Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.182 Laboratory Assignment I
Lab 1: Measurement of Detection Thresholds

You may practice the parts of this laboratory wherever you have a quiet environment with a pair of earphones and a PC or MAC that can deliver sounds. You should conduct the formal experiments in the laboratory of the Sensory Communications Group of the Research Laboratory of Electronics (36-744) at times that the Teaching Assistant will arrange. Not only are laboratory quality earphones and sound-treated booths available, but also the sound generation/delivery system is calibrated.

You may use Internet Explorer, Safari, or Mozilla Firefox (preferred) to run the protocols. When using your own computer, set the sound level so that the noise is loud but comfortable. Use the same level settings for all protocols.

The three protocols used in this laboratory exercise may be accessed from the *Laboratory Assignments* section of

http://web.mit.edu/6.182/www/

Background

This laboratory exercis is concerned with measuring your ability to hear weak sounds in a noise background. While the precise value of the minimum value of sound intensity that you can detect in noise is of interest, the main focus of the exercise is comparison of different methods of measuring this value.

Measurements of a listener's ability to detect sounds are made in both scientific research and in clinical practice. This laboratory exercise is concerned with methodological issues that arise in such measurements. You will compare four different methods of characterizing detection abilities. In addition, for each method you will examine the effects of practice and training on the performance of the listener, and study the ability of each method to detect changes in performance. These methodological issues are pervasive and occur when one attempts to measure many psychoacoustic phenomena.

Two basic methods of testing are used in psychoacoustics: *fixed level* and *adaptive* procedures. Fixed level procedures, such as the *method of constant stimuli*, test a number of *predetermined* levels in an attempt to estimate the function which relates some measure of performance, such as percentage of correct responses, to a measure of the stimulus, such as sound pressure level. Often a criterion measure, such as the *detection threshold,* is then estimated by interpolation from this curve. An adaptive procedure is one in which the stimulus presented on a given trial is determined by the subject's responses on previous trials. The rules for adjusting the stimulus[1] are intended to achieve a specified level of performance on the part of the subject.

In general the choice of measurement procedures depends upon one's application. For each application, a good procedure would be efficient, yielding reliable measures of performance in minimal testing time. The reliability of an experimental measurement is inversely related to its variability (as might be determined by repeated measurements) and its bias (systematic difference between true and measured values).

Fixed level and adaptive procedures have different advantages so their usefulness is a function of the researcher's needs. The trade-offs often occur between accuracy and speed. Fixed level procedures can provide useful estimates of the detection threshold if the stimulus levels tested bracket the true value and if the test levels provide sufficient resolution. In order to ensure that the bracketing is adequate a relatively large range of levels must be tested. Since it is difficult to make use of the results of trials in which the stimulus is clearly audible or clearly inaudible to improve the accuracy of the threshold estimate, a considerable fraction of the testing effort can be wasted.

Adaptive procedures can make more efficient use of test time to the extent that they concentrate testing effort on stimulus levels near the threshold value. Of course, all methods are adaptive, in the sense that experimenters typically adjust the range of levels to match the listeners demonstrated performance, even in procedures that are nominally fixed-level. The adaptive procedures in use today employ much more rapid adjustments: test levels

[1] A set of rules currently in wide use is discussed in a paper by H. Levitt: "Transformed Up-Down Methods in Psychoacoustics," *J. Acoust. Soc. Am.* **49**, pp 467-477.

may be changed on the basis of only one or two responses. The availability of electronically controlled stimulus generators and programmable computers that can keep track of responses and adjust the selection of test levels automatically accounts for the widespread use of these methods in current research.

Laboratory Procedures

This laboratory exercise is intended to measure your ability to hear tones presented in a noise background. You should make the measurements monaurally, using your better ear if you have a hearing loss, or your right ear if you have normal hearing.

The laboratory consists of two parts. The first part will be preparatory, consisting of familiarization with and practice on the procedures and will be conducted at home or at an Athena terminal. The second part will be the formal measurements and will be conducted in the sound rooms (36-744) of the Auditory Perception Laboratory of the Research Laboratory of Electronics.

For both parts of the laboratory exercise, you will need a computer with a web browser such as *FireFox, Safari,* or *InternetExplorer.* Go to the following web page

http://web.mit.edu/6.182/www

and browse down the page to *Laboratory Assignments.*

Protocols

This exercise consists of three Protocols and requires three laboratory sessions. Although one listener might be able to complete all three protocols in a single lab session, this is not the best plan. Fatigue would very likely set in, causing the data obtained to be of questionable value. It would be preferable to have each partner spend about one hour serving as listener and one hour controlling the experiment. To avoid fatigue, it is advisable for that one hour to be broken up into two half-hour sub-sessions. Thus each listener should serve as a subject for one-half of the first hour and one half of the second hour.

It is strongly suggested that you familiarize yourself with all three protocols either at home or at an Athena Workstation, discarding any data that you may collect. You have probably not participated in experiments like this before. By familiarizing yourself in this way, the protocols will not be a surprise for you when you come to lab and take data. Ample time is provided in the class schedule for you to conduct the formal experiments if you begin taking data seriously in the first laboratory session.

Data should be taken only after you have had practice with each Protocol. Protocols 1 and 2 should be performed by each subject during each lab session. You should administer them a total of five times during the first and second formal laboratory sessions and twice on the third laboratory session. They provide the reference level needed by Protocol 3 and can serve as a basis for estimating the effects of repeated testing. Protocol 3 should be performed at least three times, in the third lab session.

The target stimulus in all protocols is a 1 (or 3) kHz sinusoid, o roughly 500 msec duration. The purpose of Protocols 1 and 2 is to determine the minimum intensity at which this tone can be detected when added to a bandpass 80 (or 50) dB SPL Gaussian noise of 4.9 kHz bandwidth. Because the tone to be detected is presented in an additive noise background, the *masked threshold* is being determined. Presentation in a quiet background would be required to determine the *absolute threshold* as in clinical audiometry. The noise background minimizes the effects of extraneous sounds, and the data will be relevant when the topic of masking is discussed later in the subject.

Instructions

Although you will obtain the data that you need to record if you select "Brief" as the "Results" option, you may want to choose one othe other options to learn more about how you performed in the experiment. Select "Yes" as the "Feedback" option for Protocols 2 and 3.

