Effectiveness of a New Tablet Based Hearing Screening System Compared to Traditional Audiometry, Among a Cohort of Individuals With a High Incidence of Hearing Loss

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Abstract

Improvements to the intervention structure for hearing aid patients are being considered, in the form of an innovative new touch-screen tablet based hearing test. The concept behind this test is a lightweight web based software component, installed on a calibrated computer and headphone combination.

The purpose of this paper is to test and validate the system to define its ability to offer accurate screening. To do this, a cohort of individuals with a high rate of hearing loss was chosen; a group of 60+ aged subjects from a local care home on the south coast. Each individual underwent an audiometric evaluation, using both the traditional audiometer, and the Tablet system, and the results compared.

The results showed that there was a 6.1 dB average difference between audiogram points on the tablet compared to the Maico MA51. This is in comparison to 5.7 dB that was previously identified when comparing two other traditional audiometers to the same MA51. This is well within specification of the intended use of the Tablet based screener, as a precursor to further hearing specialist intervention.

1. Introduction

Traditionally there is only one easy way to administer hearing screening tests to people; full audiometry. While audiometry has a long standing record (dating back to 1880 [5]), and is considered the gold standard in hearing assessment, it suffers from some practical flaws. One particular flaw is the variation in performance that can be experienced due to differing headband tensions, and different calibration schedules. The biggest flaw however is the fact that a qualified audiometrist needs to be present to administer the test. This makes the test quite expensive, particularly time consuming, and compared to an automated test such as a blood pressure test, difficult to organise.

Improvements to the current hearing impairment intervention structure are being considered that will lead to overall better patient care. One of the ways in which this can be achieved is by increasing the frequency and availability of hearing testing, so that more people can be accurately diagnosed. Due to the inability of the current amount of audiologists to cope with the extra demand from a greatly increased level of testing, a technological solution was sought to reduce the time and cost demands from an increased testing regime. The subject of this study is to ascertain the efficacy of a new touch-screen automated screening system, developed by Audiology-Online.

The premise of the system is to provide a preliminary test to inform patients of a potential hearing issue before they commit to booking a full audiological test. This will increase the availability of effective screening, not only leading to an increased number of patients with access to treatment, but also categorising patients so that audiologists can concentrate time and resources on individuals with real otological problems. This will help make the intervention system more efficient, and can lead to a higher level of patient care.

2. Methods

2.1. Procedure

The audiometry was conducted on all of the subjects in the morning of the test day. The audiometry section of the test was performed to BSA (British Society of Audiology) standard procedure, beginning with otoscopy, and using the 2 down, 1 up method during the actual test[4]. This procedure is also based on that specified by BS EN ISO 8253-1[2], and therefore fulfils both recommended procedures. The audiometry was also carried out by two trained individuals who had taken the BSA Industrial Audiometry certification. Audiograms and otoscopy notes were recorded and filed for each individual.

The Tablet test was administered in the afternoon session, and due to the nature of the intuitive touch interface was minimally supervised. The system operates in the following way:

The user presses the start button on the screen in order to start the test. They are then prompted to enter their name, date of birth, and GP, which in this case was a test individual. This is to allow the relevant medical professional to receive the test results, and then organise further testing or referral as necessary. The test then begins, with a series of questions to define if the subject has contra-indications to their access into the Direct Access Adult Hearing Service. These questions are alerted to the medical professional receiving the test results to allow them to make an informed decision on the route of referral. Next the test prompts if the subject can hear a tone, by playing in one ear only. At this stage the headphones can be reversed if they have been placed incorrectly, and a screen prompt declares this. The system then plays a test tone at 60 dBHL, to determine if the individual's loss is such to prevent them hearing the standard tone presentations. This acts as a "safety tone" so that users with good hearing are not exposed to loud sounds unnecessarily. After this the test begins in earnest, wherein the individual is asked to count the amount of tones that can be heard at different frequencies, while the system reduces the tone presentation from 60 dBHL to 20 dBHL, or 80 dBHL to 45 dBHL if the user responded that they could not hear the 60 dBHL test tone previously. After repeating the tone presentations for the following frequencies; 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 6 kHz, the user is prompted that the test is finished, it sends the results to the "GP", and then resets ready for the next individual.

The subjects were then invited to make comment on the test procedure, and how they found it, compared to traditional audiometry.

2.2. Ethics

This study achieved ethical approval from the ethics committee at Southampton Solent University on 25/6/2013.

The study aimed to include a cohort of individuals with a higher than average occurrence of hearing loss, in order to provide data that would be relevant to a hearing screening system with operating amplitude levels of 20 dBHL to 80 dBHL. With this in mind, a care home was chosen on the south coast, with access to individuals ages 60+ with hearing difficulties.

The subjects were chosen by the care home manager, with no gender or age selection bias other than the 60+ requirement.

The subjects were as follows:

Subject	Gender	Age	D.O.B.
1	F	63	6/8/50
2	M	92	1/11/21
3	F	71	9/12/41
4	F	83	8/15/29
5	F	90	3/20/23
6	M	89	3/21/24
7	F	90	2/6/23
8	M	93	1/15/20
9	F	91	7/10/21

Table 1: Complete list of screening test subjects, 3 male, 6 female.

2.3. Equipment

The study is a simple comparison of the resulting output of the tablet system compared to a traditional audiometer.

The tablet system consists of an Acer W700 Tablet computer, running Windows 8, and a pair of Beyerdynamic DT770 circum-aural headphones. The tablet computer is set up to run customised web software produced by Audiology-Online Ltd, which allows tone presentation at different frequencies in the audiometric bands (250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, and 6 kHz), and calibration of headphones and computer system combinations to the British Standard output levels.

The Tablet system was calibrated by the use of an IEC artificial ear manufactured by Larson Davis (model number AEC201, with a type 2 adaptor), to the headphone output levels specified in the British Standard for Sennheiser HDA200 headphones[1]. This is due to the standardising work having not commenced for a generic profile for circum-aural headphone designs, though this work is planned in the future to refine this calibration process.

The audiometer used to compare the tablet to was the Maico MA51, which holds a current traceable calibration certificate from a suitable laboratory. An otoscope was also used in the audiometry process on each individual.

All participants read and understood an information form detailing the aims of the study, and signed a consent form.

3. Results

The full results table is produced in appendix A.

