PARAMETER IDENTIFICATION FROM PHONIATRICAL EXAMINATIONS

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Abstract. In works [1, 2, 4] we introduced problems of the voice range examination. We also introduced our own proposal of the algorithm and the application of the software system. This work concerns with predicative abilities of individual examination parameters. There are examined some properties of identified parameters of our system and for a comparison there are examined also properties of parameters of the Multi-Dimensional Voice Program, [5]. The study is focused on a comparison of values in the pre-surgical and in the post-surgical phase. An evaluation of the information content of the measured quantity has some statistical problems. This work deals with their formulation and with some possible methods of their solution.

Keywords: Phoniatry and Laryngology, Hypothesis Testing, Correlation Analysis, Voice Range Profile, Multi Dimensional Voice Analysis

AMS classification: 62M10, 68T50, 92C50

Motto: *"Is it possible to choose such a datum which measures objectively the result of the executed surgery on vocal cords?"*

1. Introduction

The goal of this work is to find out dependencies between identified data. The easiest way to do so is to use the correlation structure, which quantify the correlation between identified data. Next goal of this work is (see Motto) data examination from the point of view of the pre-surgical and the post-surgical values. This imply an attempt to define scales from some data which could be used by the post-surgical state evaluation. In the evaluation were included 342 records from 137 patients. 204 records were pre-surgical and 138 records were post-surgical. Each record includes 64 items in total. Nine of them are identification items, i.e. patient's code, sex, diagnosis, presence of the voice range item, presence of the multidimensional analysis item, type of the voice examination – with the vowel *a* or with standard text reading, presence of the voice load and relative time of examination with regard to the date of the surgery. Another 22 items represent particular parameters of the Voice Range Profile (VRP) from the system [1] and last 33 items represent parameters of the voice examination realised by methods of the multidimensional analysis, Multi-Dimensional Voice Program (MDVP), see [5]. Among the set of records exist some by which were not measured all their items. Detailed list of parameters (with description) of VRP and MDVP is in the appendix of this article.

2. Correlation structure

A test of the cross-correlation was used for basic examination of a relationship between parameters and methods of the measurement (which are source of those parameters). This test is based on correlation relationships of data, which corresponds to parameters:

$$r_{x,y} = \frac{cov(x,y)}{\sigma_x \sigma_y}, r_{x,y} \in \langle -1, 1 \rangle,$$

$$cov(x,y) = \frac{1}{n} \sum_{i=1}^{n} (x_i - \mu_x)(y_i - \mu_y),$$

where:

$$\sigma_x = \frac{1}{n} \sum_{i=1}^{n} (x_i - \mu_x)^2, \sigma_y = \frac{1}{n} \sum_{i=1}^{n} (y_i - \mu_y)^2,$$

$$\mu_x = \frac{1}{n} \sum_{i=1}^{n} x_i, \mu_y = \frac{1}{n} \sum_{i=1}^{n} y_i.$$

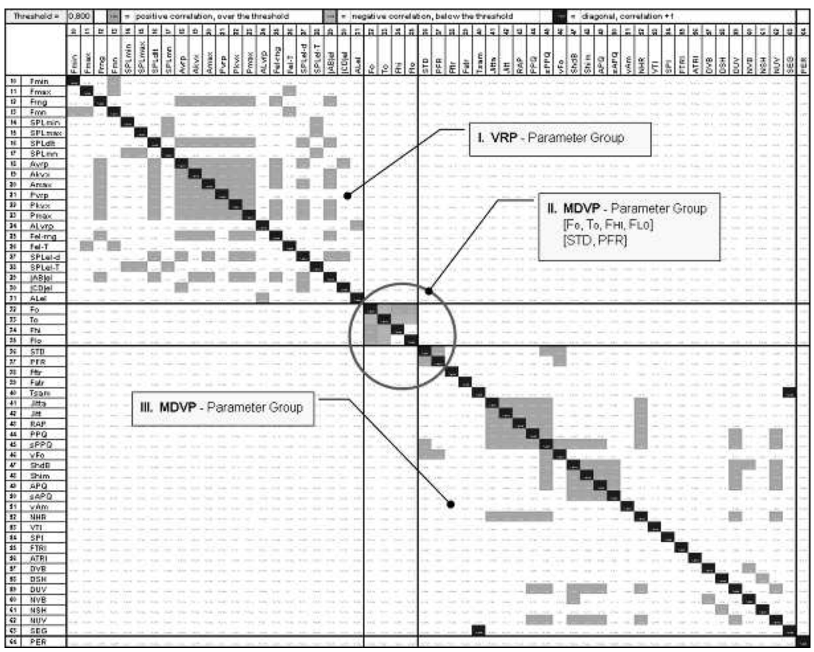

Figure 1. Over-threshold correlations for the threshold $\pm 0,80$.

