AIRCRAFT CREW: RESOURCES OF INTERACTION

Arinicheva, Olga V., *St. Petersburg State University of Civil Aviation, St. Petersburg, Russia.*
Malishevsky, Alexey V., *St. Petersburg State University of Civil Aviation, St. Petersburg, Russia.*
Vlasov, Evgeny V., *St. Petersburg State University of Civil Aviation, St. Petersburg, Russia.*

ABSTRACT

The results of experiments carried out in 2011–2015 with professional pilots and students of St. Petersburg State University of Civil Aviation are analyzed. The aim of the study was to test the efficiency of interaction in the two-member crew of the aircraft using a variety of evaluation criteria. In particular, socionic criteria were considered as well as characteristics of individual styles of behavior, and data of indirect sociometry. Statistical criterial dependences are provided. Article continues previously considered topic (see World of Transport and Transportation, 2014, Iss. 5).

Keywords: civil aviation, aircraft crew, interaction of pilots, style of behavior, inter-type relations, sociometry, CRM.

Background. *Ineffective interaction in aircraft crew is a problem that worries the international aviation community since the mid-1970s, when it was officially formulated. The reason for focusing attention on such an extraordinary issue was a tragedy of DC-8-61 aircraft of the «United Airlines» on 28.12.1978 during the landing approach at the international airport of Portland. As a result of the accident investigation commander of the crew was called a culprit, who ignored observations of his colleagues about the low level of fuel during flight [1]. Plane crash stressed the need to change the order of interaction within the aircraft crew. As a result, special programs and techniques had been introduced that fundamentally changed the work of flight teams. In the first place it comes to CRM programs (Cockpit / Crew Resource Management) [2, 3].*

However, despite the measures taken, the problem remains till now topical. Everyone remembers the heavy crash on 07.09.2011 of international charter flight AKY9633, transporting hockey club «Locomotive» (Yaroslavl) to Minsk [4]. As one of the causes of this crash IAC calls uncoordinated actions of the crew in the final run-up phase. Another example is a crash of Tu-154 of «Dagestan Airlines» on 04.12.2010 at Domodedovo airport. Among the causes of the air crash (AC) investigators named lack on the part of the aircraft commander of leadership and incorrect distribution of responsibilities in the crew and independent, yet not always correct, actions of pilots, insufficient training of a commander from the point of crew resource management (CRM) [5].

The same situation is abroad. Thus, on 16.02.1998 during the approach to landing at the airport Taipei-Chiang Kai Shek (Taiwan) aircraft A300–622R of «China Airlines» crashed.One of the reasons of AC was that the interaction between a captain and a co-pilot was unsatisfactory [6]. A similar case was recorded on 22.05.2010 in Mangalore, when a Boeing 737 of «Air India Express» at landing skidded off a runway and burst into flames. Before that co-pilot has repeatedly recommended to the commander to go to the second round, but the attempt to do so was made after the commencement of running of the aircraft on the runaway [7]. One can cite many more similar examples, but one thing is clear – the problem of increasing effectiveness of cooperation in the aircraft crew remains unsolved.

Objective. *The objective of the authors is to further investigate a topic of effective interaction within the aircraft crew.*

Methods. *The authors use general scientific methods, comparative analysis, key elements of socionic, sociological, psychological methods.*

Results. *The problem of enhancement of crew interaction can be solved in two ways. First is training on effective interaction on CRM programs [2, 3], and it is now in fact the only one used. The second is correct designation of aircraft crews, the authors have previously mentioned its necessity and possible options for addressing the issue [8–15].*

However in all cases criteria for assessing effectiveness of cooperation in the crew are necessary, including a prognostic criterion to represent the effectiveness in advance. As such, we often considered socionic criteria [8–15], but in [8–9] criteria are identified, which are based on the use of individual styles of behavior (ISB).

Also [9] suggested the desirability of attracting the methods of multivariate statistical analysis, and [16, 17] showed the different variable selection algorithms for construction of a linear regression models using a range of performance criteria. Work [8] using the method of multiple regression analysis managed to obtain the expression

$$Æ = 3{,}4\Delta_S + 0{,}2\Sigma_S + 12{,}6 - 4{,}15R_S,$$

which is the dependence of the evaluation value of effectiveness of interaction Æ by criterion $ъ_{04}$ [9, 13] on variables that characterize ISB (see. Pic. 1). The values Σ_S, Δ_S and R_S are determined by expressions:

$$\Sigma_S = |\overline{r_1}| + |\overline{r_2}|;$$

$$\Delta_S = ||\overline{r_1}| - |\overline{r_2}||;$$

$$R_S = \sqrt{(E_1 - E_2)^2 + (L_1 - L_2)^2 + (R_1 - R_2)^2},$$

where E_i, L_i, R_i are coordinates on the grid μ_2, determining i-th ISB;

$$|\overline{r_i}| = \sqrt{E_i^2 + (L_i - 50)^2 + (R_i - 50)^2}$$ *is vector module*

