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Visualization of the quality (state) of the psychological climate in the team based on the speech interaction acoustic information processing

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Abstract

Methods for visualizing the state of the psychological climate in a team based on the speech interaction acoustic information processing are proposed. The speaker's psycho-emotional stress level is used as the initial data for assessing the state of the psychological climate in the team. Two main approaches have been identified, aimed at visualizing the personal level of conflict in each member of the team and visualizing the overall psychological climate in the team. To visualize the personal level of conflict, it is suggested to use pie charts that show the level of interpersonal relations of the employee with the rest of the team. To visualize the state of the psychological climate in the team, it is suggested to use a circular graph that allows to display all interpersonal relationships existing in the team. To display the level of personal conflict, different forms of information are used. The quantitative form allows you to display a numerical estimate of the level of conflict in the form of a sector area in the case of using pie charts, or as the length of a segment of the chord of the graph. The qualitative form of information presentation makes it possible to display data on the conflict in the form of a shade of red. The use of two forms of data mapping makes the visualization of information more visual and structured, which increases the efficiency of its operational use. Conducted laboratory testing of the proposed methods of visualization confirmed their effectiveness in solving problems of human factor management.

Keywords: psychological climate, human factor, acoustic technologies, personnel management.

1. Introduction

Safety and trouble-free operation of hazardous facilities largely depends on the so-called psychological climate in the team. Psychological climate is usually understood as a set of personal and interpersonal indicators, characterizing, first of all, the level of interaction in the team, the level of conflict, the stress-resistance of the team members, the level of self-regulation and self-control skills possession. The psychological resource of the team is of special importance. This characteristic determines the ability to correctly, quickly and smoothly solve emerging problems in stressful situations in the event of abnormal and emergency operation of a hazardous object. The most important indicator in this respect is the reaction time of the team members. Ensuring reliable trouble-free operation of a hazardous object requires, among other things, constant monitoring of the psychological climate in the team (working shift crew, calculation, crew) that performs operational management of such a facility.

Implementation of continuous monitoring of the psychological climate in the team is a complex scientific, methodical and technical task. One of the ways to solve it is using acoustic technologies to assess the current psycho-emotional state of each team member [1, 2]. The most informative in this regard is the analysis of the team members speech [3-7].

Analysis of human speech to assess the current psycho-emotional state of a person

is used in practice quite widely. So, for example, psychology usually operates with several levels of analysis of speech information, focused on the study of its psychosemantic [8], paralinguistic [9], psycholinguistic [10], pragmatic [11] and syntactic aspects [12].

Unfortunately, many of the listed aspects of speech are available for analysis only for long enough oral messages. For example, with periodic examinations in specialized laboratories of psychophysiological support of hazardous objects. In these cases, it is possible to fairly reliably estimate, for example, a set of psycholinguistic parameters of speech. Typical representatives of the above mentioned parameters are, for example, the Trader coefficients, the objectivity of action and directivity [13]. The first two of these factors estimate the ratio of the verbs number to the number of adjectives and nouns respectively in the fragment of speech. The third coefficient is defined as the relative number of speech expressive words.

Specificity of a dangerous object management personnel speech processing is its fairly short duration. As a rule, these are short oral commands and orders. This circumstance determines the relevance of the application, in the first place, of a paralinguistic analysis of speech. Such an analysis usually includes an assessment of the speech tempo, its loudness, melody, dynamics of changes in the timbre and the fundamental tone, as well as determining the nature of the filling of pauses between words [14-19]. This type of analysis also makes it possible to determine the gender characteristics of the speaker [20-22]. The practical applicability of this approach is due to the protocol of command interaction adopted on most dangerous objects. This protocol assumes the obligatory repetition of the commands and orders accepted for execution by the team members. This allows for the personalized processing of verbal orders of the management team, as well as the responses of the performers.

Unfortunately, the direct practical use of paralinguistic analysis of speech in most cases is very difficult. The main causes are a high level of acoustic noise and interference in the workplace, as well as the simultaneous conduct of oral dialogue by various team members. One of the possible ways to solve this problem is the author's approach, which assumes the use of a multichannel phased acoustic system with high spatial selectivity for recording the speech signal [1]. High selectivity is achieved due to the formation of a multi-beam directional pattern by the receiving system. In this case, the spatial orientation of each petal corresponds to the location of the team members in the room. The formation of such a directional pattern, as well as the processing of the speech signal is carried out in a fully automatic mode. In view of the computational complexity of the problem being solved, the approach involves the use of modern means of parallel data processing.

