Psychophysiological determinants of drivers' condition

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Abstract

The psychophysiological state of vehicle drivers is of key importance for road safety and for the life and health of other users of the transport infrastructure. A number of external factors may contribute to gradual deterioration of the driver's condition and undiagnosed illness may result in abrupt health disorders.

The objective of this paper is to establish, on the basis of tests, surveys, and measurements, an index reflecting the psychophysiological state of a vehicle driver.

The research was based on a database of results for a group of 15 rested volunteer drivers. The results were classified into two subgroups corresponding to two components of the index: physiological and psychological.

On the basis of arranged data, a method was proposed to calculate the FIZ and PSY indices.

As a result of the research, we have obtained determinants of the psychophysiological condition of the subject drivers and a group of correlated indices. They are candidate items (inter alia) of a short survey aimed to verify the short-term condition of a driver.
Keywords: biomedical engineering, physiology, accidents, traffic – psychology, automobile driver examination, road safety.

1 Background

The technological capabilities offered by modern civilization make society highly mobile, enable unlimited transport of people and goods, support the

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economic development and migration of people, and enable reaching the farthest parts of the world.

The means of transport closest to our everyday life is the car and its universality has resulted in the development of a complex road transport system. In consequence of that, road traffic is today the largest contributor to the total number of communication-related accidents [1].

This paper is about the causes of road events which constitute a risk to the life and health of road users and result in severe social and economic burdens. We focus on the driver, and specifically on his/her physical and mental predispositions and limitations.

The drivers who cause road accidents include predominantly those who ignore the traffic regulations, behave irresponsibly, ignore the speed limits, and especially those who drive with bravado or under the influence of alcohol [1]. Furthermore, the statistics collected for the years 2005–2007 show that drivers around the age of 20 were involved in road accidents almost three times more frequently than those 20 years older [2].

The significant factors related to the road situation and drivers' health condition and affecting the road safety include:

- fatigue: physical, local, general, "cerebral" (drowsiness), mental, lack of energy; those symptoms slow down the response time, increase the number of errors, impede the perception, and increase the aggression level (which are symptoms similar to those after use of alcohol or intoxicants) [3],
- stress, which indicates the direct connection between the body and the mind – it manifests itself through increased pulse and blood pressure [3] and significantly contributes to cardiovascular disorders [4],
- attention strain – resulting from an excessive number of signals reaching the driver; focusing the attention for a long time is very tiring and is more significant that other factors [5],
- microclimate – this is particularly reflected in the behavior of the neural system and the mental sphere [5],
- sight disorders: dazzling, visual illusions [5], twilight vision disturbances [6],
- decision-making and attention-division processes: the ability to extract significant information from a complex background (perception style), ability to divide attention among various tasks, response time in performing complex tasks [1],
- perception and intellectual processes – the influence of memorized experiences, personal attitudes, needs, and external stimuli [1],
- temperament and personality characteristics – they determine the diversification of the self-regulation style and the level of resistance to stress [1],
- cardiovascular system – pulse rate changes may indicate drowsiness or irritation of the driver [7], untreated disorders may lead to dangerous cardiovascular incidents [8–10].

The Directive of the European Community Council [11] and the Regulation of the Minister of Health of the Republic of Poland [12] define the requirements for physical and psychical conditions of candidates for drivers of motor vehicles.

Despite the selection assumed in the legal regulations and implemented thereunder, roads are used also by drivers with hidden disorders, either not diagnosed initially or acquired after obtaining the driving license.

Therefore, it is necessary to periodically verify the health status of the drivers and – even more importantly – to monitor the parameters identifying their condition on a continuous basis.

In consideration of the above issues, we have taken on as our objective developing an index which would reflect the psychophysiological condition of drivers. Our additional objective was selecting a subset representative for the determined index from the full set of results (tests and measurements).

2 Material and methods

The research was based on a database of results of surveys, tests, and measurements performed on a group of 15 rested volunteer drivers. They were classified into two subgroups corresponding to two components of the index: physiological (hereinafter "FIZ") and psychological (hereinafter "PSY"). Subsequently, permitted ranges for elementary results were set. The individual tests (separately in the FIZ and PSY subgroups) were ordered according to the importance of the described properties, with classification into the following categories: fatigue, impairment of consciousness, and loss of psychomotor ability. Each property was assigned a corresponding weight, as shown in Table 1

Table 1: Items of the physiological property survey, with their assigned weights.

