40	39.3	<u>9</u>	50	50	40	39.1
<u>-3.2</u>	55	54.3	45	44.7	16.9	55	55	45	44.3
<u>1.2</u>	60	59.3	50	49.7	22.7	60	60	50	49.6
<u>3.1</u>	65	64.3	55	54.7	26	65	65	55	54.5
2.7	70	69.3	60	59.7	26.9	70	70	60	59.4
0.3	75	75.3	65	64.7	26.6	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	64.3	20	18.4	N	65	65	20	18.4
N	65	64.3	25	23.2	-5.7	65	65	25	24
N	65	64.3	30	27.8	<u>0.2</u>	65	65	30	29
N	65	64.3	35	32.7	<u>5.4</u>	65	65	35	34
-10.3	65	64.3	40	38.1	<u>10.7</u>	65	65	40	39
<u>-6.5</u>	65	64.3	45	43.7	15.7	65	65	45	44.6
<u>-1.2</u>	65	64.3	50	48.7	20.8	65	65	50	49.6
<u>3.7</u>	65	64.3	55	53.7	25.3	65	65	55	54.5
8.8	65	64.3	60	58.7	28.3	65	65	60	59.5
12.7	65	64.3	65	63.7	26.4	65	65	65	65

SUBJECT 2/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	29.7	4.8	30	29	30	29.5
N	35	34.2	35	34.7	<u>9.2</u>	35	34	35	34.4
N	40	39.3	40	39.7	<u>13.9</u>	40	39	40	39.5
N	45	44.3	45	44.6	<u>17.9</u>	45	44	45	44.5
N	50	49.3	50	49.3	21.2	50	49.8	50	49.5
1.1	55	55.3	55	53.7	24.1	55	55	55	55
<u>9.5</u>	60	60.3	60	58.7	28	60	60	60	60
<u>7.8</u>	65	65.7	65	67	31.4	65	65	65	65
...	70	**73.4	70	*83.5	33.1	70	70	70	70
...	75	**79.3	75	**91.8	33	75	75	75	75
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	20	18.2	10.8	30	30	20	19.8
N	35	34.3	25	24.1	<u>15.8</u>	35	35	25	24.7
N	40	39.3	30	29.8	<u>19.9</u>	40	40	30	29.5
N	45	44.3	35	35.7	<u>22.9</u>	45	45	35	34.3
2.6	50	49.3	40	41	24.3	50	49.9	40	39.5
<u>4</u>	55	55.3	45	46.8	23.1	55	55	45	44.5
<u>5</u>	60	60.4	50	52	18.1	60	60	50	49.6
<u>5.8</u>	65	66.2	55	*57.6	24.9	65	65	55	55
...	70	**72.6	60	**64.7	30.8	70	70	60	60
...	75	**79.6	65	**72.7	35.9	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	66.3	20	*17.5	N	65	65.8	20	19.7
N	65	66.3	25	23.9	N	65	65.7	25	24.7
-2.7	65	65.8	30	29.3	0.1	65	65	30	29.6
<u>-0.1</u>	65	65.4	35	34.8	<u>4.9</u>	65	65	35	34.6
<u>4.4</u>	65	66.1	40	40.8	<u>9.7</u>	65	65	40	39.4
<u>8.6</u>	65	66	45	46.3	<u>14.7</u>	65	65	45	44.7
9.9	65	66.1	50	51.7	19.6	65	65	50	49.7
4.1	65	66.3	55	*58.4	24.5	65	65.4	55	55
...	65	**68.2	60	**67.4	28.6	65	65.7	60	60
...	65	**68.7	65	**74.2	31.7	65	65.6	65	65