This approach makes it possible to isolate the useful voice signal of each team member against a background of intense acoustic noise. Paralinguistic analysis of speech makes it possible to identify signs that correlate with the level of nervous excitement of the speaker [9, 14-19]. A typical sign, for example, is the so-called tremor of the voice. This effect, in particular, manifests itself in the modulation of the speaker's speech frequencies [16-19]. Thus, the approach allows real-time assessment of the level of stress of each team member. At the same time, it is possible to obtain estimates of the level of mutual hostility due to the levels of stress on the part of the talking parties.

For the correct solution of personnel issues, not only the current level of stress among the team members is important, but also the dynamics of its development. The presentation of objective data about the current psycho-emotional team state, as well as the dynamics of its change in compact and visual form, is an urgent task. The solution of this task is in demand, first of all, with the provision of trouble-free operation of hazardous objects. No less important areas are also conducting training sessions on simulators, as well as conducting specialized classes to develop self-regulation and self-control skills.

Visualization of information about the current personal psychoemotional state of all team members using conventional time diagrams [15, 17-19] is of little use. The main reason is a large number of graphs, which must be constantly displayed on the monitor and analyzed.

It should be noted that in practice, graphs are widely used to represent interpersonal relations [23]. However, their classical appearance is not suitable for displaying the dynamics of changes in interpersonal relations in the team.

The aim of the study is to develop methods for visualizing the state of the psychological climate in a team based on the processing of the received acoustic information about the speech interaction of its members.

2. Description of the interaction and psychological climate in the team

To describe interpersonal interaction in the team, it is proposed to use the author's technique [1], which involves the use of a matrix

$$Q[i, j],\ i=1, \dots, N,\ j=1, \dots, N,$$

where N is the total number of the team members.

Each element of the given matrix q_{ij} characterizes the level of psycho-emotional stress arising in the i-th team member during his oral communication with the j-th team member. For this reason, the diagonal elements of the matrix are usually equal to zero, since the case of oral communication between the team member and the change of himself is not considered:

$q_{ij} = 0,\ i=j,\ i=1, \dots, N.$

The possible range for changing the values of the matrix Q elements is usually $0 \le q_{ij} \le 100$ [1]. It can distinguish a number of characteristic subranges characterizing the different levels of a person's psycho-emotional tension:

- $0 \le q_{ij} \le 30$ – relaxed, relaxed state;
- $30 < q_{ij} \le 70$ – area of increased tension, slight irritation;
- $70 < q_{ij} \le 100$ – an area of intense irritation, inadequate behavior, hysterics.

Symmetric elements of the matrix q_{ij} and q_{ji} do not always correlate with each other. So, in the case of the same mutual rejection between the i-th and j-th team members, these elements can be practically identical, and their numerical value is in the range 30-100:

$30 \le q_{ij} = q_{ji} \le 100.$

However, in most cases, such matrix elements have different meanings. In this case, the value of one of these elements can be in the region corresponding to a relaxed state, and the value of the other element is in the region of increased mental stress, for example:

$0 < q_{ij} < 30,\ 30 \le q_{ji} \le 100.$

The author's technique allows to describe both long-term and short-term effects of interaction in the team. So, if the values of the matrix Q characterize the psycho-emotional state of each team member over a sufficiently long time interval, then we can talk about its quasistatic character. In this case, it can be a whole work shift, or a week, a month, or even a year. In such cases, the results of the matrix analysis can be used to reasonably solve the questions of the staffing of work teams, professional selection and appointment to new posts.

When solving training tasks aimed at developing teamwork skills, teaching self-control and self-control methods, one must deal with the dynamic matrix Q. Matrix Q in this case characterizes the current psycho-emotional state of the team members. This condition can vary greatly during the entire training session. In this case, the formation of the dynamic matrix Q and its visualization are one of the main elements of modern learning technology with so-called biological feedback [24].

The essence of the training, testing, or learning technology with biofeedback is the use of an information channel that provides visualization for the trained, tested or learned person of current information about its functional and psycho-emotional state. For this purpose, the current bioparameters of a person are registered. For example, heart rate and its variability,

breathing parameters, blood pressure, reaction time, excitation level of the peripheral nervous system. Analysis of these bio-parameters allows you to assess the current state of a person. For this, in practice, computerized processing of data obtained from sensors recording the bio-parameters mentioned above is usually used.

