Questionnaires as screening tools to identify persons with hearing deficiencies

Fragebögen als Screening-Verfahren zur Identifikation von Personen mit Hörstörungen

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Abstract: The aim of the study was the development and the selection of an easy to use questionnaire for the screening of hearing deficiencies in the realm of an automated screening station and in epidemiological studies. Two questionnaire tools were compared using a postal survey: The Hearing-Dependent Daily Activities (HDDA) Scale with values between 0-24 points and the HearCom Questionnaire (HCQ), ranging from 0 to 1.0.

From N = 873 questionnaires sent out, 443 data sets were used. For these participants, current and resilient audiogram data were available. The mean age was M = 66.5 years (52.6 % male) and 37.9 % of the participants were using hearing aids. The mean pure tone average (PTA) on the better ear was 26.5 dB HL (averaged for 0.5, 1.0, 2.0 und 4.0 kHz). This corresponds approximately to the WHO threshold of hearing impairment. The sum score of the HDDA showed higher correlation with the PTA in comparison to the HCQ. For the HDDA, a sensitivity of 90.6 % and a specificity of 80.1 % were determined. According to Receiver Operating Characteristic (ROC) curves for the worse ear (≥ 26 dB HL), a cut-off score of ≥ 19 was the most suitable one. For the HCQ, a cut-off value of 0.74 was determined with sensitivity and specificity of 74.6 % and 85.5 %, respectively.

Due to the better sensitivity and ROC characteristics, a lower number of items and a lower rate of missing data, we suggest using the HDDA with a conservative cut-off criterion of ≥ 19 as an appropriate screening tool in Germany for the assessment of hearing deficiencies.

Keywords: Hearing impairment, adult hearing screening, questionnaire, HDDA, sensitivity, specificity

List of abbreviations:
BEA: Better ear average
HDDA: Hearing-Dependent Daily Activities Scale
HCQ: HearCom Questionnaire
HearCom: EU Project “Hearing in the communication society”
HL: hearing loss
PTA: Pure tone average
ROC: Receiver-Operating-Characteristic
SD: Standard deviation
WEA: Worse ear average

Zusammenfassung: Ziel der Studie war die Entwicklung und Auswahl eines ökonomisch zu handhabenden Fragebogens zur Ermittlung von Hörstörungen im Rahmen einer automatisierten Messstation und epidemiologischer Studien. Es wurden zwei Fragebogenverfahren als Screening-Instrumente im Rahmen einer postalischen Studie miteinander verglichen: Die Hearing-Dependent Daily Activities (HDDA) Skala mit Werten zwischen 0-24 Punkten und der HearCom-Fragebogen (HCQ) mit einer Skala von 0 bis 1.0.

Von N = 873 versendeten Fragebögen konnten insgesamt N = 443 Datensätze verwendet werden, bei denen aktuelle tonaudiometrische Daten vorlagen. Das mittlere Alter betrug M = 66,5 Jahre (52,6 % männlich) und 37,9 % der Teilnehmer waren Hörgeräteträger. Im Mittel hatten die Probanden auf dem besseren Ohr einen Hörverlust von 26,5 dB HL gemittelt über die Frequenzen 0,5, 1,0, 2,0 und 4,0 kHz, was in etwa der tonaudiometrischen Schwelle der WHO Definition hörbeeinträchtigt vs. nicht hörbeeinträchtigt entspricht. Der HDDA zeigte durchweg höhere Korrelationen zum PTA als der HCQ-Fragebogen. Für den HDDA konnte eine Sensitivität von 90,6 % und eine Spezifität von 80,1 % bei einem Cut-off von ≥ 19 auf Basis von Receiver Operating Characteristic (ROC) Kurven ermittelt werden, wenn das jeweils schlechtere Ohr (≥ 26 dB HL) berücksichtigt wurde. Für den HCQ Fragebogen wurde ein Cut-off Wert von 0.74 für das schlechtere Ohr bestimmt, mit einer Sensitivität von 74,6 % und einer Spezifität von 85,5 %.

