Facial Emotional Expression Assessment in Parkinson's Disease by Automated Algorithm Based on Action Units

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Abstract—**This work is devoted to the study of expression and interpretation of six basic emotions: anger, disgust, fear, happiness, sadness, surprise in patients with Parkinson's disease in comparison with the healthy control group of patients. The study involved 16 patients in each group. Each patient's face was recorded using a 2D camera while performing 3 tasks: displaying a neutral state, displaying 6 basic emotions by researcher request, displaying 6 basic emotions depicted on the images. Action units were determined on each video frame. The percentages of emotional expressions in each video were determined, and the intensity of the recognized expressions for each task using the emotion recognition algorithm based on action units. The difference between emotional expressions and the neutral state was calculated as Euclidian distance between vectors of action units to quantify the changes in facial expression between the Parkinson's disease and healthy control groups. To analyze the differences between the groups, the non-parametric Mann–Whitney U-test was used. The obtained results show changes in the emotional expressions in the Parkinson's disease group in comparison with the healthy control group, Parkinson's disease patients show a decrease in the expressiveness of face and the intensity of the emotional expression.**

I. INTRODUCTION

Parkinson's disease (PD) is a slowly progressing chronic neurological disease characteristic of people of an older age group [1], which refers to degenerative diseases of the extrapyramidal motor system. The disease is in second place after Alzheimer's disease in prevalence. PD is characterized by the presence of resting tremor, stiffness (rigidity), slowing down of movements with a decrease in their amplitude (bradykinesia), impaired gait and / or body position. Slow motion is almost always found. The range of motion for PD patients also decreases, called hypokinesia. It is noticeably in fine motor skills of the hands [2], [3] and also in facial expression. Stiffness and hypokinesia can lead to muscle pain and feeling of tiredness. The extension of hypokinesia to the muscles of the face leads to hypomimia, the face becomes "masked" [4].

There are many works devoted to the analysis of facial expressions and emotional state in PD patients. The authors of the study [5] presented the results of assessing changes in emotional expression in 17 PD patients and 17 healthy control (HC) subjects. The patients were asked to show 4 basic emotional expressions at the request of a clinician and after simulating a visual signal on the screen. The difference between the facial model and the neutral baseline was calculated to quantify the changes in emotional expressions in the tasks. The authors reported the difference between PD expressions and standard expressions. The results of their study show that HC subjects reported more higher distance between facial emotional expression and neutral facial expression than PD patients during different tasks. HC subjects shows show more pronounced movements in facial expressions then PD patients. Noticed, that anger and disgust are most impaired in PD patients.

In [6], facial expressions were evaluated using OpenFace free access software [7]. OpenFace calculate the basic movements performed by individual muscles or muscle groups, called action units (AUs). 127 PD patients and 127 HC subjects performed various tasks, where their facial expressions were recorded on a video camera. The authors report about differences in the facial expressions between PD patients and HC subjects, noticed, the AU4 were expressed more often, but AU12 were expressed less often during different tasks in PD patient. The average value of the AU4 in the PD group was higher than in the HC group. The maximum value of the AU12 in the HC group was higher than in the PD group.

The study [8] also noted a decrease in emotional expressiveness in PD patients. In total, 18 PD patients and 16 HC subjects participated to the experiment. The facial recording was carried out using a 3D optical system and special markers applied to the face. A decrease in the motor activity of the face during the emotional expression is shown in comparing the HC group and the PD group. There was a general decrease in emotion recognition in PD patients for the next emotions: disgust, sadness, and fear. Moreover, the velocity and amplitude of all six basic emotional expressions were reduced in the PD group.

In the study [9], the authors presented a specialist's assessment of expression of 6 basic emotions by 40 PD patients and 17 HC subjects during special tasks. In this study, the authors found that there is a global decrease in the static and dynamic emotional expressions of PD patients, and a deficit in posing the following emotions: happiness, surprise.

In a study [10] 12 PD patients and 12 HC subjects were tested in posed and spontaneous facial expression. The authors show a decrease in spontaneous smiles and noticed that the facial reactivity of PD patients was reduced.

