The mapping of voice parameters in connected speech of healthy Common Czech male speakers

Mapování hlasových parametrů v souvislé řeči zdravých mužských mluvčích obecné češtiny

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This study examines a set of voice parameters to map objective ranges of voice-source characteristics of healthy male speakers of Common Czech. Objective assessment of voice quality is conducted mainly in speakers with voice pathologies, typically using sustained vowels as basis for measurements. In our study, we focused on non-pathological voices and performed acoustic measruments of the voice parameters which are believed to reflect glottal characteritics. The analyses were based on the open vowels [a aː] extracted from fifty healthy male speakers who performed a reading task. Voice parameter estimation included f_0 perturbation measures (jitter and shimmer), harmonicity (HNR), Cepstral Peak Prominence (CPP), and harmonic amplitude measures which reflect short-term spectral slope (e.g., H1−H2, H2−H4, or H1−A3). The obtained data relate to connected speech and are compared to the measurements on sustained vowels.

1. Introduction

The role of voice in everyday social interactions could hardly be underestimated; it is an important part of our communication and it also represents a rich source of information about the speakers reflecting their physical, psychological and social characteristics [1]. Voice quality can be treated in a broad perspective, when it comprises specific settings at both the laryngeal and supra-laryngeal (articulatory) level [1]. In a narrower perspective, voice quality only refers to phonatory modifications (i.e., changes in the manner of vocal fold vibra-tions). In this paper, we are interested in the laryngeal level only, and voice quality will thus pertain only to phonation.

Differences in voice quality may arise due to anatomical and physiological factors; apart from these biological aspects, however, socio-cultural aspects also play a considerable role [2, 3]. Voice quality as a significant idiosyncratic aspect of an individual's speech pattern is also examined within the field of forensic phonetics. Acoustic analyses focus on measuring voice parameters enabling to capture inter-speaker variability. In the Czech context, this research area is addressed, for instance, by Weingartová et al. [4].

Generally, when assessing voice quality, speech scientists may make use of methods deriving from three viewpoints: articulatory, where we describe the phonatory behaviour *per se*, perceptual and acoustic. Perceptual ratings of voice quality reflect subjective assessment but the overall impression of the voice can be decomposed into a few dimensions that are perceptually distinct and correspond to various terms, such as breathiness, roughness etc. Assessing voice quality using perceptual rating scales [1, 5, 6, 7] should remain constant across different listeners and voices, so that all the listeners use the measurement tools in the same way, and ratings across different voices can be compared in a meaningful manner. Voice quality is thus assumed to be constant across listeners, so that it can be dealt with as an attribute of the voice signal itself rather than a listener's perception product [8: 73–74]. In most cases, valid and reliable judgments of voice quality require trained judges, especially when it comes to the auditory-perceptual assessment of voice disorders [6].

Measuring acoustic parameters of voice quality is of great interest to scientists dealing with various voice pathologies. Their findings enable clinicians to diagnose voice disorders and are used in voice re-education aiming at acquiring appropriate phonation habits in patients suffering from vocal disorders [3, 6].

Acoustic analyses are used to provide measurements and quantification of various voice parameters, examining voice quality and phonation types in an objective way. The most common acoustic measures reflecting variability in the voice signal are *jitter, shimmer* and *HNR* (harmonics-to-noise ratio). These parameters are commonly used in clinical practice when evaluating voice disorders and voice quality disruptions such as breathiness, roughness and hoarseness, because they are relatively low-cost and non-invasive [6].

Jitter corresponds to variations in frequency between successive vibratory cycles [9, 10]. Jitter measurements can be conducted in two different ways – by peak-picking or waveform matching [9]. The latter tries to identify the time distance at which two consecutive waveshapes look most similar, while the peak-picking technique strives to find time locations where waveform amplitude is at its maximum. It is frequently a lack of precise control of vocal fold vibration that mainly affects jitter; patients with

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voice pathologies often have a higher percentage of jitter. A typical percentage range indicating frequency variation from cycle to cycle for sustained phonation in young healthy adults stated by most researchers is 0.5–1.0 % [10]. Values above 1.04 % are considered pathological [9, 10].

Shimmer provides measurements of variations in amplitude between successive vibratory cycles. The methods used to measure shimmer are identical to jitter, but while jitter takes into account the duration of periods, shimmer considers the peak amplitude of the signal [10]. The amplitude variation of the sound wave is expressed in percentage or decibels. The value 3.81 % is stated as limit for detecting pathological voices [10].