Until recently, such sensors used mainly classical contact sensors, for example, pressure, pulse, skin-galvanic reaction, photoplethysmogram, motor activity. However, the presence of a large number of connecting wires, as well as the sensors themselves, create significant inconveniences, impede free natural movement and, most importantly, exert a strong psycho-emotional impact on a person. And this can lead to a distortion of estimates of the current state of a person.

For this reason, non-contact remote technologies have been used recently to register current human bio-parameters. These technologies in a fully passive mode measure the required bio-parameters. The most promising technologies of this class are acoustic and optical. In the minimal variant, it is possible to use only acoustic technology, which allows, by processing, first of all, spectral information, to determine a whole set of bio-parameters characterizing the current state of the nervous system, the respiratory system and the cardiovascular system of man.

Visualization in real time of information about the current functional and psycho-emotional state is carried out simultaneously with the issuance of estimates. For example, the condition is normal, or relaxed, or very excited and even stressful. Receiving such information, a person with the help of special techniques tries to restore his state to the category of normal. A typical example can serve as special breathing exercises, the fulfillment of which during the testing, training, or learning helps to reduce heart rate and blood pressure.

Thus, the principal moment in the use of technology with biological feedback is the possibility of obtaining estimates of the current state of a person. The availability of such data for the trainee allows in the automated mode to practice the skills of self-control and self-regulation.

3. Taking into consideration the team structure

The entire team can be divided into ordinary members (executors) and the management members. The number of the latter even for small teams, shifts and divisions can be from one to 3-5 people and depends, first of all, on the complexity of the tasks performed. To solve complex tasks, the management part of the team usually includes a general head of the team and at least deputies in various important areas of production activities.

The conducted statistical researches show that ordinary team members have the greatest fluidity. Usually these are young employees with low qualifications and little experience in the enterprise. In their mass they do not possess the skills of collective work and the culture of communication at the necessary level, they do not always observe the production discipline. The management representatives, as a rule, have significant work experience, have high qualifications and a culture of communication in the team. The turnover of staff for this category is minimal. For these reasons, the most relevant is the monitoring and analysis of interpersonal relationships among ordinary team members, as well as between ordinary team members and the team management. Monitoring of interpersonal relations between the representatives of the team management for the reasons listed above is less relevant.

Taking into consideration the typical structure of the team, the matrix Q in the general case has the following form [1, 2]:

$$Q[i,j] = \begin{bmatrix} RR[i,j] & RG[k,l] \\ GR[m,n] & GG[s,d] \end{bmatrix},$$

where

the submatrix RR[i, j], i=1, … , NR; j=1, … , NR characterizes the relations between the ordinary team members;

the submatrix RG[k, l], k=1, … , NR; l=1, … , NG characterizes the relations between the ordinary team members and representatives of the management;

the submatrix GR[m, n], m=1, ... , NG; n=1, ... , NR characterizes the relationship between management and ordinary team members;

the submatrix GG[s, d], s=1, ... , NG; d=1, ... , NG characterizes the relationship between the management members;

NR - the total number of the ordinary team members;

NG - the total number of the management members;

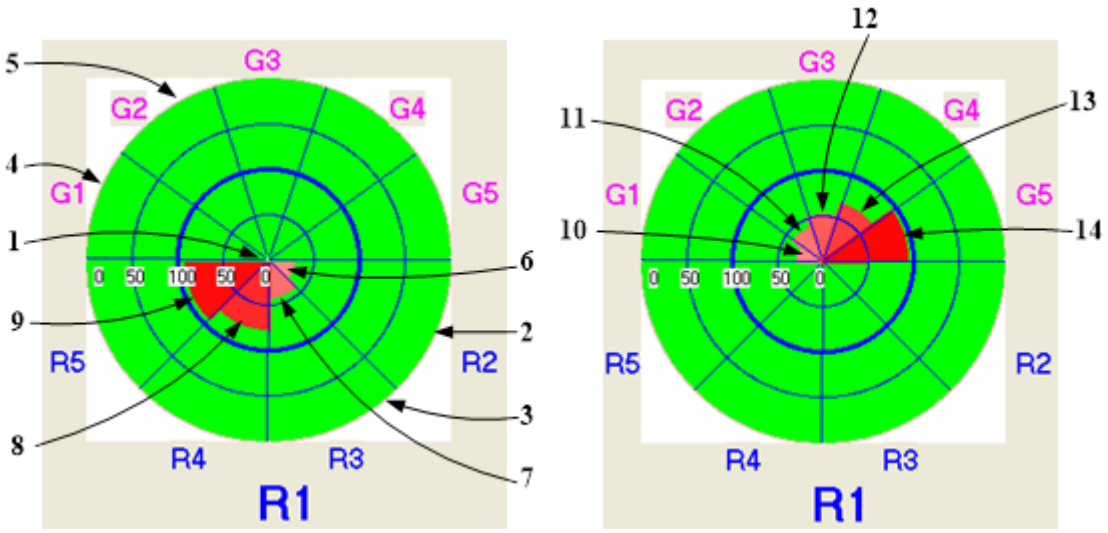
NR + NG = N.