SUBJECT 2/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
0.5	30	29.3	30	28.7	N	30	30	30	29.6
<u>5</u>	35	34.3	35	33.7	N	35	34.9	35	34.6
<u>9.6</u>	40	39.3	40	38.7	-2.2	40	40	40	39.5
<u>12.7</u>	45	44.3	45	43.7	<u>3.9</u>	45	45	45	45
15.8	50	50.3	50	48.7	<u>8.5</u>	50	50	50	50
17.8	55	55.3	55	54.5	<u>13.2</u>	55	55	55	55
16.3	60	60.3	60	59.7	18.3	60	60	60	60
33.2	65	65.3	65	64.7	23.1	65	65	65	65
33.3	70	70.4	70	69.7	28	70	70	70	70
27	75	75.3	75	76.1	31.2	75	75	75	75
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
-1.1	30	29.3	20	19.2	9.7	30	30	20	19.6
<u>4.6</u>	35	34.3	25	24.3	<u>14.2</u>	35	35	25	24.5
<u>7.1</u>	40	39.9	30	29.6	<u>17.9</u>	40	39.8	30	29.5
<u>7.7</u>	45	45	35	34.7	<u>20.8</u>	45	44.8	35	34.6
4.8	50	50.3	40	39.7	21.5	50	50	40	39.5
10.8	55	55.3	45	44.7	19.9	55	55	45	44.6
17	60	61.1	50	49.7	24.9	60	60	50	50
26.3	65	66.3	55	54.7	31.9	65	65	55	55
33.2	70	71.5	60	59.9	36.8	70	70	60	59.7
***	75	**86.2	65	**73.8	38.3	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	66.2	20	19.6	12.7	65	65	20	19.7
N	65	66.3	25	24.6	<u>17.5</u>	65	65	25	24.6
1.3	65	66.3	30	29.6	<u>20.9</u>	65	65	30	29.6
<u>7.5</u>	65	66.3	35	34.6	<u>22.8</u>	65	65	35	34.6
<u>11.3</u>	65	66.3	40	39.7	22.2	65	65	40	39.9
<u>16.2</u>	65	66.3	45	44.7	18	65	65	45	45
21.2	65	66.3	50	50.3	18	65	65	50	50
26	65	66.3	55	55.6	23.6	65	65	55	55
30.2	65	66.3	60	60.7	30.6	65	65	60	60
33.2	65	66.3	65	65.7	32.5	65	65	65	65

SUBJECT 3/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	28.7	-1.5	30	30.9	30	29.4
N	35	34.3	35	33.7	<u>4.4</u>	35	36	35	34.6
N	40	39.3	40	38.7	<u>11.1</u>	40	41	40	39.5
-6.7	45	44.3	45	43.7	<u>15.6</u>	45	46	45	44.6
<u>-2.5</u>	50	50.3	50	48.7	19.6	50	51	50	49.5
<u>0.8</u>	55	55.3	55	54.5	23.7	55	56	55	54.6
<u>0.8</u>	60	60.3	60	59.7	28.5	60	60	60	60
3.8	65	65.3	65	64.7	31.9	65	65	65	65
12.3	70	70.4	70	69.7	31.8	70	71	70	70.5
10.9	75	75.3	75	76.1	30	75	76	75	75.8
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	20	19.2	1.2	30	30.3	20	18.8
N	35	34.3	25	24	<u>9.6</u>	35	35	25	24
-7.5	40	39.3	30	28.7	<u>16.6</u>	40	40	30	29
<u>-6.5</u>	45	44.3	35	33.7	<u>22.1</u>	45	45	35	34
<u>-3.3</u>	50	50.3	40	38.7	25.4	50	50	40	39
<u>-0.8</u>	55	55.3	45	43.7	25.2	55	55	45	44
-1.8	60	60.3	50	49.3	19.2	60	60	50	49
-4.3	65	65.3	55	54.4	26.9	65	65	55	54.6
11.8	70	70.3	60	59.7	35	70	70	60	60
14.6	75	76.3	65	64.7	40	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	65.8	20	19.6	-4.2	65	65	20	19.5
N	65	66.2	25	24.7	<u>1.9</u>	65	65	25	24.7
N	65	66.3	30	29.7	<u>6.2</u>	65	65	30	29.4
N	65	66.3	35	34.7	<u>9.8</u>	65	65	35	34.6
-10.4	65	66.3	40	39.7	10.5	65	65	40	39.6
<u>-8.8</u>	65	66.5	45	45.5	10.9	65	65	45	44.7
<u>-1.4</u>	65	67.3	50	50.2	11	65	65	50	50
<u>1.2</u>	65	67.3	55	55.6	8.2	65	65	55	55
6.4	65	67.3	60	60.6	3.8	65	65	60	60
5	65	67.3	65	65.7	-5.4	65	65	65	65