Protocol 1

Protocol 1 uses the *method of limits* to estimate the threshold of detection, the value of the sound pressure of a stimulus that is just detectable. In this method, you are presented a tone of varying intensity as asked to indicate whether you "heard" the tone. The stimulus

intensities are either systematically decreased (*descending limits*) or systematically increased (*ascending limits*) from presentation to presentation.

In descending limits, the signal level is initially well above the subject's threshold and then the level is decreased until the subject responds "No"to the question, "Do you hear the tone?" The *descending threshold* for a given test is taken to be the level at which the responses change from "Yes" to "No". In ascending limits the signal level is initially well below the subject's threshold and then increased at fixed intervals until the subject responds "Yes"to find the *ascending threshold*. In both cases the starting point and the set of step-sizes are varied to discourage response patterns based on counting.

You should enter the parameters that you are told to us for your experiment (`Tone Frequency` and `Noise Level`) and set the `Initial Tone Level` to be 10 dB higher than the `Noise Level`. Setting `Results` to `Brief` will cause only the thresholds to be listed; `Full` causes the test levels and responses to be listed as well.

Protocol 1 should take less than two minutes to administer. During the first and second laboratory sessions, you should conduct one run for practice, and four runs for actual testing. Conduct the practice and two testing runs before switching with your lab partner; conduct the other two testing runs after you resume serving as a listener. You should record the ascending and descending thresholds after each run and enter them into Table 7.

During the third laboratory session, you should conduct one run for practice, and two runs for actual testing. Conduct the practice run and one testing run before switching with your lab partner; conduct the other one after you resume serving as a listener. You should record the ascending and descending thresholds after each run and enter them into Table 7.

Protocol 2

A two-interval two-alternative forced-choice procedure is used in this protocol. A burst of noise is presented in each of two intervals. A tone is added to the noise in either the first or the second with equal likelihood. The listener's task is to specify which of the two intervals contains the tone. You should select "Yes" as the feedback option.

Two experiments are performed: an *upward biased* experiment and a *downward biased* experiment. The upward biased experiment begins well above the estimated threshold with decreasing stimulus levels expected at the end of the first run. The downward biased experiment begins well below the estimated threshold in the upward biased experiment with increasing stimulus levels expected at the end of the first run. Eight runs are performed for each experiment.

As with Protocol 1, you should enter the parameters that you are told to us for your experiment (`Tone Frequency` and `Noise Level`). Good values for `Maximum Turnarounds` and `Turnarounds to Average` are 7 and 4. Setting `Results` to "Brief" will cause only the thresholds to be listed; `Extended` lists the history of turnarounds; `Full` causes the test levels and responses to be listed as well.

Because you have performed Protocol 1, you have a rough estimate of the threshold that Protocol 2 is likely to produce. The `Initial Tone Level` should be 15 dB higher than the

average value measured in Protocol 1 for an upward biased experiment and 15 dB lower than the average value measured in Protocol 1 for a downward biased experiment.

Protocol 2 should take less than 5 minutes to administer. During the first two laboratory sessions, you should conduct one run for practice, and four runs for actual testing. Conduct the practice run and two testing runs before switching with your lab partner; conduct the other two after you resume serving as a listener. Always conduct an upward biased measurement before a downward biased measurement. Record the upward biased and downward biased thresholds after each run and enter them into Table 10. You will use these estimates of threshold to establish the testing level for Protocol 3.

During the third laboratory sessions, you should conduct one run for practice, and two runs for actual testing. Conduct the practice run and one testing run before switching with your lab partner; conduct the other one after you resume serving as a listener. Record the upward biased and downward biased thresholds after each run and enter them into Table 10.

Protocol 3

Protocol 3 uses the *method of constant stimuli,* a two-interval two-alternative forced-choice procedure: each trial consists of one interval of either noise or tone plus noise, with equal likelihood. As in Protocol 2, the listener's task is to specify which of the two intervals contains the tone. This method differs from the Up-Down method in that tone level is fixed during the experiment. You should select "Yes" as the feedback option.

As with Protocol 1, you should enter the parameters that you are told to use for your experiment (`Tone Frequency` and `Noise Level`). For `Tone Level` you should enter the average of the values obtained with Protocol 2 on the day you perform Protocol 3. You should specify `Trials` as 80 during the formal testing. Setting `Results` to "Brief" will cause only the total number of times each response was made when each stimulus was presented to be listed; `Extended` lists the conditional probabilities that each response was made when each stimulus was presented as well; `Full` causes the test levels and responses to be listed as well.

Protocol 3 should take less than 10 minutes to administer. After practicing for 40 trials, you should conduct one run during the first lab session, two during the second lab session, and four during the third lab session. Use the final estimate of threshold yielded by Protocol 2 as the signal level. During the third laboratory session, you should administer this protocol after Protocols 1 and 2.

Record number of times you made each response (first and second) to each stimulus condition (tone presented in first/second interval) in Table 11.

Laboratory Sessions

Session 1 should consist of a practice run of Protocol 1, two testing runs of Protocol 1, a practice run of Protocol 2, two testing runs of Protocol 2. After this, you should allow your

lab partner to be tested. When testing resumes, it should consist of two testing runs of Protocol 1, two testing runs of Protocol 2, and one administration of Protocol 3.

Session 2 should consist of a practice run of Protocol 1, two testing runs of Protocol 1, a practice run of Protocol 2, two testing runs of Protocol 2, and one administration of Protocol 3. After this you should allow your lab partner to be tested. When testing resumes, it should consist of two testing runs of Protocol 1, two testing runs of Protocol 2, and one administration of Protocol 3.

Session 3 should consist of a practice run of Protocol 1, a testing run of Protocol 1, a practice run of Protocol 2, a testing run of Protocol 2, and two administrations of Protocol 3. After this you should allow your lab partner to be tested. When testing resumes, it should consist of a testing run of Protocol 1, a testing run of Protocol 2, and two administrations of Protocol 3.

Item	Value
Group	
Audiostation	
Ear	
Tone Frequency (Hz)	
Noise Level (dB SPL)	

Table 1: Background Information.

