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Research Article

A universal measure for the comparison of methods devoted to the objective threshold determination

Ein universeller Maßstab für den Vergleich von Methoden zur objektiven Schwellenbestimmung

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Abstract

Background: The determination of the threshold of hearing using the auditory evoked potentials is primarily based on the visual or automatic recognition of the response. The transition from the stimulus level range below to above threshold is characterized in that the probability of the occurrence of a response increases from zero to unity. Thus, the threshold can be regarded as a quantity which is of fundamentally statistical nature; this raises the question whether statistical concepts can be useful in the comparative evaluation of different methods.

Material and methods: Auditory evoked potentials with three methods (auditory brainstem response (ABR) with click stimulus, cortical electric response audiometry (CERA) with tone pulse of 1,000 Hz and 500 Hz auditory steady-state response (ASSR)) were measured with high resolution in twelve subjects in the vicinity of the response threshold. Depending on whether or not a response could be identified, each individual record contributed either 0 or 1 to the sequence of numbers which characterizes the series of measure cords. From these discrete jump functions, the threshold is determined and averaged over all subjects after normalization ("individual threshold level" ITL) and subsumed in 3-dB-groups (ABR and CERA) or 6-dB-groups (ASSR). The resulting curve reflects the probability for the occurrence of a response as a function of threshold related stimulus level. The grand average data obtained for each of the three methods were fitted with a Boltzmann function (weighted least squares fit), and the slope of the resulting curve at its inflection point was determined.

Results: The slope at the inflection point of the discrimination function was 28.3 percent/dB for the ABR, 13.7 percent/dB for CERA and 6.1 percent/dB for the ASSR, the values for the width of the threshold transition (increase of probability from 27 percent to 73 percent) were 0.9, 2.0 and 4.1 dB, respectively. These results are not presented in order to score the above-mentioned methods but merely as examples for the quality measure defined and tested here.

Conclusion: The slope of the discrimination function is a measure of the accuracy of the method and can therefore be used as a universal benchmark for comparing different methods. In contrast to other approaches, this comparison scale is not affected by the variability of other audiometric measures and their susceptibility to the influence of factors related to the subjects. It therefore makes sense to characterize the quality of an objective hearing test by the method-specific discrimination function measured in small dB-steps in the stimulus level range around the response threshold.

Zusammenfassung

Hintergrund: Die Bestimmung der Hörschwelle mit Hilfe der akustisch evozierten Potentiale beruht primär auf der visuellen oder maschinellen Erkennung der Reizantwort. Der Übergang vom unter- zum überschwelligen Reizpegelbereich ist dadurch gekennzeichnet, dass die Wahrscheinlichkeit für das Auftreten einer Reizantwort von Null auf Eins ansteigt. Somit ist die Schwelle ein fundamental statistischer Begriff; es erhebt sich die Frage, ob die konsequente Beachtung der statistischen Natur bei der vergleichenden Bewertung verschiedener Methoden vorteilhaft ist.

Material und Methode: An 12 Probanden wurden akustisch evozierte Potentiale mit drei Methoden (brainstem electric response audiometry (BERA) mit Click-Reiz, cortical electric response audiometry (CERA) mit Tonpuls 1.000 Hz und auditory steady-state response (ASSR) bei 500 Hz) in der nahen Umgebung der Reizantwortschwelle mit hoher Auflösung gemessen. Je nachdem, ob eine Reizantwort identifiziert werden konnte, trug jede Einzelmessung mit 0 oder 1 zu einer die Messreihe charakterisierenden Zahlenfolge bei. Aus dieser diskreten Sprungfunktion wurde die Schwelle bestimmt und nach Normierung der Schwelle („individual threshold level" ITL) und Zusammenfassung der Werte in 3-dB-Gruppen (BERA und CERA) bzw. 6-dB-Gruppen (amplitude modulation following response (AMFR)) die über alle Probanden gemittelte Wahrscheinlichkeit für das Auftreten einer Reizantwort in Abhängigkeit vom schwellenbezogenen Pegel ausgewertet. An die solchermaßen gewonnenen Daten wurde für jede der drei Methoden eine Boltzmann-Funktion angepasst (least squares fit) und die Steigung im Wendepunkt der resultierenden Kurve bestimmt.