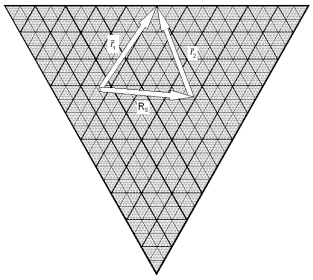
on the grid μ_2, determining i-th ISB($i = \overline{1,2}$).

Let's consider the value ($3{,}4\Delta_S + 0{,}2\Sigma_S + 12{,}6 - 4{,}15R_S$) as an independent efficiency criterion, that is as a supplementary criterion to the previously demonstrated one, denoting it as $з$, i. e.

$$з = 3{,}4\Delta_S + 0{,}2\Sigma_S + 12{,}6 - 4{,}15R_S.$$

Table 1 shows correlation between components of the socionic model of intertype relations (for intertype relations (IR) according to V. V. Gulenko [18]), as well as a general prognostic indicator of interaction effectiveness ($ъ_{04}$) [9, 13] and the criterion $з$ for 1903 pairs of pilots. The results were obtained in a authors' survey of 235 pilots during 2011–2015.

Theoretically, since the value of $з$ according to the plan of E. M. Kaimakova [8, 16, 17] was to approximate



Pic. 1. Evaluation of interaction effectiveness on the sum (Σ_S) and the difference (Δ_S) of vector modules, determining ISB on the grid μ_2 and the distance between points, determining ISB on the grid μ_2 (R_S) [9].

an estimate Æ, obtained by the criterion $\mathfrak{Z}_{04}$, efficiency should be the higher, the greater is $\mathfrak{Z}$. Consequently, its correlation with components of the socionic model of intertype relations corresponds to the possibility [19] of emergence of favorable IR, and the criterion $\mathfrak{Z}_{04}$ should be positive, and correlation wth indicators, determined by the method of A. M. Etkind [20] (summary normativity (N), valence (V) and total assessment on the color test of relations (Σ_{NV})) should be negative. In general, so it happened, but the correlations were very weak, as it is evident from Table 1.

Theoretically, it was assumed that «favorability» of IR in a pair adversely affects any difference for any of four psychological dichotomies (PD). In [13] it was shown that it is extremely unfavorable to have mismatching PD «rationality – irrationality» (P / I) (the fourth position in the four-digit code). Mismatching in PD «extraversion – introversion» (E / I) (first position in the four-digit code) will also be

Table 1

Correlations between components of the socionic model of intertype relations (according to V. V. Gulenko [18]), as well as general prognostic indicator of interaction effectiveness ($\mathfrak{Z}_{04}$) [9, 13] and the criterion $\mathfrak{Z}$ in pairs of pilots

Intertype relations according to V.V. Gulenko			Pilots (235 people; 1903 pairs)		
			rcorr	Correlation significance	Rank
1	1111	identity	-0,0376	R ≤ 0,95	12
2	1110	quasiidentity	-0,1307	R > 0,999	16
3	1101	ratioidentity	0,0013	R ≤ 0,95	8
4	1100	ratioorder	-0,0751	R > 0,99	14
5	1011	irratioidentity	0,0208	R ≤ 0,95	7
6	1010	irrationorder	-0,0856	R > 0,999	15
7	1001	SuperEgo	0,0617	R > 0,99	4
8	1000	activation	-0,0217	R ≤ 0,95	11
9	0111	neutralization	0,0468	R > 0,95	5
10	0110	glassiness	-0,0593	R > 0,99	13
11	0101	ratiomirage	0,0935	R > 0,999	3
12	0100	irratiorevision	0,0005	R ≤ 0,95	9
13	0011	irratiomirage	0,0955	R > 0,999	2
14	0010	ratiorevision	-0,0060	R ≤ 0,95	10
15	0001	dualization	0,1343	R > 0,999	1
16	0000	conflict	0,0436	R ≤ 0,95	6
$\mathfrak{Z}_{04}$			0,0328	R ≤ 0,95	
N			-0,0167	R ≤ 0,95	
V			-0,0421	R ≤ 0,95	
Σ_{NV}			-0,0360	R ≤ 0,95	

clearly unfavorable, though to a lesser extent. And mismatching in PD «logic – ethics» (L / E) (second position), and «sensory – intuition» (S / I) (third position) affects the «favorability» of IR much weaker than the effect of mismatching in PD E/I and PD R/ I. So we can neglect them actually, because they are almost not significant [13]. Comparing these conclusions with data shown in Table 2, it is obvious that the data confirmed only that mismatching in PD R / I is clearly unfavorable. As for other PD, it is rather the opposite. In general, on this sample indicator $\mathfrak{Z}$ has not revealed any positive differences as compared with Σ_S, Δ_S and R_S.