Aufgrund der besseren Sensitivität und ROC Charakteristik, des geringeren Umfanges und der geringeren Rate fehlender Werte wird der HDDA bei einem konservativem Cut-off Wert von ≥ 19 als geeigneter deutschsprachiger Fragebogen zur Ermittlung von Hörstörungen als Screening-Instrument empfohlen.

Schlüsselwörter: Hörbeeinträchtigung, Hörscreening für Erwachsene, Fragebogen, HDDA, Sensitivität, Spezifität

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Introduction

Recent studies estimate that treatable hearing loss is spread across roughly 17% of the European population (Shield 2006; Heger and Holube 2010). In Germany, the prevalence of hearing loss is 15.7 %, as found in a resilient epidemiological study conducted by von Gablenz and Holube (2015). Despite the amount of hearing loss, people are often reluctant to have their hearing tested by professionals. One important contribution to the explanation is that many people do not know of their hearing loss because it often develops slowly over time. Several studies indicate that it can take up to 10 years from the beginning of a hearing loss to hearing aid provision (Davis et al. 2007). There are some indicators that an untreated hearing loss is associated with cognitive deterioration (Lin et al. 2014) and a decrease of Quality of Life aspects (e. g. Chisolm et al. 2007), such as depression, social isolation, psychological well-being, and work related functioning.

A solution to shorten the untreated time interval and to protect vulnerable sub-groups in the occupational or military domain may be providing publicly available hearing screening tests to check the hearing ability without the restrictions of long lasting diagnostic procedures.

We suggest performing automatic hearing screening without supervision by trained staff. If the hearing tests are chosen appropriately, this could result in reduced workload for hearing professionals, as well as in highly objective test results. Such automatic hearing screening may e.g. be performed in waiting areas of medical/paramedical institutions, in occupational medicine or in other places where potentially affected people spend idle time. In the case that the automatic screening is performed close to a hearing professional, the test results may be used as input for the anamnesis.

HörTech combined three available hearing screening tests into a demonstrator of an automated hearing screening station. Such a station is intended to be a stand-alone device that can be used by interested individuals without guidance by another person. The test procedures involved are a pure tone audiogram measured in quiet (called APTA for Automatic Pure Tone Audiogram, see Bisitz and Silzle 2010), a speech reception test measured in noise (digit triplets tests, see Zokoll et al. 2012; Buschermöhle et al. 2014; Jansen et al. 2014), and questionnaire tools assessing the subjectively perceived hearing deficiency. Up to now, it is not clear, which questionnaire tool is an appropriate one.

We identified two questionnaires as candidates for a questionnaire tool: The Hearing-Dependent Daily Activities (HDDA) Scale from Hidalgo et al. (2008), and the HearCom Questionnaire from Lyzenga and Koopman (2008). For both of the questionnaires, resilient cut-off scores for the German versions area are missing.

In a previous study with Spanish speaking participants, the HDDA showed a sensitivity of 80 % and a specificity of 70 % (Hidalgo et al. 2008), based on the criterion for hearing impairment of Ventry and Weinstein (1983), i. e. HL ≥ 40 dB at 1 and 2 kHz on at least one ear. According to this criterion 43.6 % of the persons had a hearing loss. The HDDA is available in German and is implemented in the Unitron app „uHear“, however there is no documented forward-backward translation, as well as sensitivity and specificity values for the German version. The HearCom Questionnaire (Lyzenga and Koopman 2008) showed a sensitivity of 85 % and a specificity of 81 % for the Dutch version; the criterion for having a hearing impairment was a PTA < 29 dB HL on the better ear (averaged at 1.0, 2.0 and 4.0 kHz). The respective cut-off was determined in both studies based on Receiver Operating Characteristic (ROC) Curves.