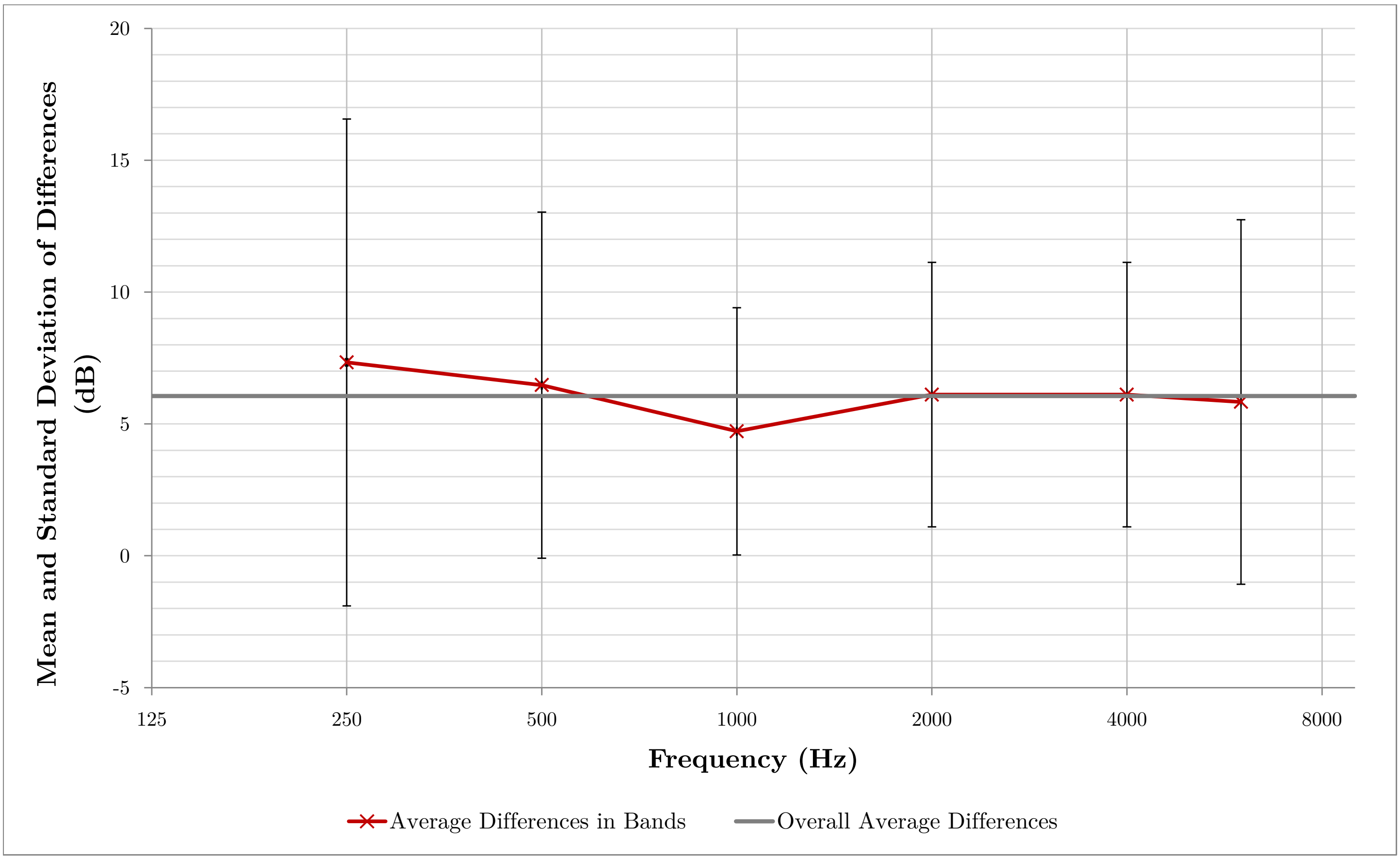

Figure 1: A graph showing the average and standard deviation of difference in each frequency band, and the total average error