HNR enables researchers to quantify the ratio between periodic and aperiodic components in the signal. HNR estimation can be carried out in two ways: on a time-domain basis (using autocorrelation) and on a frequency-domain basis. In the former case, HNR is computed directly from the acoustic signal, while in the latter case, HNR measurements are conducted from a transformed representation of a waveform [11]. The higher an HNR value is, the more sonorant and harmonic a voice is. HNR values below 7 dB are considered pathological [10, 12].

In time-domain analyses, jitter and shimmer estimations rely on the identification of cycles of vocal fold vibration in speech signals (so-called *pitch marks*), which might have some limitations. For instance, in case of severely dysphonic or aperiodic vowel samples, the degree of disturbance or perturbation may be so high that an accurate location of cycle boundaries is difficult and, in turn, fundamental frequency (f_0) detection is impossible. Another potential problem may arise when using continuous speech samples containing variations in pitch and loudness as well as rapid consonant–vowel and vowel–consonant transitions [6, 13]; as mentioned above, jitter and shimmer are typically measured in sustained vowels.

Cepstral-based techniques represent an alternative approach towards extracting f_0 and towards estimating the relative amplitude of harmonic versus noise components; importantly, these techniques eliminate the need for identifying cycle boundaries [6]. Cepstrum, a Fourier transform of the power spectrum of the speech signal, is a spectral-based method comprising prominent peaks – rahmonics (anagram of harmonics). A cepstrum of an acoustic signal displaying a well-defined harmonic structure shows a prominent peak; this *cepstral peak prominence* (CPP) is a measure of the amplitude of that cepstral peak which corresponds to f_0, normalized for overall signal amplitude. The amplitude of CPP thus reflects both harmonic organization and the overall amplitude of the signal [14]. It has been used by a number of investigators to evaluate voice quality, as it provides valid and reliable measurements not only in sustained vowel samples, but also in continuous speech [6, 13, 15].

Apart from *jitter, shimmer, HNR* and *CPP*, *harmonic amplitude measures* are commonly used when examining glottal characteristics, representing short-term acoustic manifestations of voice quality. These parameters are sensitive to varying degrees of vocal fold adduction in normal speakers. Based on theoretical models, they are related to the existence and size of glottal chink [16]. Differences in amplitudes of the first and second harmonics (H1−H2) and the harmonic amplitudes located closest to the first, second and third formant frequencies (H1−A1, H1−A2, H1−A3) of the voice spectrum have been found useful when quantifying the degree of glottal adduction in different voices [16, 17]. The amplitude of the first harmonic relative to that of the second (H1−H2) is used as an indication of the open quotient, i.e., the proportion of a glottal cycle in which the glottis is open. As the OQ relates to the overall glottal stricture, the H1−H2 measure is used to characterize the differences along the glottal constriction continuum [16, 17, 18] The amplitude of the second harmonic relative to the fourth (H2−H4) has also been found to be an important acoustic measure for distinguishing modal from nonmodal phonation [19], especially in cases when H1−H2 does not seem to work [18].

The amplitude of H1 relative to a higher frequency component can quantify the strength of higher frequencies in the spectrum relating to the closing velocity of the vocal folds, and perhaps to muscle tension. Thus, H1−A1, H1−A2 and H1−A3 are measured. These parameters can also distinguish modal and breathy phonation in some languages [18, 20] where H1−H2 does not seem to be useful. The amplitude of the first harmonic relative to that of the first formant prominence in the spectral domain (A1) reflects the bandwidth of F1, and may also be affected by source spectral tilt. H1−A1 is an indication of the presence of a posterior glottal chink, i.e., the degree to which the glottis fails to close completely during the closing phase [16, 17]. The amplitude of the first harmonic relative to that of the strongest harmonic in the second formant (H1−A2) is used as an indicator of the source spectral tilt (i.e., energy decrease with increasing frequency) at the mid formant frequencies [16]. Finally, H1−A3 reflects the spectral tilt at the higher formant frequencies, [16, 17, 21].

Harmonic amplitude measures can be compared across different speakers and vowels only if the measures are corrected for the effect of F1, F2 and F3 vocal tract resonances (frequencies and bandwidths) on harmonic amplitudes; uncorrected values reflect both the voice source and the supra-glottal filter. The corrected harmonic amplitude values are denoted with an asterisk, e.g. H1*−H2*, H1*−A1* etc. [17, 18, 22].

The objective of this study is to provide the aforementioned voice measure estimation in young healthy Czech male speakers of common Czech. A number of studies dealing with voice parameters published so far concentrate mainly on speakers with voice disorders or on patients with neurodegenerative diseases whose impact on voice quality has been scientifically proved [23]. This study seeks to establish quantitative ranges against which it would be possible to gauge the production of non-pathological voice.