The aim of this study is to select the questionnaire with the best sensitivity/specificity ratio following Receiver Operating Characteristics (ROC) Curves to be used for the implementation in a screening station and also for large-scale epidemiological studies. Additional requirements are outlined by Buschermöhle et al. (2014). The test should be: independent (i.e. not industry driven), anonymous or confidential (addressing data privacy protection rules and laws), quick and easy to avoid frustration as well as inexpensive.

Methods

Questionnaires

The HDDA consists of 12 items addressing hearing problems/hearing abilities (0 = permanent/no, I am not able to, 1 = sometimes/with some difficulties, 2 = never/yes, without difficulties). The scores from each of the 12 items are added up resulting in a total score ranging from 0 – 24. The German version of the HDDA taken from the Unitron app „uHear" was checked and validated by a structured forward-backward translation of the US version. Only slight modifications were needed, which were considered for the German wording of the items, see Appendix I.

The HearCom Questionnaire consists of 18 questions addressing hearing ability (0.00 = almost never, 0.33 = sometimes, 0.67 = often, 1.00 = almost always). The scores are averaged to a total score ranging from 0.00 – 1.00. During the HearCom project (Vlaming et al. 2011) the German version was developed by a forward-backward translation procedure. This version was used in the current study. Both questionnaires (see Appendix I and II with the respective English and German versions) start with a short instruction text emphasizing that the questions refer to the unaided situations (i. e. without wearing hearing aids).

Postal survey and first order exclusion criteria

N = 873 test persons of the Hörzentrum Oldenburg GmbH received the written request to fill out both questionnaires in December 2014. For the test persons selected an audiogram of the period from January 2013 to November 2014 was available in the database. N = 681 questionnaires were sent back, which means a response rate of 78 %. The participants were asked if their self-evaluated hearing loss has increased significantly since the last assessment of a pure-tone audiogram. N = 117 test persons did not answer the question or stated that the hearing status had changed noticeably. These persons were excluded from further analysis. Therefore, applicable audiograms were available from the remaining 564 test persons.

For the statistical analysis SPSS 19.0 was used.

Results

Second order exclusion criteria

First inspections of the data showed that the PTA (WHO 2001 better ear average of the frequencies 0.5, 1.0, 2.0 + 4.0 kHz; BEA) of the audiograms measured in 2013 showed a weaker correlation to the HearCom total score (r = 0.62), as audiograms dated from January to June 2014 (r = 0.70) and from June 2014 (r = 0.79). For the HDDA the timeliness of the PTA had less influence on the correlations between its total score and PTA (2013: r = -0.80, January-June 2014: -0.76, later than June 2014: r = -0.79). The effect that the audiograms' timeliness had different influence on the comparative questionnaires was controlled by taking only audiograms measured in 2014 into account. The number of data sets thus decreased to N = 477. As in the HearCom study (Lyzenga and Koopman, 2008), only participants with a PTA of ≤ 60 dB (BEA according to WHO) were considered, we applied this exclusion criterion too; after this N = 439 data sets remained. The Hörzentrum's random sample was supplemented by N = 31 participants of the Central Military Hospital in Koblenz (Bundeswehrzentralkrankenhaus Koblenz) resulting in N = 470 data sets.

An analysis of missing data showed 5.3 % of the HDDA and 7.4 % of the HearCom values were missing (percentage of items answered by 'is not applicable').

If more than two questions of the HDDA and more than three questions of the HearCom Questionnaire were not responded, those data sets were excluded from further analysis. In all other cases missing data were replaced by mean values. So we ended up with a total of N = 443 data sets to be analyzed. For the N = 31 participants of the Bundeswehr only the sum scores of the HDDA and HCQ were available (the automated screening station stored only sum scores), i. e. data for the single items (as well as demographic information) were not available.