In [11], described an approach based on the automated determination of AUs by video to assess facial expressiveness. The study involved 7 PD patients and 8 HC subjects. The study revealed differences in spontaneous emotional expression between PD patients and HC subjects.

In the study [12], the authors show, that the level of spontaneous and posed facial expression is reduced in the PD group in response to unpleasant odors, but there is no difference between groups in posed emotional facial expressions. This study involved 22 PD patients and 22 HC subjects. In [13], the difficulties in the task of perceiving emotional faces were reported for PD patients. The authors of the study [14] found that reduced facial expression correlates with self-reports of PD patients, and with the Unified Parkinson's Disease Rating Scale (UPDRS) [15].

In the article [16], 97 works aimed at the study of emotional expressions were noted. The authors of the article provide an overview of the works connected with emotional expressions analysis in PD patients in comparison with HC subjects for 6 basic emotions (anger, disgust, fear, sadness, surprise, and happiness) and neutral state. The authors note conclusions about the general decrease in expressiveness presented by the authors of other works. Thus, of the 97 works examined, 64 % report a decrease in facial expressions, 44 % speaks about impairment of the expression level for anger, 47 % for disgust, 54 % for fear, 51 % for sadness, 30 % for surprise, 27 % for happiness and 42 % for neutral expression. Also, it seems to be more difficult for people with PD to recognize emotions, although this assumption is contradictory [17].

Despite the large number of works devoted to the study of facial expressions in PD patients, a unified approach determinating the differences in facial expressions between groups has not been established, moreover not all authors take into account six basic emotions. Nonetheless, the study of emotional expressions in PD is relevant, as emotional expressions play a large role in communication, and thus its impoverishment reduces the quality of patients' life. This work is devoted to the determination of the differences in emotional expression and emotional interpretation by automated methods based on AUs in PD patients in comparison with HC subjects.

III. MATERIALS AND METHODS

A. Action units' automatic detection

The emotion recognition algorithms [18], [19], [20] based on AUs gives good results and are suitable for this research. It was shown that the OpenFace free access software has good correlations of AUs intensity when checking on public databases with various facial expressions, the average correlation is 0.73 for all AUs [7]. OpenFace can determine the intensity of expression (from 0 to 5) of the AUs of mimic activity (AU 1, 2, 4, 5, 6, 7, 9, 10, 12, 14, 15, 17, 20, 23, 25, 26, 28 , 45) according to the 2D image of the face. For each AU, its presence or absence is determined (parameter AU_c, has a value

of 0 or 1) and the intensity of manifestation (parameter AU_r, has a value from 0 to 5).

B. Emotional recognition

The emotion recognition, the calculation of the intensity of the displayed emotions was carried out according to the algorithm of emotion recognition [18], based on FACS [21]. This algorithm is not based on machine learning. It allows to apply it to the different patients groups with any size of the group, since do not have to create a training and test sample. And thus, the recognition results are not depend on the training sample [18]. The algorithm is based on the calculation of the arithmetic mean value of AUs presented in the prototypes of the emotional expression of FACS. The sets of AU are presented in the prototypes of the expression of basic emotions (anger, disgust, fear, happiness, sadness, surprise) are presented in Table I.

TABLE I. THE SETS OF AUs

Emotional expressions	AUs set according to FACS
Anger	4,5,7,10,17,23,25,26
Disgust	9,10,15,17,25,26
Fear	1,2,4,5,20,25,26
Happiness	6,12
Sadness	1,4,11,15,17
Surprise	1,2,5,26

The study was carried out on static images obtained by decomposing video into frames. In processing the video sequence, the AUs values were determined on each frame and recorded in a file. Thus, the feature space for emotion recognition includes 34 features (AU_vector = [AU01_c, ..., AU17_c, AU01_r, ..., AU17_r]). For each AU, the intensity of its manifestation was calculated as the product of the parameter AU_r and AU_c.

C. Statistical significance

In this study, we did not make any assumptions about the nature of the data distribution, so we will use a nonparametric criterion to calculate statistical values. To assess the statistical significance of the differences between the HC and PD groups, the Mann-Whitney U-test (U) was chosen. Initially, the null hypothesis is accepted that there are no differences between the samples. The significance level at which the null hypothesis is rejected is set as $p < 0.05$. Data in which there are statistically significant differences between the groups are highlighted in the tables.

