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Computer Software Applicable in Rehabilitation, Cardiology and Molecular Biology

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***Abstract*—** We have developed a computer program consisting of 6 subtests assessing the children hand dexterity applicable in the rehabilitation medicine. We have carried out a normative study on a representative sample of 285 children aged from 7 to 15 (mean age 11.3) and we have proposed clinical standards for three age groups (7-9, 9-11, 12-15 years). We have shown statistical significance of differences among the corresponding mean values of the task time completion. We have also found a strong correlation between the task time completion and the age of the subjects, as well as we have performed the test-retest reliability checks in the sample of 84 children, giving the high values of the Pearson coefficients for the dominant and non-dominant hand in the range $0.74 \leq r \leq 0.97$ and $0.62 \leq r \leq 0.93$, respectively.

A new MATLAB-based programming tool aiming at analysis of cardiologic RR intervals and blood pressure descriptors, is worked out, too. For each set of data, ten different parameters are extracted: 2 in time domain, 4 in frequency domain and 4 in Poincaré plot analysis. In addition twelve different parameters of baroreflex sensitivity are calculated. All these data sets can be visualized in time domain together with their power spectra and Poincaré plots. If available, the respiratory oscillation curves can be also plotted for comparison. Another application processes biological data obtained from BLAST analysis.

***Keywords*—** Biomedical data base processing, Computer software, Hand dexterity, Heart rate and blood pressure variability.

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I. Introduction

MANUAL performance of man is closely related to the multidirectional control of the central nervous system e.g. by a much greater volume of cortex engaged in controlling the actions of the upper than the lower limb. The hand is a receptor of much information from the environment and in everyday life like all kinds of grips are of vital importance for ordinary activities in daily life. The loss of hand or its dysfunction is a great handicap. The rehabilitation of patient with upper limb dysfunctions should be directed to maximum possible restoration of manual functioning. The assessment of progress in rehabilitation should be performed in a possibly objective way.

The aim of the first part of the study reported in this paper was: to work out computer aided tests checking the hand dexterity in children aged from 7 to 15; to establish clinical standards for three age groups of healthy children and that of students, taking into account performance of dominant and non-dominant hands; to check the test-retest reliability by performing two series of measurement of the time of the test completion in large group of school age children.

Heart rate variability (HRV) provides information about autonomic neural regulation and condition of the heart and cardiovascular system. Some methods measuring HRV have been standardized and are successfully used in clinical application [1].

However, new methods are still developing and their outcomes and usefulness are examined. One of them is the Poincaré plot analysis (PPA) of the RR interval (RRI) [2][3]. This non-linear method is believed to show both short and long term HRV.

Although modern medical equipment enables blood pressure measurement, the role of blood pressure variability (BPV) is less known and its interpretation not well established so that that subject deserves some more attention.

Fast changes in blood pressure can influence the length between successive heart beats, leading to so called baroreflex sensitivity (BRS) which is now a prognostic factor in cardiology. There is a number of methods to estimate BRS [4][5], using the BPV and HRV measures in the time as well as in the frequency domain.

In order to support a comprehensive investigation of HRV, BPV and BRS as well as biomolecular data base processing,

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special programs were designed and implemented in the MATLAB and C++ environment, respectively.

II. Materials And Methods (hand dexterity)

Six task (described in detail in [6]) have been developed to check manipulation dexterity of the hand, called: blocks (in Polish – klocki), labyrinth (labirynt), circle (koło), board (plansza) and centres (środki). The program is written in MS Visual Basic 5.0 and operates on PC platform with Windows 95 (or higher) operating system. The user interface is worked out in Polish. The idea of the tests is based on the fact that the mouse control requires movements of all joints of the upper limb and on the top of that, the isolated movement of index finger, which is important for finger tip pinch. In the simplest version, used in the study, the mouse moves in the horizontal plane, which does not require rotation on the elbow. However, the restriction can be easily removed by using a table of variable inclination with respect to the horizontal plane.