Ergebnisse: Die Steigung im Wendepunkt der Diskriminationsfunktion betrug 28,3%/dB für die BERA, 13,7%/dB für die CERA und 6,1%/dB für die AMFR; für die zur Steigung reziproken Breite des Schwellenübergangs (Anstieg von 27% auf 73%) ergaben sich die Werte 0,9 dB, 2,0 dB und 4,1 dB.

Schlussfolgerung: Die Steigung der Diskriminationsfunktion ist ein Maß für die Genauigkeit der verwendeten Methode und kann somit als Maßstab für den Vergleich verschiedener Methoden verwendet werden. Im Gegensatz zu anderen Ansätzen wird dieser Vergleichsmaßstab von vielen der allgegenwärtigen Störfaktoren nicht beeinflusst. Es bietet sich daher an, die Qualität einer objektiven Hörprüfung durch die in Schwellennähe mit hoher Pegelauflösung gemessene methodenspezifische Diskriminationsfunktion zu charakterisieren.

Introduction and question

The inventory of methods for determining the hearing threshold from acoustically evoked potentials has been considerably expanded in recent years [1], [2], [3], [4]. The advantage of the resulting diversity is offset by the disadvantage of limited comparability: the available methods differ fundamentally in terms of their frequency specificity, the detection technique (transient or poststimulatory versus steady-state or perstimulatory responses) and in terms of the accuracy with which the presence or absence of a stimulus response can be detected and thus the stimulus response threshold determined. This complicates the comparison and thus the user's decision in favor of one or the other method. As a result, the comparison of objective and subjective thresholds has established itself as the measure by which the choice is made between two methods or devices which, according to their audiological claims, are in competition with each other for the same target group and application [5]. However, this criterion has the disadvantage that not only the test specimen (the objective method) but also the standard (behavioral audiometry) is subject to errors. Among the factors which have an impact on the result of pure tone audiometry, the reaction of the subject and its dependence on attention, concentration, maturity and routine are the most important. The error of the behavioral threshold lies in the order of at least ±5 dB [6]. If different methods are compared on the basis of the difference between objective and subjective thresholds with regard to their accuracy, a further disadvantage comes into play: due to the use of different stimuli, it is not always clear which of the behavioral audiometric thresholds is suitable as a control variable. Finally, among the factors limiting the comparability of experience reports from different sources is the variability associated with deriving ("extrapolation") the hearing threshold from the primarily determined stimulus response threshold [7], [8], [9], [10], [11]. In this situation, it could prove useful to have a universal measure for method comparison that is independent of other audiometric measures. This paper proposes and justifies an approach based on the sharpness of the threshold transition. Although this transition is only a small detail among the many characteristics of a method, it plays an important key role.

Table 1: Results of all ABR measurements (individual recording sequences composed of 10 to 15 measurements in 12 subjects). Each stimulus level is assigned a zero or a one, depending on whether a response could be detected in the associated record.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stimulus level in dB nHL	15	17	18	19	20	21	22	23	24					
Response 0/1	0	0	1	0	0	1	1	1	1					
Stimulus level in dB nHL	19	20	21	22	23	24	25	26	27	28				
Response 0/1	0	0	1	1	1	1	1	1	1	1				
Stimulus level in dB nHL	5	6	7	8	9	10	11	12	15	18	22			
Response 0/1	0	0	0	0	1	1	1	1	1	1	1			
Stimulus level in dB nHL	19	21	23	25	26	27	28	29	30	31	32	33	34	35
Response 0/1	0	0	0	0	0	1	0	1	1	1	1	1	1	1
Stimulus level in dB nHL	9	10	11	12	13	14	15	16	17	18	19	20	30	40
Response 0/1	0	0	0	0	0	0	1	0	1	1	1	1	1	1
Stimulus level in dB nHL	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Response 0/1	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Stimulus level in dB nHL	14	15	16	17	18	19	20	21	22	23	24	25	30	
Response 0/1	0	0	0	1	1	0	1	1	1	1	1	1	1	
Stimulus level in dB nHL	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Response 0/1	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Stimulus level in dB nHL	20	21	22	23	24	25	26	27	28	29	30	40		
Response 0/1	0	0	1	1	1	1	1	1	1	1	1	1		
Stimulus level in dB nHL	16	17	18	19	20	21	22	23	24	25	30			
Response 0/1	0	0	0	0	1	1	1	1	1	1	1			
Stimulus level in dB nHL	18	19	20	21	22	23	24	25	26	30				
Response 0/1	0	0	1	1	1	0	1	1	1	1				
Stimulus level in dB nHL	9	10	11	12	13	14	15	16	17	20	30			
Response 0/1	0	0	1	1	1	1	1	1	1	1	1			

Approach and method

Based on the idea that a dichotomous result is expected and obtained when searching for a stimulus response regardless of the hearing ability of the subject, the 12 subjects included in the study were not examined in detail with regard to a possible hearing impairment. However, it was at least known that none of the test subjects (8 adult women and 4 adult men) had a known hearing problem, but the hearing threshold was not determined as it was not relevant for the evaluation intended here.