In Figure 1 there are three basic groups of tested parameters. First group of linked data are parameters measured by the VRP, see [1]. Second group is composed of part of data of parameters from MDVP, see [5]. Third group is the rest of data corresponding to parameters from MDVP, see [5]. Interesting group which is second group composed of multidimensional analysis parameters: Fo, To, F_{HI}, F_{LO}, see Figure 2.

		Fo 32	To 33	Fhi 34	Flo 35	
32	Fo	1,0	-1,0	0,9	0,9	Average Fundamental Frequency [Hz]
33	To	-1,0	1,0	-0,9	-0,9	Average Pitch Period [ms]
34	Fhi	0,9	-0,9	1,0	0,8	Highest Fundamental Frequency [Hz]
35	Flo	0,9	-0,9	0,8	1,0	Lowest Fundamental Frequency [Hz]

FIGURE 2. Detail of correlation structure for the second group and for the threshold $\pm 0,80$.

Negative correlations are obvious. It is the relationship between frequencies and periods. In fact, this block is the interval description of the basic vocal cords frequency; see [2] and [5].

If we lower our requirements for the correlation, we can also include data of multidimensional analysis parameters STD and PFR in this block, see Figure 3.

		STD 36	PFR 37	
36	STD	1,0	0,9	Standard Deviation of Fo [Hz]
37	PFR	0,9	1,0	Phonatory Fo - Range in semi-tones

FIGURE 3. Detail of correlation structure for parameters STD and PFR and for the threshold $\pm 0,80$.

In the meaning of the relationship measured by the correlation we can alternatively consider these parameters as self-standing group in spite of they come from estimations of other probability parameters of random quantities from the third block. From correlation matrixes and from their threshold interpretation it is obvious that methodologies [1] and [5] are not in close relationship and it is possible to consider them as two different views of the same phenomenon with very complicated structure, because it goes about sound expresses of vocal cords device. The correlation analysis acknowledges physiological-technical assumption, so parameters of VRP have the quantitative character and parameters of MDVP have the quality character. Furthermore, in both groups of VRP and MDVP there are obvious clusters of parameters.

Their existence results from their physical properties with the relationship to the physiology of vocal cords:

VRP:

circumference and content field area	$[A_{VRP}, A_{KVX}, P_{VRP}, P_{KVX}, P_{MAX}]$,
dynamical field extent	$[F_{range}, \triangle SPL]$,
regression line slope	$[\alpha_{VRP}]$
VRP circumscribed ellipse slope	$[\alpha_{EL}]$

MDVP:

confirmation of existence	
of linked subgroups	$[Jitter, Shimmer]$,
of frequency fluctuation	$[Jitta, Jitt, RAP, PPQ, sPPQ, vFO]$,
of amplitude fluctuation	$[ShdB, Shim, APQ, sAPQ, vAm]$,
inner group of frequency and period parameters	$[Fo, To, F_{HI}, F_{LO}]$,
subgroup of frequency and period parameters	$[STD, PFR]$.

3. Comparison of Values of Parameters Before and After Surgery

We can statistically formulate the problem of comparison of pre-surgical and post-surgical values as tests of hypotheses about parameters for those two groups of measuring. A basic problem could be tests of the agreement in the location (tests of hypotheses about mean values agreement) and tests of the agreement in the variability (tests of hypotheses about the variance). For tests of the agreement were used following statistics:

a) The test about the agreement in the location (mean value of the parameter)

$$u_{statistics} = \frac{\mu_{BEFORE} - \mu_{AFTER}}{\sqrt{\frac{\sigma^2_{BEFORE}}{n} - \frac{\sigma^2_{AFTER}}{n}}}$$

where:

μ_{BEFORE}	is the average from values of parameters before the surgery,
μ_{AFTER}	is the average from values of parameters after the surgery,
σ_{BEFORE}	is the sample variance from values of parameters before the surgery,
σ_{AFTER}	is the sample variance from values of parameters after the surgery.

b) The test about the agreement in the variability (variance)

$$F_{statistics} = \frac{\sigma^2_{BEFORE}}{\sigma^2_{AFTER}}$$

First, tests of the agreement in the location of the examination before and after the surgery were realized, regardless of other identification parameters. Results are in Tables 1, 2 and 3.