	Descending		Ascending	
Run	Threshold	Presentations	Threshold	Presentations
	dB SPL		dB SPL	
Prac.				
1				
2				
3				
4				
Prac.				
5				
6				
7				
8				
Prac.				
9				
10				

Table 2: Results obtained using the Method of Limits.

	Upward Biased		Downward Biased	
Run	Threshold	Presentations	Threshold	Presentations
	dB SPL		dB SPL	
Prac.				
1				
2				
3				
4				
Prac.				
5				
6				
7				
8				
Prac.				
9				
10				

Table 3: Results obtained using the Up-Down Adaptive Method.

Run	$N(1,1)$	$N(1,2)$	$N(2,1)$	$N(2,2)$	Tone Level dB SPL
1					
2					
3					
4					
5					
6					
7					

Table 4: Results obtained using the Method of Constant Stimuli. $N(i,j)$ is the number of j responses ($j = 1$ for responses "first", $j = 2$ for responses "second") when the stimulus is i ($i = 1$ when the tone is presented in the first interval, $i = 2$ when the tone is presented in the second interval).

Experiment Details

The stimuli are 450 ms bursts of tone centered within a 500 ms burst of noise. The rise/fall times of the noise are 10 ms, of the tone 25 ms. The on time of the noise is 480 ms, of the tone 400 ms. Thus the tone is completely covered by the noise. The noise is filterd by second order Butterworth filters to a bandwidth of 100–5000 Hz.

Protocol 1

The initial level for the ascending limits measurements is 10–15 dB less than the threshold determined by the descending limits procedure.

The ascending threshold is usually higher than the descending threshold. When a single estimate of the detection threshold is needed, ascending and descending thresholds are usually averaged. The rationale for this is that when levels are presented in descending order, there is a bias for the response "Yes". When the tone levels are presented in ascending order, there is a bias for the response "No". Therefore, averaging the ascending and descending thresholds tends to cancel the biases.

Protocol 2

The two 500 ms bursts of noise are separated by 400 ms of silence.

Testing begins at an arbitrary tone level and changes as a result of the pattern of correct and incorrect responses made by the listener. A *run* is a series of steps (increases or decreases in tone level) in only one direction. Runs are terminated by *turnaround points* at which the stimulus level is decreased after an ascending run (sequence of increases) or increased after a descending run (sequence of decreases).

The level of the tone is adjusted according to an up-down procedure developed by H. Levitt[2] The criteria for changing stimulus levels can be found in entry 2 of Table I in the Levitt paper. The level increases if the response is incorrect (a turnaround point for descending runs), stays the same if the response is correct, and decreases if the response has been correct for two consecutive trials (turnaround point for ascending runs). According to Levitt's analysis, these criteria should cause the stimulus level to converge to a performance level of 70.7% correct responses.

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The estimated "threshold" (nominally corresponding to 70.7 % correct responses) is the average of the stimulus levels at the final 4 turnaround points. The first three turnarounds

[2] "Transformed Up-Down Methods in Psychoacoustics," *J. Acoust. Soc. Am.* **49**, pp 467-477.

are not included in the average.

Trial	Dirction	Turns	Step	Level	Response
1	0	0		60	+
2	0	0		60	+
3	D	0	10	50	−
4	U	1	5	55	+
5	U	1		55	+
6	D	2	5	50	−
7	U	3	2	60	+
8	U	3		60	+
9	D	4	1	59	

Table 5: Sample track of the Up-Down Adaptive Method. The directions are: U - increasing level, D - decreasing level, 0 - undetermined direction. Levels are in dB. A correct response is designate +. An incorrect response is designated -.

The step size starts at some initial and relatively large value, 10 dB, and stays at that value until a turnaround occurs. At successive turnarounds the step size is reduce to 5, 2, and 1 dB. It is then used to compute the next stimulus value. For convenience the minimum value of the step size is 1.0 dB. A possible initial sequence of trials is shown in Table 5.

Presentations cease when the total number of turnarounds exceeds a specified value, in this case seven. The threshold reported is the average of the last four turnaround values. The first turnpoints are not included in the average as they may be unduly affected by by the arbitrary initial value.

Protocol 3

The purpose of Protocol 3 is to determine how well Protocol 2 estimates the tone level that corresponds to a probability of responding correctly of 0.707. If the probability of responding correctly were 0.707 and 80 trials were performed, the number of correct responses would be expected to fall in the range 48–65 in roughly 95% of repetitions of the experiment. If the Protocol 2 estimate of the tone level were too high (or too low), if the obeserver became fatigued or inattentive during the administration of Protocol 3 (or if the observer learned a new, reliable, cue for detecting the tone in Protocol 3), the number of correct responses would fall outside this range.

The suggestion that you test 80 trials is a compromise. Fewer than 50 trials won't likely give an accurate estimate of the probability of correct respons and more than 150 trials is likely to tax the subject's endurance.

Response bias might cause an observer to do less well than expected in Protocol 3. An *unbiased* observer should be correct as many times when the tone was presented in the first

interval as when it was presented in the second. Assuming that 80 trials are tested, and that the tone is presented in both intervals with equal likelihood, then an observer who detects tones (in either interval) with a probability of 0.707 should be correct 23–34 times when the tone is presented in the first (or second) interval. If the observer exceeds 34 correct respnses when the tone is presented in one interval and falls below 23 correct responses when the tone is presented in the other interval, he/she has demonstrated a response bias, a tendency to favor one response over the other. If the observer exceeds 34 correct responses for both intervals of tone presentation, he/she has demonstrated greater *sensitivity* in Protocol 3 than in Protocol 2.

Report

Prepare a report on your results. Your report should include a discussion of your measurements, an analysis of the results, and a discussion of this analysis. You need not repeat any of the discussion in this document in your write-up. In particular, it is not necessary to repeat a the description of protocols, except in so far as you may have modified them.

Your report should be submitted in printed form, prepared by a formatting word processor such as Word or LaTex. Please double space the report.

Be sure to specify

- Your Laboratory Group.
- The name of your partner(s).
- The ear you tested.
- The Audiostation you used.
- The frequency of the tone you used.
- The level of the noise you used.

You should present all your raw data tables in an appendix at the very end of your laboratory report. The body of your report should include tables of processed data and graphs. These may either be folded in the body, or inserted after the body but before the appendix.