The selected submatrices RR, RG and GR make it possible to visualize the personal characteristics of the ordinary team members. Visualization of the personal characteristics of the management members located in the GG submatrix can, if necessary, be carried out by analogy with the visualization of the data of the RR submatrix.

The methods of visualization considered in the work are focused, first of all, on solving the problems of analyzing the level of conflict between each of the ordinary team members, and also analyzing the quality of the psychological climate in the team.

4. Visualization of the personal conflict level

Figure 1 illustrates the proposed method for visualizing the level of personal conflict in the example of an ordinary team member R1. For the example considered, NR=5 and NG=5.



a) b)

Fig.1. Visualization of the personal conflict level of the employee R1 in interaction with the ordinary team members (a) and the management representatives (b)

For this purpose, it is proposed to use a circular diagram, the center of which 1 corresponds to the ordinary team member R1. The entire field of the pie chart is divided into sectors. At the same time, in the sectors of the lower semicircle of the diagram (Fig. 1a), based on the data of the RR submatrix, the conflict indicators of the member in question are shown with other ordinary members. For example, in sectors 2 and 3, the interaction of a team member R1, respectively, with the ordinary members R2 and R3 is displayed. Similarly, in the upper semicircle of the diagram (Fig. 1b), based on the data of the RG submatrix, the indicators of conflict with the representatives of the management team are displayed. For example, in sectors 4 and 5, information is provided on the level of conflict between team member R1 and managers G1 and G2, respectively.

The pie chart uses two forms of data mapping. Quantitatively, the levels of conflict are displayed in the form of parts of the corresponding sectors, painted in red tones. The size of these areas is proportional to the level of conflict. The maxi-

mum conflict level (100 units) on the diagram corresponds to a circle of half radius.

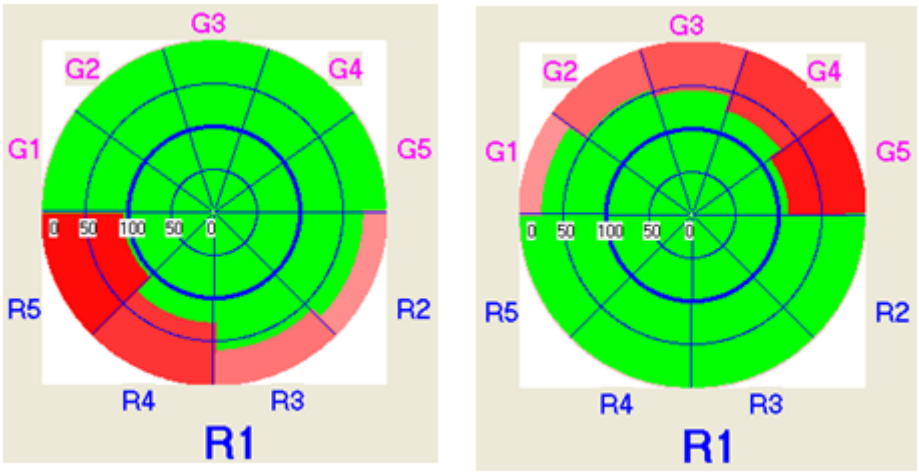
Qualitatively, the levels of conflict are also displayed in a shade of red. At the same time, brighter red colors, for example, 8, 9 and 13, 14 correspond to high conflict rates, and more faded, for example, 6, 7 and 10, 11, 12 - to low indicators. In the considered visualization example the following values of the submatrix RR elements for the team member R1 were used:

$RR[1, j = 1, \dots, 5\,]$ = {0, 32, 45, 80, 95}.

