**Abstract:**

A human’s threshold of hearing is the minimum [sound level](http://en.wikipedia.org/wiki/Sound_level) of a [pure tone](http://en.wikipedia.org/wiki/Pure_tone) that an average ear with normal [hearing](http://en.wikipedia.org/wiki/Hearing_(sense)) can hear while no other sound is present.

This report presents the results of an experiment performed to determine whether 10 evenly spaced points over a decade (between the frequencies 1000Hz to 10000Hz) are enough to characterize the shape of a subject’s threshold of hearing. Our hypothesis is true if tone levels between the test points can be estimated through linear interpolation.

**Hypothesis:**

10 evenly spaced test points over a decade are sufficient for characterizing the shape of a subject’s threshold of hearing.

**Method:**

Part 1: Calculating 10 evenly spaced points on a logarithmic scale:

To determine 10 evenly spaced points on logarithmic scales, logarithms are used. The start and endpoint are both put in a logarithmic base 10 expression to calculate the exponents needed. and = 4. We then find 10 evenly spaced points between 3 and 4, and calculate .

The 10 evenly spaced points are as follows:

Table : Frequencies used to generate sound files

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1000 | 1291.549665 | 1668.100537 | 2154.43469 | 2782.559402 |
| 3593.813664 | 4641.588834 | 5994.842503 | 7742.636827 | 10000 |

These numbers will represent the frequencies on which we will perform the experiment.

Part 2: Generating wav files at the given frequencies:

Matlab was used to generate a sound file for each frequency. Every frequency contains 35 tones, attenuating at 1.5 dB/tone, at a sampling rate of 44100 Hz. The interval of silence between tones was set to 0.15 seconds and each tone lasted for 0.3 seconds.

The code used for this part is shown below.

Part 3: Recording results from subjects:

The subject used Microsoft headphones in a quiet office to make sure no noise interferes with the result. The 10 wav files were present on the physical computer and were not streamed or compressed in any way.

The subject first calibrated the volume by listening to a sound file created for the 3500Hz frequency five times and recording the value. The mean was then calculated and referred to as the reference value.

The subject then listened to each file 5 times, and recorded the number of tones heard in each file. The average of tones heard was calculated and converted to decibels using the formula:

Part 4: Calculations

After collecting all the required data, linear interpolation was then used to predict the next value based on the previous two values. Comparing the actual recorded data with the predicted values will test the hypothesis.

**Results**

Below are the tables with the measurements taken during the experiment and needed calculations

Table : Tone counts at each frequency

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Frequency (Hz) | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Mean |
| 1000 | 13 | 14 | 13 | 12 | 12 | 12.8 |
| 1291.55 | 13 | 13 | 12 | 13 | 13 | 12.8 |
| 1668 | 14 | 14 | 13 | 14 | 14 | 13.8 |
| 2154.43 | 17 | 18 | 18 | 18 | 18 | 17.8 |
| 2782.5594 | 23 | 23 | 22 | 23 | 23 | 22.8 |
| 3583.81 | 24 | 24 | 23 | 24 | 25 | 24 |
| 4641.588 | 24 | 24 | 25 | 24 | 25 | 24.4 |
| 5994.8425 | 22 | 22 | 22 | 23 | 21 | 22 |
| 7742.63683 | 18 | 19 | 17 | 18 | 18 | 18 |
| 10000 | 13 | 14 | 13 | 14 | 13 | 13.4 |

Table : dB values at each frequency

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Frequency (Hz) | Db 1 | Db 2 | Db 3 | Db 4 | Db 5 | Mean dB |
| 1000 | 21.6 | 20.1 | 21.6 | 23.1 | 23.1 | 21.9 |
| 1291.55 | 21.6 | 21.6 | 23.1 | 21.6 | 21.6 | 21.9 |
| 1668 | 20.1 | 20.1 | 21.6 | 20.1 | 20.1 | 20.4 |
| 2154.43 | 15.6 | 14.1 | 14.1 | 14.1 | 14.1 | 14.4 |
| 2782.5594 | 6.6 | 6.6 | 8.1 | 6.6 | 6.6 | 6.9 |
| 3583.81 | 5.1 | 5.1 | 6.6 | 5.1 | 3.6 | 5.1 |
| 4641.588 | 5.1 | 5.1 | 3.6 | 5.1 | 3.6 | 4.5 |
| 5994.8425 | 8.1 | 8.1 | 8.1 | 6.6 | 9.6 | 8.1 |
| 7742.63683 | 14.1 | 12.6 | 15.6 | 14.1 | 14.1 | 14.1 |
| 10000 | 21.6 | 20.1 | 21.6 | 20.1 | 21.6 | 21 |

In order to get the interpolated frequency, the geometric mean between 2783Hz and 3594Hz was calculated using the formula below.

Table : Tone counts at average frequency

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Frequency | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Mean |
| 3162Hz | 23 | 24 | 23 | 24 | 23 | 23.4 |

Converting the mean to dB, and comparing it with the geometric average of the two frequencies 2783Hz and 3594Hz:

Table : Interpolated Vs. Measured dB Values

|  |  |  |  |
| --- | --- | --- | --- |
| dB Measured Average | dB Interpolated | Error dB | Std. Dev |
| 5.9 | 6 | 0.1 | 0.0707 |

**Additional Verification of Results using multiple Linear Interpolation**

Table : Multiple Linear Interpolation of dB across frequencies

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency (Hz) | Mean dB | Interpolated Value (dB) | Error in dB |
| 1000 | 21.9 | - | - |
| 1291.55 | 21.9 | - | - |
| 1668 | 20.4 | 21.9 | 1.5 |
| 2154.43 | 14.4 | 18.4647 | 4.0647 |
| 2782.5594 | 6.9 | 6.647 | -0.253 |
| 3583.81 | 5.1 | -2.666 | -7.766 |
| 4641.588 | 4.5 | 2.722 | -1.778 |
| 5994.8425 | 8.1 | 3.73 | -4.37 |
| 7742.63683 | 14.1 | 12.75 | -1.35 |
| 10000 | 21 | 21.85 | 0.85 |

Figure : Graph of interpolated frequency vs. measured frequency

**Results and Conclusion:**

Table : Results

|  |  |  |  |
| --- | --- | --- | --- |
| dB Measured Average | dB Interpolated | Error dB | Std. Dev |
| 5.9 | 6 | 0.1 | 0.0707 |

The measured average dB was calculated to be: 5.9 dB at a frequency of 3163Hz.

The interpolated dB was calculated to be: 6.0 dB at the same frequency.

Since our interpolated value is not significantly different from the average of measured values ( we can conclude that our hypothesis is true. 10 evenly spaced points are enough to characterize the shape of a subject’s threshold of hearing with respect to frequency.