Test results	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Fmin	Fmax	Fmg	Fmn	SPLmin	SPLmax	SPLdif	SPLmn	Avrp	Akox	Amax	Pvrp	Pkox	Pmax	ALvrp	Fel-mg	Fel-T	SPLel-d	SPLel-T	|AB|el	|CD|el	ALel
Mean value - **BEFORE**								■											■			
Mean value - **AFTER**																						
Variability - **BEFORE**					■																	
Variability - **AFTER**												■										

TABLE 1. The list of measured parameters where hypothesis mentioned above were confirmed for the acceptance level $\alpha = 0.05$ against the alternative hypothesis of the agreement before and after the surgery for the group of parameters of VRP, see [1].

Test results	32	33	34	35	36	37
	Fo	To	Fhi	Flo	STD	PFR
Mean value - **BEFORE**					■	■
Mean value - **AFTER**						
Variability - **BEFORE**					■	■
Variability - **AFTER**						

TABLE 2. The list of measured parameters where hypothesis mentioned above were confirmed for the acceptance level $\alpha = 0.05$ against the alternative hypothesis of the agreement before and after the surgery for the inner group of parameters of MDVP, see [5].

Test results	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
	Fftr	Fatr	Tsam	Jitta	Jitt	RAP	PPQ	sPPQ	vFo	ShdB	Shim	APQ	sAPQ	vAm	NHR	VTI	SPI	FTRI	ATRI	DVB	DSH	DUV	NVB	NSH	NUV	SEG	PER
Mean value - **BEFORE**	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■		■	■						■		
Mean value - **AFTER**			■														■									■	■
Variability - **BEFORE**	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■		■		■	■	■	■	■	■		
Variability - **AFTER**																											

TABLE 3. The list of measured parameters where hypothesis mentioned above were confirmed for the acceptance level $\alpha = 0.05$ against the alternative hypothesis of the agreement before and after the surgery for the third group of parameters of MDVP, see [5].

From noted Tables 1, 2 and 3 and observed values it is obvious that two groups of parameters of examination data exceed the others. One group for which we can accept none of noted hypotheses against the alternative hypothesis of agreement in the location and in the variability. Above all, it goes about data which relate to parameters examined by methodics VRP, see [1] and "frequency" data examined by methodics MDVP, see [5], specially (F_O, T_O, F_{HI}, F_{LO}, STD, PFR).
The second group involves data of parameters by which we could verify a larger variability before the surgery, i.e. in the significant count of those parameters it is possible to accept noted hypotheses against alternative hypotheses of agreement

<table>
<tr><th rowspan="2">Test results</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><th>Fmin</th><th>Fmax</th><th>Fmg</th><th>Fmn</th><th>SPLmin</th><th>SPLmax</th><th>SPLdlt</th><th>SPLmn</th><th>Avrp</th><th>Akvx</th><th>Amax</th><th>Pvrp</th><th>Pkvx</th><th>Pmax</th><th>ALvrp</th><th>Fel-mg</th><th>Fel-T</th><th>SPLel-d</th><th>SPLel-T</th><th>|AB|el</th><th>|CD|el</th><th>ALel</th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>Mean value - „A“</td><td></td><td>■</td><td>■</td><td>■</td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mean value - „TEXT“</td><td></td><td></td><td></td><td></td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Variability - „TEXT“</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td></td><td></td><td></td><td></td><td></td></tr>
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TABLE 4. The list of measured parameters where noted hypothesis were confirmed for acceptance level $\alpha = 0.05$ against alternative hypothesis of agreement for the first group of parameters of VRP, see [5]. It goes about a comparison of those groups of data: a) scanning and analysis of vowel *a*; b) scanning and analysis by the reading text.

in the location and in the variability. It goes about parameters measured by the methodics MDVT, see [5]. For this there exists following explanation. The methodics MDVP considers mostly quotient data or data in which is the quotient or another measuring involved. This methodics is oriented on parameters with small variability by common population. They could have self normal, or type values. The surgery mainly returns a patient to the normal health state. Those parameters have small sensitivity of changes and do not have a signalling ability. By those parameters dominate the qualitative character over the quantitative character and their using leads to the threshold evaluation; therefore it is not possible to reliably measure by them.