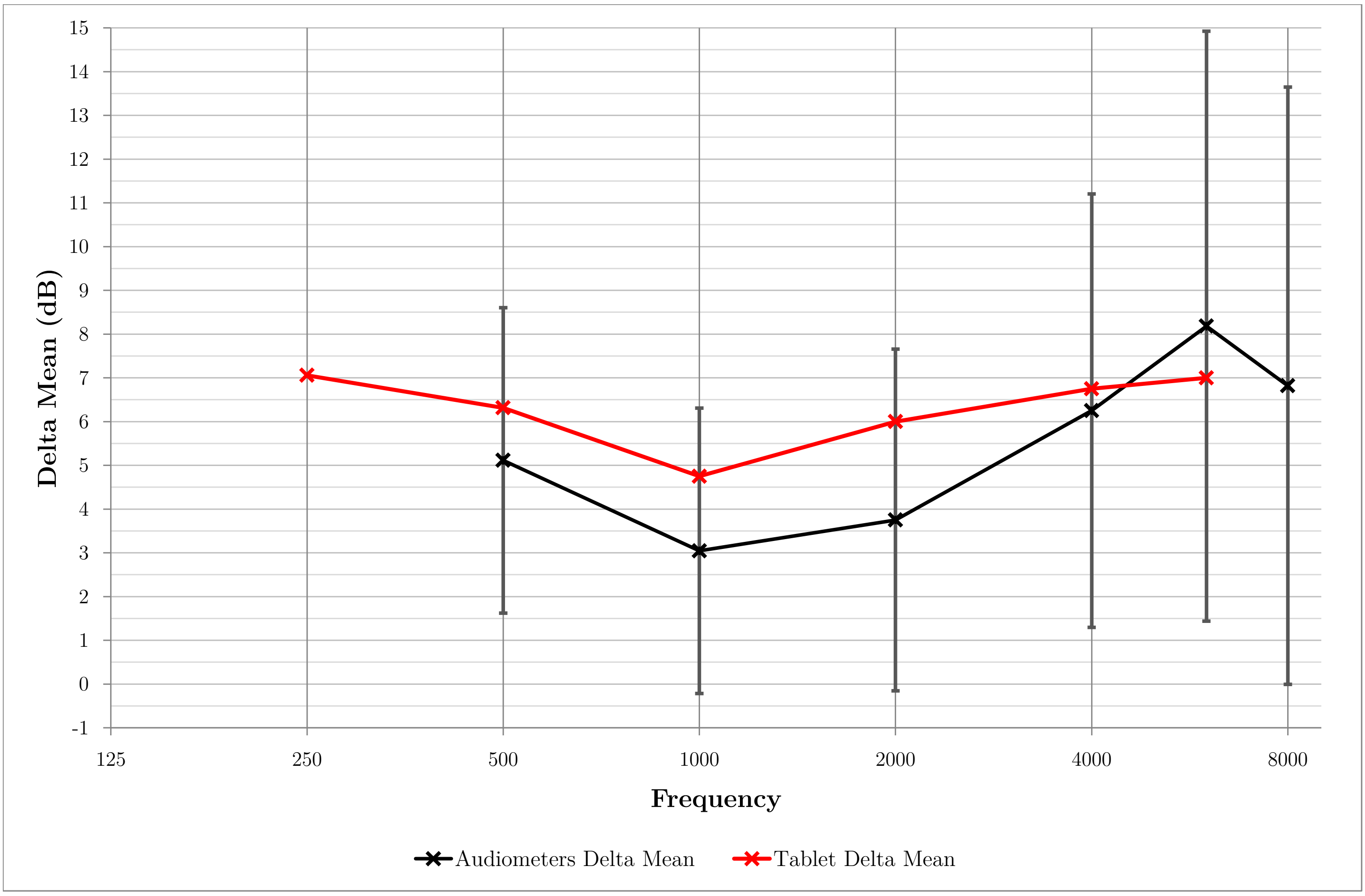

Figure 2: A graph showing the average differences of the Tablet and the Maico MA51, and two other audiometers and the Maico MA51.

250	500	1000	2000	4000	6000	Total Average difference
7.3	6.5	4.7	6.1	6.1	5.8	6.1

Table 2: The average differences between the tablet system and traditional audiometry in the audiometric bands

4. Discussion

As can be seen from the table and graph on page 5, the average difference between the Tablet system and traditional audiometry is 6.1 dB. This margin or error is perfectly acceptable in the context of a screening system, especially considering the test takes around half the time of the traditional audiometry test, takes minimal to no supervision to conduct, and is designed as a precursor to further traditional intervention.

In order to accurately compare the outcome of this trial with the typical level of variability experienced in traditional audiometry, data from a previous experiment can be considered [3]. In this study, a group of 11 people were tested with a different audiometer, at the same time of the day and week, over 3 weeks. For the purposes of this paper, these data were then compared to the respective output of the Maico MA51, the audiometer that was used as the comparison in this study. The mean differences (Delta) between the Tablet and the MA51, and other audiometers and the MA51 were then plotted, on the graph on page 5. This comparison shows that the mean differences in any given band between the Tablet system and MA51 are within one standard deviation of the differences one can expect from comparing normal audiometers, and is even a lower mean difference in the 6 kHz band.

Comparing the total average errors across the spectrum, the Tablet achieves 6.1 dB, while the comparison of traditional audiometers produces 5.7 dB. This result, while very slightly higher, fits within the general level of variance attributable to audiometers.

The shape of the curve on figure 1 (page 4) shows that there is more likely to be a larger difference in the low and high frequency ranges. This is to be expected, and is likely due to headphone placement variability, causing a resonance at low frequency, and suffering from directivity effects at high frequency.

One issue that arose while testing is a misunderstanding of the Tablet test procedure. When the test prompts the user to count the amount of tones, two of the test subjects read the instruction incorrectly, and were counting the 60 dB "safety tone" As the first presentation of the test to count. This issue has since been corrected in the test software, however the audiograms for test subjects 1 and 7 have been corrected for this error, and the revised versions used in the calculations of differences. Both the originals and corrected versions are available in the appendices.

Probably the largest source of error in this study was the low overall grasp of the test elements. Due to the nature of care home residents, some subjects found both the traditional audiometry test and the Tablet System difficult to understand, and therefore introduced a variable to the test. This may account for the high levels of congruence seen between the two different system tests on some individuals, and the slightly more erratic traces seen on others. Further testing would be advisable to establish if there is a higher success rate among younger candidates with hearing impairment. There is also a large variable in the form of physical differences between individuals, such as head size and shape, seating position, presence of a high backed chair (wheelchair), etc, all of which could impact the headphone placement and concentration level of the subjects, leading to test variance.

Test subjects were all hearing aid equipped when entering the experiment, which proves that they had been administered traditional audiometry in the past, which would have made it more familiar to them. This may explain the slightly higher rate of difference between the Tablet system and the MA51, which may prove to negligible if tested on inexperienced patients, or younger subjects better able to understand the nature of the Tablet test.

The worst level of congruence between the two systems seen on any single audiogram is that of subject 1. In the amended form, the average difference between the two systems is 12.1 dB, a difference of 3.8 dB above the next highest, subject 8, at 8.3 dB. Omitting this outlier from the test beings the average down to a mere 5.3 dB.