D. Experiment

For the face video recording, the patient located opposite the camera at a distance of 0.7-1.2 m. The camera is located on a tripod, at the patient eye level. The 2D image is recorded using a Logitech C920 camera. The recording began and ended at the command of the specialist. The patient is asked to complete 3 tasks:

1. to display the neutral state for 5 sec;

2. to display 6 basic emotions (anger, disgust, fear, happiness, sad, surprise) by posing;

3. to display 6 basic emotions depicted on the images by interpreting. There are images in Fig. 1.

The average time of video recordings is 3.62 ± 1.06 sec. for the second task, 3.8 ± 1.43 sec. for the third task.
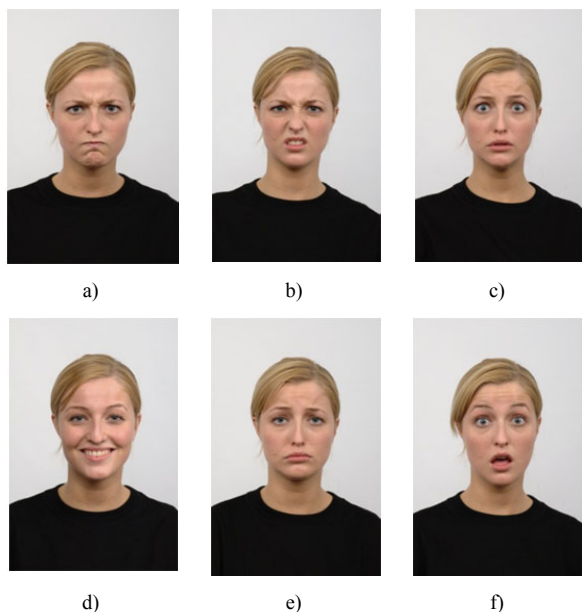

Fig. 1. The emotional expressions of the RAFD open access database [22]: a) anger, b) disgust c) fear d) happiness e) sadness f) surprise

E. Database

PD patient were recorded in the Federal State Budget Scientific Institution "Scientific Center of Neurology". HC subjects were recorded in the Research and Educational Medical-Technological Centre of Bauman Moscow State Technical University. The study used data from 32 patients: 16 patients with PD (6 women, 10 men), average age 58.3 ± 13.5, disease duration 8.2 ± 4.8, average stage value according to Hoehn & Yahr [23] 2.5 ± 0.6, and 16 patients (13 women, 3 men) HC group, average age 49.2 ± 10.1. Among the group of patients with PD, 1 patient with the first stage of the disease according to Hoehn & Yahr, 5 patients with the second stage, 9 patients with the third stage. For each patient, 13 videos were recorded: 6 for posed task, 6 for interpreted task, and 1 for a neutral state. Thus, the total database contains 416 videos.

IV. RESULTS AND DISCUSSIONS

A. Emotion recognition

Emotion recognition was carried out of each patient on 2 videos: displaying posed emotion by specialist request, displaying interpreted emotion depicted on the photo. An emotional expression was recognized on each frame of the video using the automatic algorithm based on AUs. The median value, 25 % quartile (Q25), 75 % quartile (Q75) of each recognized emotional expression during posed and interpreted task were calculated for HC and PD groups. The values are presented in Tables II-XIII. The proportion of emotional expressions on each video for each patient was calculated by dividing the number of frames with one of the six basic emotions by the total number of frames in the video. To determine the neutral expression, the intensity threshold of the expressed emotion was 1.5, i.e. if the calculated value of

the intensity is less than the threshold; the emotion is recognized as neutral. A dash in the tables means that the given emotional expression was not expressed in this specific exercise.