On the contrary, the first group of data are parameters of VRP, where individual variability is greater. The reasons for that are on the one hand individual population differences (sex, age, history of the voice load, mental condition – stress, etc.) and on the other hand voice field is measured by two ways. First is a scanning and analysis of the vowel *a* and the second one is a field scanning and analysis of the reading text. For those two groups were realised analogous tests of hypotheses as tests for groups before and after surgery. Results are in Table 4.

From results are in Table 4 it is obvious, that both types of the examination (i.e. by the vowel “a” and by the reading text) could not be taken as the same. Except results presented above were realized similar comparison tests for the set of records according to particulars diagnoses. There were confirmed differences, but with regard to the small dimension of particular groups it is not possible to consider them as fully valid.

4. Problem of Double Randomness

In the given environment and marked data we are working with a double randomness. First randomness is in the patient, rather in his type value, e.g. F_O – basic vocal cords frequency. Second randomness is the fact that the patient is examined in various physiological and environmental conditions. Implicitly we work with a pair of random variables: the random variable of the type parameter of the given individual, which is a random sample from population:

- the random variable of the type parameter of the given individual, which is a random sample from population: $a \in A$ where $f(a)$ is a density of the distribution of the parameter α of individuals in the given population;
- the random value of the examination parameter of the given variables $a \in A$ where $f_x(x/a)$ is a density of the distribution of the examination data x of the individual described by the parameter α.

Hence, for the density of both random variables holds:

$$f(x,a) = f_x(x/a)f(a),\ x \in X,\ a \in A.$$

For the density of the distribution of the examination data x, regardless of which individual it is, holds:

$$f_x(x) = \int_A f(x,a)\,da = \int_A f_x(x/a)f(a)\,da;\ x \in X.$$

The respond mean value of the random variable of the examined individual is:

$$E\{x\} = \int_X x \int_A f(x,a)\,da\,dx = \int_X \int_A x f_x(x/a)f(a)\,da\,dx.$$

The change of the order of integration gives (Fubini's theorem, A and X are in most real cases intervals $[+\infty, -\infty]$):

$$E\{x\} = \int_A f(a) \left(\int_X x f_x(x/a)\,dx \right) da.$$

If holds: $a = \int\limits_X x f_x(x/a)\,dx$, i.e. definition parameter of individual α is the mean value of observed datum value (x), then it is possible to write:

$$E\{x\} = \int_A f(a) \left(\int_X x f_x(x/a) dx \right) da = \int_A a f(a) da = E\{a\}.$$

Therefore an average of observed data in such parametrically heterogeneous population and in accordance to our assumptions converges to the mean value of the population. We could obtain comparable results for the variance and their estimation and for the decomposition of set into parts. Thus the problem is at least to eliminate an individuality influence of each measurement. The task is to transform each individual´s examination (pair before and after the surgery of the given individual) on one hand with preservation of patient's individuality and on the other hand with assumption that each observation (from different individual) has the same distribution. Those two requirements are in a contradiction; hence next presented solution will be a compromise of those.

4.1. **Invariance against Parameter of the Location.** The problem concerns about a shift of the parameter value x caused by influence of the parameter value of the individual α. Let us have two independent and identically distributed random variables ($x_1 = before$ and $x_2 = after$ the surgery) $x_1, x_2 \in X$. Then, independently of the shape and the type of the distribution, a random variable $\xi = x_1 - x_2$ has zero mean value. If there appears the same shift of both variables x_1, x_2, it will have no effect to the random variable ξ and will holds:

$$\xi = x_1 + k - (x_2 + k) = x_1 - x_2;\ k \in R_1.$$

Independent variables could represent observations of the given patient before and after the surgery. Thereby the difference won't depend on individual parameters of values. A general solution of the invariance problem against the location is to find out all solutions of the functional equation:

$$g(x_1 + k, x_2 + k) = g(x_1, x_2);\ x_1, x_2, k \in R_1.$$

4.2. **Invariance against Parameter of the Scale.** A solution of this problem is also trivial. Let us have two independent and identically distributed random variables x_1, x_2, and random value:

$$\xi = \frac{x_1}{x_2} \text{ a } \eta = \frac{x_1 - x_2}{x_1} = 1 - \frac{x_2}{x_1}.$$