The following measurements were carried out on all test subjects:

- Brainstem electric response audiometry (BERA) (ZLE Munich) biphasic click with 0.1 ms duration alternating, rate 31.25 stimuli/s stochastic, analog filter 100 to 3,000 Hz, 4,000 averages, digital filter 300 to 1,800 Hz, visual identification of the stimulus response
- Cortical electric response audiometry (CERA) (ZLE Munich) tone pulse 1,000 Hz with 500 ms duration, rate 0.49 stimuli/s stochastic, analog filter 1 to 100 Hz, 64 averages, digital filter 4 to 7 Hz, visual identification of the stimulus response
- Auditory steady-state response (ASSR) (GSI Madison) carrier frequency 500 Hz and modulation frequency 46 Hz (modulation depth 100% AM and 10% FM in phase), automatic signal detection according to a statistical procedure based on the phase and amplitude of the signal [12].

The specified parameters (stimulus, filter limits, averaging number, etc.) correspond to the values commonly used in practice. Within each series of measurements, the stimulus level was initially selected to be sufficiently above threshold to allow a stimulus response to be expected. After roughly localizing the stimulus response threshold, the stimulus level in the region of the threshold transition was varied in 1 dB steps (ASSR: 5 dB steps). The result of a series of measurements is shown in two rows of the table in Table 1. The number of measurements carried out within a series was between 10 and 15 (mean value: 11.5), the total number of all individual measurements was 404. With one exception (CERA in test subject 12), all measurement series were complete for all test subjects.

The graphical processing of the stimulus level-related 0–1 number sequences results in the indicator functions shown in Figure 1. From these, the individual threshold L_0 defined by the virtual intersection with the horizontal line at y=0.5 is determined arithmetically, geometrically or iteratively (Figure 2). The step from the individual (subject-related) indicator function to the global discrimination function (specific only to the measurement method) is carried out by renormalizing the (horizontal)

