Variances in the Audiogram Data of Individuals Undertaking Audiometry on Different Calibrated Audiometers

August 7, 2013

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Abstract

This test was performed on a cohort of university employees and students, to measure the variation in audiogram data that can be experienced when using different traceably calibrated audiometer systems, over a period of 3 weeks.

The test group was: a Maico MA51, Siemens Unity 2, and a Kamplex KLD23, all of which were traceably calibrated up to 3 months before the tests took place.

The results showed a reasonably large spread of data points, with a much higher level of variation in the high frequency area. Mean and standard deviation results are provided to show the variability on each test subject, with the peak standard deviation of audiometer variance at 20.21 dB.

1. Introduction

In the field of audiology, hearing assessment using a manually operated audiometer is considered the gold standard for accuracy. It is for this reason that it is vitally important to make efforts to continually assess the accuracy and practicality of the practice, in order to see that it meets modern requirements.

This study is designed to assess a cohort of individuals to determine their hearing thresholds, and then compare this to assessments made with different audiological devices, over subsequent weeks. The aim is to determine if the practice properly meets requirements of patients, and identify sources of error that could contribute to an incorrect assessment, and therefore diminish patient care.

2. Methods

2.1. Procedure

For this test, a cohort of people who were concerned about their hearing were assembled, using a promotion in a University-wide email. The people therefore were not selected with any gender or age bias, other than those imposed by the demographic of the University staff and students.

The test schedule was designed over 3 weeks, with the subjects taking the test at the same time of day each week. The reason for this is to negate learning effects as much as possible, wherein people become ”better” at the tests over time. The tests were at a constant time of the day in order to control for varying levels of concentration experienced during the day, which might effect the test. This was kept to as much as possible, however due to the nature of testing people it was sometime necessary to be flexible. The dates and times were noted on the audiogram sheets.

Each of the tests were performed to BSA (British Society of Audiology) procedural guidelines [5], which are based on, and stand alongside the British Standard procedure [3]. A precursor to the audiometric exam in these guidelines is otoscopy, which was performed on all patients before each test, and any otological abnormalities noted. According to guidelines the subjects were also asked relevant questions to assess their hearing state at the time, including enquiring about any recent loud noise exposure, or otorhinolaryngological issues that were ongoing. The answers to these questions were recorded in the subject notes.

Subjects were measured over normal au-
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diometric frequencies, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz

2.2. Equipment

The test took place in a Hemi-anechoic chamber with a noise floor of 16 dBA, in order for noise to not be a factor in the test.

The audiometer test group is as follows:

- Maico MA51
- Siemens Unity 2
- Kamplex KLD23

The only other specialist equipment used was an otoscope.

3. Results

The full table of results can be found in the appendix.

Figure 1: The average Standard Deviations across audiometric bands

4. Discussion and Conclusions

Due to the fact that all of the audiometers on test use the same headphone type (TDH-39p), they are all calibrated using the same calibration parameters, as defined in BS EN ISO 389-1 [1]. Due to this, the audiometers all performed similarly in assessing the hear-
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ing acuity of the subjects on test. There are some sources of error in the measurement process, however that are worthy of note.

Primarily the ambiguity of the calibration process defined in BE EN ISO 8235-1 [3] leads to a potential source of error. There is no mandatory accreditation body or scheme that operates in relation to calibration of audiometric devices, the standard simply states that the calibration centre must be a “Suitable Laboratory”[3], which can be interpreted in a variety of ways. The RETSPLs (Reference Equivalent Sound Pressure Levels) that are defined for the TDH-39 headphones are provided twice, once for a reference coupler designed for the headphones, and again for the more modern IEC artificial ear [2] design that is proposed as the new calibration standard [1]. Again, this is not ideal, providing two sets of calibration specifications can lead to confusion and inaccuracy. It is therefore agreed with the findings of the National Physical Laboratory in their recommendation[6] of revisions to BS EN ISO 60318 to only include a specification for calibration on the IEC artificial ear.

Another source of error is the use of different headband designs in the use of TDH-39 headphones, which supply varying tension to the subject’s ears. A further experiment could be proposed to measure the same calibrated headphone cups on individuals using different band designs and conditions, in a similar way to this experiment. As it stands, it is reasonable to assume that headphone tension differences attribute some of the variability seen in these data.

It is worth noting that variance is very subject dependant. The highest standard deviation in results across the three tests was subject 2, with 20.21, which represents a large variability. Looking at the raw data, it can be seen that this was caused by a wayward result on the first test in the left ear at 6 kHz. It can be hypothesized that higher levels of variability could be due to different levels of patient noise exposure, or even simply down to their mood or concentration.

Subject variability is more pronounced in the high frequency areas of the audiogram, as evidenced by the graph on page 3. There are two main reasons that could attribute this error. One is that directionality effects in the TDH-39 headphone design can cause headphone placement to be a factor, with some audiologists potentially placing the headphones onto the patient’s ears in a more on-axis orientation, causing a louder response than other tests. The other main factor could be temporary threshold shift caused by exposure to loud noise [4]. Human ears are more efficient in the 6 kHz range [7], and so this frequency area is more likely to be effected by threshold changes due to loud noise.

Overall there is a 4.09 average standard deviation across the data, which is a significant variation in a gold standard test.
5. Appendices

A. Subject Audiograms

Figure 2: A graph of all three audiometer outputs for subject 1
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Figure 3: A graph of all three audiometer outputs for subject 2
Figure 4: A graph of all three audiometer outputs for subject 3
Figure 5: A graph of all three audiometer outputs for subject 4
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Figure 6: A graph of all three audiometer outputs for subject 5
Figure 7: A graph of all three audiometer outputs for subject 6
Audiometer variances: Subjective measurement

Figure 8: A graph of all three audiometer outputs for subject 7
Audiometer variances: Subjective measurement

Figure 9: A graph of all three audiometer outputs for subject 8

![Graph showing audiometer outputs for subject 8](image-url)
Figure 10: A graph of all three audiometer outputs for subject 9
Figure 11: A graph of all three audiometer outputs for subject 10
Audiometer variances: Subjective measurement

Figure 12: A graph of all three audiometer outputs for subject 11
Figure 13: A graph of all three audiometer outputs for subject 12
B. Mean and Standard Deviation Graphs

Figure 14: A graph of the mean and standard deviation error bars for subject 1

![Graph showing mean and standard deviation error bars for subject 1]
Figure 15: A graph of the mean and standard deviation error bars for subject 2
Figure 16: A graph of the mean and standard deviation error bars for subject 3
Figure 17: A graph of the mean and standard deviation error bars for subject 4
Figure 18: A graph of the mean and standard deviation error bars for subject 5
Figure 19: A graph of the mean and standard deviation error bars for subject 6
Figure 20: A graph of the mean and standard deviation error bars for subject 7
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Figure 21: A graph of the mean and standard deviation error bars for subject 8
Figure 22: A graph of the mean and standard deviation error bars for subject 9
Figure 23: A graph of the mean and standard deviation error bars for subject 10
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Figure 24: A graph of the mean and standard deviation error bars for subject 11
Figure 25: A graph of the mean and standard deviation error bars for subject 12
References