5. Appendices

A. Subject Audiograms

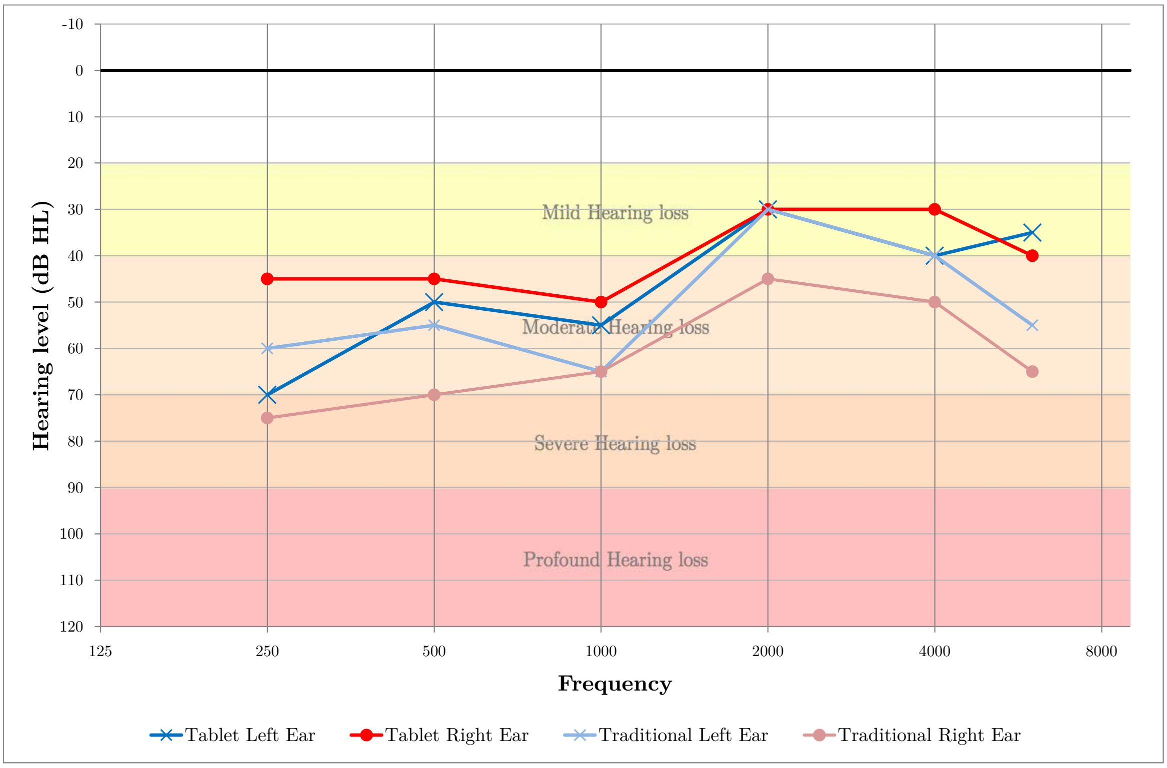

Figure 3: Audiogram comparison for subject 1

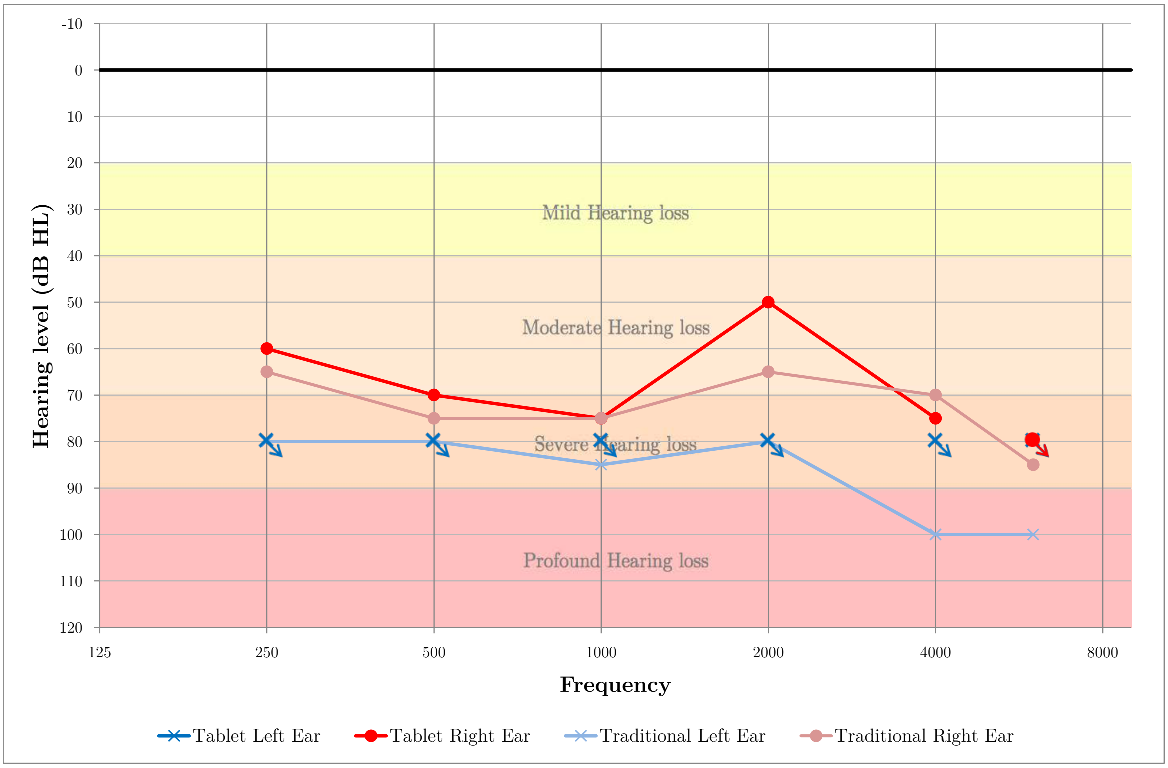

Figure 4: Audiogram comparison for subject 2

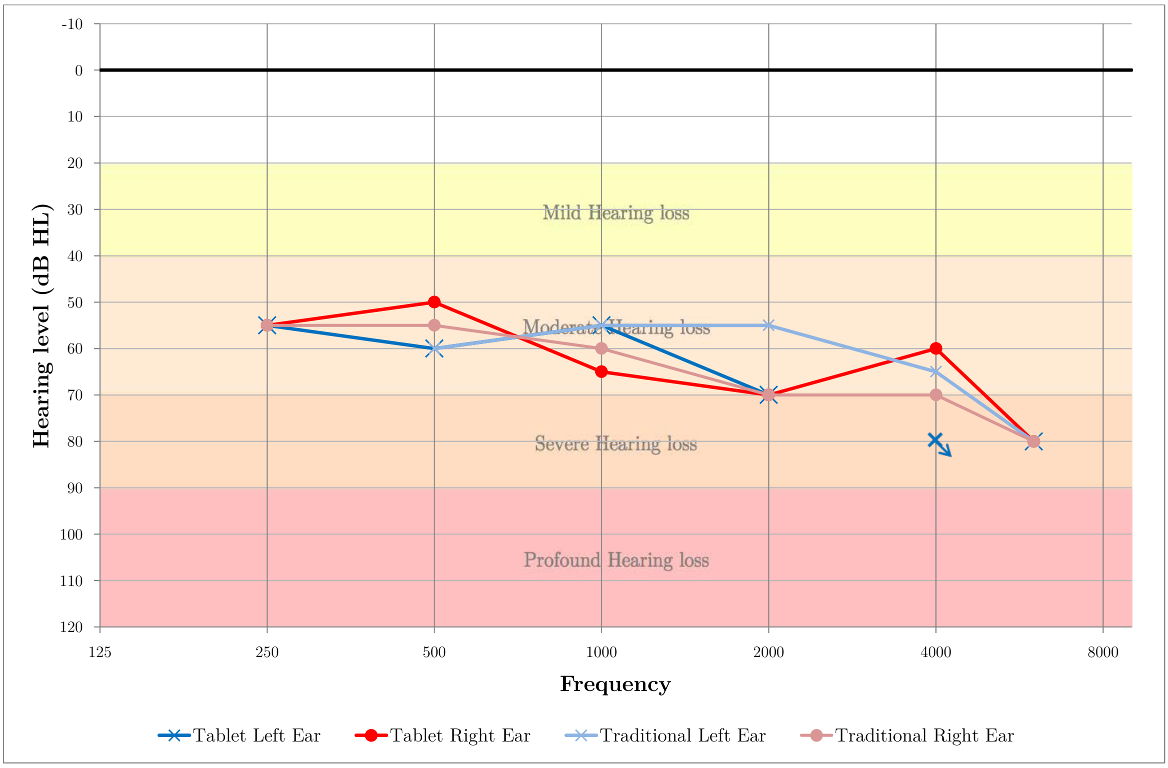

Figure 5: Audiogram comparison for subject 3

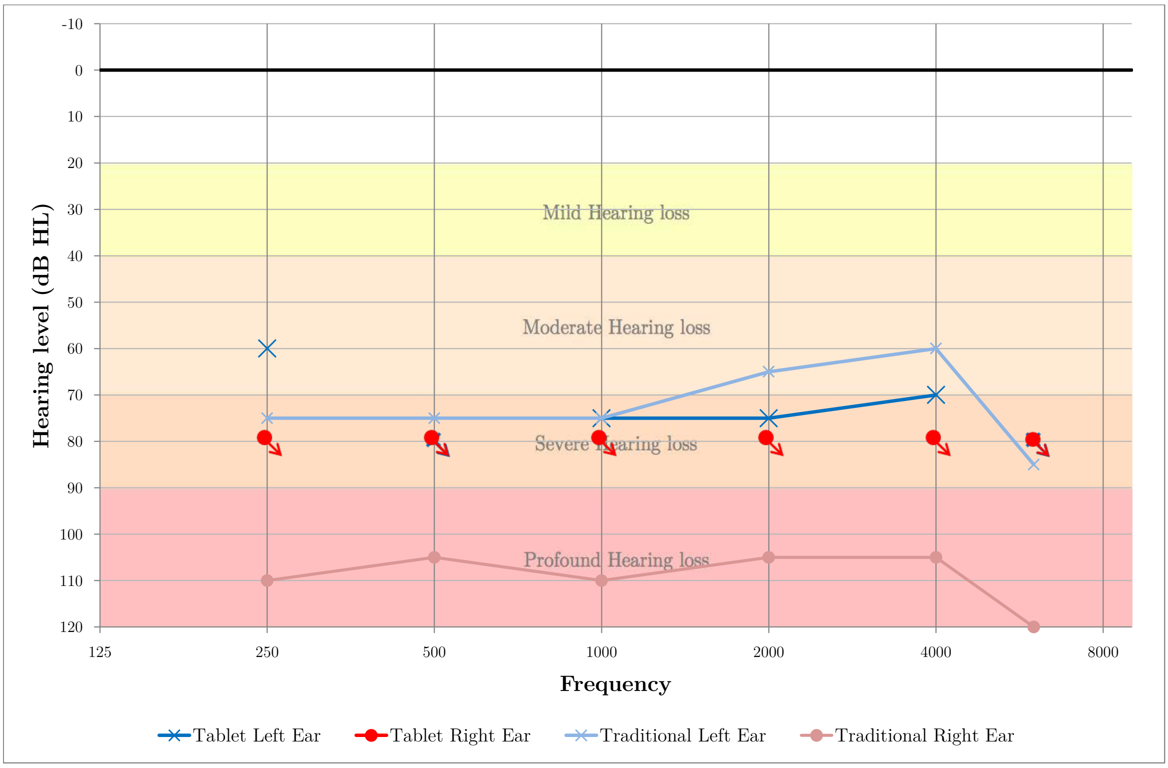

Figure 6: Audiogram comparison for subject 4

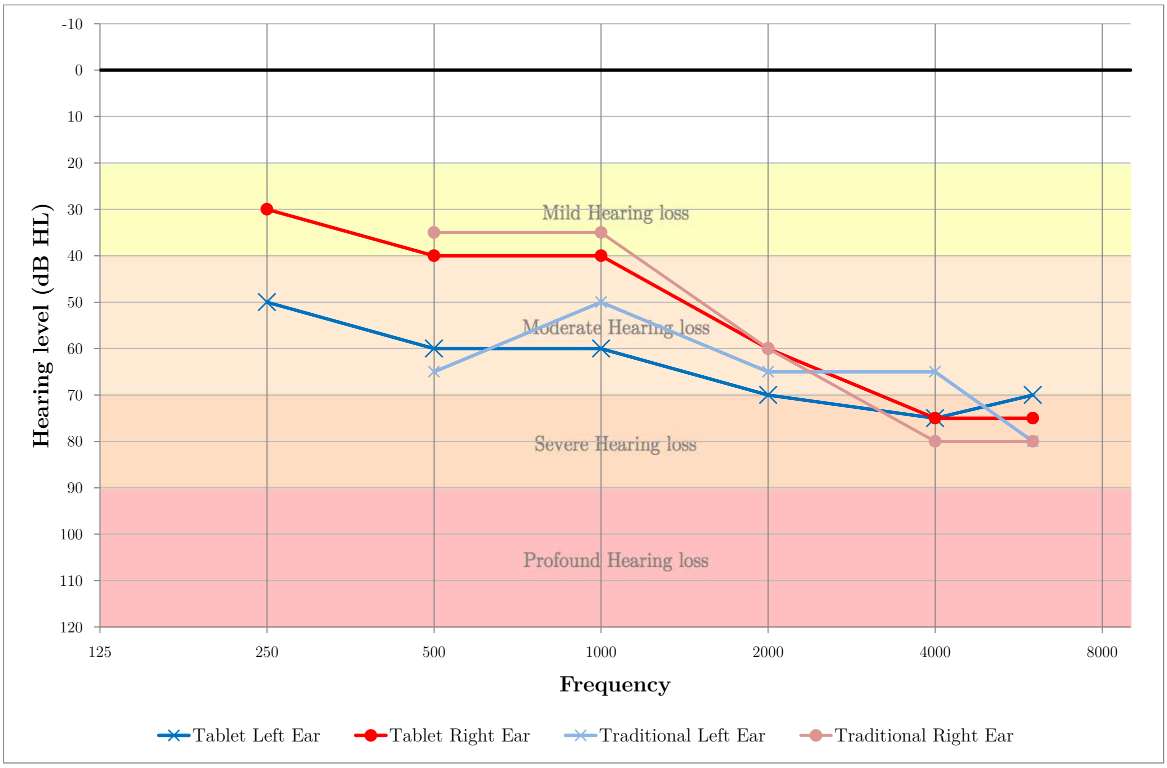

Figure 7: Audiogram comparison for subject 5

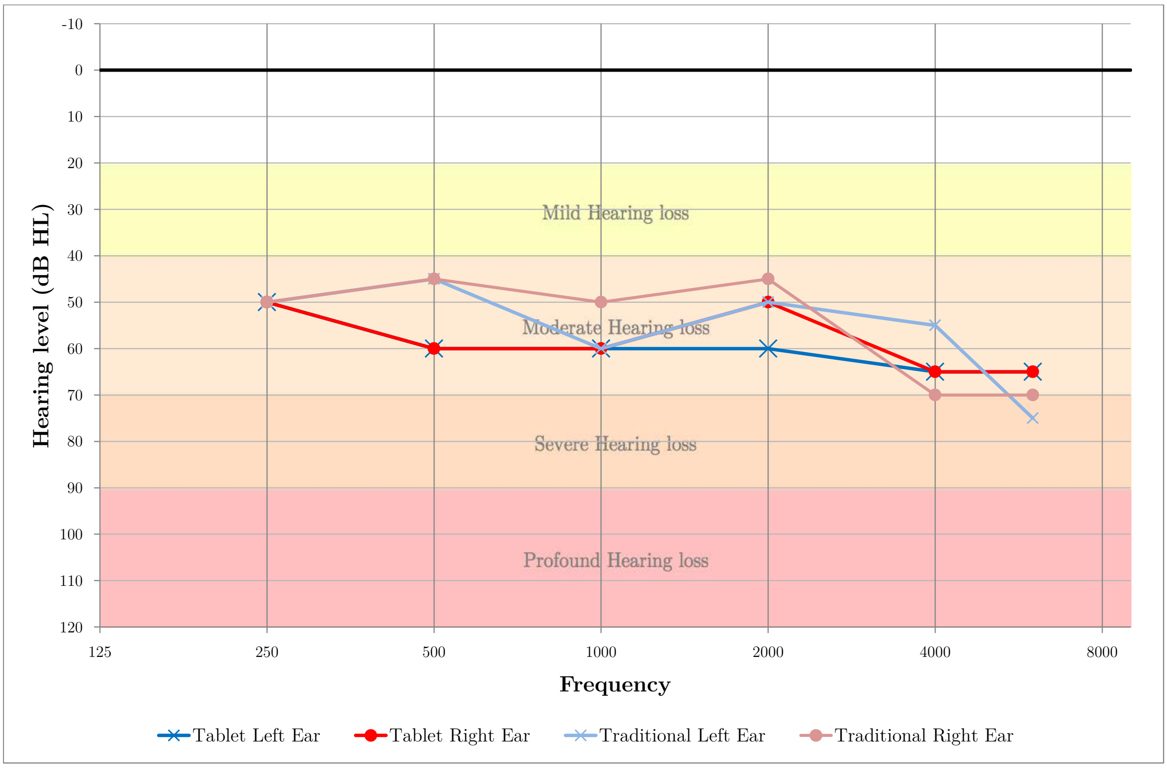

Figure 8: Audiogram comparison for subject 6

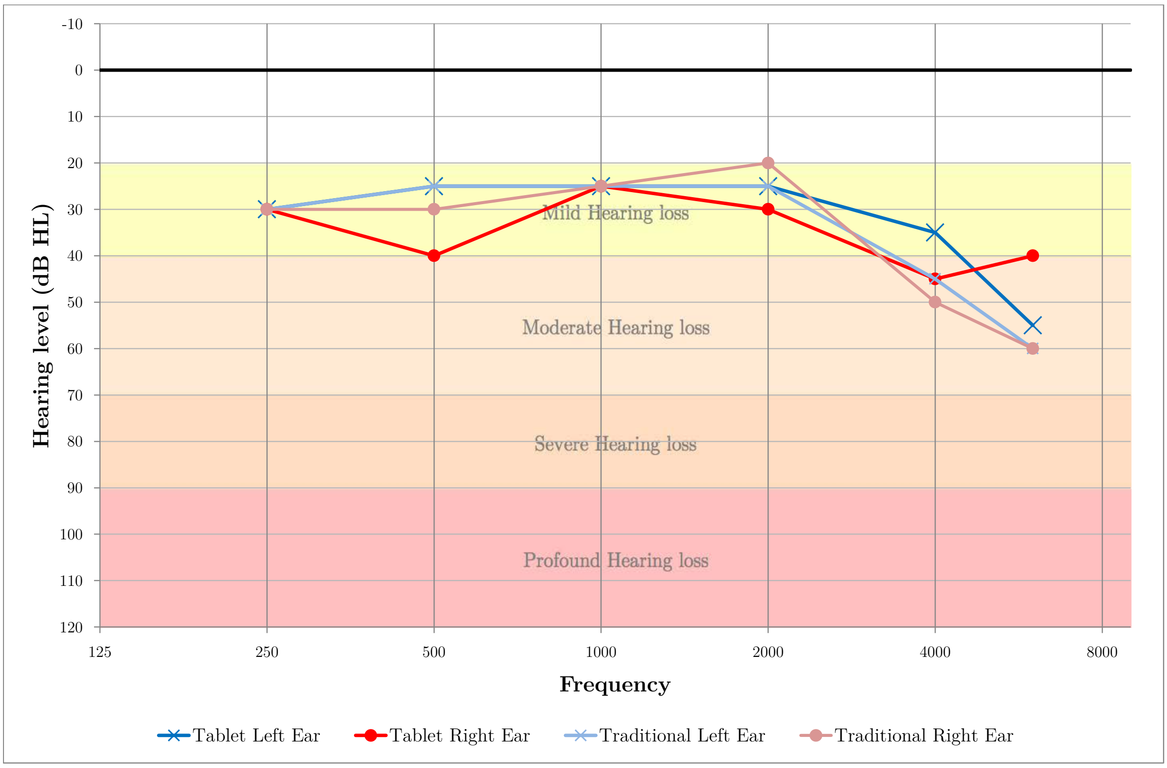

