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The influence of frequency-dependent hearing loss to unaided APHAB scores

J. Löhler[1,2] · B. Akcicek[1] · B. Wollenberg[2] · T. Kappe[3] · P. Schlattmann[4] ·
R. Schönweiler[5]

Abstract Hearing loss can be measured by pure-tone and speech audiometry. The subjective hearing impairment can be assessed using questionnaires. The APHAB determines this for four typical hearing situations. It has not been researched previously whether a particular frequency-specific hearing loss leads to a particular unaided APHAB score in one of the subscales or not. Clarification could be helpful using the unaided APHAB as an instrument for primary diagnostics of hearing loss independently of whether hearing aids were subsequently fitted or not. A total of 4546 records from a database were analysed; the average age of the subjects was 69.3 years. Using a multivariant mixed linear model, a possible correlation was examined between a frequency-specific hearing loss (0.5–8.0 kHz) and particular unaided APHAB scores for its subscales. Furthermore, it was determined whether the subject's gender has a corresponding impact. There was no evidence of gender-specific dependence of the unaided APHAB scores. For the EC scale frequencies above 0.5 kHz, for the RV scale all frequencies and for the AV scale the frequencies at 1.0 and 2.0 kHz showed a significant correlation between hearing loss and the APHAB score. For each decibel of hearing loss there was an average rise in the APHAB score for the EC and RV scale of approximately 0.2 percentage points and an average decrease in the AV scale of 0.1 percentage points for each frequency. For the BN scale there was no evidence of this kind of correlation. The very varied possibility between individuals compensating for hearing loss in situations with background noises could be that there is no correlation between frequency-specific hearing loss and an associated unaided APHAB score. The described frequency-specific influence of hearing loss to the EC and RV score could be explained by fewer compensating possibilities for the patients in these specific hearing situations than for the BN scale described. Using the unaided APHAB form in primary diagnostics of hearing impairment is helpful for understanding individual problems.

Keywords Unaided APHAB · APHAB · Hearing loss · Pure-tone audiometry · Questionnaire

Introduction

Questionnaires are an important component in audiological evaluation. In addition to pure tones, loudness discomfort, and speech audiometry, they are providing the subjective perspective from the individual that may help the clinician to fully understand the extent of the patient's hearing difficulties.

A whole number of question inventories have been used internationally for decades [1, 2], but only some of them have been regularly included in clinical practice. This is largely due to a lack of validation or complicated

✉ J. Löhler
loehler@hno-aerzte.de

1 Scientific Institute for Applied ENT-Research, German Professional Association of ENT-Surgeons, Maienbeeck 1, 24576 Bad Bramstedt, Germany

2 Department of ENT-Surgery, Universital Hospital Schleswig–Holstein, Campus Luebeck, Luebeck, Germany

3 ENT-Office, Dortmund, Germany

4 Institute for Medical Statistics, Informatics and Documentations, Universital Hospital Jena, Jena, Germany

5 Section of Phoniatrics and Pedaudiology, Department of ENT-Surgery, Universital Hospital of Schleswig–Holstein, Campus Luebeck, Luebeck, Germany

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implementation [3]. There are some questionnaires generally used for primary diagnostics in hearing loss and some for measuring the outcome of hearing aid fitting. In this case a distinction is usually made between question inventories, which record a patient's satisfaction with a fitted hearing aid or which determine the potential benefit of having hearing aids. In particular, when it comes to health fund providers, evidence of a benefit is especially important.

It has not been cleared whether we can use a questionnaire originally composed for measuring the outcome of hearing aid fitting for primary diagnostics of hearing loss in general if we use its first part only. One condition in this case would be a different point of time, as to when the inventory will be used. Furthermore, the dependency between scores and hearing loss should be cleared up.

The abbreviated profile of hearing aid benefit (APHAB) developed by Cox and Alexander in 1995 consists of 24 single questions from four subscales on everyday hearing situations [4–6]. The ease of communication scale (EC) describes hearing situations in a quiet environment, the BN scale (background noise) represents hearing situations with background noises, the reverberation scale (RV) involves hearing situations in large spaces, and the aversiveness of sounds scale (AV) measures the perception of loud sound events.