The program-task blocks (Fig.1) gives on the screen one window and three text fields which give the score, time left to complete the test and test duration. The person tested is asked to arrange colour blocks given in the bottom rectangle in the way shown in the left square. The blocks are arranged by driving the mouse cursor on the block, clicking the mouse and moving the block to a desired place. The block is released with another click of the right or left button, depending on the hand tested. The score depends on the number of correctly positioned blocks. The time of the tasks completion is limited to 120 seconds. To perform the task labyrinth, whose window is shown in Fig. 2, the person tested is asked to draw a broken line connecting the human figure with the tree. The task should be completed as quickly as possible and can be performed along a given path. The correctly covered path is shaded, whereas any deviation from the path is signalled by a sound and recorded as a mistake. The user can continue moving the cursor only having come ask to the point at which the mistake was made. The person taking the test ball is asked to take the ball out of the container, which is performed by driving the mouse cursor onto the left icon. Then the ball should be placed in a similar container on the right side of the screen. The idea is to move the ball as quickly as possible along the shortest possible path. The window shows the scores – the length of the path relative to the shortest possible path as well as the time of moving the ball. The idea of the task called the circle, is to move the cursor within the ring displayed on the screen to complete a circle. The movement is marked by the shaded area within the ring. The task should be completed as quickly as possible and any deviation from the proper course is recorded as a mistake. The person taking the test board is asked to hatch the rectangular fields on the board by choosing the field and clicking the mouse. The test is completed after all the fields have been marked or after an allowed time of 120 seconds. The windows display the score, time left to complete the test and time elapsed from the start of the test. The idea of the task centres is to mark the centres of circles displayed on the screen with the greatest possible accuracy. The sequence of marking the centres is important, so the computer shades the already visited next. Except time the program measures also the distance from the geometrical centre to the point marked.

The studies were carried out in two steps. At first the tests were performed at two elementary schools in Poznan in the control group of 285 children and the subjects were randomly selected children aged from 7 to 15. In general each child performed only 3 tasks with two hands to eliminate the effects of getting tired and distracted attention. Next we studied a group of 84 elementary school pupils at another primary school in Poznan. Each level of teaching was represented by 12 randomly chosen volunteers. The children were from 7 to 15 years of age, the average age was 10,5±2,4. The children were of different age, sex, either familiar with a computer or not able to use it. Prior to performing the test, the children were instructed about the aim and the methods of approaching the tasks, they could also check the particular applications. The tests were chosen at random to avoid the effect of selection and were performed while sitting down. Each test was performed using the left and the right hands and repeated three times with each hand. Statistical analysis was carried out for the mean results from three attempts. Each child was asked about earlier computer experience- if constant and intense the child was qualified to a group of computer-familiar children, otherwise to a group of computer unfamiliar ones. In the test–retest reliability study, after one week the same children performed the same tests in the same conditions once again. We have also performed similar measurement in a group of students studying physics and computer science.

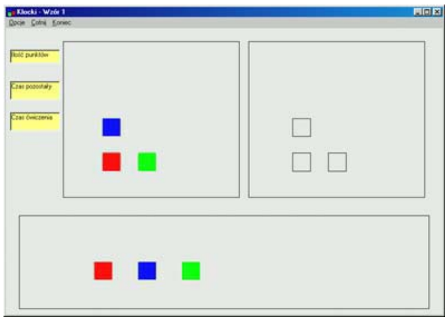

Fig. 1 The window of the subtest blocks

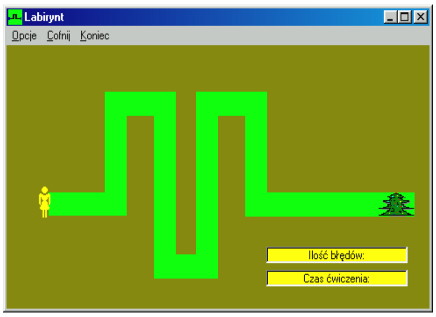

Fig. 2 The window of the subtest labyrinth

III. FUNCTIONALITY OF THE MATLAB AND DATA BASE PROCESSING TOOLS

The raw data were collected in the Cardiology Unit following the established standards. The 3-channel chest ECG as well as finger blood pressure (Portapres 2, FMS, The Netherlands) were recorded by an A/D converter (Porti 5, TMSI, The Netherlands). Sampling frequency was equal to 1600 Hz. Each recorded measurement lasted about 5 minutes.