A sample of fifty male speakers will be used to map acoustic parameter value ranges of voice-source characteristics based on a read speech task.

2. Method

2.1. Material

Recordings of fifty male speakers aged between 19 and 43 years (mean age: 24.7 years, SD: 6.1 years) were selected from the Database of Common Czech, a reference database for forensic purposes [24]. The speakers, who reported no voice or hearing problems, were recorded while reading a phonetically rich text of 150 words including all the Czech phonemes and their context-dependent variants in their natural voice; the length of the recording was approximately 60 seconds. Based on reported findings ([25: ch. 4] for a review), no age-related vocal changes were assumed in the speakers.

The recordings were acquired in a quiet environment using a portable recorder Edirol R09 and its in-built microphone, at a sampling rate of 48 kHz.

2.2. Parameter extraction and analyses

For each speaker, we extracted the voice quality parameters from 30 manually segmented /a a:/ vowels (16 phonologically short and 14 long vowels). Only phrase-internal vowels were chosen for analysis, so as not to confound the measurements by phrase-final phenomena such as creak or breathiness. However, vowels in all segmental contexts (incl. nasal) were included. Boundaries of the target vowels were determined based on the phonetically motivated recommendations for manual segmentation of the speech signal [26]. Briefly, the boundaries were located at the onset or the offset of full vowel formant structure. In case of the transition phase, the boundaries were placed in the temporal midpoint of this area. The total number of 1,500 target vowel sounds (30 vowels × 50 speakers) had to be reduced to 1,492, as the visual and auditory inspection revealed that 8 target items were of different vowel quality, due to an error in the speakers' reading.

Jitter, shimmer and HNR measurements were extracted using a Praat script [27] with the default settings for each parameter. As for jitter, values of local jitter (the most common measurement) were extracted using waveform matching (see section 1). The measure represents the average absolute difference between consecutive periods divided by the average period, and is expressed as a percentage [9, 10]. Shimmer measurements were performed using local shimmer parameter expressing the average absolute difference between the amplitudes of consecutive periods divided by the average amplitude. Similarly to local jitter, it is expressed as a percentage. HNR extraction, representing the degree of acoustic periodicity expressed in dB, was conducted by means of the cross-correlation method, as recommended for voice analysis in Praat [27].

The spectral magnitudes of H1*–H2*, H2*–H4*, H1*–A1*, H1*–A2* and H1*–A3* as well as CPP values were automatically extracted using Voice Sauce, a free stand-alone software [28], using the labelled Praat TextGrids. In order to estimate the location of harmonics, f_0 measurements needed to be carried out. We used the Voice Sauce default algorithm STRAIGHT [29] detecting f_0 at 1ms intervals and computing the harmonic magnitudes pitch-synchronously over a three-cycle window. This method eliminates much of the variability obtained in spectra computed over a fixed time window, and is equivalent to using a very long FFT window, providing more accurate measurements without relying on large FFT calculations [22].

CPP calculations in Voice Sauce are based on the algorithm [14] using a variable window length which is equal to five pitch periods by default. The obtained data are then multiplied with a Hamming window and transformed into the real cepstral domain. The CPP is estimated by conducting a maximum search around the quefrency of the pitch period. The peak is normalized to the linear regression line calculated between 1 ms and the maximum quefrency [22, 30].

The raw voice parameters data were processed in R [31] and visualised using the package *ggplot2* [32]. The statistical (mean, standard deviation, as well as the median in the final summarizing table) are computed for all analyzed vowels.

3. Results and discussion

The estimated values of the respective voice parameters will be presented in the following subsections. A table summarising the extracted mean values is presented in section 4 (Table 1). In section 3.5, we will focus on the relationship among the acoustic measures, and finally, we will comment on some speakers' results.

3.1. F_0 perturbation measures: jitter and shimmer

Fig. 1a shows the value ranges of the jitter measure for each speaker. The mean value is 1.83 % (SD: 1.97 %; 95% confidence interval: 1.73–1.94 %) and is above the threshold value of 1.04 % for pathological voices [10]. The mean value for the shimmer measure is 13.02 % (SD: 6.75 %; 95% confidence interval: 12.66–13.38 %) and is also higher than the pathological threshold of 3.81 % [10]. The shimmer value ranges for individual speakers are displayed in Figure 1b.