No., physiological property	Weight W0[1]	Weight W1[2]
1. Age	1	2
2. Height	1	1
3. Body mass	1	8
4. BMI (body mass index)	1	9
5. Blood pressure before the test (systolic/diastolic)	1	7
6. Blood pressure after the test (systolic/diastolic)	1	6
7. Self-assessment of the sleep quality	1	13
8. Self-assessment of the physical fitness	1	11
9. Physical activity per week	1	12
10. Self-assessment of the current physical and mental state	1	10
11. Average sleep duration	1	14
12. Duration of the last sleep	1	15
13. Number of smoked cigarettes	1	4
14. Diet supplements taken	1	3
15. Medicines currently taken	1	5
[1]Constant weight. [2]Weight in the universal criterion.		

and Table 2. The test significance and allowed value ranges were established on the basis of the literature and statistical analysis of the obtained results (for the subject group).

A diagram of the methodology is shown in Figure 1.

We attempted to maintain homogeneity of the selected sample of drivers. The sample is characterized, among others, by the following properties:

- average age of 32 (from 26 to 45),
- average body mass of 89.5 kg (from 67 to 105 kg),
- average height of 182 cm (from 176 to 190 cm),
- most subjects with higher education, living in cities with a population above 500.000,
- average level of physical fitness (physically active for 2–3 hours a week on average).

Table 2: Psychological tests with weights corresponding to the property significance.

No., test name	Weight W0[1]	Weight W1[2]	Weight W2[3]	Weight W3[4]
1. General survey: car driving experience, education, place of living	1	2	2	2
2. Results from the Japanese Questionnaire	1	18	8	11
3. Results from the Piórkowski Apparatus	1	13	12	15
4. Results from the Alternating Apparatus (cross-test)	1	14	13	18
5. Results from the Poppelreuter Table Test	1	12	14	9
6. Results from the Raven Test	1	3	5	4
7. Results from the FCZ-KT Test	1	7	4	5
8. Results from the EPQ-R Test	1	4	3	3
9. Results from the COPE Test	1	5	6	6
10. Results from the FLIM Test	1	17	11	7
11. Results from the LVT Test	1	10	16	16
12. Results from the RT Test (forms S5 and S9)	1	16	9	12
13. Results from the B19 Test	1	11	15	17
14. Results from the ATAVT Test	1	8	18	10
15. Results from the DT Test	1	15	10	14
16. Results from the PP Test	1	9	17	13
17. Results from the PSS-10 Test	1	6	7	8
18. Results from the MEQ Test	1	1	1	1

[1]Constant weight.
[2]Weight for the “fatigue” criterion.
[3]Weight for the “impairment of consciousness” criterion.
[4]Weight for the “loss of psychomotor ability” criterion.

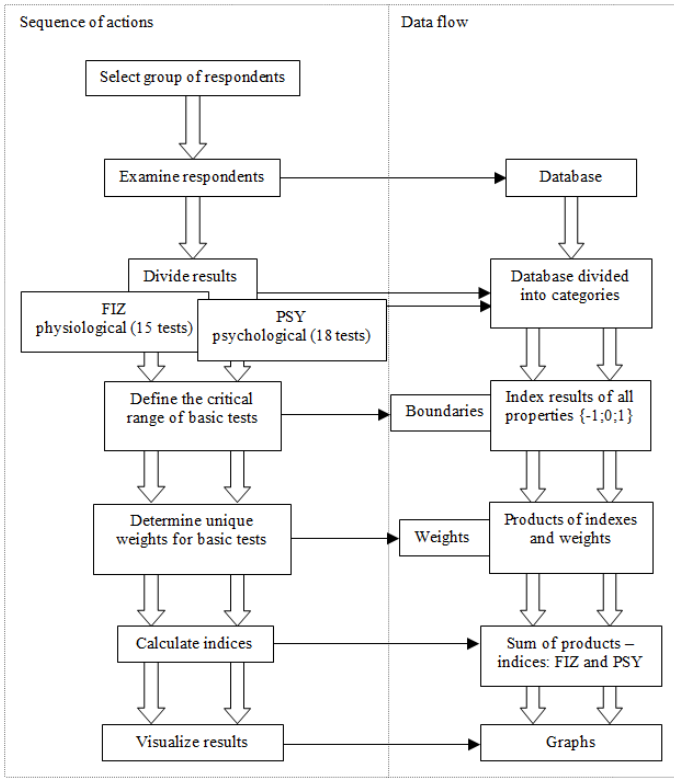

Figure 1: Diagram of the methodology.