The recorded signals were pre-processed using the special software – RASCHlab from the libRASCH project [7]. From ECG signal, positions of the R peaks in the QRS complexes were found and the length between proceeding R waves (referred to as the RR interval) were obtained. From the blood pressure signal, the values of systolic (SBP) and diastolic pressure (DBP) were determined for every beat. In addition, the following two parameters were obtained: the difference between systolic pressure and previous diastolic pressure (denoted by PP1), and the difference between systolic pressure and following diastolic pressure (PP2).

Our software is designed to process the RR, SBP, DBP, PP1 and PP2 data. For each data set the mean value and the standard deviation (SD) are determined.

For these data sets the frequency analysis can be performed. Here we have applied the Welch method. It is based on Fast Fourier Transform algorithm, reducing the amount of noise present in signal by averaging proceeding spectra. Within the Welch method the data sets were split into five parts with 50% overlapping.

In the frequency domain four parameters can be determined: total power of spectrum (TP), power in high frequency (HF) band (0.15 – 0.4 Hz), power in low frequency (LF) band (0.05 – 0.15 Hz) and also ratio LF/HF.

In the Poincaré plot analysis not only two standard descriptors SD1 and SD2 but also two other parameters: S representing the area of the ellipse, and the ratio of SD2/SD1[8] can be found for each data set.

The program includes three baroreflex sensitivity descriptors: the parameter xBRS estimated using cross-correlation method [5] and two other BRSα and BRSβ defined as

$$BRS_\alpha = \sqrt{\frac{LF_{RRI}}{LF_{BP}}} \qquad (1)$$

$$BRS_\beta = \sqrt{\frac{HF_{RRI}}{HF_{BP}}} \qquad (2)$$

where LF_{RRI} and HF_{RRI} are low and high frequency power spectra measured from RRI signal, and LF_{BP} and HF_{BP} are the corresponding frequency spectra measured from different kind of blood pressure (SBP, DBP, PP1 and PP2). All together, twelve different descriptors of BRS can be calculated.

The program both calculates the parameters and enables the graphical representation of the data sets and their analysis such as the Poincaré plots with properly fitted ellipses or power spectra. At the bottom in Figure 3 these outcomes are supplemented by the respiratory oscillation curve and its spectrum in frequency domain.

The data base processing tool Blast++ is an application designed to organize data obtained from GenBank at the National Center for Biotechnology Information (NCBI) with the use of the BLAST tool. The Basic Local Alignment Search Tool (BLAST) finds regions of local similarity between sequences. The program compares nucleotide or protein sequences to sequence databases and calculates the statistical significance of matches. It can be used to find functional and evolutionary relationships between sequences as well as help identify members of gene families [9][10]. Such analysis provides a wealth of data, implying the problem of management of huge datasets. The Blast++ application, written in the C++ programming environment, helps molecular biologists non-expert in informatics to organize the information obtained by the use of BLAST with respect to the species from which the sequences were derived and their particular genes, simplifying browsing through them.

III. RESULTS AND DISCUSSION

The collected experimental data assessing the manual dexterity have been subjected to statistical processing using the program Instat. It has been established that aspect of normality of distribution and uniform variance, the optimum procedure for our data was to transform them to a logarithmic scale. Therefore, the times talked about in the following part of the paper should be understood as natural logarithms of the real time measured in seconds.

The first problem considered was the difference in dexterity between the dominant and non-dominant hand. The results proved a considerable statistical significance of the dexterity of the dominant and non-dominant hands, usually on the level of $p<0,0001$.