Both the estimated jitter and shimmer values are above the stated limits for detecting voice pathologies. However, as already mentioned above, the stated threshold values refer to the measurements performed on sustained vowels [9, 10], while our voice parameter extraction is based on continuous speech, which causes fast changes in pitch and formants [6, 13, 33]. The jitter and shimmer measures are thus necessarily higher than the pathological threshold,

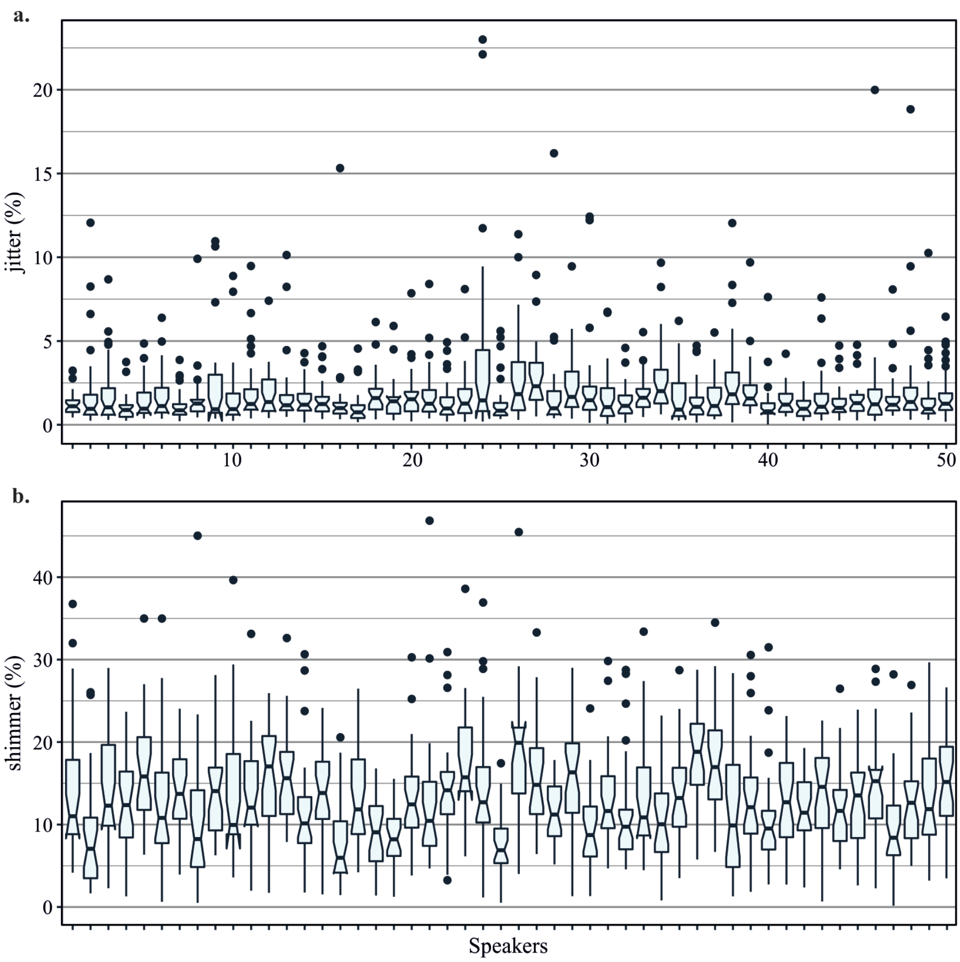

Figure 1: **a.** jitter value ranges, x-axis displays 50 speakers, y-axis shows jitter values (%). **b.** shimmer value ranges, x-axis displays 50 speakers, y-axis shows shimmer values (%)

and it is clear that they do not reflect any voice pathology (Boersma, 2017, personal communication); in fact, proposing perturbation values and ranges corresponding to healthy voices in connected speech is the main objective of this study.

3.2. Harmonicity (Harmonics-to-noise ratio, HNR)

Figure 2a shows the value ranges for each speaker. The mean value is 9.41 dB (SD: 4.05 dB; 95% conf. int.: 9.20–9.62 dB), which is well above the threshold value of 7 dB for voice pathologies and is in line with previous findings [10, 12, 34]. It will be useful to compare our data with previous studies. For example, Yumoto and Gould [34] examined the HNR parameter in relation to the degree of hoarseness in both healthy speakers and speakers with laryngeal disorders pre- and post-operatively using a sustained /ɑ:/ vowel. The estimated HNR for the healthy speaker group ranged between 7 and 17 dB with the mean of 11.9 dB (12.2 dB for males and 11.5 dB for women) compared to the estimated value range between −15.2 and 9.6 dB with the mean of 1.6 dB in preoperative speakers. It can be seen in Figure 2a that only two speakers' values in our sample fall below 7 dB.

