Arh hig rada toksikol 1990;41:305–314

Review
UDC 614.87

WORKPLACE – WORKER – ENVIRONMENT. AN EXPERT SYSTEM

J. Sušnik, S. Pušnik and T. Sušnik

Occupational Health Centre, Ravne na Koroškem

Received July 23, 1990

In the expert system described stresses due to the workplace and the life environment are represented by characteristics, which are graded from 0 to 5. The same is true of capabilities of the man. The algorithm looks for the compatibility of one with the other. Examples of characteristics, the function of the certainty factor and of steps of examination depth are shown, with particular reference to the cardiovascular subsystem. The expert system »Workplace – Worker – Environment« is proposed to serve as a basic tool in occupational health care.

The compatibility of worker's capacities with stresses at work may be considered as the very fundamental issue of occupational health care. Within the dynamic process of adaptation priority has to be assigned to ergonomics. That, of course, presumes the knowledge of stresses and capacities expressing them in comparable rating values. The huge number of resulting and hard-to-match data calls for computerisation of search. That is, in short, the background of the expert system »Workplace – Worker – Environment«, which matches man's characteristics with those of the workplace and his everyday environment.

HYERARCHICAL TREE

The system is conceived as a hyerarchical tree. The knowledge base of the same grade is arranged on the same horizontal level representing the branches. Knowledge proceeds to depth (the tree actually stands on its top) and simultaneously to breadth to

* A paper on this topic was presented at a meeting held in Zagreb on 9th and 10th November 1988 on the occasion of the 40th anniversary of the Institute for Medical Research and Occupational Health, University of Zagreb.

more specialized items. Each »Workplace – Worker – Environment« system is basically organized in four steps of (knowledge) depth. The first step is based on observations and interviews, like history and inspection, or assessed workplace analysis (AWPA). The knowledge of the second step derives from routine examinations, represented for instance by medical and psychological basic techniques, or routine measuring procedures of the workplace. With the third step the routines used become more specialized. The fourth step is characterized by more sophisticated approaches, often directed to a specific purpose, using however the routine expert knowledge drawn in the form of specific examination programmes. The steps of depth are assigned numbers 1 – 4. The characteristics increase their validity with depth. The results of the next (deeper) step will therefore cancel the results of the preceding one. Our rule is that only the results of the adjoining step, the one above and the one below, are accepted to be matched, otherwise the answer is refused. That means, for instance, that the outcome of a specialist medical examination cannot be confronted with the outcome of an assessed workplace analysis, because the former approach refers to the third step of depth and the latter to the first one. This rule will, hopefully, equilibrate the usually very disbalanced estimates of the knowledge of the workplace (which is poor) and that of the worker's capabilities (which is usually extensive).

CHARACTERISTICS

Single items of the three systems are defined as characteristics. Each characteristic is graded by a specific key, like those of Position Analysis Questionnaire (PAQ) (1 – 3), depending on importance, duration, frequency or intensity of the characteristic.

The manual »Assessing Workplace Analysis« (4) offers a list of about 350 characteristics concerning working means, materials and operations and, predominantly, questions about the working system, working tasks, working demands, work-related stresses, strains and health risks. Each characteristic is defined by a code number, estimation rate (usually 0 – 5), and a numerical value (factor) of certainty (0.1 – 1.0) (5). The method had good examples in Das Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse (AET) (6) and the formerly cited PAQ. An analogous manual referring to the worker and to his everyday environment is in preparation.

ALGORITHM

The general rules and user's interface of the system have been elaborated. Some subsystems have been put in function, the others are waiting to be developed. The main question concerns not so much the lack of enthusiasm and knowledge, as the never ending lack of funds. Firstly the characteristics of the workplace that have been defined as critical can be selected according to a simple computer programme, thus making the base of preventive health care. Likewise, all characteristics with a low certainty factor may be taken out, and proposed for »deepening« the method of examination.