On a seven-point scale the patient is asked to assess without hearing aids, and in the case of benefit measuring, after wearing hearing aids in a second course, the extent to which the situation described in 24 different questions impairs his hearing subjectively in each case. The responses are coded A–G, where A indicates always and G never, which are assigned to percentiles ranging from A at 99 % to G at 1 %. Traditionally, it is possible to determine cumulatively the benefit of hearing aids for each subscale by taking the difference between the results before and after they have been fitted. The APHAB is available in many different languages. In 2010 and 2012, investigations were carried out on the APHAB with German-speaking patients, which showed no difference from the specified US norms [7, 8]. Since April 2012, the APHAB has been an integral part of the resources policy in Germany [9, 10] and, therefore, the most commonly used inventory in the context of diagnostics to statutorily insured patients, which includes about 90 % of the German population. Accordingly, the APHAB plays an outstanding role under all inventories in Germany.

Taking only the first part of the questionnaire (unaided), in which hearing problems without hearing aids are assessed, allows the use of the APHAB for primary assessment of hearing loss. Thus, no differences of scoring between aided and unaided self-perception in using hearing aids are necessary. Therefore, the APHAB must be given to the hearing-impaired patient at an early stage on the diagnostic pathway and done so together with pure-tone and speech audiometry.

Using the APHAB as an initial instrument of diagnostics it would be interesting to investigate the dependence of a specific APHAB score and hearing loss. Years ago, a qualitative but not quantitative correlation was demonstrated between the unaided APHAB scores of the EC and RV scale and three different calculated types of hearing loss [11]. However, in this reference, audiograms in three frequencies were averaged arithmetically to classify audiogram types. Considering that the decibel scale is logarithmic, this could be a difficult approach in a mathematical sense although it is widely used and accepted. A sloping loss of either polarity, or a flat loss, could all translate to the same figure, but represent a wide range of difficulties. Likewise, the impact of a certain frequency on subjective hearing ability could not be demonstrated by this method. The sample size of this study was also small ($n = 60$), and the spread of the three postulated hearing loss categories resulted in overlaps between the groups and the three audiogram categories described only a high-frequency skewed drop of varying degrees (mild, moderate, severe).

Methods

An APHAB database was established in Germany several years ago [12]. At present, from more than 90 ENT clinics and practices thousands of individual APHAB records and associated audiograms have been collected in this database. In this database 4546 records of hearing-impaired patients were collected by the cutoff date of 28 October 2013 both via online method or paper-and-pencil and later data entry by internet-based access. All data are stored in a central server. In all cases of subsequent hearing aid fitting, the first part of the APHAB (so-called "unaided") was given to the subject before hearing aid fitting. So the APHAB was used as a primary element of diagnostics in hearing loss as described above. Within this study the terms "APHAB score" and "APHAB value" cover results by this first part only. Thus, calculating differences between aided and unaided scores gaining an APHAB benefit was not performed. Therefore, the results of average scores for each APHAB subscale within this study are also represented in this single, unaided APHAB assessment. In addition to the individual results for the APHAB questions, the associated pure-tone audiogram data were also entered. The database did not include a record of patients who showed hearing loss greater than 60 dB HL in a comparison of the air conductions of both ears in frequencies at 0.5, 1.0 and 2.0 kHz based on the three-frequency table (Table 1, [7,

Table 1 Three-frequency table to define the degree of hearing impairment [7, 8]

	Hearing loss at 2.0 kHz				
	<20	20–35	40–55	60–80	>80
Total hearing loss at 0.5 and 1.0 kHz					
0–35	None	Slight	Moderate	Moderate–profound	Profound
40–75	Slight	Slight	Moderate	Moderate–profound	Profound
80–115	Moderate	Moderate	Moderate	Moderate–profound	Profound
120–160	Moderate–profound	Moderate–profound	Moderate–profound	Moderate–profound	Profound
>160	Profound	Profound	Profound	Profound	Profound

Findings from the sound audiogram of the inferior ear, measured in 5 dB steps. Subjects with a difference of >60 dB HL between the left and the right ear were initially excluded from the database

8]) so as to avoid influences of compensating effects in case of severe hearing loss asymmetry. Of course, this will not limit the view to the worse ear. Furthermore, incomplete records for calculations involved in this study were eliminated.