3.3. Cepstral Peak Prominence (CPP)

Figure 2b displays the value ranges for the CPP measure extracted automatically using Voice Sauce. The mean value is 20.28 dB (SD: 3.69; 95% conf. int.: 20.26–20.30 dB). There exists a negative correlation between the CPP and the levels of aperiodicity of the glottal source – the higher the CPP, the lower the degree of aperiodicity in the voice signal [13, 15, 18]. As an acoustic measure of voice quality, some researchers evaluated the effectiveness of CPP in predicting breathiness ratings, and our results will thus be compared with theirs. Hillenbrand et al. [14] tested the parameter in healthy native English speakers who were asked to produce sustained vowels in nonbreathy, moderately breathy and very breathy phonation. The results confirmed that periodicity measures, namely CPP, provide the most accurate predictions of perceived breathiness [15, 18]. These findings were also confirmed for dysphonic voices and continuous speech [15]. In their study, Hillenbrand and Houde [15] provide exam-

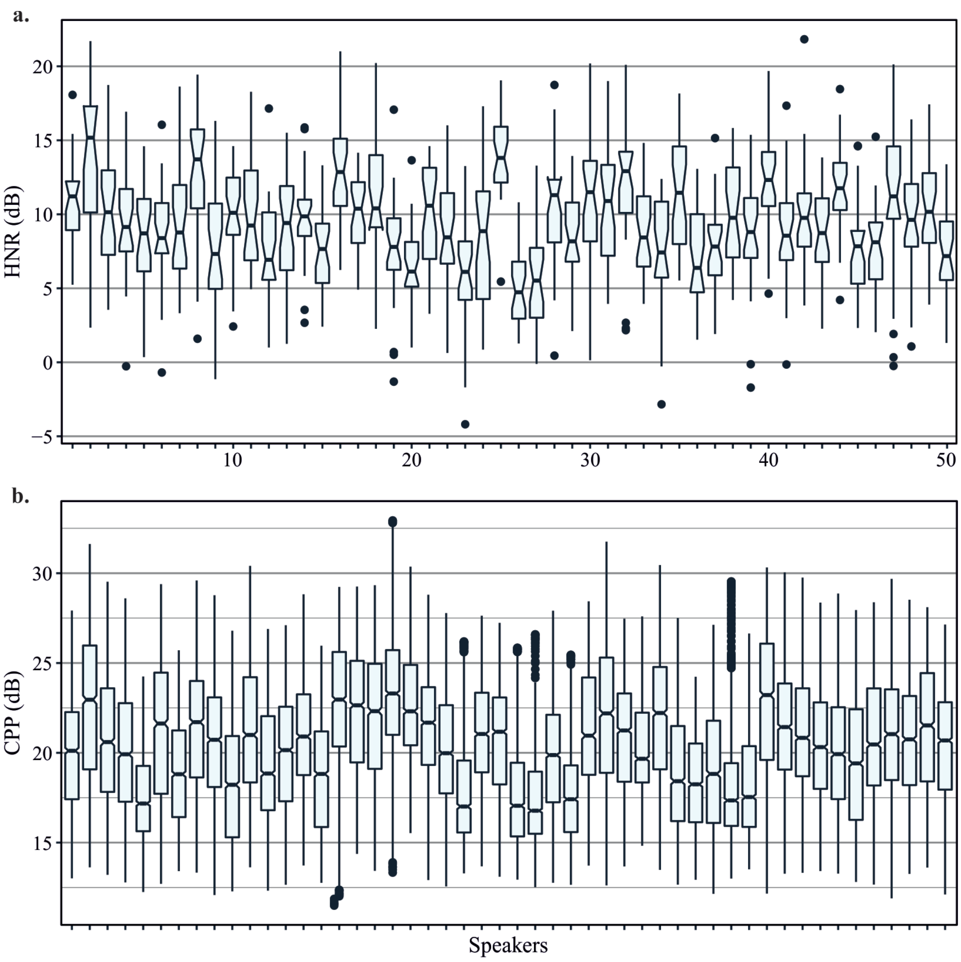

Figure 2: **a.** HNR value ranges, x-axis displays 50 speakers, y-axis presents HNR values (dB). **b.** CPP value ranges, x-axis displays 50 speakers, y-axis presents CPP values (dB)

ples of the CPP measures for signals perceived as nonbreathy and moderately breathy: 21.6 dB and 13.1. dB, respectively. Garellek and Keating [36] reported the CPP mean value of 22.5 dB for modal phonation extracted from /a, æ, o/ uttered in words by male speakers. The mean values for both creaky and breathy phonations were lower than the value of 20 dB. The CPP mean value we obtained should therefore reflect a nonbreathy/modal phonation.