The main questions, however, are the following: A. Are abilities of the worker X compatible with the demands of the workplace Y? If they are not, A.1 Which (in)abilities of the worker are not compatible? A.2 Which demands of the workplace are not compatible? B. Which workplaces from the given population of workplaces nY are compatible with the abilities of the worker X? C. Which workers from the given population of workers nX are compatible with the demands of the workplace Y?

Answers to these questions will give information on the workability of a single worker at a single workplace (A), sources of work inability and possible ergonomic solutions (A.1 and A.2), search of adequate workplace for a given worker (B), the extent of the workplace incompatibility with man's workabilities (C).

The system works in the mode of forward chaining using »if-then« rules to deduce a problem solution from initial data. These are represented by characteristics evaluated with attribute values (scores). The user enters the commands by highlightening the menu and proceeds in the manner of a scrolling dialogue. The algorithm matches the estimation rates of characteristics of the workplace on one side with those of the worker on the other looking for the answer of compatibility (Figures 1 and 2). In Figure 1 the compatibility of stresses at the workplace with the worker's capabilities is figuratively demonstrated like a tube through which stresses and (dis)abilities pass. While stresses grow (0 to 5), disabilities decrease (5 to 0). Figure 2 demonstrates the dynamic interaction of work stresses, defined by characteristics and worker's capabilities,

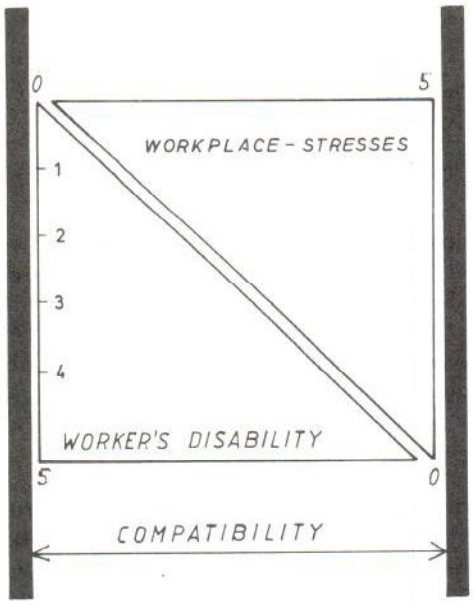

Figure 1. *Compatibility of work stresses and worker's capabilities*

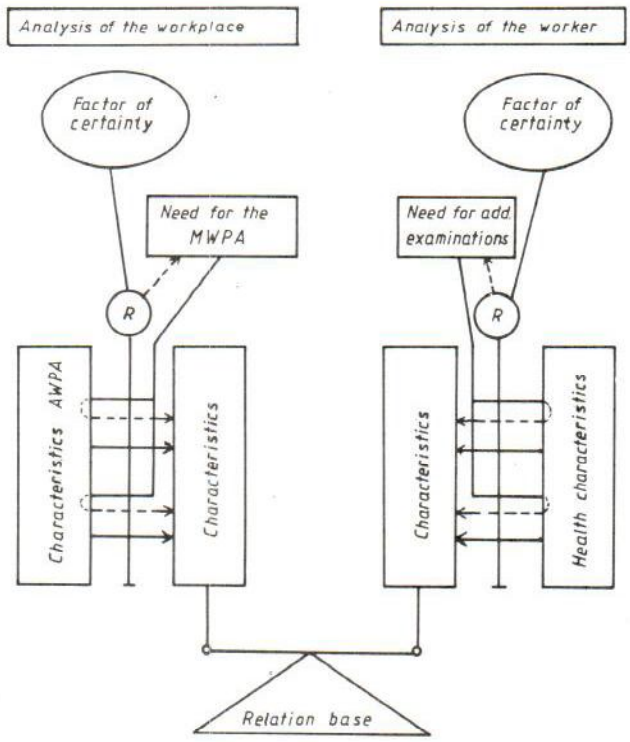

Figure 2. *Interaction between work stresses and worker's capabilities*

analogously defined by characteristics. If the applied methods of examination do not ensure sufficient certainty to the characteristic, the need for a deeper analysis will be required. For instance, the characteristics defined by AWPA will have to be measured (MWPA) by more and more sophisticated methods, or on the other hand worker's history and clinical status (health characteristics) will have to be taken by means of more and more sophisticated medical techniques.