Using a multivariate mixed linear model a possible correlation was investigated between the APHAB score for the average result of the four subscales EC, BN, RV and AV, and the hearing loss in the air conductions at frequencies of 0.5, 1.0, 2.0, 4.0, and 8.0 kHz. As such, the unaided APHAB scores were the dependent variables and the results of the audiogram the independent variables. A further independent variable was their gender.

The subjects' participation for data storing was voluntary. The Ethics Commission of the Schleswig–Holstein Medical Association and the state data protection officer approved the research method.

Results

A total of 4546 records were evaluated. Of these, 1950 were men (42.9 %) and 2596 women (57.1 %). The average age was 69.3 years (standard deviation ± 16.7 years), for men at 69.8 years (±17.1 years), for women at 68.8 years (±16.2 years). Figure 1 shows the percentage representation by age group.

A total of 375 cases were not assigned to any hearing loss group based on the three-frequency table, as the required data were incomplete for the frequencies at 0.5, 1.0, and 2.0 kHz. These cases were not included in further assessments, so that 4171 cases were primary available. Table 2 shows the spread of these subjects among individual groups based on the three-frequency table (Table 1, [7, 8]). In addition, 192 more cases had to be eliminated due to incomplete data at 4.0 and 8.0 kHz or incomplete APHAB data, which were not detected by the three-

frequency table method conducted previously, so that in result 3979 cases were available for final analysis. This modifies a little the ratio between the two gender groups (53.1 % male, 46.9 % female). Given its irrelevance to our study, the rate of subjects fitted subsequently with a hearing aid was not documented.

The unaided APHAB score's dependence on the subject's gender

Using a mixed linear model, the values of the APHAB score were examined and provided for the four APHAB subscales (EC, BN, RV, AV) in relation to dependence on the subject's gender in 3979 cases, the results appear in Table 3. The average APHAB score for the individual subscales was somewhat higher for men than for women, so men reported more disability in these cases.

The unaided APHAB score's dependence on frequency-specific hearing loss

Using a multivariate mixed linear model, the dependency of average APHAB scores was examined in 3979 cases for the frequencies 0.5, 1.0, 2.0, 4.0, and 8.0 kHz in general and for the four subscales (EC, BN, RV, AV); the results, in particular the average changes in APHAB score per decibel of hearing loss, appear in Table 4.

In a first step, we investigated if there was any influence using the frequency-specific values of hearing loss of the right or the left ear in particular. In all frequencies and APHAB subscales this was not found to be the case.

For the EC scale there is no significant correlation between hearing loss and the corresponding APHAB score for the frequency of 0.5 kHz, but there is a significant correlation for all the other frequencies examined. For each decibel of hearing loss there is an average rise in the APHAB score for the EC scale of just under 0.2 percentage

Fig. 1 Distribution of age classes (all *green*, male *blue*, female *yellow*), n = 4546
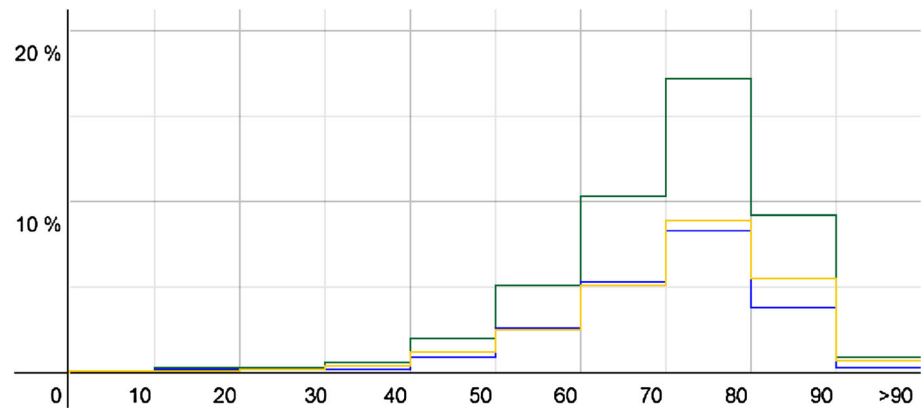