3.4. Harmonic amplitude measures

The value ranges for H1*−H2*, as automatically extracted in Voice Sauce, are captured in Figure 3a. The mean is 1.83 dB (SD: 6.04; 95% conf. interval: 1.79–1.86 dB). As a correlate of the Open Quotient, lower values indicate a greater glottal constriction [18]. Cross-linguistically, H1*−H2* also represents one of the most successful measure of phonation type [35] and is often cited as an acoustic correlate of breathiness (e.g. [21]). Nevertheless, it seems to be a more reliable predictor of breathiness ratings for sustained vowels than for sentences or continuous speech [15]. H1*−H2* values for nonbreathy and breathy phonation were reported in [15]: 1.7 dB and 19.3 dB, respectively. Hanson and Chuang [17] obtained the following mean values using sustained vowel production in healthy speakers: men: 0.0 (SD: 1.8) dB and women: 3.1 (2.0) dB. Narra et al. [16] also used sustained vowels for their measurements in healthy speakers and present the following mean values for H1*−H2* (sustained /a/): 7.18 (SD: 3.7) dB for male and 11.49 (2.73) dB for female speakers.

H2*−H4* parameter estimation yielded the mean of 9.37 dB (SD: 6.09; 95% conf. int.: 9.33–9.4 dB). Figure 3b displays the value ranges for all our speakers. Similarly to H1*−H2*, H2*−H4* is also mentioned as a significant acoustic correlate of the perception of the contrastive breathiness in some languages [19]. Garellek et al. [20] measured H2*−H4* and H1*−H2* of the samples of sustained /a/ which were inverse-filtered and copy-synthesized to find out how they correlate with the perceived breathiness. The obtained mean values in dB for H2*−H4* were 8.93 (SD: 3.74) for men and 11.57 (4.99) for women, and for and H1*−H2* 6.13 (4.11) for men and 8.93 (4.55) for women, respectively.

Finally, let us look at the value estimations of the amplitude of the first harmonic relative to that of the