Analysis of Results

In analyzing the results of this experiment, you will have to average your data sets and to compare the differences between averages of different data sets.

Recall that the average (mean) of N items of data, $X_1, X_2, \ldots, X_N$ is

$$\widehat{X} = \frac{1}{N} \sum_{i=1}^{N} X_i$$

and that the sample standard deviation is s, where

$$s^2 = \frac{1}{N-1} \sum_{i=1}^{N} \left(X_i - \widehat{X} \right)^2$$

In making comparisons between two data sets, the *standard error of the mean,* S provides a useful rule of thumb:

$$S = \frac{1}{\sqrt{N}} s.$$

Roughly speaking, data sets with means $\widehat{X_1}$ and $\widehat{X_2}$ are significantly different if $\left|\widehat{X_1} - \widehat{X_2}\right|$ is more than twice the standard error of the mean of the difference:

$$\sqrt{S_1^2 + S_2^2}.$$

Analyze your data by carrying out the following steps.

1. Enter the averages and standard deviations of the Ascending, Descending, and Average Thresholds into Table 8. Plot the average measurements of Ascending, Descending, and Average Thresholds made by the Method of Limits for runs 1-10 on Fig. 1. Use the same ordinate for both Fig. 1 and Fig. **??**.

2. Enter the averages and standard deviations of the Upward, Downward, and Average Thresolds into Table 10. Also enter the average number of presentations into Table 10. Plot your measurements of Upward, Downward, and Average Thresholds made with the Up–Down Adaptive Method for runs 1-4 and runs 5-8 on Fig. **??**.

3. Reduce the data obtained with in Protocol 3 by computing the proportion of times you answered correctly on each administration of the protocol. The proportion correct to when the stimulus is i ($i = 1$ when the tone is presented in the first interval, $i = 2$ when the tone is presented in the second interval) is

   $$P(i|i) = \frac{N(i,i)}{N(i,1) + N(i,2)}.$$

   The overall he proportion of correct responses is

   $$P_C = \frac{N(1,1) + N(2,2)}{N(1,1) + N(1,2) + N(2,1) + N(2,2)}.$$

   Place the the results into Table 12.

   Plot the proportion of times that you responded correctly (P_C) as a function of test administration in Fig. **??**. Plot the difference in the proportion of times that you responded correctly when the tone was presented in the first interval and the second interval ($P(1|1) - P(2|2)$) as a function of test administration in Fig. **??**.

   Plot the proportion of times that you responded correctly (P_C) as a function of tone level in Fig. **??**.

   Compute the *correlation coefficient* - r between P_C and test level. If P_i is the value of P_C when the tone level is L_i,

   $$r = \frac{\sum_{i=1}^{7} (L_i - m_L)(P_i - m_P)}{\sqrt{\sum_{i=1}^{7} (L_i - m_L)^2 \sum_{i=1}^{7} (P_i - m_P)^2}}$$

where

$$m_L = \frac{1}{7}\sum_{i=1}^{7} L_i$$

and

$$m_P = \frac{1}{7}\sum_{i=1}^{7} P_i.$$

Discussion of Results

Now that you have analyzed your data, you should address issues of measurement in the body of your laboratory report. You may include graphs and/or tables in the body or at the end of your report (before the appendix with the raw data).

Your discussion will summarize your observations and offer an interpretation of your results. The discussion should be in paragraph form, with headings, and should not simply list answers to questions. Thus, for example, it is not appropriate simply to say

> The value of the threshold measured by Method A is less than that by Method B.

It would be more appropriate to provide reasoning that supports this conclusion, for example by saying:

> The average value of the threshold by Method A (20 dB SPL) is significantly less than that by Method B (25 dB SPL) by more than twice the standard error of the difference between the means (2 dB SPL). This is not unexpected because the time required to perform the measurements for Method A was much larger than for Method B.

Within your discussion, you should focus on the following issues:

- Comparison of Threshold Estimates
- Detailed Comparison of Protocols 2 and 3
- Results of Protocol 4
- Clinical Implications

Comparison of Threshold Estimates

Compare the estimates of detection threshold values obtained using Protocol 1 (taking threshold as the average of the stimulus levels reported by the Upward and Downward Method of Limits, Protocol 2 (taking threshold as the stimulus level that leads to a specified percentage of correct responses), and 3 (taking threshold as the interpolated stimulus level that leads to the same percentage of correct responses). Take the following factors into account:

- Protocol 1 used a subjective method. Protocols 2 and 3 used objective methods.
- Protocol 2 used a two-interval procedure. Protocol 3 used a one-interval procedure.
- Protocol 1 was administered before Protocols 2 and 3.

1. You should have taken data under Protocols 1 and 2 in three laboratory sessions. Consider Protocols 1 and 2 separately in answering the following question.

    - Is there evidence that masked thresholds for the non-practice runs changed from lab session to lab session?

      The standard errors of the measurements taken in runs 1-4 (and runs 5-8 and runs 9-10) provides a quatitiative measure that can be used to answer this question. If the difference between the mean measurement in one lab session and the mean measurement in another lab session exceeds twice the standard error of the mean of the difference, it is likely that there was a difference between ascending and descencding thresholds.

2. Both Protocols 1 and 2 used two different measurements that were averaged to estimate thresholds.

    - Is there evidence that the "ascending threshold" was consistently higher than the "descending threshold" in Protocol 1? The standard errors of the measurements provides a quatitiative measure that can be used to answer this question.
    - Is there evidence that the "upward-biased threshold" was consistently higher than the "downward-biased threshold" in Protocol 2?

3. Now compare the results you obtained in Protocols 1 and 2.

    - Which of the Protocols produced the lowest and highest estimates of the masked detection threshold for the tone.
    - Note that there is no "correct" value for the masked threshold. Which Protocol yielded the most consistent estimates of the masked threshold?
    - Both Protocols 1 and 2 made a pair measurements of the masked threshold. Protocol 1 estimated thresholds using descending and ascending limits and Protocol 2 estimated thresholds using upward and downward biased adaptive runs. In one measurement of each pair, the tone level was initially above threshold and in the other measuremen the tone level was initially below threshold.t Did you find that the difference between the estimates of threshold yielded by descending and ascending limits was greater or smaller than the difference between the estimates of thresholds yielded by the upward and downward biased adaptive runs. You should have 10 pairs of differences to compare.