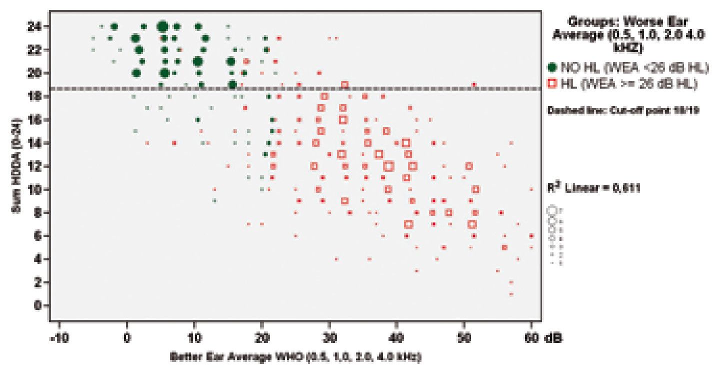

Figure 1: Correlation of the BEA in dB with the sum score of the HDDA. Green circles: inconspicuous in terms of hearing deficiencies based on the conservative criterion worse ear, PTA (WEA) < 26 dB WEA; red boxes: conspicuous in terms of hearing deficiencies, PTA (WEA) ≥ 26 dB; Cut-off: ≥ 19 (see below ROC analysis)

Abbildung 1: Korrelationen des BEA in dB mit dem Summenscore des HDDA. Grüne Punkte: unauffällig nach dem konservativen Kriterium, PTA (WEA) < 26 dB; rote Quadrate: auffälliges Ergebnis, WEA ≥ 26 dB; Cut-off: ≥ 19 (s. u. ROC Analysen).

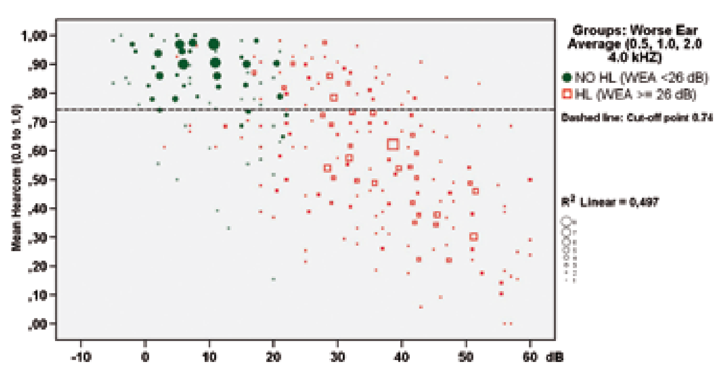

Figure 2: Correlations of the BEA in dB with the sum score of the HCQ. Green circles: inconspicuous in terms of hearing deficiencies based on the criterion worse ear, WEA < 26 dB; red boxes: conspicuous in terms of hearing deficiencies, WEA ≥ 26 dB; Cut-off: 0.74 (see below ROC analysis).

Abbildung 2: Korrelationen des BEA in dB mit dem Mittelwert des HearCom-Fragebogens. Grüne Punkte: unauffällig nach dem Kriterium schlechteres Ohr, WEA < 26 dB; rote Quadrate: auffälliges Ergebnis, WEA ≥ 26 dB; Cut-off: 0.74 (s. u. ROC Analysen).

Description of the final sample (N = 443)

The age of the random sample was M = 66.5 years (Std = 13.2). 52.6 % were male and 37.9 % used hearing aids at the time of the survey. According to the Ventry and Weinstein criterion (1983) 44 % of the test persons had a hearing loss. The PTA values of the better ear (BEA) of the final sample was 26.5 dB HL (Std = 16.2); median = 27 dB HL. The PTA of the worse ear (WEA) of the final sample was 34.3 dB HL (Std = 21.8); median = 33 dB HL.

Correlations between PTA and the questionnaires

The total score of the HDDA correlated with the better ear average (BEA) with r = 0.78 (see Figure 1) and with the worse ear average (WEA) with r = 0.71. The correlation of the HearCom Questionnaire with the BEA was r = 0.70 (see Figure 2) and with the WEA r = 0.64. Both questionnaires HDDA and HearCom correlated with each other with r = 0.88.