Another problem considered was the difference between computer – familiar children and others from the population of healthy children. The results of t-Student tests for the dominant hand revealed statistically significant differences with some exceptions in the group of youngest children [6].

In the next step we checked the differences in the hand dexterity between different age groups to establish clinical standards (see Table I). The variance analysis of the results or the dominant as well as non-dominant hands proved the statistically significant differences between the averages results in all age groups. Therefore, the data given in the second, third and fourth column of the table should be treated as standards values for healthy children, and the systematic decrease in the time of the task completion with age should be considered a statistically important feature describing increasing dexterity of hand with age.

TABLE I
THE CALCULATED NORMS OF THE TASK COMPLETION IN FOUR AGE GROUPS AND THE VALUES OF THE CORRELATION COEFICIENT OF THE TEST-RETEST STUDY FOR THE DOMINANT HAND

Task	7-8	9-11	12-15	Students	r
Blocks	3.01±0.48	2.59±0.45	2.21±0.41	1.77±0.29	0.84 (0.76 - 0.89)
Labyrinth	3.06±0.39	2.71±0.43	2.38±0.32	1.98±0.23	0.87 (0.80 - 0.92)
Ball	0.82±0.32	0.55±0.32	0.38±0.39	0.31±0.34	0.80 (0.66 - 0.89)
Circle	2.54±0.43	2.33±0.39	1.93±0.37	1.50±0.33	0.76 (0.58 - 0.87)
Board	4.06±0.45	3.71±0.44	3.29±0.38	2.79±0.21	0.94 (0.89 - 0.96)
Centres	3.37±0.40	3.05±0.44	2.71±0.42	2.78±0.23	0.76 (0.60 – 0.86)

The most important element of the second part of our work was an analysis of regression and correlation of the results obtained in the two series of measurements. The degree of agreement between results of measurements made at different times and in the same condition can be calculated by correlation and the Pearson coefficient is *a measure of reliability* of the assessment tool.

The last column of Table I presents results of detailed analyses of correlation and regression for all tasks obtained for the dominant hand. The subsequent rows give the Pearson (r_p) coefficients of linear correlation together with their 95% confidence intervals (in parentheses). The values of the Pearson coefficients given in Table I are similar to those determined for the dynamometric and the functional tests widely used in clinical settings. For example, it was found in [11] that 0.83<r<0.88, depending on the kind of grip; in [12] - 0.60<r<0.99, depending on the hand and the test chosen; in [13] - 0.68<r<0.88; in [14] - 0.89<r<0.99 and in [15] - r=0.93. We also note that our recent test-retest reliability study, using the JAMAR hand dynamometer, performed in the group of 61 children, yields r=0.98 and r=0.97 for the dominant and the non-dominant hand, respectively.