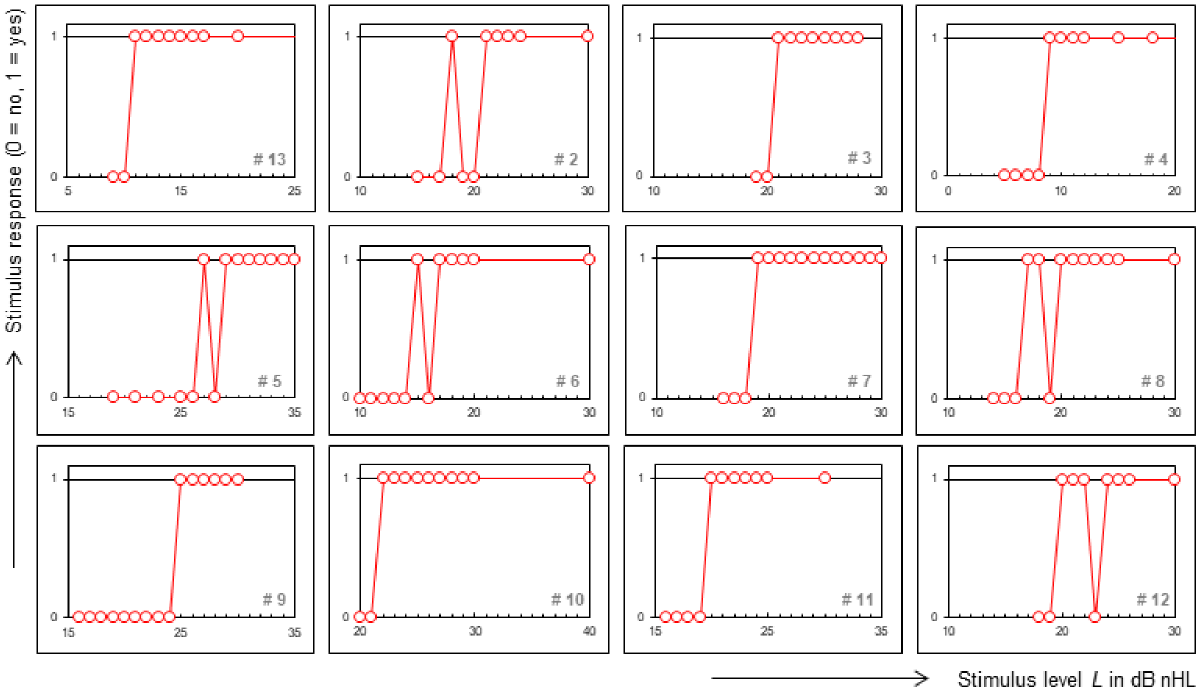

Figure 1: Individual indicator functions constructed from the 12 data sets shown in Tab. 1 (ABR measurements of all subjects). The horizontal axis represents the stimulus level (in dB nHL), the vertical axis has two discrete values: 0 for absent response and 1 for detectable response.

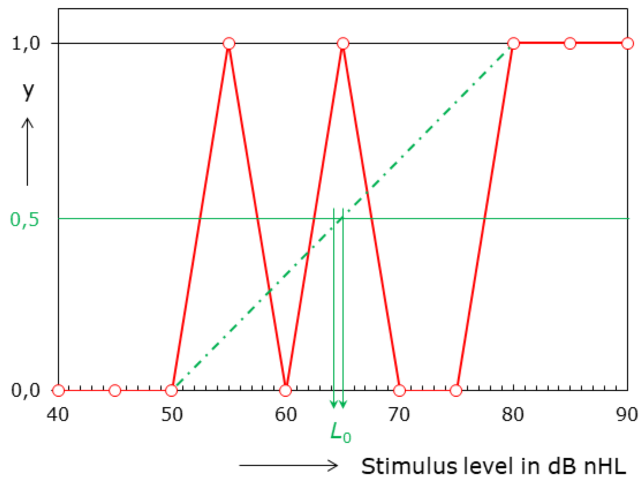

Figure 2: Indicator function for describing the observed threshold behavior in relation to the absence (y=0) or presence (y=1) of the stimulus response as a function of the stimulus level L (ASSR 500 Hz subject 08). The threshold (L_0≈65 dB in the case shown) can be determined arithmetically or geometrically or by means of an iteration procedure (fitting of a sigmoidal function).

level scale and subsequent averaging over all individuals (elimination of the individuality of the stimulus response threshold by horizontally shifting each indicator function by the amount L_0 and forming the mean values of the (0, 1) values of all N subjects within classes of width 3 dB, 5 dB or 6 dB). The results are shown in Figure 3. The error bars correspond to the standard errors obtained by dividing the standard deviation by $\sqrt{n}$ (n=number of numerical values within a class).

The data of the discrimination functions were fitted with a Boltzmann function using the weighted least squares method:

$$p(L)=\frac{1}{1+e^{-4(L-L_0)s_0}} \text{ or } p(L)=\frac{1}{1+e^{-(L-L_0)/u}} \text{ with } u=\frac{1}{4s_0}. \quad (1)$$

Free parameters were the position L_0 of the inflection point and the slope s_0 at the inflection point or the reciprocal measure u for the width of the rise in the curve. Since the data were processed in such a way that all measurement series coincide in their threshold L_0, the result obtained for this parameter is, as expected, very close to the zero point of the horizontal axis even for the curves averaged over all subjects: L_0=–0.1 dB “individual threshold level” ITL (auditory brainstem response (ABR)), L_0=–0.3 dB ITL (CERA) and L_0=–1.5 dB ITL (ITL=individual threshold level). Due to the arbitrary definition of the zero point, these numerical values should not be regarded as relevant results of the evaluation. The position L_0 of the inflection point is identical to the threshold (also referred to as L_{50} in the literature), as the asymptotic function values are exactly 0 and 1.