Thereof it is obvious that the random variable $\xi = \frac{x_1}{x_2}$ does not depend on the same parameters of the scale of both components, because holds:$\xi = \frac{kx_1}{kx_2} = \frac{x_1}{x_2};\ k \neq 0$. A general solution of the invariance problem against the scale is to find out all solutions of the functional equation:

$$g(kx_1, kx_2) = g(x_1, x_2);\ k \in R_+.$$

4.3. **Invariance against Parameter of the Location and Parameter of the Scale.** This task is more complicated and do not have such simple solutions as in previous cases. Previous paragraphs offer this transformation:

$$\eta_1 = \frac{x_1 - x_2}{\sigma_\xi}$$

where invariance against the change of the scale holds only for $k > 0$; σ_ξ is common and equal standard deviation of both random variables. This is impossible to use, because we cannot determine to the given parameter its individual σ_ξ for each patient, because it is not practically realizable, neither estimable. It is possible to use some functions of following type:

$$\eta_2 = \frac{x_1 - x_2}{|x_1 - x_2|} = sign(x_1 - x_2)\ \in [-1, +1]$$

Again, the invariance against the change of the scale holds only for $k > 0$. Therefore, it is not possible to rotate with the scale. In fact, this transformation is a confrontation of both random variables in which is lost an effect of the measurement. A general view of this problem leads in finding all solutions of the functional equation:

$$g(kx_1 + r, kx_2 + r) = g(x_1, x_2);\ x_1, x_2, r \in R_1;\ k \in R_+.$$

This task is complicated, therefore we use the value before the surgery (x_1) and the value after the surgery (x_2) in following transformation:

$$\xi = x_1 - x_2; \quad \eta_1 = \frac{x_1}{x_2}; \quad \eta_2 = \frac{x_1 - x_2}{x_1} = 1 - \frac{x_2}{x_1}; \quad \text{or} \quad \eta_2 = \frac{x_1 - x_2}{x_1} * 100\%$$

$$\eta_3 = sign(x_1 - x_2) \ \Leftrightarrow x_1 \neq x_2; \quad \eta_3 = 0 \ \Leftrightarrow x_1 = x_2.$$

Mentioned solutions on the data level are fully invariance.

5. Scale Deduction

A problem of the scale deduction is to find a function and parameters before and after the surgery, that it will be possible to quantitatively measure a quality of the executed surgery. It is essential how the patient feel positive changes in the quality of the voice. Next essential thing is the change of the patient's communication ability with his environment. With regard to those presumptions it is possible to formulate just some necessary conditions, so that we can use it for the purpose of the measuring. Next some statistical and probability requirements will be formulated:

- values of the scale uniform distribution on the fixed interval (from 0 to 100% or from -100% to $+100\%$);
- transformation for measured data the scale should be purely monotone. If it is possible it should be linear as well, so that statements about scale data could be easily transformed onto statements about source data.

If the distribution function of the measured data is known and is purely monotone, it is possible to write:
Let ξ is a random variable, with the range based by some interval, with increasing distribution function $F(x)$ and with density of probability $f(x)$; If the transformed random variable $\eta = F(\xi)$ exists ($F(*)$ is distribution function of $F(x)$), then the random variable η has uniform distribution on the interval $[0, 1]$;

$$F_\eta(x) = P\{\eta < x\} = P\{F(\xi) < x\} = P\{\xi < F^{-1}(x)\} = F\left(F^{-1}(x)\right) = x_{\langle 0,1\rangle}$$

That was a view on the assumption that distribution function is available. For real problems it is not acceptable presumption, because:

- distribution function of measured data is unknown,
- we work with the sample of the distribution function,
- quality of sample distribution function decreases as number of observations decrease,
- quality of sample distribution function decreases as inhomogeneity of the statistical set decrease.

Therefore we have to involve another requirement of the stability of the scale transformation. A term of stability we had formulated exactly in our work [3]. Hence results, that choice of the "scale data" should lead onto the measured parameter, which distribution is close to the uniform distribution. This could be realized by the test of equality with target distribution. In such procedure it comes up the problem of finding out an interval in which values are. Next problem is a choice of the appropriate quantization (small count of observation in acceptable quanta). Therefore it was chosen this procedure:

- construction of the transformation function to the modified sample distribution function,
- test of the distance of this function from its linear approximation,
- using a determination coefficient R^2,
- for $R^2 \to 1$ is the statement about uniformity of original observation more reliable.

The results of testing of scale data are presented in following figures and tables.