TABLE II. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED ANGER FOR HC AND PD GROUPS

Emotion	Anger Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	0.74 (0.0, 9.33)	0.28 (0.0, 46.12)
Disgust	-	0.0 (0.0, 11.83)
Fear	0.0 (0.0, 4.21)	-
Happiness	-	-
Sadness	0.95 (0.0, 17.9)	-
Surprise	-	-
Neutral	63.02 (28.38, 95.08)	68.7 (20.82, 98.77)

TABLE III. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED ANGER FOR HC AND PD GROUPS

Emotion	Anger Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	4.01 (0.0, 35.67)	0.6 (0.0, 30.61)
Disgust	0.0 (0.0, 14.25)	-
Fear	-	-
Happiness	-	-
Sadness	0.0 (0.0, 24.94)	-
Surprise	-	-
Neutral	39.02 (11.15, 88.35)	92.4 (37.68, 99.62)

During posed anger, the median value of anger presence in HC group is 0.74 %, in PD group is 0.28 %, i.e. in HC, the value is higher, but obtained values are insignificant. During interpreted anger, the number of anger presence in HC group is 4.0 %, in PD group 0.6 %, i.e. in HC; the value is higher, but values are too insignificant. Sometimes anger was expressed by patient as disgust or sadness, but more often anger was calculated as neutral state, because the intense of expressed anger emotion was lower than threshold. The number of expressions as calculated as neutral state in PD group is higher than in HC during the interpreted task, the difference in median value is 58.38 %.

TABLE IV. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED DISGUST FOR HC AND PD GROUPS

Emotion	Disgust Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	0.0 (0.0, 22.42)	12.58 (2.81, 46.16)
Disgust	3.12 (0.0, 42.8)	18.81 (1.46, 50.91)
Fear	0.0 (0.0, 4.61)	-
Happiness	-	-
Sadness	0.0 (0.0, 8.3)	-
Surprise	-	-
Neutral	44.26 (22.14, 61.4)	30.27 (11.06, 85.27)

TABLE V. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED DISGUST FOR HC AND PD GROUPS

Emotion	Disgust Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	0.0 (0.0, 3.1)	-
Disgust	63.78 (48.93, 90.84)	76.01 (34.77, 94.74)
Fear	0.26 (0.0, 5.33)	-
Happiness	0.0 (0.0, 0.56)	-
Sadness	-	-
Surprise	-	-
Neutral	17.09 (0.0, 34.01)	23.99 (5.26, 50.74)

During posed disgust, the median value of anger presence in HC group is 3.12 %, in PD group is 18.81 %, i.e. in PD, the value is higher by 15.69 %. During interpreted disgust, the number of disgust presence in HC group is 63.78 %, in PD group 76.01 %, i.e. in PD the value is higher by 12.23 %. In some cases disgust was expressed as anger in PD group during posed task, or as neutral state for posed and interpreted task in both groups. The number of expressions as calculated as neutral state in HC group is higher than in PD during posed task, the difference in median value is 13.99 %, but during interpreted task this value is higher in PD group, the difference in median value is 6.9 %.

TABLE VI. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED FEAR FOR HC AND PD GROUPS

Emotion	Fear Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	0.0 (0.0, 4.62)	-
Fear	0.0 (0.0, 57.23)	0.0 (0.0, 0.62)
Happiness	-	-
Sadness	0.0 (0.0, 0.85)	-
Surprise	0.0 (0.0, 0.67)	0.0 (0.0, 7.38)
Neutral	50.8 (22.79, 96.79)	75.9 (41.76, 100.0)

TABLE VII. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED FEAR FOR HC AND PD GROUPS

Emotion	Fear Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	0.0 (0.0, 3.79)	-
Fear	25.0 (6.27, 74.74)	3.78 (0.0, 28.29)
Happiness	-	-
Sadness	0.0 (0.0, 0.11)	-
Surprise	7.66 (0.0, 16.97)	4.16 (0.96, 9.3)
Neutral	19.17 (5.5, 36.93)	82.12 (57.81, 94.2)

During posed fear, the median value of fear presence in HC and PD groups is 0.0 %, i.e. more than half patient from each groups expressed fear as another emotion or their expression might be insignificantly with low intensity. Thus, fear was calculated as neutral state. The number of expressions as calculated as neutral state in PD group is higher than in HC during posed task, the difference in median value is 25.1 %. During interpreted fear, the number of fear presence in HC group is 25.0 %, in PD group is 3.78 %, i.e. in HC the value is higher by 21.22 %. In some cases fear was expressed as surprise or as neutral state, in both groups during interpreted task. The number of expressions as calculated as neutral state in PD group is higher than in HC during interpreted task, the difference in median value is 62.95 %.