The properties of the function (1) are determined by the parameters u and s_0. In the range $L_0 \pm u$ around the inflection point, the curve increases from 27% to 73%:

$$L = L_0 - u \Rightarrow p(L) = \frac{1}{1+e} \approx 0.27$$

$$L = L_0 + u \Rightarrow p(L) = \frac{1}{1+e^{-1}} \approx 0.73$$

The linear approximation of the curve using a tangent at the inflection point makes the meaning of the parameter u clearer and the occurrence of factor 4 in the link between u and s_0 understandable: in the range $L_0 \pm u$, the tangent increases from 25% to 75% and in the range $L_0 \pm 2u$ from 0% to 100% (see Figure 3, right-hand image in the middle row).

Results

The results of the evaluation are shown in Figure 3. The presentation of the individual values (left column of the figure) shows that measurements with both negative and positive signal detection occur for the ABR in the range from around –2.5 to +2.5 dB ITL, for the CERA in the range from around –5 to +5 dB ITL and for the ASSR in the range from around –15 to +15 dB ITL. This already indicates that the methods investigated here indicate the threshold transition less clearly in the order mentioned.

In order to verify this observation and summarize it in figures, the data were grouped into classes of 3 dB (ABR and CERA) and 5 dB (amplitude modulation following response (AMFR)) and mean values were calculated within each class. This leads from the individual-specific indicator function (with the discrete values 0 and 1 depending on the relative stimulus level) to the method-specific discrimination function (with the continuous probability “p(response)” between 0 and 1 for the occurrence of a stimulus response). The discrimination function is shown together with the Boltzmann function fitted to the data in the right-hand column of Figure 3 and Figure 4. Apart from one outlier in the CERA and some possibly systematic deviations in the ASSR, the curve reproduces the points resulting from the measurements in a satisfactory manner.

The most important result of fitting an analytical function to the data is the slope s_0 at the inflection point of the discrimination function; it is s_0=28.3%/dB for the ABR, s_0=13.7%/dB for the CERA and s_0=6.1%/dB for the AMFR; these figures indicate the maximum percentage by which the probability of a stimulus response occurring increases (i.e. at the inflection point) when the stimulus level increases by 1 dB. The values u=0.9 dB (ABR), u=2.0 dB (CERA) and u=4.1 dB (ASSR) were obtained for the width of the threshold transition reciprocal to the slope (increase in probability from 27% to 73%).

Discussion

Without any doubt there is a great need among users of objective audiometric procedures for a quality measure that enables the comparative assessment of different methods with regard to their accuracy in threshold determination. The effort to meet this need has prompted the working group AGERA (*Arbeitsgruppe Elektrische Reaktions-Audiometrie* of the *Arbeitsgemeinschaft Deutschsprachiger Audiologen, Neurootologen und Otologen*) to develop recommendations for the use of objective hearing testing methods in the context of follow-up after failed newborn hearing screening [5]. While working on this document, it became clear that not only was there no comparative study of all methods that could be used to objectify the hearing threshold, but also that there was no standard that could be used to make this comparison possible and meaningful. The usual approach – namely the consideration of the deviation between objective and subjective threshold – contains unnecessarily many sources of error: the subject groups of different authors are composed differently, the determination of the behavioral threshold can be problematic particularly in young children, the examination procedures differ in the method of signal detection, the rules for extrapolating the hearing threshold from the stimulus response threshold are not uniform and often only vaguely defined, and several other factors. This leads to the unfavorable situation that not only the method to be tested but also the standard of comparison is subject to errors. In mathematical terms, this is equivalent to the convolution of the unknown response behavior with the transfer function of an inaccurate observation.

In the search for alternatives, a closer examination of the problem initially leads to the conclusion that the determination of any threshold is always associated with inaccuracies [13]. Irrespective of whether the reaction to the stimulus consists of a conscious response from the subject or an evoked signal that can be registered with measuring devices, very weak stimuli will lead to no response, very strong stimuli to a certain response, and stimuli lying between these extremes to a questionable response. The transition between absent and present stimulus response is not infinitely narrow, nor is the function by means of which this transition can be reproduced as a jump from zero to one infinitely steep. As in many other areas of audiometry (see e.g. [14]), the sharpness of the threshold transition can be described by the slope of a discrimination function that satisfies the above formula (1). The width of the transition, described by the parameter u, is reciprocal to the increase in the probability of detecting a stimulus response, which is quantitatively described by the slope s_0 at the inflection point of the curve. If the asymptotic values of the discrimination function are 0 (for L→–∞) or 1 (for L→+∞), the inflection point (defined by the maximum value of the slope) and the threshold level L_0 (defined as the stimulus intensity at which the probability of a stimulus response occurring is exactly 50 percent) are identical.