SUBJECT 3/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	30	**28	30	28.3	N	30	30	30	29
...	35	**32.6	35	33.7	0.8	35	35	35	34
...	40	**36.7	40	39	<u>7.9</u>	40	40	40	38.9
...	45	**40.2	45	44.7	<u>14</u>	45	45	45	43.8
...	50	**44.5	50	49.7	<u>18.2</u>	50	50	50	48.7
...	55	**49	55	54.7	22.2	55	55	55	54
...	60	**53.1	60	59.7	27.1	60	60	60	59
...	65	**59.4	65	65.4	31.5	65	65	65	64
...	70	**67.2	70	70.7	33.1	70	70	70	69.1
...	75	**77.2	75	77.5	30.4	75	75	75	74.4
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	30	**24.9	20	17.6	6.2	30	29.9	20	19.5
...	35	**31.3	25	22.6	<u>15.1</u>	35	34.6	25	24.7
...	40	**36.1	30	28.4	<u>21.2</u>	40	39.2	30	29.7
...	45	**41.1	35	33.6	<u>25.4</u>	45	44.4	35	34.2
...	50	**47.2	40	38.6	26.9	50	49.9	40	39
...	55	**53.7	45	43.7	23.3	55	55	45	44
...	60	**60.3	50	48.6	24	60	60	50	49.1
...	65	**67.5	55	53.9	31.3	65	64.7	55	54.5
...	70	**78.4	60	60.1	37.2	70	69.9	60	60
...	75	**88.6	65	66.9	41.1	75	74.9	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	65	**65.8	20	18.4	-1.2	65	65	20	19.2
...	65	**66.8	25	23.3	<u>4.2</u>	65	65	25	24.7
...	65	**67.6	30	28.7	<u>6.5</u>	65	65.9	30	29.8
...	65	**70.4	35	34.3	<u>11.7</u>	65	66	35	34.3
...	65	**70.5	40	39.2	16.9	65	66	40	39.5
...	65	**70.7	45	44.3	17.1	65	66.4	45	45.2
...	65	**70.9	50	49.6	22.3	65	67.1	50	48.9
...	65	**69.5	55	54.5	28	65	*69	55	53.1
...	65	**70	60	59.7	30.2	65	*67.9	60	58.5
...	65	**70.5	65	64.7	33.7	65	67	65	63.3

SUBJECT 4/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	28.7	N	30	30	30	29.1
N	35	34.3	35	33.6	0.6	35	35	35	34
N	40	39.3	40	38.7	<u>2</u>	40	40	40	39
N	45	44.3	45	43.7	<u>12.7</u>	45	45	45	44
N	50	50.2	50	49.7	<u>16.7</u>	50	50	50	49
N	55	55.3	55	54.7	18.9	55	55	55	54
N	60	60.3	60	59.7	18.3	60	60	60	59
N	65	65.3	65	64.7	16.9	65	65	65	64
12.9	70	70.3	70	69.6	18	70	70	70	69
16	75	75.3	75	74.9	26.4	75	75	75	74
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	20	18.9	N	30	30	20	20
N	35	34.3	25	24.1	-0.1	35	35	25	24.2
N	40	39.3	30	29.5	<u>5.2</u>	40	40	30	29.8
N	45	44.3	35	34.7	<u>9.4</u>	45	45	35	34.4
N	50	50.3	40	40.3	<u>10.7</u>	50	50	40	39.5
-2.9	55	55.3	45	45.7	10.6	55	55	45	44.4
<u>-1.1</u>	60	60.3	50	50.9	9	60	60	50	49.6
<u>7.4</u>	65	65.3	55	56.4	7.6	65	65	55	54.4
1.1	70	70.3	60	60.7	10	70	70	60	59.4
21.4	75	76.3	65	65.7	18.2	75	75	65	64.5
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	65.3	20	19	N	65	65	20	20.7
-5.7	65	65.3	25	23.7	N	65	65	25	24.8
<u>-5.2</u>	65	65.3	30	28.6	N	65	65	30	29.3
<u>-1.5</u>	65	65.3	35	33.7	N	65	65	35	34
<u>2.1</u>	65	65.3	40	39.3	-5.2	65	65	40	39
5.1	65	65.3	45	44.7	<u>-1.9</u>	65	65	45	44
8.4	65	65.3	50	49.7	<u>3.3</u>	65	65	50	49
8.5	65	65.3	55	54.7	<u>7.9</u>	65	65	55	54
6.4	65	65.3	60	59.7	12.6	65	65	60	59
-2.2	65	65.3	65	64.7	16.7	65	65	65	64