TABLE VIII. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED HAPPINESS FOR HC AND PD GROUPS

Emotion	Happiness Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	1.61 (0.0, 16.66)	0.0 (0.0, 12.01)
Fear	0.18 (0.0, 2.76)	-
Happiness	33.76 (0.0, 70.74)	0.0 (0.0, 43.19)
Sadness	-	-
Surprise	-	-
Neutral	30.46 (6.56, 54.55)	64.28 (24.22, 100.0)

TABLE IX. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED HAPPINESS FOR HC AND PD GROUPS

Emotion	Happiness Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	2.18 (0.0, 21.16)	0.0 (0.0, 6.55)
Fear	0.0 (0.0, 0.2)	-
Happiness	74.26 (32.26, 91.34)	19.46 (0.0, 56.48)
Sadness	-	-
Surprise	-	-
Neutral	0.0 (0.0, 11.02)	50.3 (7.33, 82.31)

During posed happiness, the median value of happiness presence in HC group is 33.76 %, in PD group is 0.0 %, i.e. in HC, the value is higher by 33.76 %. During interpreted happiness, the number of happiness presence in HC group is 74.26 %, in PD group is 19.46 %, i.e. in HC the value is higher by 54.8 %. In some cases happiness was expressed as disgust or as neutral state for posed and interpreted task in both groups. The number of happiness expression as calculated as neutral state in PD group is higher than in HC during posed task, the difference in median value is 25.1 %, during interpreted task, the difference in median value is 50.3 %.

TABLE X. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED SADNESS FOR HC AND PD GROUPS

Emotion	Sadness Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	0.0 (0.0, 15.48)
Disgust	0.0 (0.0, 6.38)	0.0 (0.0, 2.63)
Fear	0.0 (0.0, 2.12)	-
Happiness	-	-
Sadness	0.0 (0.0, 28.73)	-
Surprise	0.0 (0.0, 1.28)	-
Neutral	61.26 (34.12, 78.27)	90.65 (55.72, 100.0)

TABLE XI. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED SADNESS FOR HC AND PD GROUPS

Emotion	Sadness Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	0.66 (0.0, 49.14)	0.0 (0.0, 1.26)
Fear	0.0 (0.0, 2.29)	-
Happiness	-	-
Sadness	26.16 (0.37, 36.79)	-
Surprise	0.0 (0.0, 0.15)	-
Neutral	24.41 (3.33, 53.86)	98.1 (83.41, 100.0)

During posed sadness, the median value of sadness presence in both groups is 0.0 %, moreover in PD Q75 is 0.0 % too, it means that may be no one patient who expresed sadnnes correctly or level of expressivity is very low. During interpreted sadness, the number of sadness presence in HC group is 26.16 %, in PD group is also 0.0 %. In some cases sadness was expressed as several another emotion: anger, disgust,fear, surprise or as neutral state for posed and interpreted task in both groups. The number of sadness expression as calculated as neutral state in PD group is higher than in HC during posed and interpreted task, the difference in median value for posed task is 29.31 %, the difference in median value for interpreted task is 73.69 %.

TABLE XII. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING POSED SURPRISE FOR HC AND PD GROUPS

Emotion	Surprise Posed	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	0.0 (0.0, 2.59)	0.0 (0.0, 0.33)
Fear	11.7 (0.0, 63.39)	0.18 (0.0, 1.68)
Happiness	-	-
Sadness	-	-
Surprise	0.0 (0.0, 6.87)	3.88 (0.0, 23.6)
Neutral	39.06 (20.64, 61.6)	85.02 (44.78, 98.46)