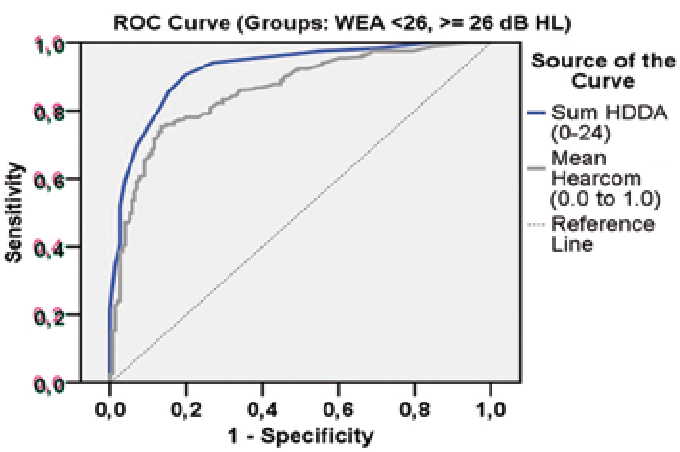

Figure 3: ROC curves for WEA: Comparison HDDA (blue line) vs. HCQ (grey line)

Abbildung 3: ROC-Kurven des schlechteren Ohres (WEA): Vergleich HDDA (blaue Linie) vs. HearCom-Fragebogen (graue Linie)

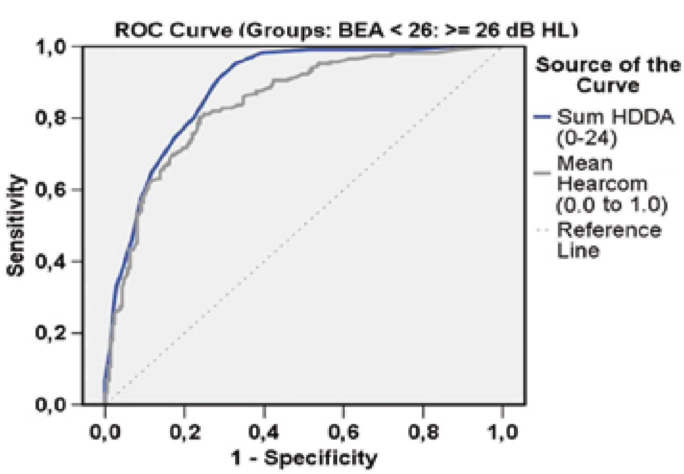

Figure 4: ROC curves for BEA: Comparison HDDA (blue line) vs. HCQ (grey line)

Abbildung 4: ROC-Kurven des besseren Ohres (BEA): Vergleich HDDA (blaue Linie) vs. HearCom-Fragebogen (graue Linie)

Figure 2 and 3 show that fewer cases were interpreted as false negative (according the worse ear) using the HDDA questionnaire in comparison with the HearCom Questionnaire. According to this, more persons with a hearing loss due to the audiogram were rated as inconspicuous using the HearCom Questionnaire.

Please note that the respective conspicuous and inconspicuous cases in Figure 2 and 3 are based on the Worse Ear Average (WEA) as more conservative criterion, so that, e. g., some of the inconspicuous cases are marked with red boxes left from 26 dB HL. These inconspicuous cases according BEA cases are conspicuous cases according WEA in cases of an asymmetrical hearing loss.

ROC analysis

Sensitivity, the true positive rate, measures the proportion of positives that were correctly identified as hearing impaired (true positive rate); specificity measures the proportion of negatives that were correctly identified as not being hearing impaired (true negative rate). ROC curves illustrate the performance of a dichotomous variable. The curve shows the true positive rate versus the false positive rate (false alarm; computed by 1-specificity) at different threshold settings.