However, the considered sample has quite a lot of flaws. A significant part of the information presented here was gathered during the preliminary preparation for teaching CRM or MCC programs, and was followed by clearly negative attitude of aircraft crews to the test procedure. In other words, there is reason to believe that there had been a lack of motivation and even dishonesty of a number of participants in the poll.

*Besides, those samples allow to compare only criteria indirectly evaluating the effectiveness of interaction. Thus, socionic criteria assess **alleged** convenience of solely **information exchange** (interaction), criterion Σ_S – total optimality of styles of behavior, criteria Δ_S and R_S – differences in styles of behavior (which is not always evil), and indicators of A. M. Etkind N, V and Σ_{NV} indicate the general acceptance or rejection of each other, but the former still does not guarantee a good interaction. Using direct criteria of efficiency of interaction is possible only in specially organized experiments, but there we are waiting for a number of serious problems.*

Let's consider one of these experiments, conducted in the period from November 2014 to January 2015 by student-pilots of the graduating class of University of Civil Aviation. Input data and its most significant results are presented in detail [21]. Here we consider only the organization of the experiment and some conclusions obtained thereof.

The study involved 40 pilots – graduates. The first phase concerned their psycho-diagnostics and diagnostics of motor computer skills. The experiment used the program «Ring-2» [22] (development of E. V. Vlasov) and «Viper» [9] (development of P. V. Brovkin). Each participant performed one test and five scoring attempts in each exercise.

At the second stage, students were divided into four groups according to their level of computer skills. Using the data of psycho-diagnostics, and using the test «MM-1» (the fifth version) [23] socionic models of intertype relations were calculated for all possible 780 pairs. Then on the basis thereof the researchers received prognostic socionic criteria of efficiency of interaction in a pair $\mathfrak{Z}_{04}$ from the expression [9, 13]:

$$\mathfrak{Z}_{04} = \mathfrak{Z}_{(+)} - \mathfrak{Z}_{(-)},$$

where $\mathfrak{Z}_{(+)} = (6\Omega_1 + 6\Omega_3 + 6\Omega_5 + 6\Omega_7 + 3\Omega_9 + 3\Omega_{11} + 3\Omega_{13} + 3\Omega_{15}) / 8$;

$\mathfrak{Z}_{(-)} = (6\Omega_{16} + 6\Omega_{14} + 6\Omega_{12} + 6\Omega_{10} + 3\Omega_8 + 3\Omega_6 + 3\Omega_4 + 3\Omega_2) / 8$;

Ω_i is i-th component of SMIR, calculated for intertype relations according to V. V. Gulenko [9, 13].

For these 780 pairs prognostic criteria based on style of behavior were calculated [8, 9].

Finally, actual performance criteria of interaction, interpreted as results of indirect (color) sociometry, i. e. normativity (N), valence (V) and the total score (Σ_{NV}), were determined with the help of TSC by the method described by A. M. Etkind [20].

Table 2

The sum of ranks of correlations between components of the socionic model of intertype relations and criterion ʒ in pairs of pilots with their match and mismatch

PD	E/I	L/E	S/I	R/I
Position in the four-digit code	1st	2nd	3rd	4th
Match of sign	87	80	80	42
Mismatch of sign	49	56	56	94

At the time of writing of the article the listed criteria used in [21] were corroborated with above described criterion ʒ.

At the third stage organizers of the experiment made an attempt to divide those 40 people into two contrasting groups of 10 pairs in each, in one of which prognostic socionic criteria $ʒ_{04}$ would be good, and in the other – bad, but with approximately the same level of motor computer skills. That is, the researchers were trying to select a pair so that when evaluating Æ = 5+ or Æ = 1 on criterion $ʒ_{04}$ one member of the pair would have been in the first group (the best-ranking computer skills), and the other would have been in the fourth (the worst rank skills), or one would have been in the second group, and the other would have belonged to the third group. However, since priority was given to the partition on criterion $ʒ_{04}$, then unsuccessful pairs were obtained.