SUBJECT 4/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.6	30	27.7	N	30	29.4	30	29.5
N	35	34.3	35	32.7	-1.4	35	34.7	35	34.6
N	40	39.5	40	38.1	<u>4.2</u>	40	40	40	39.3
N	45	45.3	45	43.7	<u>10.2</u>	45	45	45	44
N	50	50.3	50	48.7	<u>14.8</u>	50	50	50	49
-4.4	55	55.3	55	53.7	18.1	55	55	55	54
<u>2.2</u>	60	60.3	60	59.2	18.2	60	60	60	59
<u>7.2</u>	65	65.3	65	64.7	17.1	65	65	65	64
-1.1	70	70.3	70	69.7	16.9	70	70	70	69.5
21.3	75	76.3	75	74.6	24.2	75	75	75	74.6
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	30	65.3	20	18.9	N	30	30	20	20.3
...	35	65.3	25	24.1	-4.5	35	35	25	24.7
...	40	65.3	30	29.5	<u>2.2</u>	40	40	30	29.4
...	45	65.3	35	34.7	<u>7.4</u>	45	45	35	34.5
...	50	65.3	40	40.3	<u>10.2</u>	50	50	40	39.3
...	55	65.3	45	45.7	10.5	55	55	45	44
...	60	65.3	50	50.9	10.1	60	60	50	49
...	65	65.3	55	56.4	8.3	65	65	55	54
...	70	65.3	60	60.7	7.5	70	70	60	59
...	75	65.3	65	65.7	14.5	75	75	65	64.4
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	64.3	20	19.3	N	65	65	20	20.9
N	65	64.3	25	23.6	N	65	65	25	24.9
N	65	64.3	30	28.5	N	65	65	30	29.5
-4.8	65	64.3	35	33.6	-4.9	65	65	35	34.6
<u>-0.2</u>	65	64.3	40	38.7	<u>-5</u>	65	65	40	39
<u>3.1</u>	65	64.3	45	43.7	<u>-1.1</u>	65	65	45	44
<u>6.9</u>	65	64.3	50	48.7	<u>3.5</u>	65	65	50	49
8.8	65	64.3	55	54.3	8.6	65	65	55	54
8.6	65	64.3	60	59.3	13.1	65	65	60	59
6.2	65	64.3	65	64.7	17.2	65	65	65	64

SUBJECT 5/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	29.5	N	30	29.8	30	29.6
N	35	34.3	35	34.6	N	35	34.8	35	35
-1	40	39.3	40	39.7	-2.2	40	39.6	40	40
<u>4.6</u>	45	44.3	45	44.7	<u>5.2</u>	45	44.7	45	45
<u>9.2</u>	50	50.3	50	49.7	<u>10.1</u>	50	49.4	50	50
<u>13.6</u>	55	55.1	55	54.7	<u>12.9</u>	55	54	55	55
17.5	60	60.3	60	59.7	19.7	60	59	60	60
20.2	65	65.3	65	64.7	27.1	65	65	65	65
18.8	70	70.4	70	70	29.3	70	70	70	70
28.1	75	75.3	75	75.7	17.4	75	75	75	75
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	20	18.7	N	30	30	20	19.8
N	35	34.3	25	23.2	0.1	35	35	25	24.9
6.4	40	39.4	30	27.6	<u>9.1</u>	40	40	30	29.9
<u>6.2</u>	45	45.2	35	32.7	<u>15.3</u>	45	45	35	35
<u>8.8</u>	50	50.5	40	37.7	<u>21.2</u>	50	50	40	40
<u>8.8</u>	55	56.4	45	42.7	24.9	55	55	45	45
...	60	**62.6	50	48.5	24.6	60	60	50	50
...	65	**69.4	55	54.1	20.8	65	65	55	55
...	70	**74.1	60	59.4	29	70	70	60	60
...	75	**80.3	65	64.6	35	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	65	65.3	20	**17.1	N	65	65.6	20	19.6
N	65	65.3	25	22.6	-2.9	65	65.9	25	24.7
N	65	65.3	30	27.7	<u>1.7</u>	65	66	30	29.7
-3.6	65	65.3	35	32.7	<u>5.7</u>	65	66	35	34.5
<u>2.2</u>	65	65.3	40	37.7	<u>10.9</u>	65	66	40	40
<u>6.3</u>	65	65.3	45	42.9	15.3	65	66	45	45
<u>11.2</u>	65	65.3	50	48.7	19.6	65	66	50	50
15.5	65	65.3	55	53.7	21	65	66	55	55
17.9	65	65.3	60	58.7	21.2	65	66	60	60
19.2	65	65.3	65	63.7	28	65	66	65	65