On the basis of data prepared in this manner, a method was proposed to calculate the FIZ and PSY indices:

$$\text{FIZ} = \frac{\sum_{i=1}^{m} a_i \, x_i}{\sum_{i=1}^{m} i} \tag{1}$$

$$\text{PSY} = \frac{\sum_{i=1}^{n} b_i \, y_i}{\sum_{i=1}^{n} i} \tag{2}$$

where:
i – sequential number of the physiological/psychological property
n, m – number of measurements/properties/tests
a_i, b_i – weight of the i-th property
x_i, y_i – result (index) of the i-th property, derived from the assumed critical ranges, with one of the following values: {–1, 0, 1}.
The indices for neutral weights are denoted as FIZ_W0 and PSY_W0, and for weights in the individual criteria as: FIZ_W1 – general criterion, PSY_W1 – fatigue, PSY_W2 – impairment of consciousness, PSY_W3 – loss of psychomotor ability.

The result index values are classified as follows: positive (66.7–100%), conditionally permitted (50–66.6%), negative (below 50% of the value range). The normality of the result value distribution was tested with the Kolmogorov-Smirnov test and Lilliefors test (for the significance level of 0.05). The correlations between the FIZ and PSY indices and the elementary test results were calculated. The results of FIZ and PSY were compared and the correlation between them was calculated. Due to insignificant deviations of the individual result distributions from the normal distribution, the Pearson correlation analysis (r) and Spearman rank analysis were applied (no significant differences in the correlation values were detected).

The final index identifying the driver's condition is established as a conjunction of the component indices (FIZ and PSY).

3 Results

The FIZ indices calculated from the assumed formulae satisfy the assumed range criteria in a very similar way. The FIZ_W0 values are significantly higher than the FIZ_W1 values. It means that application of the weights (for the FIZ_W1 set) in most cases (subjects) shifts the results towards the less advantageous values (taking into consideration the assumed ranges). Despite that, all subjects satisfy the limit criterion of –50% (Figure 2).

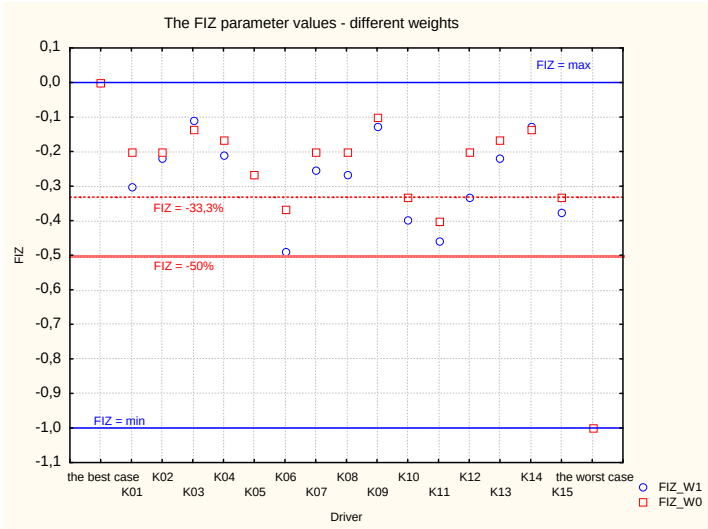

Figure 2: Values of the FIZ index relative to the assumed ranges, for various weights.

The extreme values, denoted as "the best case" and "the worst case", serve for verification of the calculation correctness by indicating the value range limits.

The subjects are identified only by labels from K01 to K15, due to the personal-data protection considerations.

The obtained and presented results show that for all categories, the PSY values are distinctly close to one another (Figure 3). Our analyses clearly show that the main factor determining the PSY value is the position of individual test results relative to the allowed ranges. On the other hand, the influence of the weights upon the whole PSY value seems to be small. More precisely, the weights can shift the result towards the negative or positive extreme only by a few percent.