For the presented example of the R1 member conflict level visualization (Fig. 1b) between him and the management representatives the following values of the RG submatrix elements were used:

$RG[1, l = 1, \dots, 5]$ = {31, 43, 55, 70, 97}.

To visualize the level of relationships of ordinary team members, as well as the management representatives with the employee R1 in question, a similar approach is used. For this purpose, the peripheral zone of the pie chart is used. Figure 2 is an illustration of this situation.



a) b)

Fig.2. Visualization of the personal conflict level between the ordinary team members (a) and the management representatives (b) in interaction with the employee R1

For the visualization examples presented in Fig. 2a and Fig. 2b, the following values of the corresponding submatrices RR and GR elements were used:

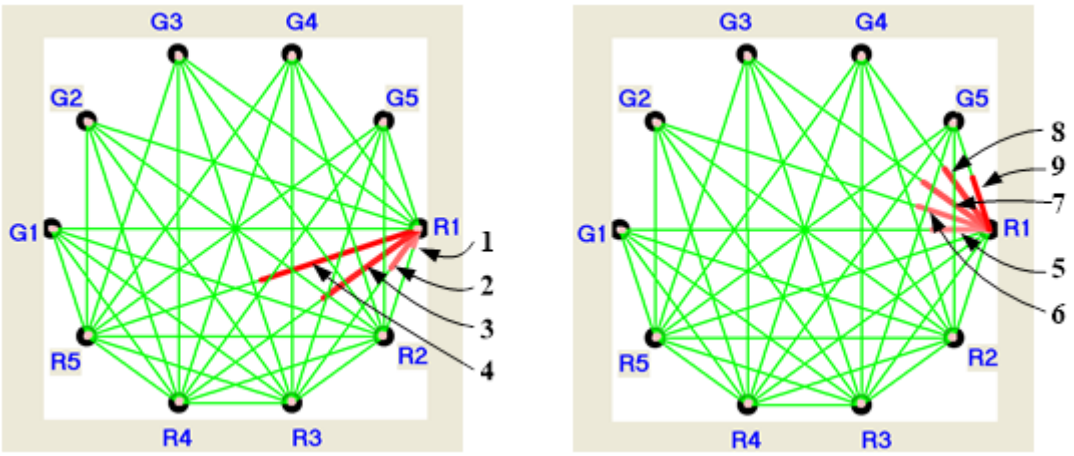
$RR[i = 1, \dots, 5, 1]$ = {0, 29, 42, 74, 96}.

$GR[1, n = 1, \dots, 5]$ = {27, 49, 58, 75, 91}.

The considered circular diagrams make it possible to visualize the personal conflict level of each team member. They can be adapted to the specified parameters NR and NG, which determines the team structure. Pie charts are characterized by high visibility and have a clear interpretation – the larger the size and brightness of the central area – the higher the conflict level of this team representative. This circumstance makes them convenient for use in conducting training sessions with biofeedback [24], as well as in dealing with personnel issues.

5. Visualization of the team psychological climate quality

To visualize the team psychological climate quality, it is proposed to use a circular graph, an example of which is shown in Fig.3. This graph is designed to show the level of conflict between the all team members.



а) б)

Fig.3. An example of visualization of the team psychological climate quality: the principle of displaying of the team member R1 conflict level in relation to the ordinary team members (a) and the management representatives (b)

The graph vertices number corresponds to the total number of the team members. The graph vertices (R1-R5) located at the bottom of the graph correspond to the team ordinary members. The graph vertices (G1-G5), located in the upper part of the graph, correspond to the management representatives. The edges of the graph are used to display the conflict levels between the team members associated with the corresponding edges of the graph.

The principles of displaying information about the personal conflicts of the team members are in many respects similar to those considered earlier. So, each edge of the graph is divided into two equal parts. The middle of the edge corresponds to a conflict rate of 100. Numerical values of the conflict level of each side are displayed by segments of red tones starting at the corresponding vertices of the graph. In this case, the length of the segments is proportional to the corresponding conflict rates. In the cases that the conflict level indicators for both sides have maximum values, the red segments are closed and the entire edge turns red. For the qualitative display of personal conflict levels, the brightness of the red tone is also used. The maximum conflict level corresponds to the brightest red color. The minimum level of conflict is pale pink.