4. Recall that the noise had a bandwidth of 4.9 kHz (37 dB) so that the noise spectral level was 37 dB less than the total noise power (in dB SPL). How do your results from Protocols 1 and 2 compare with those of Hawkins and Stevens (J. Acoust. Soc. Am. 25 (2), 6-13, 1950).

Protocol 3

Protocol 3 differed from Protocols in that it measured detection performanmce at tone levels expected to produce the same probability of responding correctly (0.707).

- It is possible that your ability to detect tones in noise was constant for the three lab sessions. If this were the case, your performace on the fixed level test used in Protocol 3 should vary systematically with the tone level that you used in testing, i.e., the proportion of correct responses would be positively correlated with the actual level of the tone used. This would be indicated by a correlation coefficent $r \geq 0.62$. Did you observe such a correlation.

- Another way of thinking about Protocol 3 is that it is designed to test the Protocol 2 estimate of the tone level that leads to a probability of responding correctly of 0.707.

  You should have administered Protocol 3 seven times in three lab sessions. As mentioned previously, if 80 trials were performed, the proportion of correct responses would be expected to fall in the range 0.66–0.76 in roughly 68% of repetitions of the experiment and in the range 0.61–0.81 in roughly 95% of the repetitions. On what fraction of the administrations of Protocol 3 did you observe that the number of correct responses fell in these ranges?

- An *unbiased* observer should be correct as many times when the tone was presented in the first interval as when it was presented in the second. The difference in proportions. $P(1,1) - P(2,2)$ would be expected to fall in the range -.10–0.10 roughly If the you exceeded 34 correct respnses when the tone is presented in one interval and fell below 23 correct responses when the tone is presented in the other interval, you have demonstrated a response bias, a tendency to favor one response over the other. On what fraction of the administrations of Protocol 3 did you exhibit response bias? Were you biased consistently from adminstration to administration of Protocol 3?

- If the Protocol 2 estimate of the tone level were too high (or too low), it may be becuse you became fatigued or inattentive during the administration of Protocol 3 (or you may have learned a new, reliable, cue for detecting the tone in Protocol 3). Comment on these possibilities.

Clinical Implications

Measurements such as that employed in Protocol 1 are similar to those made routinely in the audiological clinic. Based on your results and observations, are clinicians well advised to

continue using such methods or should they be encouraged to use the techniques employed in Protocols 2 or 3? Consider both the variability of measurements and the time required to make the measurements.

Item	Value
Group	
Audiostation	
Ear	
Tone Frequency (Hz)	
Noise Level (dB SPL)	

Table 6: Background Information.

	Descending		Ascending	
Run	Threshold	Presentations	Threshold	Presentations
	dB SPL		dB SPL	
Prac.				
1				
2				
3				
4				
Prac.				
5				
6				
7				
8				
Prac.				
9				
10				

Table 7: Results obtained using the Method of Limits.

Runs	Avg. Des.	SD. Des.	Avg. Asc.	SD. Asc.	Avg. Thr.	SD. Thr.
	dB SPL	dB	dB SPL	dB	dB SPL	dB
1 - 4						
5 - 8						
9 - 10						

Table 8: The average results (Avg.) and standard deviations (SD.) obtained using the Method of Limits.