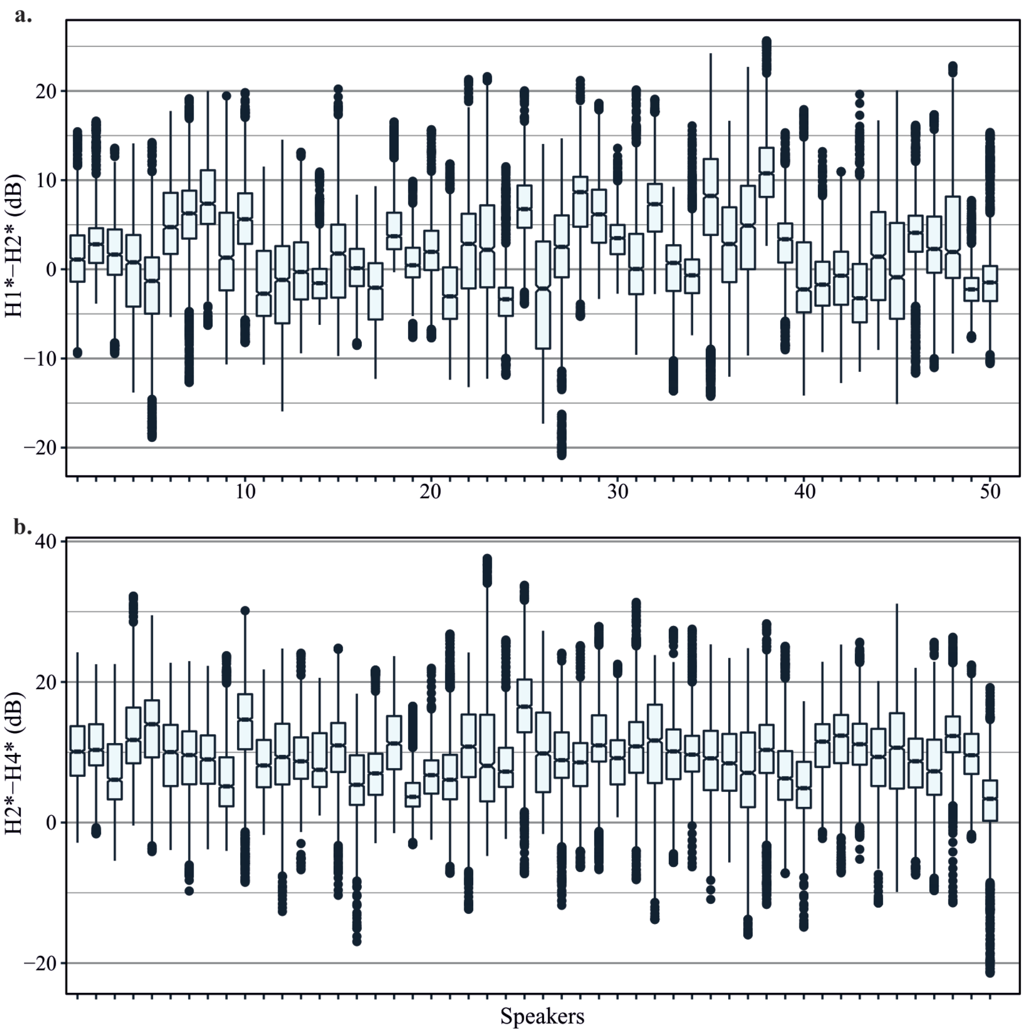

Figure 3: **a.** H1*−H2* value ranges, x-axis displays 50 speakers, y-axis presents H1*−H2* values (dB). **b.** H2*−H4* value ranges, x-axis displays 50 speakers, y-axis presents H2*−H4* values (dB)

F1, F2 and F3 prominence. Greater differences between H1*−A1*, H1*−A2* and H1*−A3* indicate less strong higher frequencies and more noise components in the spectrum [35].The mean values are: 21.43 dB (SD: 8.4) for H1*−A1*, 24.89 dB (SD: 8.42) for H1*−A2* and 18.87 dB (SD: 10.4) for H1*−A3 (see Table 1 in section 4). In [16], the following average and standard deviation values for sustained /a/ are reported: H1*−A1* in healthy men: 6.7 (2.53) dB and women 11.17 (4.54) dB, H1*−A2* 9.64 (4.79) dB in men and 12.73 (3.0) dB in women, and H1*−A3* 24.53 (6.06) dB in men and 28.79 (5.41) dB in women.

3.5. Acoustic measure relationships

Let us now have a look at the relationships among the extracted parameters. Figure 4 captures the correlations between the extracted mean values. In each case, we plotted a particular acoustic measure against CPP, as this parameter has been found to provide valid and reliable measurements in continuous speech [6, 13, 14, 15]. Spearman's rank correlation coefficient ρ was computed due to the presence of outlier values.

The plots suggest only mild or weak correlations, which confirms the relative independence of the different measures. Specifically, there is a positive correlation between CPP and HNR ($\rho = 0.4$, $p < 0.005$), and CPP and some of the harmonic amplitude measures: H1*−H2* ($\rho = -0.26$, $p < 0.1$), H2*−H4* ($\rho = -0.27$, $p < 0.1$). The negative correlation between CPP and the jitter did not even reach significance ($\rho = -0.14$, $p > 0.1$).

Correlations were stronger when we examined the interdependence of the harmonic amplitude measures. They are all positive and significant correlations: H1*−H2* *vs.* H1*−A1* ($\rho = 0.78$, $p < 0.001$); H1*−H2* *vs.* H1*−A2* ($\rho = 0.58$, $p < 0.001$), and H1*−H2* *vs.* H1*−A3* ($\rho = 0.61$, $p < 0.005$). Only the correlation between H1*−H2* and H2*−H4* was not significant ($\rho = 0.66$, $p > 0.5$), which indicates that they reflect different properties of the voice.

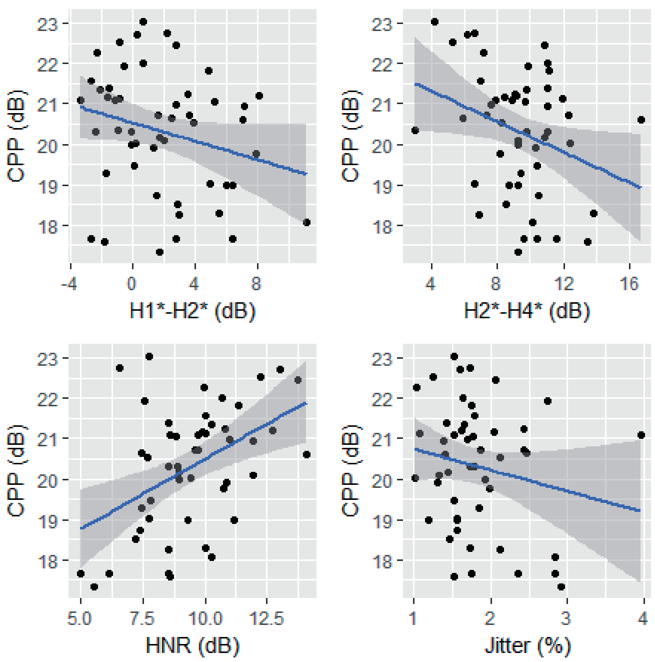

Figure 4: Scatterplots (extracted mean values) with trendlines (and 95% confidence bands). From top left: H1*−H2*, H2*−H4*, HNR and jitter plotted against CPP

3.6. Comments on particular speakers' values

Taking into account the relationships among our acoustic measures presented in the previous subsection, we will examine some speakers' mean values, taking values of the cepstral peak prominence close to the extremes as starting points.