Further, obtained pairs performed together four exercises: «Chkalovsky» [14, 24] (development of P. V. Brovkin), «Azef» [22] (development of E. V. Vlasov), «Ring-2» [22] (development of E. V. Vlasov) and «Viper» [9] (development of P. V. Brovkin). In all cases, the researchers chose for each pair respectively the best, worst and average results out of five attempts.

At the fourth stage, with the help of parametric correlation coefficient of Bravais–Pearson ($r_{corr.}$) the researchers calculated statistical relationships between all of the previously mentioned criteria of efficiency of interaction, some of which are shown in Table 3.

In order to properly evaluate the results presented in it, it should be remembered that, in accordance with theoretical predictions, increase in efficiency of interaction should lead to increase in such criteria as $ʒ_{04}$, Æ, ʒ and «average time of keeping plank within acceptable limits» in the exercise «Azef» ($T_{Azef.aver}$) [22], and, conversely, some criteria should decrease such as N, V, $Σ_{NV}$, $Σ_S$, $Δ_S$, R_S and «average transit time of a given trajectory» in the exercises «Ring-2» [22], «Chkalovsky» [14, 24] and «Viper» [9] ($T_{Ring\_aver.}$, $T_{Chkal.\_aver.}$ and $T_{Viper\_aver.}$ respectively).

As shown in Table 3, the hypothesis, declared in [9] and tested in that study, could neither be confirmed nor denied. The problem is that the actual efficiency of interaction in the pair is strongly dependent on individual motor skills, and to a lesser extent on IQ.

If we look at the statistical dependences between results of exercises, individual indicators of interaction effectiveness and components of socionic models of intertype relations according to V. V. Gulenko, we can see that statistical relationship for the exercise «Azef» was the closest one to the previous theoretical assumptions (see. Table 3). And much more significant correlations are not between average time of keeping plank within specified parameters ($T_{Azef.\_aver.}$) during five attempts, but between the worst time during five attempts ($T_{Azef.\_w.}$), and other effeciency indicators. Correlations were moderate and reached tendencies of significant relations (r <0,1). That is, the better are prognostic indicators of efficiency, none the worse as compared to a certain level, the exercise was performed (worse results were even higher). Highly significant correlations that are fully consistent with theory, were revealed between components of SMIR and socionic criteria ($ʒ_{04}$) and TSC data (Table 3). If we consider the index ʒ, it showed itself neither worse, nor better than other efficiency criteria, based on styles of behavior in the pair. Its highly significant average correlation force with the best time of keeping plank within specified parameters ($T_{Azef.\_b.}$) looks like an artifact.

It is clear that the experimental results were affected by a small number of pairs, and errors in its planning, that resulted in underestimation of the importance of the factor of individual motor skills. In addition, the selection of pairs by the criterion $ʒ_{04}$ led to the fact that correlation between the total rank ($Σ_{Rank}$) and the value $ʒ_{04}$ was virtually absent (as planned), but there was a significant correlation of average level with efficiency indicators based on the style of behavior in the pair, which also could have an impact on their relationship with direct indicators of efficiency, obtained as a result of exercise.

Although the software used and the accompanying teaching material had been successfully implemented in the educational process, in the course of it, however, various problems [25] have been identified:

- *lack of personalization and personal account of the results;*
- *lack of a common data store;*
- *lack of automated results processing system;*
- *weak control over actions of trainees.*

Let's consider the presented methodological problems. First of all, as a software package consisted in general of independent executables, it was decided to combine them into a single graphical environment containing theoretical information about CRM, as well as to provide description of all the exercises with possibilities of their launch and implementation. As each exercise keeps its own book of results, independent from other applications, comparison of achievements of students in each exercise falls on the shoulders of the teacher, which is quite difficult, especially considering the fact that when performing exercises there are no data about students, either about composition of the pairs. In fact, it becomes problematic to define scores of the student in the context of different pairs and exercises.

This fact is well illustrated by correlations identified between different indicators. The biggest difference with the rest of results was demonstrated by the time of keeping plank within acceptable limits ($T_{Azef.\_aver.}$) in the «Azef» exercise. Its tasks include development of anticipation of the pilot. Being very useful for training and warm-up, exercise is too sensitive to random errors. This greatly reduces the

Table 3

Statistical dependences between a number of criteria of interaction efficiency used in the experiment