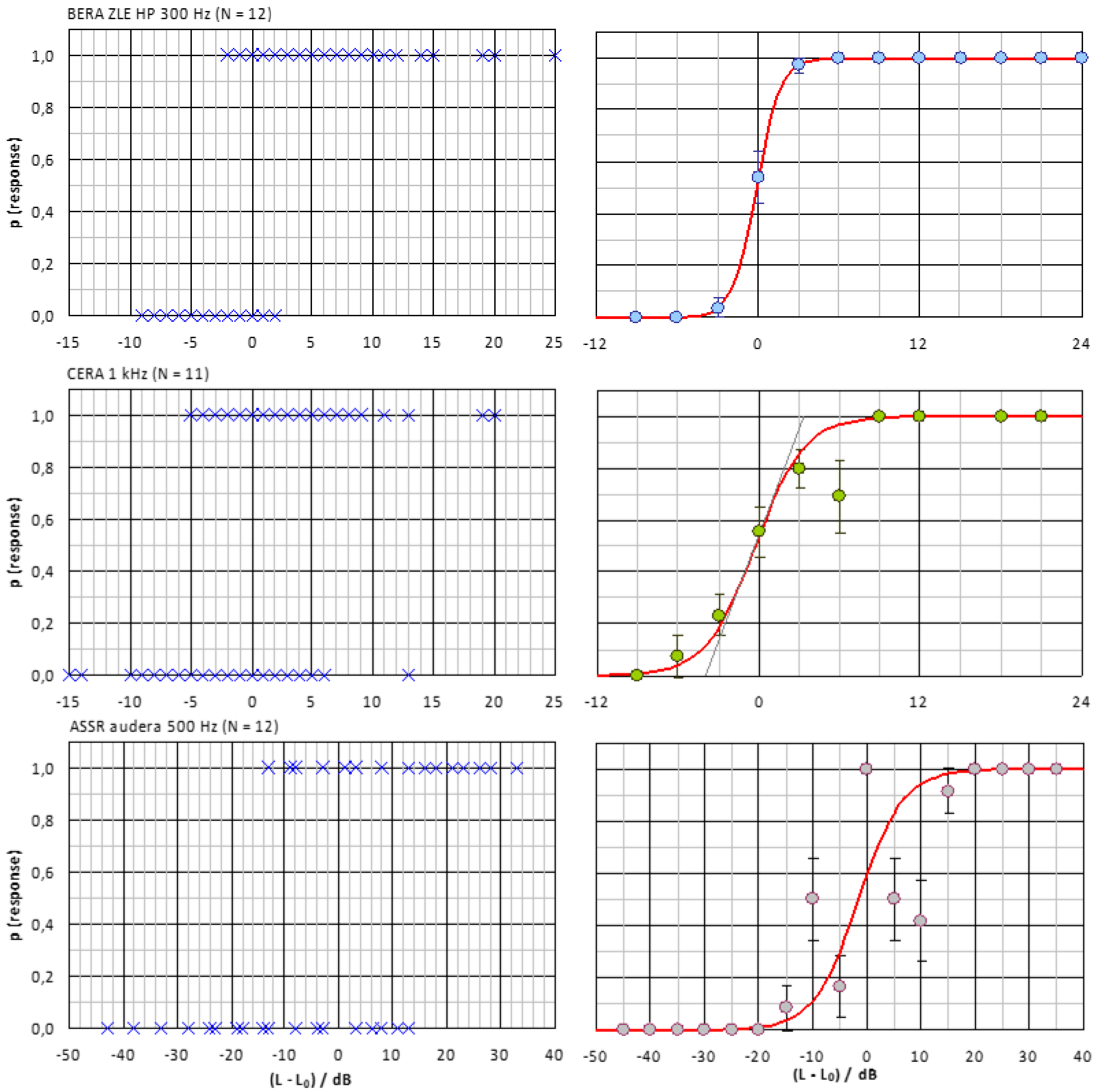

Figure 3: Relative frequency or probability of the occurrence of stimulus responses, shown for the entirety of the measurements (left) and after averaging with adjustment of the Boltzmann function (right); top: ABR (Click), center: CERA (1,000 Hz), bottom: ASSR (500 Hz); the x-axis in the bottom image covers a different range (–50 to +40 dB ITL instead of –12 to +24 dB ITL in the other sub-images) and the width of the classes for averaging is 5 dB instead of 3 dB.