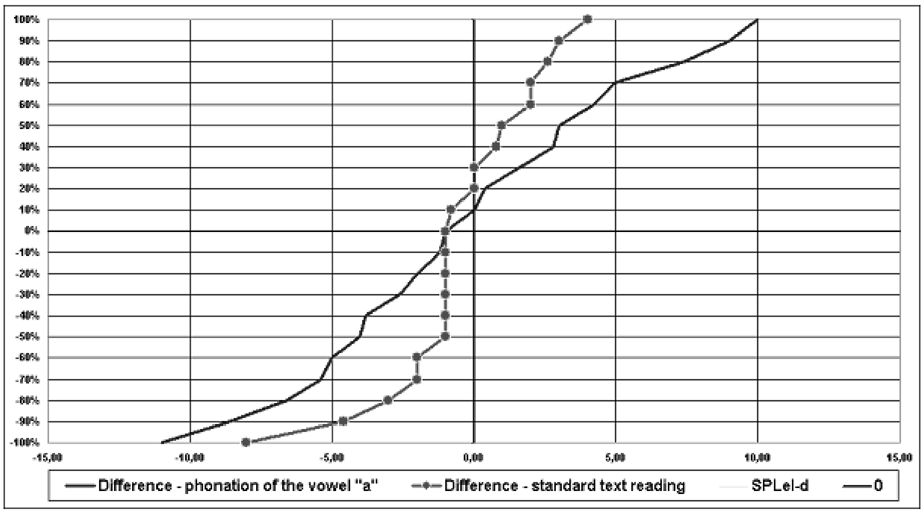

FIGURE 4. A transformation function ξ of the parameter $SPL_{el} - d$; phonation of the vowel a = appropriate scale datum $R^2 = 0,975$; standard text reading = inappropriate scale datum $R^2 = 0,851$; where holds: $\xi = x_1 - x_2$; x_1 = value before the surgery, x_2= value after the surgery.

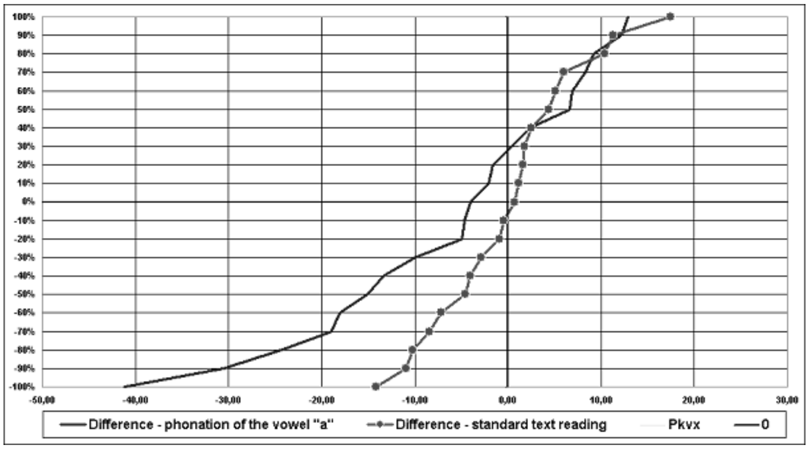

FIGURE 5. A transformation function ξ of the parameter P_{KVX}; phonation of the vowel a = appropriate scale datum $R^2 = 0,933$; standard text reading = inappropriate scale datum $R^2 = 0,948$; where holds: $\xi = x_1 - x_2$; x_1 = value before the surgery, x_2= value after the surgery.

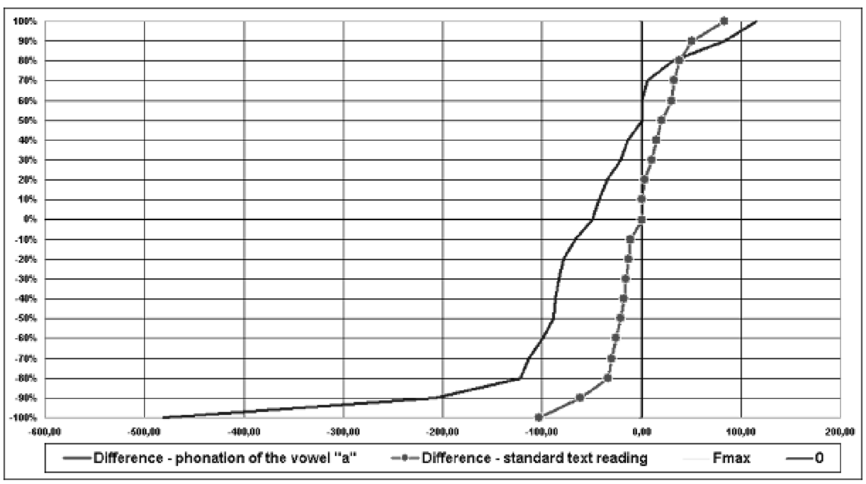

FIGURE 6. A transformation function ξ of the parameter F_{MAX}; phonation of the vowel a = appropriate scale datum $R^2 = 0,686$; standard text reading = inappropriate scale datum $R^2 = 0,893$; where holds: $\xi = x_1 - x_2$; x_1 = value before the surgery, x_2= value after the surgery.