The above conclusion does not change the fact that if specific limits are assumed to admit or reject a driver, such small shift resulting from the assumed weights may be of critical significance.

As can be seen, candidate K10 would be admitted in the "impairment of consciousness" and "loss of psychomotor ability" categories, but rejected in the "fatigue" category.

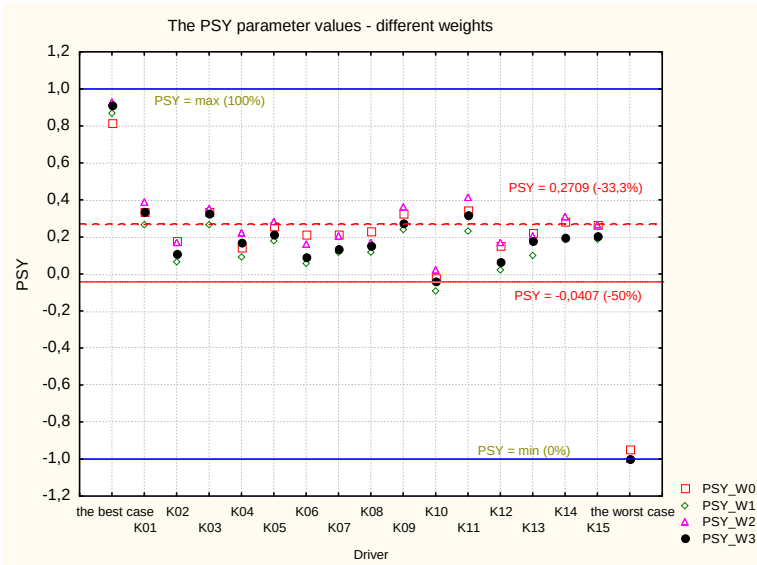

Figure 3: Values of the PSY index relative to the assumed ranges, for various categories (weights).

The normality tests show that the hypothesis of normal distribution of the variable FIZ_W1 cannot be rejected. A different case is with FIZ_W0, whose values are not distributed normally (the distribution is distinctly asymmetric). For psychological indices, the distribution normality hypothesis cannot be rejected in any category.

The analysis of significant correlations of FIZ and PSY with individual test results (Table 3, marked) shows a key relationship between the driving experience and all calculated indices. Additionally, there are the following correlations of indices without weight diversification (W0):

- FIZ with height (–0.55),
- FIZ with taken diet supplements (–0.58),
- FIZ with the number of OSA symptoms reported after work (Japanese Questionnaire) (0.62),
- PSY with the S5 response time (average motoricity time) (–0.72),
- PSY with peripheral vision (tracking deviation) (–0.69).

The general index FIZ_W1 is significantly correlated with sensitivity to stimuli.

The PSY indices by categories show the following significant correlations:

- in the "fatigue" category – with the S5 response time (average motoricity time) (–0.74) and peripheral vision (tracking deviation) (–0.73),
- in the "deteriorated situation awareness" category – similarly as in the "fatigue" category (with the correlation values of –0.73 and –0.64, respectively),
- in the "deteriorated psychomotor skills" – similarly as in the two former categories (with the correlation values of –0.80 and –0.67, respectively) and additionally with the number of smoked cigarettes (0.57) and peripheral vision (right-side viewing angle) (–0.54).

Worth noticing is the repeatable significant correlation between all PSY indices and the S5 response time (average motoricity time) and peripheral vision (tracking deviation).

Particularly worth noticing are the strong correlations of indices having a weight of '1' (FIZ_W0 and PSY_W0):

- FIZ_W0 with height, taken diet supplements, driving experience, and number of OSA symptoms reported after work,
- PSY_W0 with driving experience, S5 response time (average motoricity time), peripheral vision (tracking deviation).

Also worth noticing are the strong correlations of indices with single results (which are not components of those indices):

- FIZ_W0, and FIZ_W1 with driving experience,
- FIZ_W0 with the number of OSA symptoms reported after work,
- FIZ_W1 with sensitivity to stimuli,
- PSY_W3 with the number of smoked cigarettes.

The last examples cannot be suspected of being correlated with the results preferred through the weighting system.

The correlation between the FIZ_W0 and PSY_W0 indices is distinctly low (0.2). It means that the value of one index cannot be used to predict or estimate the value of the other index with sufficient precision.