By means of ROC analysis it could be shown that the best cut-off could be achieved with a total value of ≥ 19 using the HDDA based on a WEA ≥ 26 dB HL. The sensitivity was 90.6 % and the specificity 80.1 %. The BEA had the best cut-off at ≥ 18 with an identical sensitivity of 90.6 %, but a reduced specificity of 71.1 %; see Figure 3.

A cut-off of 0.74 with a sensitivity of 74.6 % and a specificity of 85.5 % of the WEA was determined for the HearCom Questionnaire. The BEA led to a sensitivity of 79.4 % and specificity of 76.2 %, see Figure 4.

The cut-off scores are also plotted in the scatterplots in Figures 1 and 2.

Discussion and conclusions

Screening for hearing impairment is important for a military organization to maintain hearing fitness for duty. As an employer, any risk for military staff must be reduced, hearing impairment being a crucial risk factor for operational safety. To detect hearing impairment on a regular basis, with a large number of normal hearing subjects, special efforts have to be undertaken to identify early changes. Preliminary studies show that pure tone audiometry is not sufficient predicting hearing ability with all its facets. Therefore, additional tests as speech intelligibility testing in noise or questionnaires help to identify various types of hearing impairment and early indicators.

On the other hand, testing time and convenience of health screening tests are critical in terms of acceptance. Cost efficiency can be achieved by automated testing in an environment close to the target group (e. g. soldiers), reducing traveling time of the test candidates and professional staff requirements.

Questionnaires often show low acceptance unless they are short and understandable. Therefore, questionnaires have to be selected that are short and understandable as well as highly sensitive and specific. Within the military, internationally comparable questionnaires are preferred, so all members of NATO can use them and the results can be compared.

Therefore, in order to develop a useful automated hearing assessment system in this study available multilingual questionnaires were tested and evaluated for their usefulness.

Overall, the results indicate that the HDDA is more suitable in comparison to the HearCom Questionnaire. For the HDDA the analyses have shown higher sensitivity and lower specificity scores relative to the HCQ, but a better sensitivity/specificity ratio following the ROC analyses. In comparison to the HearCom Questionnaire, the correlation with PTA is higher for the HDDA for the better ear average (BEA) and for the worse ear average (WEA). Furthermore, the HDDA is less time consuming (12 instead of 18 questions). Besides this, the items are shorter and clearer, which may be reflected by the lower rate of missing values.

The high correlation of the HDDA and the HCQ is an indicator that the two questionnaires are reflecting comparable contents, so that just one questionnaire seems to be an appropriate screening tool for subjective assessment of hearing deficiencies.

Based on our data, we conclude that the HDDA is an appropriate questionnaire to identify persons with hearing disorders from a subjective perspective to be used in two major areas.

HDDA as part of a screening station

The first one is the application in the realm of a screening station. As mentioned above, one goal is to combine three available hearing screening tests into an automated hearing screening station. The test procedures involved are (1) a pure tone audiogram measured in quiet (called APTA for Automatic Pure Tone Audiogram), (2) a speech reception test measured in noise, and (3) a questionnaire assessing the subjectively perceived hearing deficiency. The combination of these three tests would allow a concise and comprehensive assessment of the test person, because it includes three different domains of hearing.

A further advantage is the evaluation of plausibility, when using three different hearing assessment tools for screening. Screening results are often affected by the subject's motivation, concentration and intentions. On top of this, measurement quality may be compromised if non-health professionals perform the screening tests. Using three assessment tools (PTA; speech in noise testing, questionnaire) has the advantage that possible hearing deficiencies may be detected, even if for instance pure tone audiometry has gone wrong. That means, the cross correlation of test results can be used to identify quality problems in screening performance.

A future goal would be to formulate a combined gold standard for fail/pass criteria reflecting the three domains of hearing screening mentioned above.