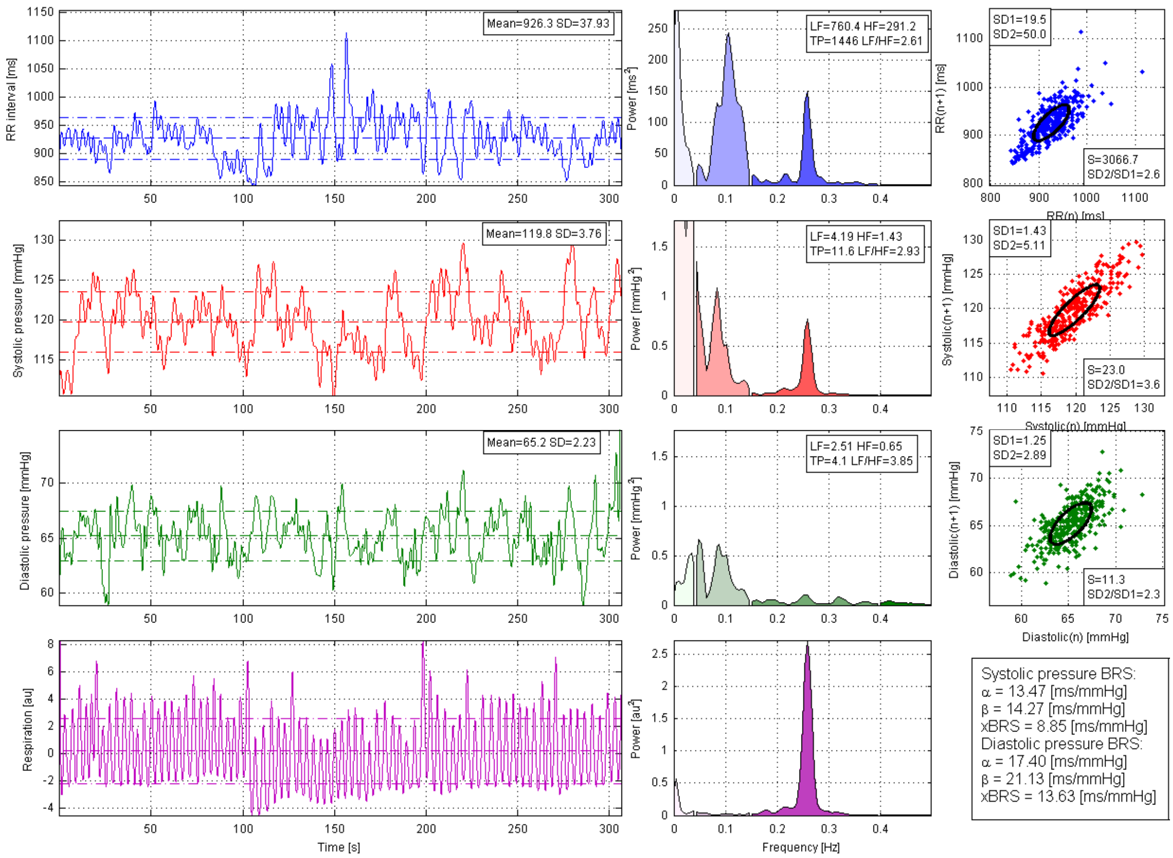

Fig 3 Exemplary draw of measured signals, power spectrums and Poincaré plots

TABLE II
MEAN VALUE AND STANDARD DEVIATION OF ALL THE PARAMETERS

Parameter	Mean value	Standard deviation
RR_Mean [ms]	852.23	140.58
RR_StdDev [ms]	58.83	30.82
RR_TP [ms2]	4068.04	5459.71
RR_LF [ms2]	1242.88	1655.19
RR_HF [ms2]	1404.48	3474.51
RR_LF/HF [j.u.]	1.49	0.95
RR_SD1 [ms]	35.36	29.45
RR_SD2 [ms]	74.41	34.19
RR_S [ms2]	10959.75	19920.71
RR_SD2/SD1 [j.u.]	2.47	0.80
Sys_Mean [mmHg]	119.44	19.93
Sys_StdDev [mmHg]	6.77	3.31
Sys_TP [mmHg2]	51.90	55.47
Sys_LF [mmHg2]	10.06	8.19
Sys_HF [mmHg2]	2.45	1.69
Sys_LF/HF [j.u.]	5.36	4.46
Sys_SD1 [mmHg]	1.78	0.49
Sys_SD2 [mmHg]	9.38	4.71
Sys_S [mmHg2]	55.00	38.84
Sys_SD2/SD1 [j.u.]	5.41	2.48
Dias_Mean [mmHg]	60.46	12.12
Dias_StdDev [mmHg]	3.88	1.29
Dias_TP [mmHg2]	15.86	14.24
Dias_LF [mmHg2]	4.62	3.02
Dias_HF [mmHg2]	1.44	1.30
Dias_LF/HF [j.u.]	4.28	2.88
Dias_SD1 [mmHg]	1.66	0.59
Dias_SD2 [mmHg]	5.20	1.80
Dias_S [mmHg2]	28.40	17.37
Dias_SD2/SD1 [j.u.]	3.32	1.18
PP1_Mean [mmHg]	58.98	12.52
PP1_StdDev [mmHg]	4.87	2.54
PP1_TP [mmHg2]	26.24	24.89
PP1_LF [mmHg2]	4.26	4.19
PP1_HF [mmHg2]	2.76	1.87
PP1_LF/HF [j.u.]	1.69	1.30
PP1_SD1 [mmHg]	2.07	0.61
PP1_SD2 [mmHg]	6.50	3.65
PP1_S [mmHg2]	44.74	37.66
PP1_SD2/SD1 [j.u.]	3.21	1.45
PP2_Mean [mmHg]	58.97	12.52
PP2_StdDev [mmHg]	5.29	2.51
PP2_TP [mmHg2]	30.20	25.79
PP2_LF [mmHg2]	6.39	5.51
PP2_HF [mmHg2]	4.10	2.87
PP2_LF/HF [j.u.]	1.79	1.31
PP2_SD1 [mmHg]	2.44	0.73
PP2_SD2 [mmHg]	7.01	3.60
PP2_S [mmHg2]	56.31	40.98
PP2_SD2/SD1 [j.u.]	2.95	1.27
Sys_BRSα [ms/mmHg]	11.37	6.18
Sys_BRSβ [ms/mmHg]	20.76	13.94
Sys_xBRS [ms/mmHg]	12.61	7.72
Dias_BRSα [ms/mmHg]	16.02	9.06
Dias_BRSβ [ms/mmHg]	27.38	14.58
Dias_xBRS [ms/mmHg]	16.65	9.10
PP1_BRSα [ms/mmHg]	18.18	9.74
PP1_BRSβ [ms/mmHg]	18.92	11.59
PP1_xBRS [ms/mmHg]	15.29	9.01
PP2_BRSα [ms/mmHg]	13.91	6.52
PP2_BRSβ [ms/mmHg]	15.08	7.60
PP2_xBRS [ms/mmHg]	12.08	5.61