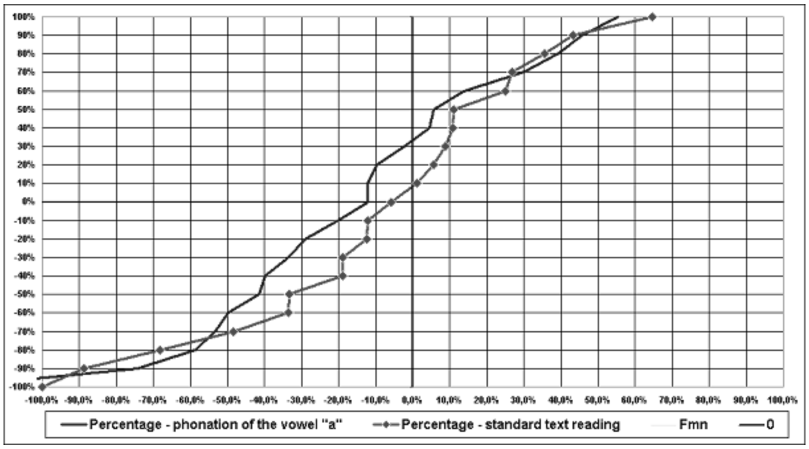

FIGURE 7. A transformation function ξ of the parameter F_{MN}; phonation of the vowel a = appropriate scale datum $R^2 = 0,935$; standard text reading = inappropriate scale datum $R^2 = 0,930$; where holds: $\xi_2 = \frac{x_1 - x_2}{x_1} * 100\%$; x_1 = value before the surgery, x_2= value after the surgery.

Threshold of select	0,930	Determination coefficient - R^2				
	Difference ξ	Difference ξ	Share η_1	Share η_1	Percentage η_2	Percentage η_2
	vowel "a"	standard text	vowel "a"	standard text	vowel "a"	standard text
Fmin					**0,965**	
Fmax						
Frng			**0,937**			
Fmn		**0,969**			**0,935**	**0,930**
SPLmin	**0,974**	**0,967**				
SPLmax						
SPLdlt	**0,987**		**0,972**			
SPLmn	**0,959**					
Avrp	**0,938**	**0,969**				
Akvx		**0,968**				
Amax						
Pvrp						
Pkvx	**0,933**	**0,948**	**0,962**			
Pmax			**0,970**			
ALvrp	**0,965**					
Fel-rng			**0,940**			
Fel-T					**0,936**	**0,942**
SPLel-d	**0,975**	0,851				
SPLel-T	**0,965**					
|AB|el						
|CD|el	**0,939**		**0,938**			
ALel						

TABLE 5. A review of all potential scales, which were judged on the basis of distribution uniformity with regard to the coefficient of the determination $R2 \geq 0,930$; (maximal value $R^2 = 0,987$ for parameter SPLdlt).

6. Conclusions

Presented task is typical statistics with ambitiously formulated target, large volume of detail statistical work and cloudy conclusions. Some new general problems have occurred in this task and it is needed to solve them. There were applied