In Figure 3, this approach is illustrated by the example of the employee R1. The segments of the ribs 1-4 (Fig. 3a) have different lengths and shades of red, which corresponds to different conflict levels of this employee with other ordinary team members R2-R5. Similarly, the segments of the ribs 5-9 (Fig. 3b) reflect the different conflict levels between the employee R1 and the management representatives G1-G5. In the examples presented in Fig. 3a and Fig. 3b, the values of the conflict levels of the RR and RG sub-matrices, similar to those used earlier, were used.

The presented form of visualization integrates in itself all available data on personal conflicts, represented in the submatrices RR, RG and GR. The form has a visual form, which allows a clear unambiguous interpretation.

6. Visualization methods experimental approbation

The considered visualization methods were used in the conduct of training sessions with various instructors to develop teamwork. Their application allowed to carry out current monitoring of the training process, as well as to identify in each team the most conflicting members.

A typical example of the conflict level visualization results of each of the five team ordinary members is shown in Fig. 4. RR, RG and GR submatrices were used for visualization with the initial data defining the personal conflict levels registered with acoustic technology. The numerical

values for the elements of the submatrices are presented in Tables 1-3.

Table 1 - Values of the RR matrix elements for the example in question

RR[i, j], i=1,...,5, j=1,...,5		The i-th team member				
		i=1	i=2	i=3	i=4	i=5
The j-th team member	j=1	0	82	65	98	75
	j=2	94	0	25	32	30
	j=3	22	15	0	22	25
	j=4	63	23	21	0	11
	j=5	37	26	18	19	0

Table 2 - Values of the GR matrix elements for the example in question

GR[m, n], m=1,...,5, n=1,...,5		The m-th team member				
		m=1	m=2	m=3	m=4	m=5
The n-th team member	n=1	38	25	11	25	16
	n=2	43	16	24	16	13
	n=3	23	23	15	31	19
	n=4	35	23	29	27	33
	n=5	45	16	12	28	16

Table 3 - Values of the RG matrix elements for the example in question

RG[k, l], k=1,...,5, l=1,...,5		The k-th team member				
		k=1	k=2	k=3	k=4	k=5
The l-th team member	l=1	45	61	74	54	66
	l=2	23	21	16	23	34
	l=3	21	18	23	15	18
	l=4	17	19	23	31	18
	l=5	18	25	26	13	13