In comparison to speech based hearing screening tests, such as the digit triplet test, the ROC and correlation analyses of the HDDA obtained comparable scores with regard to PTA. Watson et al. (2012) reported a correlation between a telephone screening test and PTA (0.5, 1.0, 2.0 kHz) of $r = 0.74$ and sensitivity and specificity values of 0.80 and 0.83, using pure-tone average >20 dB HL as the limiting criterion. Buschermöhle et al. (2015) found sensitivity and specificity values of 0.55/0.98 for the telephone test and of 0.71/0.98 for the broadband test of the digit triplets tests for PTA (0.5, 1.0, 2.0, 4.0 kHz).

HDDA as stand-alone tool

These results also show that the HDDA may be a valuable and potentially stand-alone tool for large-scale epidemiological studies as a second area of application. Many of the postal and internet studies addressing marketing aspects for hearing aid acceptance have the disadvantage that the PTA cannot be measured in large-scale studies (e. g., see Kochkin 2010, and Hougaard and Ruf 2011). Without a well-documented measure of the amount of hearing deficiencies of the participants, it is difficult to correlate these variables with other factors of e. g., acceptance or usage of hearing aids. Also, large-scale health and quality of life studies need to assess the health status based on self-reported data from the participants with an uncertainty of the dichotomous variable hearing impaired vs. not impaired, e. g., Bullinger and Kirchberger (1995). For such studies, the HDDA with only 12 questions would be a valuable tool to provide a resilient data basis.

It looks that the application of the HDDA with the respective cut-off criteria could be language/country specific, requiring reference studies for each language/country. In the Hidalgo et al. study (2008) the best cut-off criterion was ≥ 21, and in the present German study it turned out to be ≥ 19. Regarding the different methods, "Ventry and Weinstein criterion (1983)" vs. "worse ear average" for the dichotomous variable "hearing impaired vs. not impaired", a deeper look into the data reveals language/country specific differences. In both studies (Hidalgo et al. 2008, and the present one) the overall percentage of hearing loss was nearly 44 % according to the Ventry and Weinstein criterion. In the Spanish study the respondents tended to rate their subjective hearing ability much better, especially the questions 1 – 5. For instance, the Spanish study participants responded to item 1 („Have you noticed that you don't hear as well as usual/as you used to?") as follows: always = 20.7 %, occasionally = 40.3 % and never = 39 %, whereas the responses of the German study group were more 'pessimistic': always = 42.7 %, occasionally = 43.2 % and never = 14.1 %. An alternative explanation may be the different population characteristics. In the Spanish population participants >= 65 years were included with an average age of 73.3 years (44.1 % male participants). In the present study, the whole age range has been covered, beginning with participants from the age of 20 years, with an average age of 66.5 years (52 % male participants). So, it is unclear whether cross-cultural and/or sample characteristics are responsible for the different results for the HDDA. In any case it makes sense to include also younger people with hearing problems, when defining cut-off scores for occupational medicine and noisy workplaces. Beside the above mentioned different population characteristics, age specific differences in attitudes or expectations may influence answer strategies and therefore age specific cut off lines may improve test reliability in future.

The correlation analyses showed slightly higher values for the better ear hearing loss (BEA) in comparison to the worse ear hearing loss for the HDDA as well as for the HearCom Questionnaire. The ROC curves however, overall showed better plots for the WEA both for the HDDA and the HearCom Questionnaire. The specificity was better by about 10 % for the WEA for both questionnaires. For occupational medicine and also for military purposes, the true negative rate is also very important for the decision of the allocation of staff to workplaces relevant to security. The WEA criterion also seems a more conservative choice for screening tools addressing the PTA of both ears.

In summary, we suggest to use the HDDA for the screening of subjective hearing deficiencies with a conservative cut-off criterion of ≥ 19 (sum score), using the average hearing loss of the worse ear (WEA) as a basis for further tone and speech audiometric diagnostics. The screening test with the reported cut-off criterion is available as the German version of the HDDA under http://www.hoerzentrum-oldenburg.de/de/diagnostik-beratung/fragebogen.html.

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