The second highest CPP mean value was measured in Speaker 40 (S40): 22.52 dB (the overall mean across all speakers being 20.28 dB, and the mean value being higher for only one speaker, 23.06 dB). S40's HNR mean value is 12.24 dB (the overall mean: 9.41; the maximum mean value: 14.06), the H1*−H2* mean value of −0.88 dB is well below the overall mean of 1.83 (the minimum mean value: −3.43), and so is the H2*−H4* mean: 5.25 dB (the overall mean: 9.37; the minimum mean value: 3.01), and finally, S40's jitter mean value of 1.25 % is also below the overall mean of 1.83 % (the minimum value: 1.02).

The results reported in the previous paragraph imply a certain consistency across all the parameters. However, that is not always the case in all the speakers. For instance, in S2, we estimated the highest CPP mean value (23.06 dB), but S2's H1*−H2* and H2*−H4* means (2.78 dB and 10.9, respectively) are above the overall mean values (1.83 and 9.37, respectively).

Let us turn to Speaker 27 from the other end of the scale. S27 has the lowest mean value of CPP (17.32 dB) and his HNR mean of 5.57 dB is well below the overall mean of 9.41 dB. Also, this speaker's jitter mean of 2.9 % is above the overall mean. However, S27's H1*−H2* and H2*−H4* means (1.77 and 9.21, respectively) are below the overall mean values, which should not be expected considering the indicated relationships among the respective acoustic measures.

4. Conclusions

The aim of this study was to establish quantitative ranges of voice quality parameters in healthy Czech male speakers of common Czech in an objective way, based on a continuous speech reading task. The key values of all the parameters are summarized in Table 1.

Parameter	Mean (SD)	Median	Q1–Q3
Jitter	1.83 % (1.97)	1.18 %	0.72–2.12 %
Shimmer	13.02 % (6.75)	11.9 %	8.33–16.81%
HNR	9.4 dB (4.05)	9.4 dB	6.58–12.22 dB
CPP	20.3 dB (3.69)	20.2 dB	17.33–23.02 dB
H1*−H2*	1.8 dB (6.04)	1.6 dB	2.36–5.75 dB
H2*−H4*	9.4 dB (6.09)	9.2 dB	5.17–37.59 dB
H1*−A1*	21.4 dB (8.4)	20.9 dB	15.6–26.6 dB
H1*−A2*	24.9 dB (8.42)	24.3 dB	19.13–30.13 dB
H1*−A3*	18.9 dB (10.4)	18.9 dB	11.84–68.72 dB

Table 1: The estimated mean and median values and the values of the first and third quartile (Q1–Q3)

Although sustained vowel productions are commonly used to assess voice quality when conducting acoustic measurements, we decided to use a continuous speech sample based on a reading task. As human voice represents a dynamic time-varying source of vocal tract excitation, it is connected speech (characterized by rapid successions of different articulatory controls) that should provide relevant, ecologically valid data in terms of what makes speech production normal, and should enable researchers and clinicians to understand and assess the abnormality of speech production in different speech styles.

Our estimated jitter and shimmer values are above the commonly stated threshold limits for voice pathologies, especially in the case of shimmer. Needless to say, continuous speech contains variations in pitch, formants and loudness as well as rapid consonant-vowel and vowel-consonant transitions; our data thus cannot be compared with those obtained from speakers sustaining vowels for several seconds, but may provide reference for similar endeavours in the future.

The HNR measurements were conducted in a similar way as jitter and shimmer estimation, i.e. using a temporal- based method. Although the obtained mean value is quite above the stated threshold value for pathological voices, considering we used continuous speech. It would be useful to compare our data with HNR estimation using a spectral- (or more precisely, cepstral-) based technique.

Harmonic amplitudes measuring yielded somewhat higher values in most parameters compared to other studies. As in the case of the acoustic parameters mentioned above, harmonic amplitude measurements are commonly performed on sustained vowels. Finally, based on findings available in literature, the estimated CPP values seem to reflect modal phonation in most of our speakers.

While mapping voice parameters in our study, we also tried to examine the suitability/usefulness of the parameter estimations when using connected speech material. Future research might further examine the parameter extraction techniques relating to connected speech and conduct further measurements across different groups of speakers.

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