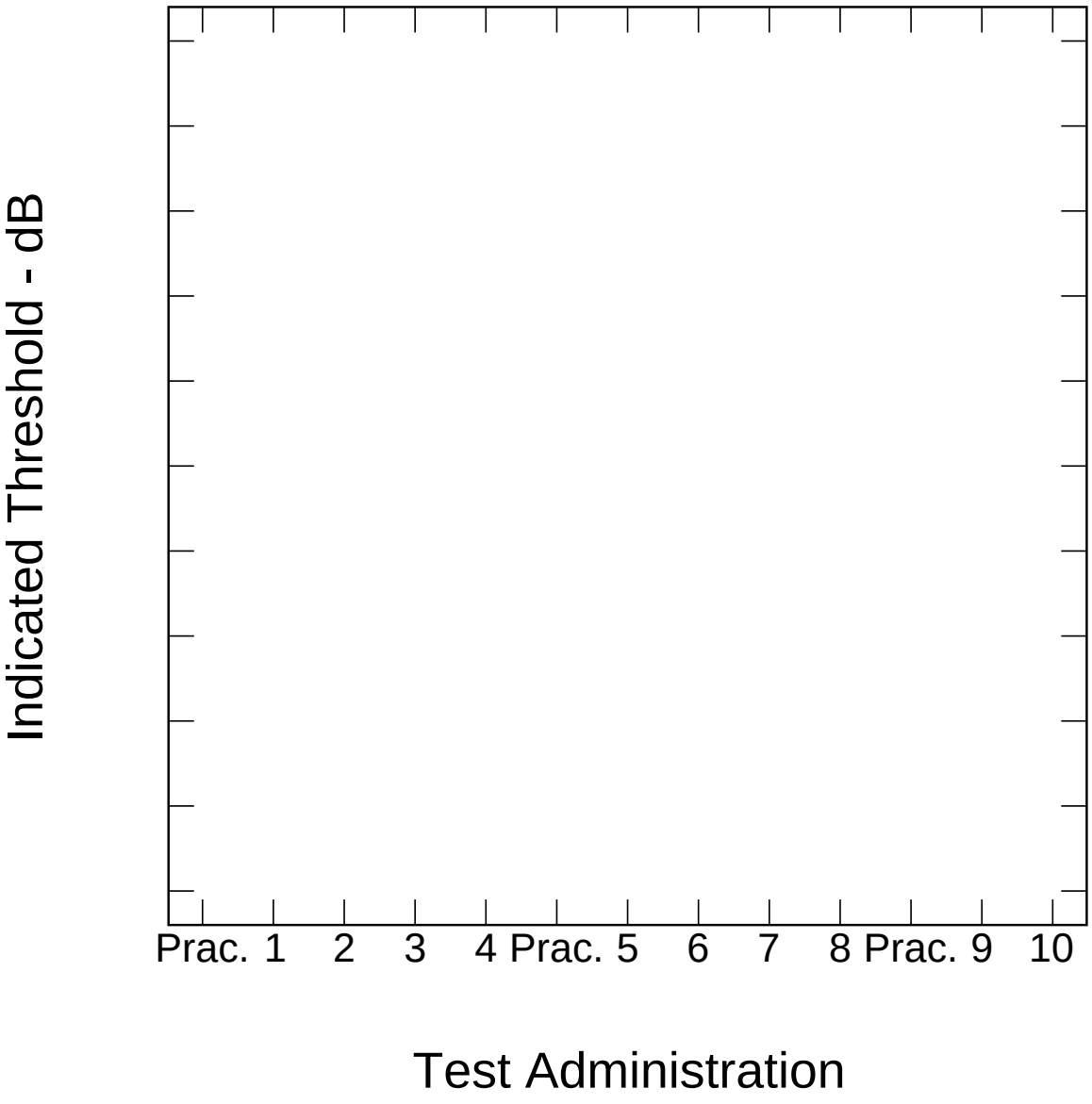

Figure 1: Threshold measurements made with the Method of Limits.

	Upward Biased		Downward Biased	
Run	Threshold	Presentations	Threshold	Presentations
	dB SPL		dB SPL	
Prac.				
1				
2				
3				
4				
Prac.				
5				
6				
7				
8				
Prac.				
9				
10				

Table 9: Results obtained using the Up-Down Adaptive Method.

Runs	Avg. Up.	SD. Up.	Avg. Down.	SD. Down.	Avg. Thr.	SD. Thr.	Avg. Pres.
	dB SPL	dB	dB SPL	dB	dB SPL	dB	
1 - 4							
5 - 8							
1 - 8							

Table 10: Results obtained using the Up-Down Adaptive Method (top table) and average results (Avg.) and standard deviations (SD.) of the measurements (bottom table).

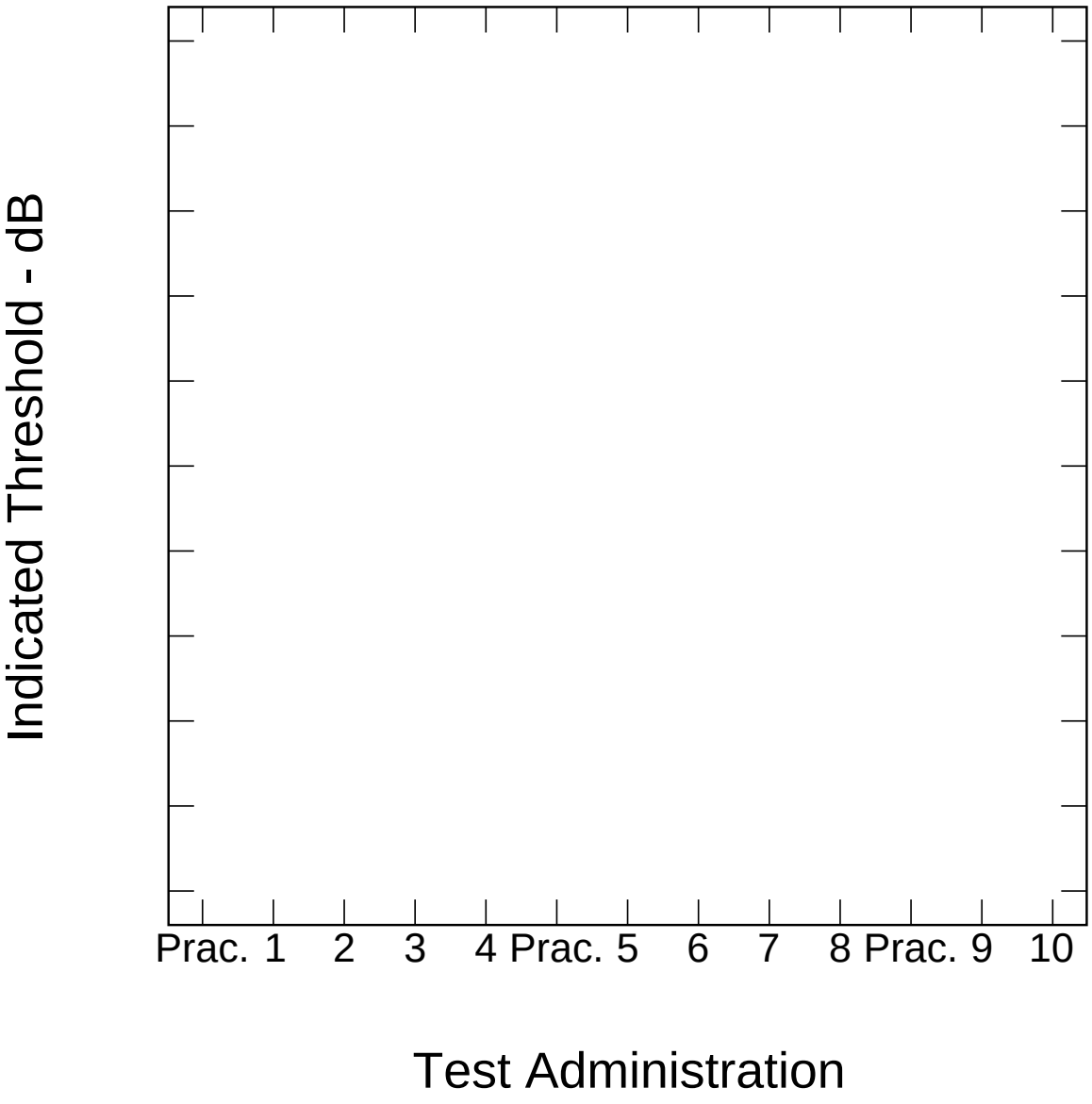

Figure 2: Threshold measurements made with the Up–Down Adaptive Method.

Run	$N(1,1)$	$N(1,2)$	$N(2,1)$	$N(2,2)$	Tone Level dB SPL
1					
2					
3					
4					
5					
6					
7					

Table 11: Results obtained using the Method of Constant Stimuli. $N(i,j)$ is the number of j responses ($j = 1$ for responses "first", $j = 2$ for responses "second") when the stimulus is i ($i = 1$ when the tone is presented in the first interval, $i = 2$ when the tone is presented in the second interval).