Figure 9: Audiogram comparison for subject 7

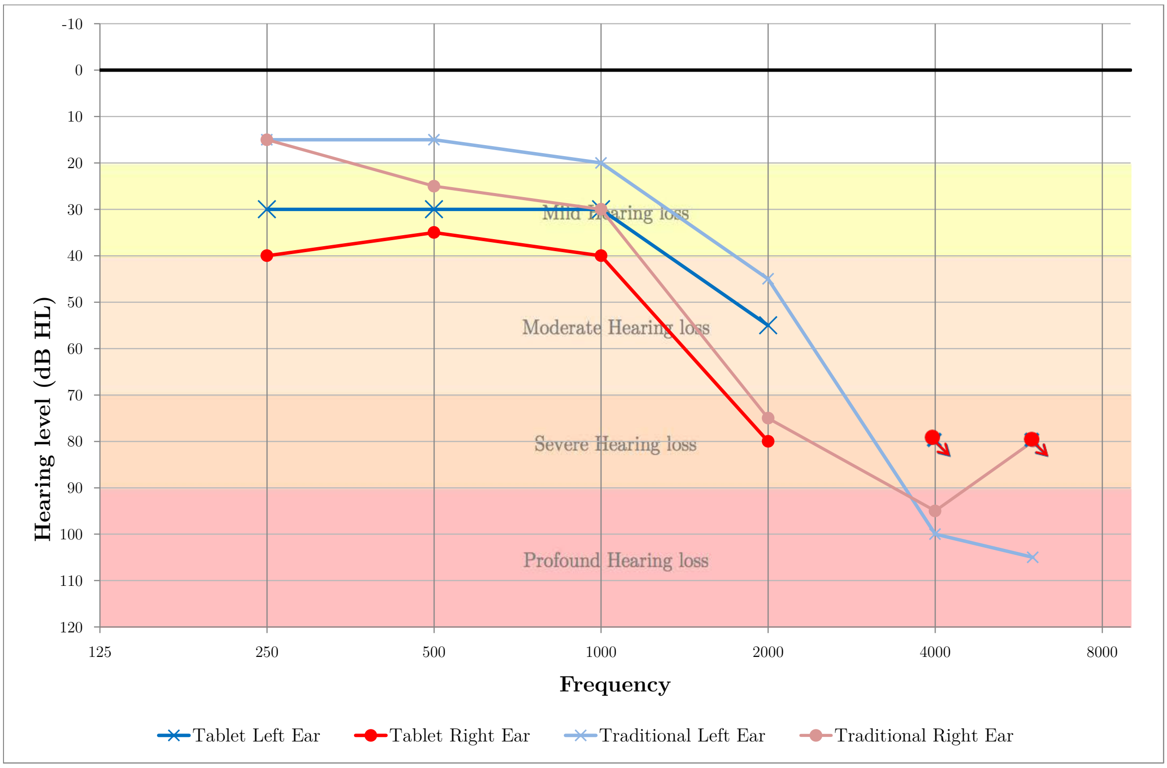

Figure 10: Audiogram comparison for subject 8

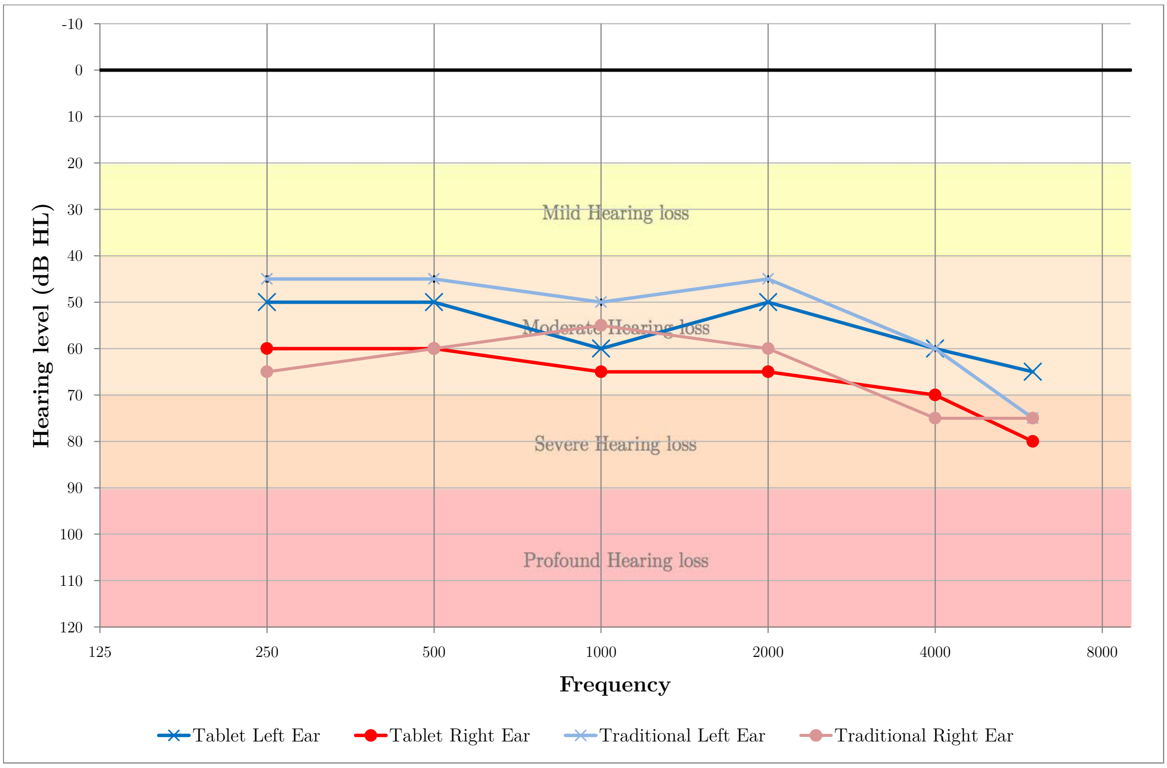

Figure 11: Audiogram comparison for subject 9

B. Audiograms Amended for Counting Error

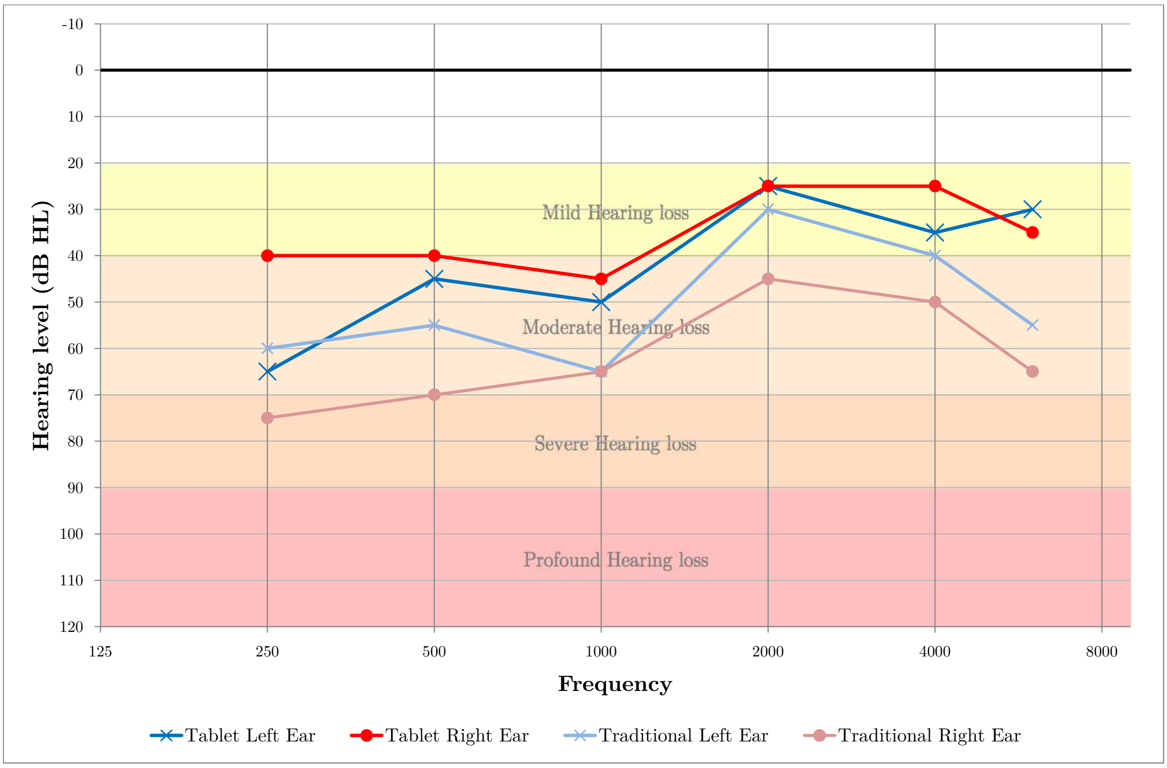

Figure 12: Amended audiogram comparison for subject 1

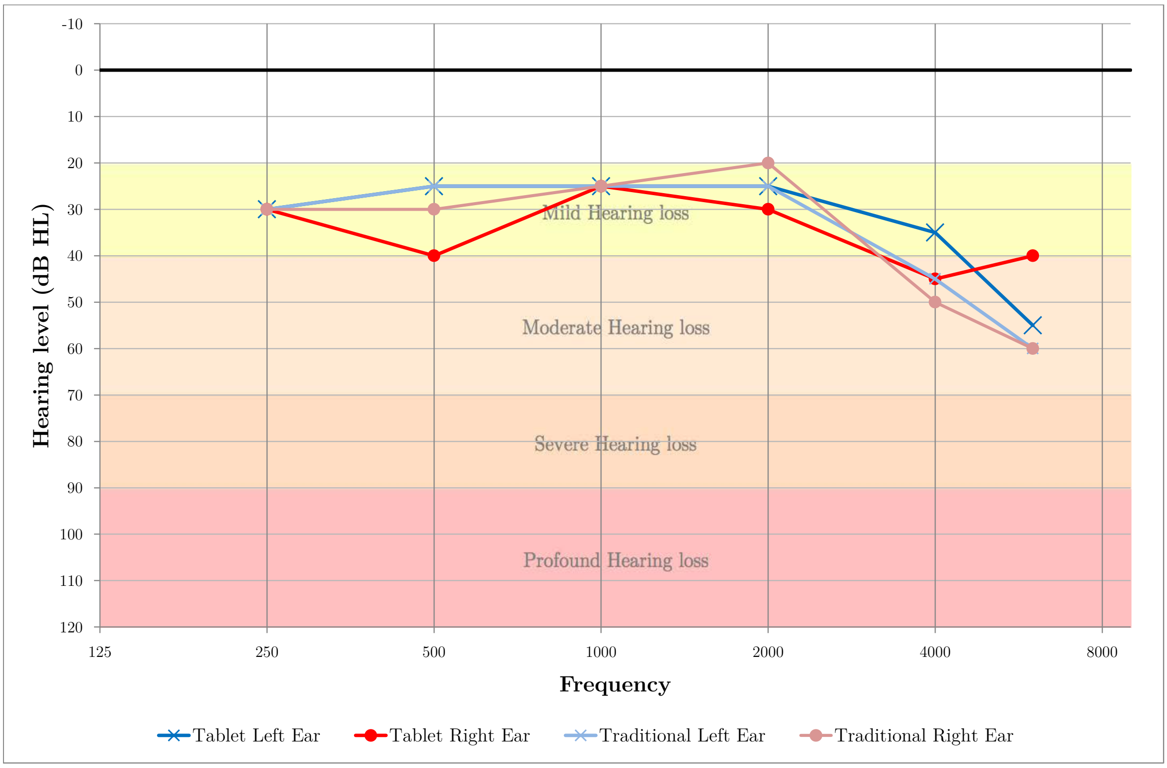

Figure 13: Amended audiogram comparison for subject 7

C. Full Table of Results

		TABLET							TRADITIONAL					
Subject		250	500	1000	2000	4000	6000		250	500	1000	2000	4000	6000