The final result of the analyses is the driver's condition index. It has a binary value indicating whether the assumed criteria (Tables 4–7) are satisfied. The value is calculated as a conjunction of the values of FIZ and PSY.

Table 3: Significant correlations of the calculated indices with the test results.

Variable	Correlations (DataFIZ&PSY&Params.sta) Marked correlations are significant at p < ,05000 N=14 (Casewise deletion of missing data) Exclude cases: 11 FIZ_W0	FIZ_W1	PSY_W0	PSY_W1	PSY_W2	PSY_W3
Age	0,25	0,14	0,42	0,46	0,42	0,48
Height (cm)	-0,55	-0,51	-0,41	-0,51	-0,49	-0,52
Systolic blood pressure before the test	-0,53	-0,37	0,12	0,15	0,14	0,05
Diastolic blood pressure before the test	-0,39	-0,26	-0,22	-0,20	-0,34	-0,29
Duration of the last sleep	0,49	0,30	-0,05	-0,13	-0,03	-0,10
Number of smoked cigarettes	0,29	0,31	0,45	0,50	0,41	0,57
Diet supplements taken	-0,58	-0,36	-0,23	-0,11	-0,16	-0,14
Car driving experience	-0,75	-0,68	-0,56	-0,62	-0,65	-0,61
Place of living	-0,47	-0,28	0,15	0,21	0,14	0,14
Number of OSA symptoms reported after work	0,62	0,48	0,16	0,22	0,32	0,27
Sensitivity to stimuli	-0,43	-0,55	-0,03	-0,16	-0,17	-0,21
S5 response time - average motoricity time	-0,44	-0,39	-0,72	-0,74	-0,73	-0,80
B19 Test - number of errors	-0,22	-0,15	-0,45	-0,49	-0,47	-0,50
DT Test - median response times 3	-0,36	-0,30	-0,48	-0,47	-0,38	-0,47
PP Test - right-side viewing angle	-0,07	-0,15	-0,48	-0,47	-0,46	-0,54
PP Test - tracking deviation	-0,42	-0,45	-0,69	-0,73	-0,64	-0,67

Table 4: Conjunction of the values of FIZ_W0 and PSY_W0.

	1 FIZ_W0	2 PSY_W0	3 FIZ_W0&PSY_W0 above -33,3%	4 FIZ_W0&PSY_W0 above -50%
K01	-0,2000	0,3333	SATISFIES	SATISFIES
K02	-0,2000	0,1759	-	SATISFIES
K03	-0,1333	0,3333	SATISFIES	SATISFIES
K04	-0,1667	0,1481	-	SATISFIES
K05	-0,2667	0,2546	SATISFIES	SATISFIES
K06	-0,3667	0,2130	-	SATISFIES
K07	-0,2000	0,2176	-	SATISFIES
K08	-0,2000	0,2315	-	SATISFIES
K09	-0,1000	0,3287	SATISFIES	SATISFIES
K10	-0,3333	-0,0185	-	SATISFIES
K11	-0,4000	0,3472	-	SATISFIES
K12	-0,2000	0,1528	-	SATISFIES
K13	-0,1667	0,2222	-	SATISFIES
K14	-0,1333	0,2870	SATISFIES	SATISFIES
K15	-0,3333	0,2639	-	SATISFIES

Table 5: Conjunction of the values of FIZ_W1 and PSY_W1.

	1 FIZ_W1	2 PSY_W1	3 FIZ_W1&PSY_W1 above -33,3%	4 FIZ_W1&PSY_W1 above -50%
K01	-0,3000	0,2705	SATISFIES	SATISFIES
K02	-0,2167	0,0692	-	SATISFIES
K03	-0,1083	0,2705	SATISFIES	SATISFIES
K04	-0,2083	0,0897	-	SATISFIES
K05	-0,2667	0,1769	-	SATISFIES
K06	-0,4875	0,0546	-	SATISFIES
K07	-0,2542	0,1170	-	SATISFIES
K08	-0,2667	0,1209	-	SATISFIES
K09	-0,1250	0,2446	-	SATISFIES
K10	-0,3958	-0,0945	-	-
K11	-0,4583	0,2305	-	SATISFIES
K12	-0,3333	0,0200	-	SATISFIES
K13	-0,2167	0,1004	-	SATISFIES
K14	-0,1250	0,2008	-	SATISFIES
K15	-0,3750	0,1901	-	SATISFIES

Table 6: Conjunction of the values of FIZ_W1 and PSY_W2.