Run	$P(1\|1)$	$P(2\|,2)$	P_C	Tone Level (db SPL)
1				
2				
3				
4				
5				
6				
7				

Table 12: Results obtained using the Method of Constant Stimuli.

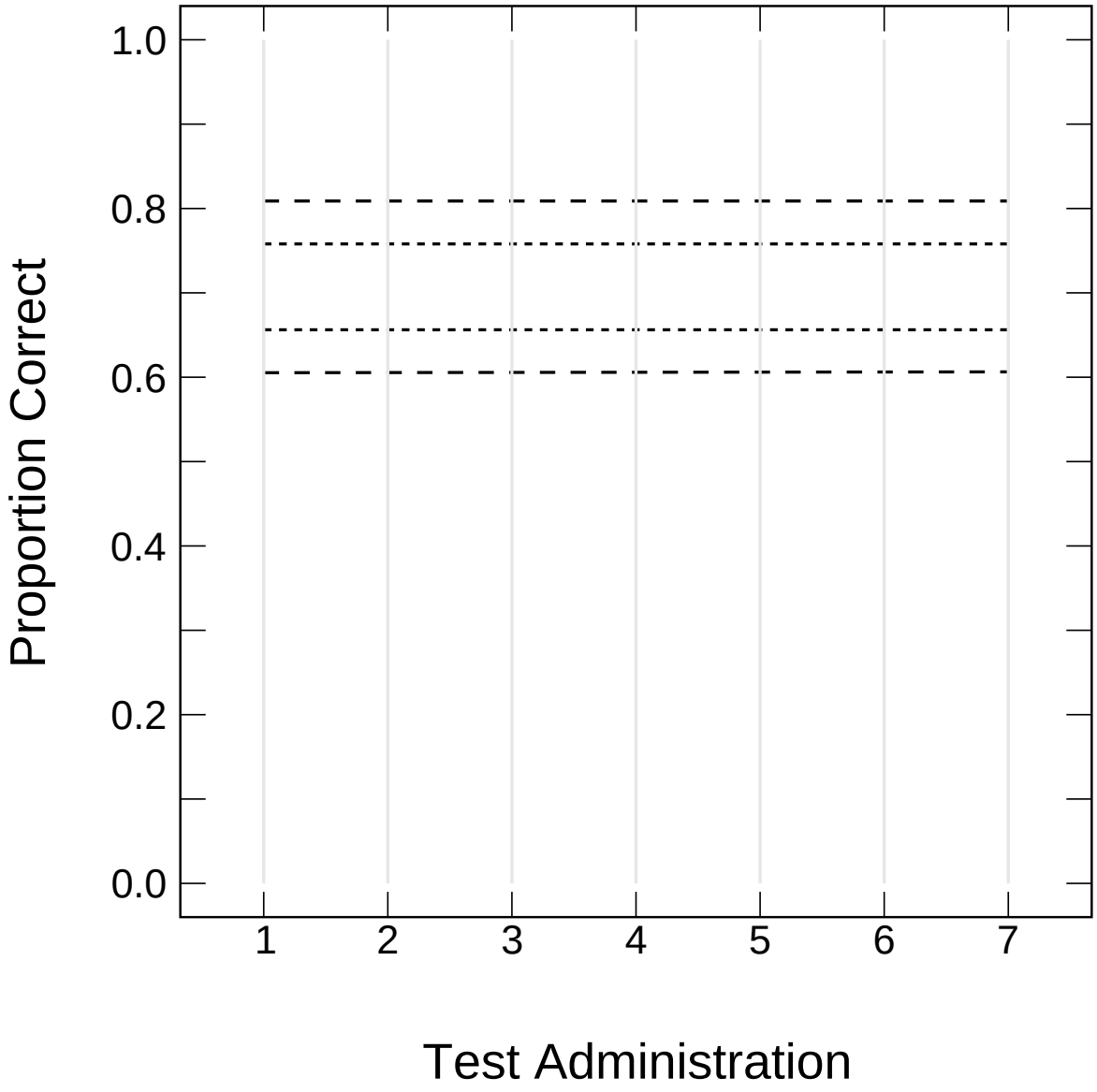

Figure 3: Proportion of correct responses (P_C) for the Method of Constant Stimuli as a function of test administration.