1	L	70	50	55	30	40	35	L	60	55	65	30	40	55
	R	45	45	50	30	30	40	R	75	70	65	45	50	65
2	L							L	80	80	85	80	100	100
	R	60	70	75	50	75		R	65	75	75	65	70	85
3	L	55	60	55	70		80	L		60	55	55	65	80
	R	55	50	65	70	60	80	R	55	55	60	70	70	80
4	L	60		75	75	70		L	75	75	75	65	60	85
	R							R	110	105	110	105	105	120
5	L	50	60	60	70	75	70	L	#N/A	65	50	65	65	80
	R	30	40	40	60	75	75	R	#N/A	35	35	60	80	80
6	L	50	60	60	60	65	65	L	50	45	60	50	55	75
	R	50	60	60	50	65	65	R	50	45	50	45	70	70
7	L	30	25	25	25	35	55	L	30	25	25	25	45	60
	R	30	40	25	30	45	40	R	30	30	25	20	50	60
8	L	30	30	30	55			L	15	15	20	45	100	105
	R	40	35	40	80			R	15	25	30	75	95	80
9	L	50	50	60	50	60	65	L	45	45	50	45	60	75
	R	60	60	65	65	70	80	R	65	60	55	60	75	75
1a	L	75	55	60	35	45	40	L	60	55	65	30	40	55
	R	50	50	55	35	35	45	R	75	70	65	45	50	65
2a	L	25	20	20	20	30	50	L	30	25	25	25	45	60
	R	25	35	20	25	40	35	R	30	30	25	20	50	60

Table 3: Full table of results (#N/A denotes missing data, a gap represents the tablet reading >80 dBHL)

References

[1] Acoustics - Reference zero for the calibration of audiometric equipment. Part 8: Reference equivalent threshold sound pressure levels for pure tones and circum-aural earphones, 2004.

[2] Acoustics - Audiometric test methods. Part 1: Pure tone and bone conduction autiometry (ISO 8253-1:2010), 2010.

[3] L G Davison et al. Variances in the audiogram data of individuals undertaking audiometry on different calibrated audiometers. *Unpublished*, 2013.

[4] British Society of Audiology. Recommended procedure - pure-tone air-conduction and bone conduction threshold audiometry with ans without masking. *British Society of Audiology Website*, 2011.

[5] SDG Stephens. The british medical profession and the first audiometers. *J Laryngol Otol*, 95:1223–35, 1981.