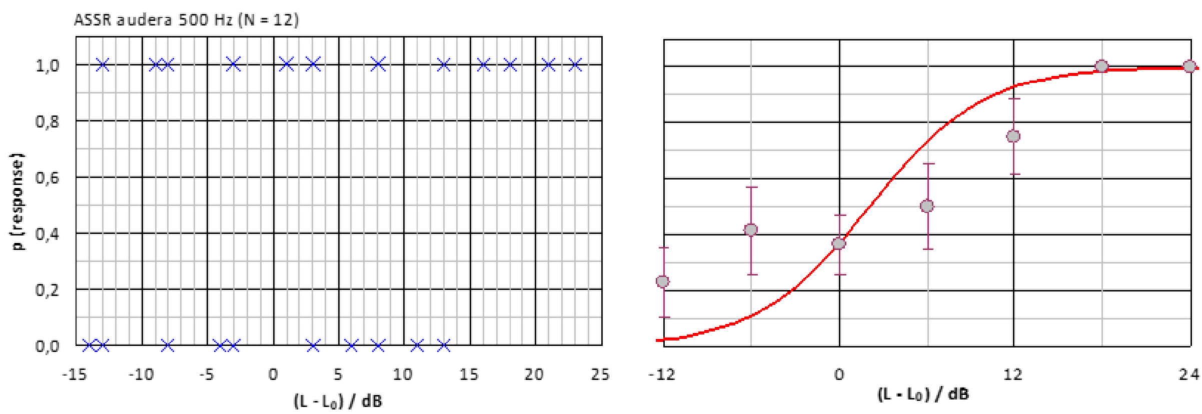

Figure 4: Stimulus level-dependent probability for the occurrence of stimulus responses at the ASSR (500 Hz) as in Fig. 3 but with the same x-axis as in the other subfigures; the width of the classes for averaging is 6 dB here.

When applied to three of a much larger number of available objective methods, the data presented in this paper reveal large differences in the accuracy of threshold determination. First of all, it should be noted that the Boltzmann function satisfactorily reflects the course of the ABR and CERA data. This is proved by the mean square deviation between the i=1, ..., m data points y_i and the associated functional values $f(x_i)$, weighted with the inverse value of the corresponding errors Δy_i and normalized to the number k of free parameters:

$$\sigma^2 = \frac{1}{k} \cdot \frac{1}{m} \cdot \sum_{i=1}^{m} \left(\frac{y_i - f(x_i)}{\Delta y_i} \right)^2$$

It amounts to 0.0033 for BERA and 0.62 for CERA, whereas systematic deviations occur in the ASSR (σ^2=1.23), which merit further investigation.

The slope s_0 derived at the inflection point of the discrimination function lies between 6.1 percent/dB for the ASSR (500 Hz) and 28.3 percent/dB for the ABR (Click). This means: at the steepest point of the discrimination function, the probability of detecting a stimulus response increases by 6.1% for the ASSR to 28.3% [sic!] for the ABR with every 1 dB increase in the stimulus level; the CERA lies in between with an increase of 13.7 percent/dB at the inflection point. Since a high accuracy is only possible with a steep boundary transition, these figures are equivalent to a clear and incorruptible ranking. Of course, the ranking presented does not apply generally to the BERA, CERA and ASSR methods as such, but only to the version used in this work. It must be assumed that every change in stimulus and measurement parameters leads to a change in the discrimination function. In particular, a reduction in the residual disturbance leads to an improvement in accuracy [15] and thus to an increase in the slope.

As the approach presented in this paper is described here for the first time, direct comparisons with the results of other studies are not possible. However, data are available from other sources that are comparable to the slope of the discrimination function in terms of the claim to assess the accuracy of threshold determination. These data describe the deviation between objective and subjective thresholds and the correlation between the two variables as well as the variability of the final results for the objective thresholds. Table 2 compares these figures taken from various studies. The comparability of the studies is limited by the fact that the parameters and subject collectives are very different. Nevertheless, it can be seen that the slope s_0 of the discrimination function, the correlation coefficient C between the audiometric threshold and the stimulus response threshold and the standard deviation σ of the difference between the audiometric threshold and the stimulus response threshold are interrelated. As expected, a cross-correlation analysis carried out for this purpose does not yield large numerical values, but at least the expected trend: a large slope s_0 is associated with a large correlation coefficient C (r=0.36) and a small variability σ (r=–0.30). If the parameters mentioned were much more interdependent, one of them could be dispensed with. The particular appeal of the approach presented here, however, lies precisely in finding a parameter specific to the test method that reflects the accuracy of the threshold determination without being subject to the influence of factors that have little or nothing to do with the actual measurement method.