Table 2 Distribution of hearing loss categories as per Table 1 among the subjects (n = 4.546)

Degree of hearing loss	Percent	Number
None	17.9	814
Slight	9.6	436
Moderate	32.0	1.453
Moderate–profound	26.6	1.209
Profound	5.7	259
Non-attributable[a]	8.2	375

[a] 375 subjects were non-attributable and excluded for further investigation

Table 3 Gender distribution for APHAB subscales scores, n = 3979

Gender	APHAB scale	Mean	Standard error	p value
Male	EC	56.3539	0.4359	<0.0001
n = 2113	BN	47.4560	0.4374	<0.0001
53.1 %	RV	48.4411	0.4416	<0.0001
	AV	51.2506	0.4380	<0.0001
Female	EC	52.9111	0.4585	<0.0001
n = 1866	BN	44.3732	0.4596	<0.0001
46.9 %	RV	46.6819	0.4658	<0.0001
	AV	47.9999	0.4596	<0.0001

points. For the BN scale there is no significant correlation between hearing loss and the corresponding APHAB score for all frequencies. For the RV scale there is a significant correlation between hearing loss and the corresponding APHAB score for all the examined frequencies. For each decibel of hearing loss there is also an average rise in the APHAB score for the RV scale of just under 0.2 percentage points.

For the AV scale there is no significant correlation for the frequencies 0.5, 4 and 8 kHz. Contrasting this, an inverse correlation can be shown for 1.0 and 2.0 kHz for the EC and RV scale. For each decibel of hearing loss there is an average fall in the APHAB score in both these frequencies on the AV scale by just under 0.1 percentage points; for these two frequencies loud hearing situations are increasingly perceived as less annoying.

Discussion

Significant differences between genders did not appear in the APHAB scores. The age group spread also showed no major gender-related variance. The gender distribution and average age were similar to former studies [7, 8].

Men reported slightly worse APHAB scores on average in all subscales, which cannot be explained. The distribution of subjects on the three-frequency table (Table 2) shows that the majority of our subjects were suffering from a progressive form of hearing loss. In view of the relatively large sample size it may be possible to make epidemiological statements on the incidence of hearing loss based on the spread of hearing loss categories given here. The non-influence of the specific values of hearing loss for the right and left ear to any APHAB score demonstrated that the use of the three-frequency table was a suitable method for avoiding influences of compensating effects in case of severe hearing loss asymmetry in our study.

The average subscale results were around 50 % (Table 3). One may suspect that a subject would answer to each item close to 50/50. But as has been demonstrated earlier [7, 8], these values only represent the average of nearly normal distributed values for each subscale.

The unaided APHAB score's dependence on a frequency

In contrast to [11], the values of standard deviation of the results in our study are small (Table 4). This improvement

Table 4 Frequency-related APHAB scores for the subscales EC, BN, RV and AV (n = 3979)

APHAB scale	Frequency (kHz)	Estimate[a]	Standard error	p value	Confidence interval	
					Lower	Upper
EC	0.5	0.0828	0.0956	0.3869	−0.1047	0.2702
	1	0.1610	0.0241	<0.0001	0.1139	0.2082
	2	0.1881	0.0232	<0.0001	0.1427	0.2335
	4	0.1622	0.0255	<0.0001	0.1123	0.2121
	8	0.1545	0.0282	<0.0001	0.0993	0.2098
BN	0.5	0.0083	0.0928	0.9286	−0.1736	0.1902
	1	0.0335	0.0234	0.1518	−0.0123	0.0793
	2	−0.0195	0.0225	0.3869	−0.0636	0.0246
	4	−0.0188	0.0248	0.4490	−0.0673	0.0298
	8	−0.0252	0.0274	0.3586	−0.0790	0.0290
RV	0.5	0.2356	0.0883	0.0076	0.0626	0.4086
	1	0.2047	0.0222	<0.0001	0.1611	0.2483
	2	0.2077	0.0214	<0.0001	0.1658	0.2497
	4	0.1583	0.0236	<0.0001	0.1120	0.2045
	8	0.1661	0.0262	<0.0001	0.1147	0.2175
AV	0.5	−0.0664	0.0862	0.4413	−0.2353	0.1026
	1	−0.0749	0.0217	0.0005	−0.1174	−0.0325
	2	−0.0659	0.0209	0.0016	−0.1068	−0.0250
	4	−0.0340	0.0230	0.1393	−0.0791	0.0111
	8	−0.0363	0.0256	0.1570	−0.0865	0.0140