SUBJECT 5/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
-3.3	30	30.3	30	28.7	N	30	30	30	29.4
<u>0.1</u>	35	35.3	35	33.7	0.1	35	35	35	34.6
<u>6.3</u>	40	40.3	40	38.7	<u>9.1</u>	40	40.5	40	39.2
<u>9.2</u>	45	45.3	45	43.7	<u>15.3</u>	45	46	45	44
11	50	50.3	50	49.2	<u>21.2</u>	50	51	50	49
11.4	55	55.3	55	54.7	24.9	55	56	55	54.1
6.5	60	60.3	60	59.7	24.6	60	61	60	59.7
17	65	65.3	65	64.7	20.8	65	66	65	64.5
27.2	70	70.3	70	69.7	29	70	71.6	70	69.4
...	75	**79.4	75	75.4	35	75	77	75	74.6
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.9	20	18.7	N	30	29	20	19.2
0.2	35	35.2	25	23.5	-3.6	35	34	25	25
<u>5</u>	40	40.2	30	28.7	<u>2.9</u>	40	39.5	30	29.4
<u>7.7</u>	45	45.2	35	33.7	<u>7.7</u>	45	44.8	35	34.9
<u>8.7</u>	50	50.3	40	38.7	<u>9.8</u>	50	50	40	39.5
9.2	55	55.4	45	44.6	9.8	55	55	45	44.5
2.6	60	61.3	50	49.7	7.1	60	60	50	49.6
12.8	65	67.1	55	54.6	5.7	65	65	55	54.5
...	70	**73.3	60	58.7	10.7	70	70	60	59.5
...	75	**81.6	65	62.8	16.8	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
...	65	**71.8	20	**17	...	65	**69.3	20	19.9
...	65	**70.6	25	**21.4	...	65	**69.8	25	24.1
...	65	**69.4	30	**25.1	...	65	**68	30	29.1
...	65	**70.4	35	**29.6	...	65	**70.1	35	33.7
...	65	**70.1	40	**34.6	...	65	**71.1	40	38
...	65	**70	45	**39	...	65	**70.1	45	43.4
...	65	**73.8	50	**42.8	...	65	**72	50	47.8
...	65	**74.3	55	**47.8	...	65	**70.4	55	53.2
...	65	**74.4	60	**52.9	...	65	**71.3	60	58.2
...	65	**75.2	65	**58	...	65	**69.2	65	63.1

SUBJECT 6/TRIAL 1

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	30	30	28.6	-4.1	30	30	30	30
N	35	35.2	35	33.7	<u>1.1</u>	35	35	35	35
1.2	40	40.2	40	38.7	<u>6.5</u>	40	40	40	39.5
<u>4.1</u>	45	45.3	45	43.7	<u>10.5</u>	45	45	45	44.4
<u>8.1</u>	50	50.3	50	49.7	14.5	50	50	50	49.6
<u>12.1</u>	55	55.3	55	54.7	18	55	55	55	54.6
16.2	60	60.3	60	60.6	20.9	60	60	60	59.7
15.3	65	65.3	65	65.7	22.2	65	65	65	65
23.7	70	71.1	70	71.7	21.1	70	70	70	70
...	75	**73.4	75	**79.5	19.3	75	75	75	75
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	30.2	20	18.7	N	30	30	20	20.1
N	35	35.3	25	23.5	1.1	35	35	25	25
1.4	40	40.3	30	28.3	<u>7.5</u>	40	40	30	30
<u>3.5</u>	45	45.3	35	33.5	<u>12.7</u>	45	45	35	34.9
<u>6.7</u>	50	50.3	40	38.7	<u>16.2</u>	50	50	40	39.4
<u>7.6</u>	55	55.3	45	43.7	18.7	55	55	45	44.4
8.8	60	60.3	50	49.2	19.2	60	60	50	49.5
11	65	65.3	55	54.7	18.5	65	65	55	54.6
21.1	70	70.4	60	60.2	17.3	70	70	60	59.6
31.2	75	75.1	65	66.2	13.6	75	75	65	65
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	65.3	20	19	N	65	65	20	20.1
N	65	65.3	25	23.8	N	65	65	25	25
N	65	65.3	30	28.7	N	65	65	30	30
N	65	65.3	35	33.7	-1.1	65	65	35	34.9
-0.8	65	65.3	40	38.7	<u>3.7</u>	65	65	40	40.4
<u>1.2</u>	65	65.3	45	43.8	<u>8.6</u>	65	65	45	44.5
<u>6.9</u>	65	65.3	50	49.6	<u>13.9</u>	65	65	50	49.5
<u>12</u>	65	65.3	55	54.7	18.4	65	65	55	54.3
15.9	65	65.3	60	59.7	22.1	65	65	60	59.9
11.3	65	65.3	65	65	22.2	65	65	65	65