These results confirm clinical usefulness of our computer tests. We note that for all the tasks $r_p>0.7$. The strongest correlation between result (lnt) from the two series was found for the test "Board". As follows from the linearity test, for the result of all task $p>0.05$, so the linear correlations are statistically significant. Statistical significance of the differences between the mean values calculated for the whole group of the children studied in two series of measurements was also established.

Here we present selected results for the HRV data gathered in the Cardiology Unit from 145 healthy young volunteers – average age 25 years. Age range was between 19 and 53 years. In the group there were 69 women and 76 men. Table II shows mean value and standard deviation of all parameters, using the statistical package.

A sample graph presenting tachograms and results of spectral analysis for RR intervals, SBP and DBP as well as respiratory curves are shown in Figure 3, which also presents Poincaré plots of RR intervals, SBP and DBP.

Presented program computes several measures of variability of cardiologic signals. The standard deviation of the RRI signal has got well known interpretation [1] and is considered as one of the most important descriptors of overall variability.

In the frequency domain the Welch method was proposed. By averaging proceeding spectra, this approach can reduce level of noise, leading to results which are more adequate and smoother then those used by the Fast Fourier Transform algorithm. On the other hand this method deteriorates the frequency resolution. However, this seems not important, since only power in a certain range of frequencies (appropriate for the HF and LF parameters) is calculated here and not for particular frequencies.

The Poincaré plot analysis is useful, as the parameters S and SD2/SD1 are believed to illustrate adequately total HRV and the balance between short and long term variability [8].

The program provides the rich set of parameters which can form the basis for further analysis of physiological and pathological interactions between the cardiac and neural systems. The clinical usefulness of the parameters should be still addressed.

IV. CONCLUSION

1. New computer tests assessing the dexterity of both hands have been developed in the Visual Basic language on the Windows platforms and proved to be test-retest reliable.
2. Normative values of natural logarithms of time (in seconds) required to complete particular tests for children age 7-15 and students have been established.
3. The computer programs have been worked out using the MATLAB and C++ programming environment, enabling user to perform computation and graphical representation of various parameters describing heart rate and blood pressure variability, and to analyze data obtained by BLAST.

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