In many of the numerous and sometimes very thorough studies that deal with the relationship between hearing threshold and stimulus response threshold, the primary focus is on the mean difference between the two thresholds, which is quite relevant for the accuracy of the method [10], [11], [16], [17]. If this difference were exactly maintained for each individual measurement, then the hearing threshold could be determined ("extrapolated") from the stimulus response threshold with a high degree of accuracy. However, due to the variability of this difference, the standard deviation (or standard error) of the threshold difference or the correlation coefficient, which describes the relationship between the two thresholds, must be considered. It must be assumed that these parameters contained in Table 2 are more closely related to the steepness of the method-specific discrimination function than the mean threshold difference. Closer relationships than those found cannot be expected, as ultimately all efforts to predict the hearing threshold from the stimulus response threshold must fail because the two thresholds are completely different measures [7]. This is particularly true for stimuli that contain more than one frequency and have only a short duration.

The concept of the method-specific discrimination function presented here for the first time is suitable for objectively ranking objective hearing test methods based on completely different principles in terms of their suitability for accurately determining the hearing threshold. Obtaining the discrimination function requires little effort, as the near-threshold measurements can be carried out on test subjects with almost any hearing performance and no further measurements need to be taken. It is not necessary to measure the stimulus responses, as only the dichotomous variable "0–1" resulting from the visual or automatic signal detection is included in the evaluation.

The approach is not based on a physiologically justified modeling of the input-output characteristic of the evoked potentials; this deficiency, which above all significantly calls into question all threshold determinations based on extrapolation, has a less disadvantageous effect here due to the use of exclusively near-threshold measurements, because it can be assumed that the amplitude at the threshold increases linearly with the level (i.e. logarithmically with amplitude or intensity of the stimulus) [18], [19], [20]. As soon as the data used to simulate the threshold behavior are more than 10 to 15 dB above the stimulus response threshold, the uncritical application of a general function according to (1) is questionable. For smaller distances from the threshold, however, it can be regarded as a valid first approximation.

The quality measure s_0 is influenced by many factors such as the parameters of the stimulus, the physiologic mechanisms of the response generators, the condition

Table 2: Comparison of the present results with those of some representative publications

	Slope s_0 in % per dB	Correlation coefficient hearing threshold/ response threshold	Standard deviation of level difference in dB
BERA Click	28.3 [this work]	0.93 [7]	11 [7] 7 [22]
CERA 1,000 Hz	13.7 [this work]	0.85 [23]	5 [24, 29]
ASSR 500 Hz	6.1 [this work]	0.97 [25] 0.72 [27] 0.92 [28]	15.6 [26] 7.78 [27] 3 to 15 [8] 10 [28]
BERA low chirp		0.87 [16]	7.68 [17]
BERA notch noise		0.67 [16]	5 [10] 9.29 [17]

of the patient, the environmental conditions and the details of signal processing. Beyond the scope of this paper, it is suitable not only for the comparison of different methods but also for studying the impact of specific parameters in order to find a parameter configuration optimized for the practical needs of objective threshold determination.

Conclusion

In the present work, the concept of a method-specific discrimination function is applied to three test procedures devoted to the objective threshold determination. The three procedures are characterized by nothing else than being part of the author's daily test inventory. In view of the urgent question of how to objectify low frequency hearing in children as effectively as possible, the application of the concept to the most promising methods – sound pulse ABR ("Notched Noise"), ABR with low chirp and extended ASSR – is already in preparation. The aim of this work was not to answer the question of the most suitable method, but to show how this answer can be found. As in many other areas, the slope of the discrimination function at the inflection point or the width of the threshold transition can be used as a universal standard of comparison, independent of many method- and individual-specific details, when assessing methods for objective threshold determination.

Note

This article was first published in German in the Zeitschrift für Audiologie [21].

Competing interests

The author declares that he has no competing interests.

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