TABLE XIII. STATISTICAL VALUES FOR RECOGNIZED EMOTIONS DURING INTERPRETED SURPRISE FOR HC AND PD GROUPS

Emotion	Surprise Interpreted	
	HC median (Q25, Q75) (%)	PD median (Q25, Q75) (%)
Anger	-	-
Disgust	0.0 (0.0, 20.94)	0.0 (0.0, 0.08)
Fear	16.34 (7.61, 33.19)	0.0 (0.0, 9.44)
Happiness	-	-
Sadness	0.0 (0.0, 0.38)	-
Surprise	36.46 (23.83, 75.36)	42.54 (6.7, 61.8)
Neutral	6.51 (1.89, 30.3)	45.38 (24.66, 65.29)

During posed surprise, the median value of surprise presence in HC group is 0.0 %, in PD group is 3.88 %,. During interpreted surprise, the number of surprise presence in HC group is 34.46 %, in PD group is 42.54 %, i.e. in PD, and the value is higher by 8.08 %. More often surprised was expressed as fear or as neutral state for posed and interpreted task in both groups. The number of surprise expression as calculated as neutral state in PD group is higher than in HC during posed and interpreted task, the difference in median value for posed task is 45.96 %, the difference in median value for interpreted task is 38.87 %.

The value of the statistical significance of the differences in recognition emotional expressions with Mann-Whitney U-test is presented in Table XIV.

TABLE XIV. STATISTICAL SIGNIFICANT DIFFERENCES BETWEEN HC AND PD IN RECOGNIZED 6 BASIC EMOTIONS DURING POSED AND INTERPRETED TASKS

Emotion	Posed		Interpreted	
	U	p	U	p
Anger	120.0	0.381	120.0	0.385
Disgust	96.0	0.062	120.0	0.388
Fear	93.0	0.062	75.0	0.023
Happiness	87.0	0.054	74.0	0.021
Sadness	82.0	0.015	43.0	0.000
Surprise	101.0	0.139	110.0	0.255

Despite, in HC and PD groups, the median value is 0.0 % statistically significant differences are present during posed sadness, due to significantly differences in Q75. Thus, we can assumption that the level of sadness expressivity is reduced in PD. During interpreted task, statistically significant differences are shown in the imitation of emotions: fear, happiness, sadness, the difference of median value is 21.22 %, 54.8 %, 26.16 % accordingly. It can be concluded that the level of imitation of these emotions for PD patient is lower than in HC group.

Our results in recognition show that neutral state more common in PD patients, that consistent with observation reported in [5], but the worst impaired emotional expressions for PD in their research do not match with ours. It can be caused by the different sensitivity of the emotion recognition algorithm to various emotions or the difference in the number of emotions for analysis, in their work it was 4. In [8] authors reported about the decrease in disgust, sadness, and fear recognition, it coincides with our suggestion in sadness, and fear.

There are studies aimed at assessing changes in the emotion recognition depending on age [24], [25]. In [24] the difference in the mean values of age between the young and elderly groups was about 30 years old, in [25] the difference was 50 years old. The difference between the groups in our study is about 10 years, and the number of patients which refer to older adults group, if age more than 66 years old, according to [24], in our dataset 4 patients from PD group and 1 participant from HC group. It not allow to make conclusion about the differences are significant. For greater confidence in our results, we plot age dependencies on the shares of emotional expressions during each task and did not find confirmation that in our study, age affects expression of emotions.

B. Emotions intensity

To calculate the intensity of emotional expressions for each patient, the average value of the intensity of expressions over the entire video was calculated. The intensity distribution diagrams for performing posed and interpreted tasks are shown in Fig. 2, 3.
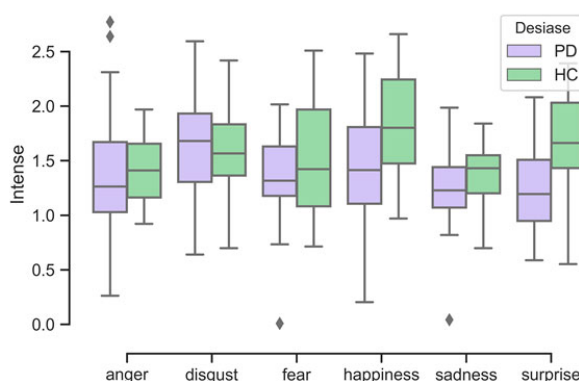