The first value	The second value	$r_{corr.}$	Correlation significance	The first value	The second value	$r_{corr.}$	Correlation significance
Σ_{IQ}	$T_{Viper\_aver.}$	-0,3298	r ≥ 0,1	$T_{Azef\_aver.}$	R_S	0,3549	r ≥ 0,1
Σ_{Rank}	$T_{Ring\_aver.}$	0,5325	r < 0,05	$T_{Azef\_aver.}$	З	-0,349	r ≥ 0,1
Σ_{Rank}	$T_{Chkal.\_aver.}$	0,4989	r < 0,05	Σ_S	Δ_S	-0,433	r < 0,1
Σ_{Rank}	$T_{Viper\_aver.}$	0,7038	r < 0,001	Σ_S	R_S	-0,425	r < 0,1
ΣRank	$T_{Azef\_aver.}$	0,0979	r ≥ 0,1	Σ_S	З	0,3499	r ≥ 0,1
Σ_{Rank}	R_S	-0,5180	r < 0,05	Σ_S	ᵡ 04	0,4449	r < 0,1
Σ_{Rank}	З	0,5406	r < 0,05	Δ_S	R_S	0,7046	r < 0,001
Σ_{Rank}	ᵡ 04	0,0290	r ≥ 0,1	Δ_S	З	-0,403	r < 0,1
$T_{Ring\_aver.}$	$T_{Chkal.\_aver.}$	0,6605	r < 0,01	Δ_S	Æ	-0,421	r < 0,1
$T_{Ring\_aver.}$	$T_{Viper\_aver.}$	0,6983	r < 0,001	Δ_S	ᵡ 04	-0,533	r < 0,05
$T_{Ring\_aver.}$	$T_{Azef\_aver.}$	-0,0742	r ≥ 0,1	Δ_S	N	0,3518	r ≥ 0,1
$T_{Ring\_aver.}$	Δ_S	-0,3043	r ≥ 0,1	Δ_S	Σ_{NV}	0,3464	r ≥ 0,1
$T_{Ring\_aver.}$	З	0,0725	r ≥ 0,1	R_S	З	0,9332	r < 0,001
$T_{Ring\_aver.}$	Æ	0,3515	r ≥ 0,1	R_S	ᵡ 04	-0,229	r ≥ 0,1
$T_{Chkal.\_aver.}$	$T_{Viper\_aver.}$	0,7670	r < 0,001	З	Æ	-0,049	r ≥ 0,1
$T_{Chkal.\_aver.}$	$T_{Azef\_aver.}$	-0,1272	r ≥ 0,1	З	ᵡ 04	0,033	r ≥ 0,1
$T_{Chkal.\_aver}$	З	0,1519	r ≥ 0,1	З	N	-0,016	r ≥ 0,1
$T_{Viper\_aver.}$	$T_{Azef\_aver.}$	0,0334	r ≥ 0,1	З	V	-0,066	r ≥ 0,1
$T_{Viper\_aver.}$	Σ_S	0,3597	r ≥ 0,1	З	Σ_{NV}	-0,04	r ≥ 0,1
$T_{Viper\_aver.}$	Δ_S	-0,3372	r ≥ 0,1	ᵡ 04	N	-0,723	r < 0,001
$T_{Viper\_aver.}$	R_S	-0,3353	r ≥ 0,1	ᵡ 04	V	-0,398	r < 0,1
$T_{Viper\_aver.}$	З	0,2269	r ≥ 0,1	ᵡ 04	Σ_{NV}	-0,629	r < 0,01
$T_{Azef\_b.}$	З	-0,6087	r < 0,01	N	V	0,7203	r < 0,001

possibilities for diagnosing the efficiency of interaction. Exercise «Ring-2» has its own shortcoming, namely a very small variation of results [25].

Instead of conclusion

As follows from the data obtained, the methodological solutions will help to get closer to the desired results. However, there is a number of difficulties in the use of individual modules without their complex processing. The solution here might be seen through introduction of a centralized repository of student personalities, comprising results of exercises, which they performed. It is necessary in order to obtain the full picture, when assessing real knowledge, competencies, and skills, to conduct a case, psychological and professional readiness of the pilot.

Lack of statistical data and a weak correlation of test results remain a significant barrier to the creation and improvement of methods for evaluating effectiveness of interaction in the aircraft crew. Therefore, further increase of knowledge base and the use of multivariate statistical analysis, because often the causes of weak correlations are related to the influence of factors unaccounted by us, will be a priority for the near future and for researchers, and for anyone who trains and supervises air staff.

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Information about the authors:
Arinicheva, Olga V. – Ph.D.(Eng.), associate professor of St. Petersburg State University of Civil Aviation, St. Petersburg, Russia, 2067535@mail.ru.
Malishevsky, Alexey V. – Ph.D.(Eng.), associate professor of St. Petersburg State University of Civil Aviation, St. Petersburg, Russia, 9909395@bk.ru.
Vlasov, Evgeny V. – Ph.D. student of St. Petersburg State University of Civil Aviation, St. Petersburg, Russia, jeka.vlasov@gmail.com.

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