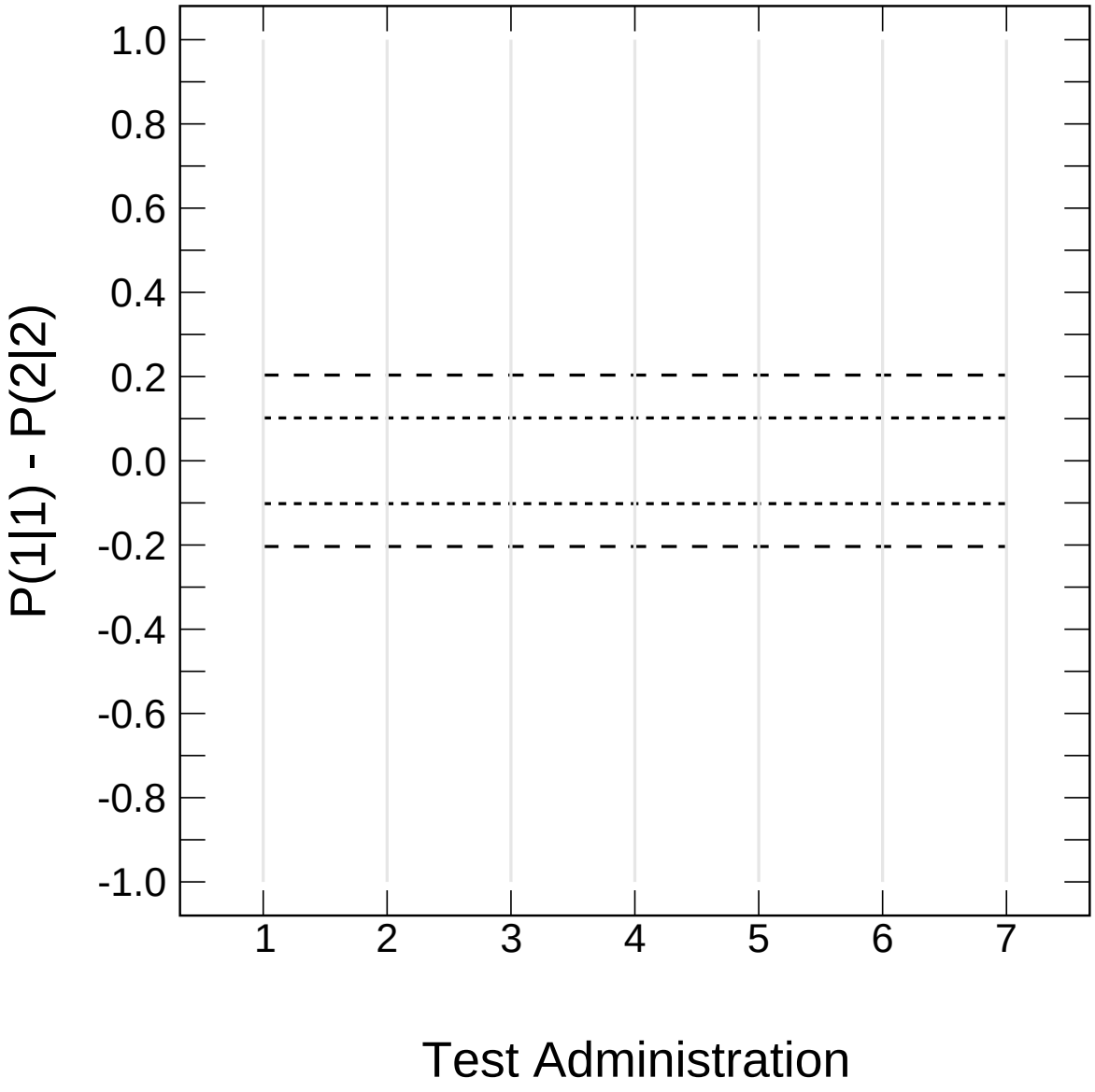

Figure 4: The difference $P(1,1) - P(2,2)$ for the Method of Constant Stimuli as a function of test administration.

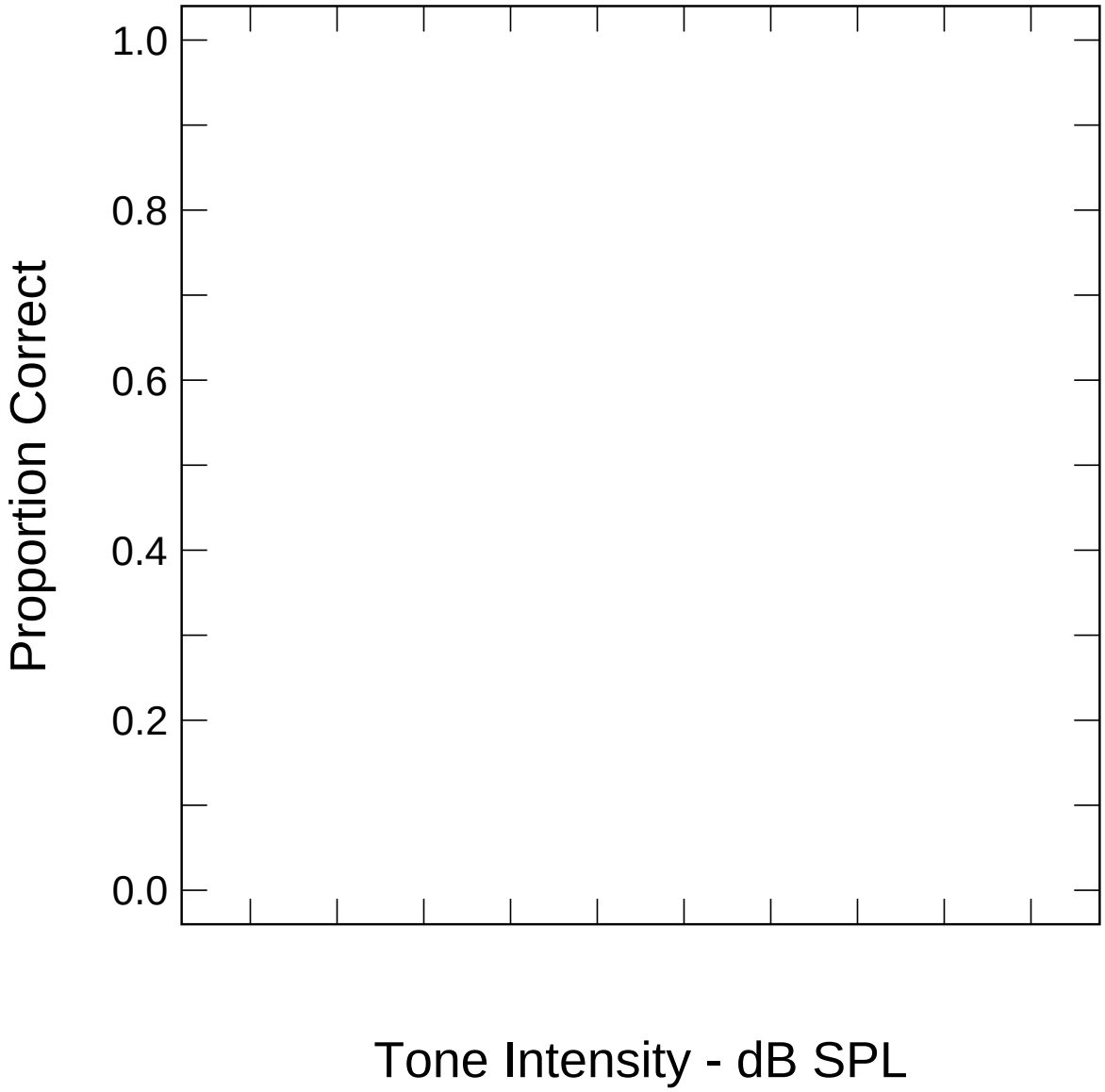

Figure 5: Proportion of correct responses as a function of tone intensity for the Method of Constant Stimuli.