code	shortcut	significance
		VRP - Voice Range Profile
10	Fmin	VRP - Lowest Fundamental Frequency of the VRP [Hz]
11	Fmax	VRP - Highest Fundamental Frequency of the VRP [Hz]
12	Frng	VRP - Frequency Range of the VRP (Fmax-Fmin) [oct]
13	Fmn	VRP - Average Fundamental Frequency of the VRP [Hz]
14	SPLmin	VRP - Lowest Sound Pressure Level of the VRP [dB]
15	SPLmax	VRP - Highest Sound Pressure Level of the VRP [dB]
16	SPLdlt	VRP - Dynamic Range of the VRP (SPLmax-SPLmin) [dB]
17	SPLmn	VRP - Average Sound Pressure Level of the VRP [dB]
18	Avrp	VRP - Area of the VRP [pixels]
19	Akvx	VRP - Area of the VRP Convex Hull [pixels]
20	Amax	VRP - Area of the VRP Circumscribed Rectangle [pixels]
21	Pvrp	VRP - Perimeter of the VRP [pixels]
22	Pkvx	VRP - Perimeter of the VRP Convex Hull [pixels]
23	Pmax	VRP - Perimeter of the VRP Circumscribed Rectangle [pixels]
24	ALvrp	VRP - Slope of the VRP Regression Line [dB/oct]
25	Fel-rng	VRP ellipse - Frequency Range of the VRP Ellipse [Hz]
26	Fel-T	VRP ellipse - Frequency Centroid of the VRP Ellipse [Hz]
27	SPLel-d	VRP ellipse - Dynamic Range of the VRP Ellipse [dB]
28	SPLel-T	VRP ellipse - Sound Pressure Level Centroid of the VRP Ellipse [dB]
29	|AB|el	VRP ellipse - Main Axis Length of the VRP Ellipse
30	|CD|el	VRP ellipse - Secondary Axis Length of the VRP Ellipse
31	ALel	VRP ellipse - Slope of the VRP Ellipse Main Axis
		MDVP - Multi Dimensional Voice Program
32	Fo	MDVP - Average Fundamental Frequency [Hz]
33	To	MDVP - Average Pitch Period [ms]
34	Fhi	MDVP - Highest Fundamental Frequency [Hz]
35	Flo	MDVP - Lowest Fundamental Frequency [Hz]
36	STD	MDVP - Standard Deviation of Fo [Hz]
37	PFR	MDVP - Phonatory Fo-Range [semi-tones]
38	Fftr	MDVP - Fo-Tremor Frequency [Hz]
39	Fatr	MDVP - Amplitude Tremor Frequency [Hz]
40	Tsam	MDVP - Length of Analyzed Sample [s]
41	Jitta	MDVP - Absolute Jitter [ms]
42	Jitt	MDVP - Jitter Percent [%]
43	RAP	MDVP - Relative Average Perturbation [%]
44	PPQ	MDVP - Pitch Perturbation Quotient [%]
45	sPPQ	MDVP - Smoothed Pitch Perturbation Quotient [%]
46	vFo	MDVP - Fundamental Frequency Variation [%]
47	ShdB	MDVP - Shimmer in dB [dB]
48	Shim	MDVP - Shimmer Percent [%]
49	APQ	MDVP - Amplitude Perturbation Quotient [%]
50	sAPQ	MDVP - Smoothed Amplitude Perturbation Quotient [%]
51	vAm	MDVP - Peak-to-Peak Amplitude Variation [%]
52	NHR	MDVP - Noise to Harmonic Ratio [%]
53	VTI	MDVP - Voice Turbulence Index [ ]
54	SPI	MDVP - Soft Phonation Index [ ]
55	FTRI	MDVP - Fo-Tremor Intensity Index [%]
56	ATRI	MDVP - Amplitude Tremor Intensity Index [%]
57	DVB	MDVP - Degree of Voice Breaks [%]
58	DSH	MDVP - Degree of Sub-harmonics [%]
59	DUV	MDVP - Degree of Voiceless [%]
60	NVB	MDVP - Number of Voice Breaks [ ]
61	NSH	MDVP - Number of Sub-harmonic Segments [ ]
62	NUV	MDVP - Number of Unvoiced Segments [ ]
63	SEG	MDVP - Number of Segments Computed [ ]
64	PER	MDVP - Total Number Detected Pitch Periods [ ]

TABLE 6. List of measured and evaluated parameters according to methodics VRP, see [1] and methodics MDVP, see [5].

methods of the correlation analysis for data which were gotten on the basis of different methodics VRP and MDVP. With exact statistical approach there were validated presumptions about properties of both methods and measured parameters, which resulted or were known from the physiological-technical approach of the examination. Next, there were proposed and tested subjects for solving a task about the choice of appropriate parameter, which has a gauge-scale character. In the next phase it is task for the application area to verify and formulate untestable hypotheses about causal relationships of investigated parameters values and the voice quality before and after the surgery. Naturally it appears a relation to the executed surgery, but also the observation of the patient's adaptation and the influence of the post-surgery rehabilitation, i.e. observation of long-term development. In this case it appears an usual problem of the medical statistics – when subjectively satisfied patients do not return for the next examination. In the contrary, patients with continuing problems are further treated; it means that following examination are under other conditions.

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