SUBJECT 6/TRIAL 2

F2P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P1	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	29.3	30	28.6	...	30	**35.5	30	**27.4
-3.3	35	34.3	35	33.7	...	35	**42	35	**31.6
<u>2.1</u>	40	39.3	40	38.7	...	40	**47.1	40	**36
<u>6.5</u>	45	44.3	45	43.7	...	45	**53	45	**40.6
<u>10.6</u>	50	49.7	50	48.9	...	50	**58	50	**45.6
14.4	55	54.4	55	54.7	...	55	**63	55	**50.4
17	60	59.2	60	60.1	...	60	**68	60	**55.5
19.9	65	64.3	65	65.7	...	65	**73	65	**60.5
27.2	70	68.7	70	71.9	...	70	**78	70	**66
...	75	**64.1	75	**79.3	...	75	**83	75	**71
F2P2	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P2	NOMINAL	ACTUAL	NOMINAL	71
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	30	30.3	20	18.7	N	30	30	20	20
-2.2	35	34.3	25	24.2	1.6	35	35	25	25
<u>1.5</u>	40	39.3	30	29	<u>7.4</u>	40	40	30	30
<u>6</u>	45	44.9	35	33.8	<u>12.2</u>	45	44.6	35	34.8
<u>9.2</u>	50	50.3	40	38.7	<u>15.8</u>	50	49	40	39.6
9.9	55	55.3	45	43.7	17.4	55	54	45	44.5
10.7	60	60.3	50	48.7	17.6	60	59	50	49.6
14.5	65	65.3	55	53.7	17	65	64.2	55	54.5
23.3	70	70.6	60	59.6	15.6	70	69	60	59.4
28.9	75	77.6	65	66.9	11.9	75	74	65	64.5
F2P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL	F4P3	NOMINAL	ACTUAL	NOMINAL	ACTUAL
Ldp	L1	L1	L2	L2	Ldp	L1	L1	L2	L2
N	65	65.8	20	18.8	N	65	65	20	20.1
N	65	65.3	25	23	N	65	65	25	24.9
N	65	65.4	30	28.4	N	65	65	30	30
N	65	65.6	35	33.6	-2.3	65	65	35	34.9
-1.8	65	65.7	40	39.1	<u>2</u>	65	65	40	39.3
<u>2.2</u>	65	65.8	45	44.8	<u>7.7</u>	65	65	45	44.7
<u>7.3</u>	65	65.3	50	49.1	<u>12.4</u>	65	65	50	49.6
<u>12.7</u>	65	65.3	55	54.3	17.2	65	65	55	54.6
17.9	65	65.9	60	59.5	21.3	65	65	60	59.5
16.1	65	66.2	65	65.3	22.7	65	65	65	65

VITA

Kimberly Anne Preissler was born in Mount Pleasant, Pennsylvania on December 19, 1965. After graduating from Troy High School in Troy, Ohio in 1983, she attended Wright State University in Dayton, Ohio for two years. For the next five years, she worked for several banks and other financial institutions in Ohio, Michigan and Georgia. Upon relocation to Tennessee with her family, she attended the University of Tennessee at Knoxville where she received her Bachelor of Arts degree with a major in Speech Pathology in August 1993. She then immediately began a graduate program in Audiology at UT. While at the university, she was employed as a graduate assistant in the Department of Audiology and Speech Pathology and continued to work in banking at First Tennessee Bank. In May, 1995 she received a Master of Arts degree in Audiology from the University of Tennessee in Knoxville. Future plans include completing a Clinical Fellowship Year in Audiology.