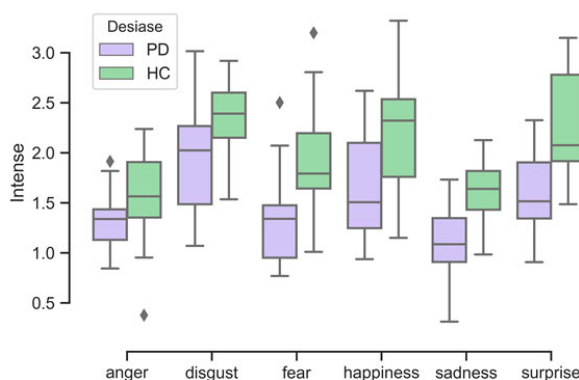Fig. 2. The diagram of the emotional expressions intensity distribution during the posed task

Fig. 3. The diagram of the emotional expressions intensity distribution during the interpreted task

The value of the statistical significance of the differences in the intensity of emotional expressions with Mann-Whitney U- test is presented in Tables XV, XVI.

TABLE XV. STATISTICAL SIGNIFICANT DIFFERENCES BETWEEN HC AND PD IN THE INTENSITY OF 6 BASIC EMOTIONS DURING POSED TASKS

Emotion	Posed		
	HC median (Q25, Q75)	PD median (Q25, Q75)	p
Anger	1.41 (1.16, 1.66)	1.26 (1.03, 1.67)	0.319
Disgust	1.57 (1.36, 1.83)	1.68 (1.31, 1.93)	0.477
Fear	1.42 (1.08, 1.97)	1.32 (1.18, 1.63)	0.178
Happiness	1.8 (1.48, 2.25)	1.41 (1.11, 1.81)	**0.024**
Sadness	1.43 (1.2, 1.55)	1.23 (1.07, 1.44)	0.150
Surprise	1.66 (1.43, 2.03)	1.2 (0.95, 1.51)	**0.018**

TABLE XVI. STATISTICAL SIGNIFICANT DIFFERENCES BETWEEN HC AND PD IN THE INTENSITY OF 6 BASIC EMOTIONS DURING INTERPRETED TASKS

Emotion	Interpreted		
	HC median (Q25, Q75)	PD median (Q25, Q75)	p
Anger	1.56 (1.35, 1.91)	1.34 (1.13, 1.44)	**0.037**
Disgust	2.39 (2.15, 2.6)	2.03 (1.49, 2.27)	**0.014**
Fear	1.79 (1.64, 2.2)	1.34 (0.95, 1.48)	**0.004**
Happiness	2.32 (1.76, 2.54)	1.51 (1.25, 2.1)	**0.009**
Sadness	1.64 (1.43, 1.82)	1.09 (0.91, 1.35)	**0.000**
Surprise	2.08 (1.92, 2.78)	1.52 (1.34, 1.9)	**0.001**

During posed happiness and surprise, significant differences between the HG and PD groups are observed. During the interpretation of all 6 basic emotions, significant differences between the HC and PD groups are observed. The intensities of emotions were higher in HC. During the interpretation of the emotions in both groups, the intensity of the emotional expression increased compared to the values obtained during the posed task.

The obtained results are comparable with [5], [6], [8], [9] in the reduction of the facial expression level.

C. The distance between emotional states and neutral state

To study the degree of emotional expressivity in comparison with the neutral state of each patient, the Euclidean distance between the AUs vector of the neutral state and the AUs vector of the posed emotional expression was calculated. The AUs vector consists of 17 AU values of the intensities of the action units calculated using the OpenFace. The higher the Euclidean distance between the vectors, the greater the expressiveness of the face was shown in comparison with the neutral state. The diagram of the emotional intensity distribution is presented in Fig. 4. The values of statistically significant differences calculated by the Mann-Whitney U-test are presented in Table XVII.