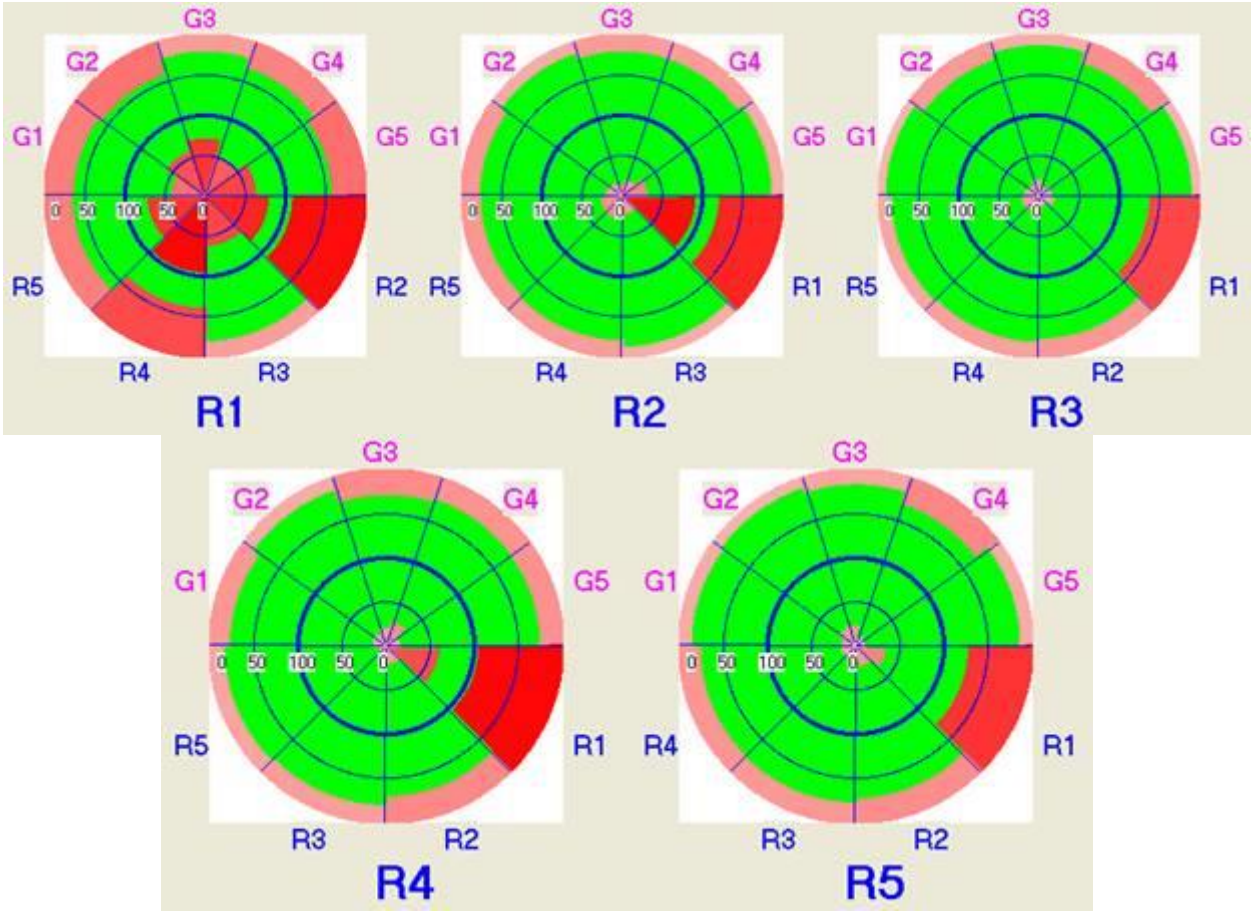


Fig.4. Visualization example of the personal conflict level in the team

An analysis of the presented pie charts shows that the employee R1 is the most personal conflict. His conflict level exceed the indicator of 50 for almost all team members. The most strenuous relationship this employee has with employees R2 and R4. At the same time, these employees R2 and R4 themselves are characterized by normal relationships with the rest of the team. For this reason, employee R1 is the first candidate for transfer from this team to another, and also the first candidate for additional training sessions on mastering the skills of self-control and self-regulation. The least controversial are the employees of R3 and R5.

Figure 5 shows the result of visualizing the quality of the psychological climate in the team in question. From the presented example it is clearly visible that in general the psychological climate in the team is benevolent. The exception is employee R1, whose behavior is fundamentally different from the rest of the team. Possible solutions to the problem are:

· replacement of this employee by another;

· appointment of a probationary period for this employee after passing through a cycle of training sessions with the aim of reducing the level of conflict.

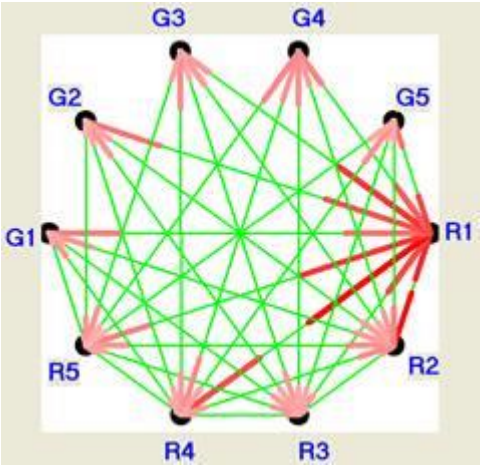


Fig.5. A visualization example of the team psychological climate quality

7. Conclusion

The considered methods of visualization make it possible to increase the visibility and information of the data by structuring the personal information obtained in the analysis of speech interaction in the team.

The method of personal conflict visualization based on the pie charts usage is one of the main constituents in the technology of conducting training sessions with biofeedback. In addition, this method is a tool for solving many human resource management tasks, as it allows us to identify in a timely manner the team members with the greatest conflict.

The method of visualizing the quality of the team psychological climate based on the use of a circular graph should be regarded as an effective tool for monitoring the current psychological health of the team, which is important for ensuring the safe and trouble-free operation of hazardous objects.

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