	1 FIZ_W1	2 PSY_W2	3 FIZ_W1&PSY_W2 above -33,3%	4 FIZ_W1&PSY_W2 above -50%
K01	-0,3000	0,3913	SATISFIES	SATISFIES
K02	-0,2167	0,1696	-	SATISFIES
K03	-0,1083	0,3538	SATISFIES	SATISFIES
K04	-0,2083	0,2261	-	SATISFIES
K05	-0,2667	0,2831	-	SATISFIES
K06	-0,4875	0,1628	-	SATISFIES
K07	-0,2542	0,2086	-	SATISFIES
K08	-0,2667	0,1672	-	SATISFIES
K09	-0,1250	0,3650	SATISFIES	SATISFIES
K10	-0,3958	0,0190	-	SATISFIES
K11	-0,4583	0,4118	-	SATISFIES
K12	-0,3333	0,1676	-	SATISFIES
K13	-0,2167	0,2027	-	SATISFIES
K14	-0,1250	0,3080	SATISFIES	SATISFIES
K15	-0,3750	0,2656	-	SATISFIES

Table 7: Conjunction of the values of FIZ_W1 and PSY_W3.

	1 FIZ_W1	2 PSY_W3	3 FIZ_W1&PSY_W3 above -33,3%	4 FIZ_W1&PSY_W3 above -50%
K01	-0,3000	0,3382	SATISFIES	SATISFIES
K02	-0,2167	0,1111	-	SATISFIES
K03	-0,1083	0,3275	SATISFIES	SATISFIES
K04	-0,2083	0,1745	-	SATISFIES
K05	-0,2667	0,2169	-	SATISFIES
K06	-0,4875	0,0897	-	SATISFIES
K07	-0,2542	0,1350	-	SATISFIES
K08	-0,2667	0,1559	-	SATISFIES
K09	-0,1250	0,2753	-	SATISFIES
K10	-0,3958	-0,0341	-	SATISFIES
K11	-0,4583	0,3192	-	SATISFIES
K12	-0,3333	0,0677	-	SATISFIES
K13	-0,2167	0,1803	-	SATISFIES
K14	-0,1250	0,1949	-	SATISFIES
K15	-0,3750	0,2061	-	SATISFIES

4 Discussion

Due to the fact that the sample was not random, the conclusions cannot be generalized to the whole population of drivers [13]. The conclusions are applicable only to the community from which the volunteers have been recruited. A driver condition index value (calculated without weighting the elementary results) differing from the fully correct level by not more than 33.3% was achieved by 5 subjects. In the "fatigue" and "loss of psychomotor ability" categories, the above criterion was satisfied for only two subjects. In the "impairment of consciousness" category, the above criterion was satisfied for four subjects. It means that two subjects retained an acceptable level of consciousness despite fatigue and loss of psychomotor ability.

A particularly distinct result of the analysis of the correlation between the calculated indices and the test results is the negative correlation (in all categories) with driving experience (the correlation is negative due to the method of survey scoring). It means that the more experienced the driver, the higher is the calculated index value.

The driver's height and the number of taken supplements decrease the FIZ_W0 value and a higher number of OSA symptoms reported after work increases the value. The PSY value is decreased in all categories by longer response times and higher tracking deviation levels. A higher sensitivity to stimuli may lead to a decrease of the FIZ_W1 level.

An interesting observation is the positive correlation between the number of smoked cigarettes and the PSY_W3 index which identifies impairment of consciousness. International studies [14] show that taking psychoactive substances containing nicotine has a limiting influence upon dementia processes and the Alzheimer disease. Therefore, it may improve the driver's memory and concentration.

5 Conclusions

In result of the research, we have obtained determinants of the psychophysiological condition of the subject drivers and a group of correlated indices. As results of elementary tests, they are candidate items (inter alia) of a short survey aimed to verify the short-term condition of a driver.

The further directions of research in the field may include comparing the results with results obtained in other circumstances (after traveling, in the evening, at high levels of psychical and physical fatigue), as well as with biological signals recorded during the driving. Also, an attempt could be made to create an automaton to generate sets of weights with an assumed level of dependency of the indices on the elementary results.

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