[a] Estimate: in case of $p < 0.01$, the APHAB subscale score in percentage points is influenced by this value for each dB of hearing loss in the frequency to which it belongs

is likely due to the very high number of participants (60 vs. 3979).

For the EC scale there is a significant dependence for all frequencies with the exception of 0.5 kHz. The correlation described indicates that with hearing problems in a quiet environment the frequencies from 1.0 kHz upwards are significant. As is well known, the frequencies of consonants are in the upper frequency range, vowels in the lower frequency range. Difficulties in discriminating between consonants lead to comprehension problems even in straightforward hearing situations. This might explain our findings for the EC scale. In the paper mentioned above [11], a correlation was demonstrated between arithmetically averaged hearing losses in decibels while including the frequency of 0.5 kHz in two cases, which is not confirmed as such in our research. In our view, this underlines the problems with the method of arithmetic averaging of logarithmic values, which lowers the influence of higher dB values.

In keeping with [11], there is no significant correlation between subjective hearing problems, which are expressed in an elevated APHAB score, and hearing loss in the pure-tone audiogram in the APHAB's BN scale, i.e. hearing situations with background noises, even though clinical experience appears to show otherwise. In the authors' opinion, this phenomenon can be explained by an extremely large variability of key compensation options for individual patients. With associative capabilities it may be possible at an individual level and in terms of pure-tone audiometry to compensate for detectable hearing loss in hearing situations with background noises. Many studies confirm this view (review in [13]). We all repeatedly encounter people who certainly show pure-tone and speech audiometric hearing loss but who have no major hearing problems in everyday situations such as in a supermarket or at a family get-together. But this might relate to something other than compensation, e.g. damage to the auditory system that cannot be measured by thresholds (such as frequency resolution, temporal resolution).

Obviously the situation is quite different—once again consistent with [11]—in a reverberant environment, which the RV scale addresses. Here there is a significant correlation between pure-tone audiometric hearing loss and deterioration in the APHAB score for all frequency ranges. Again the authors can only surmise here that the key compensatory mechanisms postulated for the BN scale do not work as they do with the EC scale. In this case perhaps there is a particular feature of hearing at the crucial physiological and psychological level of understanding in human beings. As far as we know,

there has been no previous investigation of this, and any reasons remain speculative. It is conceivable that everyday hearing situations with echoes or reverberation simply occur less frequently than those with background noises, so compensating for this situation is undertaken to a much lesser degree.

The significant correlation—not found in [11]—of pure-tone audiometric hearing loss with a decline in the APHAB score in the AV scale in both mid-range frequencies of 1.0 and 2.0 kHz is an interesting finding. Research in isophones shows that human sensitivity to loud sounds is smallest in the middle frequency [14]. This would lend weight to an increased dependence between AV score and hearing loss for the frequencies of 1.0 and 2.0 kHz. Yet conversely, hearing loss in this range may also lead to fewer disturbances from loud noises, which are measured by the AV scale. This makes the results difficult to explain.