TABLE XVII. STATISTICAL SIGNIFICANT DIFFERENCES IN THE DISTANCES BETWEEN THE VECTORS OF AUS POSED EMOTIONS AND NEUTRAL STATE

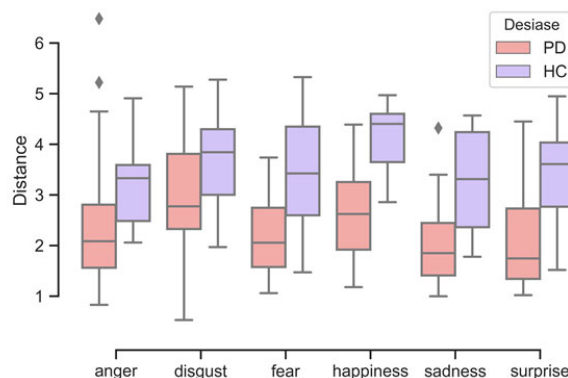| Emotion	HC median (Q25, Q75)	PD median (Q25, Q75)	p
Anger	3.33 (2.49, 3.59)	2.08 (1.56, 2.81)	**0.017**
Disgust	3.84 (3.0, 4.3)	2.78 (2.33, 3.81)	**0.017**
Fear	3.42 (2.6, 4.35)	2.05 (1.58, 2.74)	**0.002**
Happiness	4.4 (3.65, 4.6)	2.62 (1.92, 3.26)	**0.000**
Sadness	3.32 (2.36, 4.24)	1.85 (1.41, 2.45)	**0.002**
Surprise	3.61 (2.77, 4.04)	1.74 (1.34, 2.73)	**0.000**

Fig. 4. The diagram of the Euclidean distances distribution of the emotional expressions

According to the statistical significance results of the differences between the groups, the greatest distance was obtained in the HC group for all six basic emotions. This conclusion suggests that facial expressions of HC subjects are more expressive than facial expressions of PD patients.

The result of the calculation of the distance is comparable with [5], the authors reported too about higher distances between emotion expression and neutral state for the HC group.

VII. CONCLUSION

In the course of the work, the study of emotional expressions in patients with Parkinson's disease during various tasks was conducted. Patients were asked to complete 3 tasks: displaying a neutral state, displaying 6 basic emotions by researcher request, displaying 6 basic emotions depicted on the images. The experiment involved 16 patients in the healthy control group and 16 Parkinson's disease patients. To study the differences in emotional expressions in two groups, the following experiments were conducted: emotion recognition, the calculation of emotion intensity, the calculation of Euclidean distance between action units' vectors of posed emotions and neutral state. Mann-Whitney U-test was used to identify statistically significant differences.

The study of automatic emotion recognition shows a decreased number of correctly expressed emotions: sadness, during posed expression, fear, happiness, sadness during interpreted expression in Parkinson's disease patients in comparison with healthy control subjects. The differences between groups in median values for interpreted expressions are 21.22 % for fear, 54.8 % for happiness, 26.16 % for sadness. Thus, it can be concluded that the level of expressivity of sadness and the level of the interpretation of fear, happiness, and sadness emotions is reduced for Parkinson's disease patient .

A study of the emotions intensity shows significant differences between healthy control and Parkinson's disease groups in the posed expression of happiness and surprise. The different in median values of intensity between groups is 0.39 for happiness and 0.46 for surprise. Significant differences between healthy control and Parkinson's disease groups are observed for all 6 basic emotions for the interpreted task. The

different in median values of intensity between groups is 0.22 for anger, 0.36 for disgust, 0.45 for fear, 0.81 for happiness, 0.55 for sadness, 0.56 for surprise. In the healthy control group, the intensities are higher for the posed and interpreted tasks. During the interpreted task emotional expressions intensity were increased compared to the values obtained during the posed task.

The study of the facial expressivity Parkinson's disease patient, as Euclidean distance between action units' vectors of posed emotions and neutral state, showed the significant difference for all 6 basic emotions in comparison with the healthy control subject. The different in median values of distances between groups is 1.25 for anger, 1.06 for disgust, 1.37 for fear, 1.78 for happiness, 1.47 for sadness, 1.87 for surprise. This conclusion suggests that the faces of healthy subjects are more expressive than in Parkinson's disease.

The results obtained in this work confirm changes in the facial expressions in patients with Parkinson's disease and a deficit of emotional expressions in patients with Parkinson's disease in comparison with the healthy control group.

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