Individual variables were found to explain a relative amount of variance in APHAB responses due to personality attributes [15]. Hearing loss is a symptom with different possible aetiologies. Therefore, the unaided APHAB profile could be very different in, for example, Ménière's disease, otosclerosis, congenital patients or—not investigated in this study—sudden hearing loss. The investigation performed by [11] used average thresholds, which were subject to the same mathematical problems. In addition, their groups overlapped partially. However, Cox et al. calculated in [11] several different pure-tone audiograms, which allowed them to determine which set of frequencies correlated best with APHAB scores. In our study, questions arising from the frequency-specific relationship and its impact on all APHAB subscales were answered. Moreover, we think that our results support the thesis that any classification and subtyping of hearing loss by arithmetic means has only a limited benefit only. In the past, audiometric data and self-report measures of hearing handicap have been investigated by different authors [e.g. 16]. They also highlighted the difference between audiometrically calculated and self-reported hearing loss. Alternatively, it might also be possible that some of these variables (whether belonging to the calculated hearing handicap or the perceived handicap) are irrelevant. Certainly, it would be interesting to find out whether the BN score of the unaided BN scale would be worse 1 year after subsequently fitting a hearing aid or not. Another possibility may be the fact that listeners with hearing loss preserve the ability to rate the intelligibility of speech [e.g. 17]. At least, social strategies of the subjects to avoid BN environments could also lead to the lack of correlation between hearing loss and BN results.

Unaided APHAB results in comparison to other inventories

Although investigation of relationships between audiometric and self-report measures began decades before, many questions in this field remain unanswered. One of the first papers on this topic found very low relationships using pure-tone averages, the Denver Scale of Communication Function and the Social Hearing Handicap Index [16]. Over the last few years, the Hearing Handicap Inventory for the Elderly Screening Version (HHIE-S, [18]) and its related questionnaires have developed to become a preferred instrument for screening on hearing loss in developed, emerging, and developing countries. Detailed investigation yielded sensitivity and specificity and demonstrated a relationship between single-frequency hearing loss and single questions or HHIE-S scores [3, 19–21]. This research still continues today [22]. Nevertheless, this inventory is only used for screening on hearing loss. In conclusion, the APHAB could be used twice, as a diagnostic tool in hearing loss through its unaided part and as a method for measuring the benefit of hearing aid fitting. Its improved perspective on individual hearing impairments makes it more specific than a single-question investigation (e.g. "Do you have a hearing problem?"). Thus, the specific enlightening of different hearing situations is a further strength of this test, yielding a detailed description of the subjective hearing of an individual patient, independently of a possible subsequent hearing aid fitting.

Although the APHAB is too complex for screening methods we think this inventory is useful for further use by ENT surgeons and audiologists in primary measurement using the unaided part only. Due to the wide use of the APHAB in more than 90 % of all severe cases of hearing loss in Germany, these results should be completed by determination of the sensitivity and specificity of the APHAB in future. Moreover, the reverse question of this study—the dependence of frequency-specific hearing loss by APHAB scores—could be interesting as well. Indeed, it would be interesting to determine whether the traditional simultaneous assessment of both parts of the APHAB in case of hearing aid fitting was due to different results rather than by use of part one (unaided) during primary diagnostics.

Conclusion

The APHAB could be implemented in more situations than simply measuring the benefit of hearing aid fitting. Using its first part only (unaided) during the primary audiological diagnostics of hearing impairment in addition to pure-tone

and speech audiometry, it may provide more detailed information of individual hearing problems in different situations. There is a significant correlation between hearing loss in the frequency ranges above 1.0 kHz in straightforward hearing situations (EC scale), between all the examined frequencies and hearing situations with echo/reverberation (RV scale) and, conversely, hearing loss in the frequencies at 1.0 and 2.0 kHz and the perception of loud events (AV scale). For each decibel of hearing loss there is an average rise in the APHAB score for the EC and RV scale of just about 0.2 percentage points and an average decrease in the AV scale of 0.1 percentage points for these frequencies. In the case of hearing situations with background noises (BN scale) there was no evidence of significant correlation with corresponding APHAB scores. This underlines the high level of inter-individual compensation of hearing loss in very different and distinctive ways, which cannot be determined either by pure-tone or speech audiometry but only by questioning inventories such as the APHAB. In the future it would be interesting to investigate the reverse side of this study's problem, that is, whether certain APHAB scores coincide with a specific, frequency-dependent hearing loss.

Compliance with ethical standards

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