Cardiovascular subsystem – an example

As example we show the structure of the cardiovascular subsystem. Nineteen stresses and strains have been selected as relevant characteristics of the workplace and assigned spans of estimation grades and factors of certainty (F). These are: hot climate in inner rooms (grade 0 – 5, F 0.6), cold climate in inner rooms (grade 0 – 4, F 0.6), weather influence (grade 0 – 3, F 0.8), worker burdening by protective means (grade 0 – 5, F 0.9), duty for the day (grade 0 – 4, F 0.9), overtime work (grade 0 – 5, F 0.9), interpersonal

conflicts (grade 0 – 5, F 0.6), frustration (grade 0 – 5, F 0.6), time pressure (grade 0 – 5, F 0.6), heavy muscle dynamic activity of arms and upper torso (grade 0 – 5, F 0.6), heavy muscle dynamic activity of legs and lower torso (grade 0 – 5, F 0.6), energy uptake (grade 1 – 4, F 0.7), use of force at isometric muscle activity (grade 0 – 5, F 0.6), use of force at one sided dynamic muscle activity (grade 0 – 5, F 0.6), use of force at heavy dynamic muscle activity (grade 0 – 5, F 0.6), risk while driving motor vehicle in public traffic (grade 0 – 5, F 0.7), risk while exposed to electric circuit (grade 0 – 5, F 0.7), frequency and gravity of heart disturbances (grade 0 – 5, F 0.6), frequency and gravity of cardiovascular disturbances (grade 0 – 5, F 0.6).

Hot climate, for instance, will be first evaluated by AWPA as shown in Table 1. If certainty is less than 0.6, assessment may be corrected by measurements (MWPA) of

Table 1.

Estimation of the intensity and time of exposure to the hot environment. Workplace.

Hot environment	Grade Time of exposure		
	$t < 1/2$	$1/3 < t < 2/3$	$t > 2/3$
Neutral (comfortable)		0	
Little deviating from neutral	1	2	3
Considerably deviating from neutral	2	3	4
Tolerance limit	3	4	5

Table 2.

Estimation of the energy output. Workplace.

Energy uptake	Energy consumption (kJ min^{-1}) Men	Women
Low	≤ 16.3	≤ 12.1
Moderate	16.7 – 32.6	12.6 – 17.6
High	33.0 – 49.0	18.0 – 27.2
Very high	> 49.0	> 27.2

low = 1, moderate = 2, high = 3, very high = 4

summary climatic indices, body temperatures, sweat rate or the climatic component of the heart rate, i.e. parameters of the second step of depth. Further examples are energy uptake (Table 2) and interpersonal conflicts (Table 3). Energy uptake is assessed

Table 3.

Estimation of the intensity and frequency of interpersonal conflicts. Workplace.

Interpersonal conflict (intensity)	Frequency (grade)		
	Seldom (once a month)	Repeatedly (up to twice a week)	Continuously (several times a day)
Not existing		0	
Small	1	2	3
Moderate	2	3	4
Great	3	4	5

applying the table of energy consumption due to body postures and assessed activity of body segments. At the second step of depth, if certainty is less than 0.7, energy uptake can be measured as the actual oxygen consumption. Interpersonal conflicts are graduated by a combined key expressing the frequency and intensity of the characteristic. If the factor of certainty is less than 0.6, psychological examinations could bring more clarity and improve the assessment (next step of depth).

On the other side there are relevant characteristics belonging to the man. Those relating to the cardiovascular system (CVS) are condensed to five main phenomena: specific history (grade 1–4, F 0.6), specific clinical status (grade 1–4, F 0.7), blood pressure (TA) (grade 1–6, F 0.8), electrocardiogram (ECG) (grade 1–4, F 0.8), and maximal aerobic capacity (MAC) (grade 1–5, F 0.9). The figures cited have the same meaning as those in the group of the workplace characteristics. Now we give three examples of the characteristics relating to man's CVS capacities. The clinical status, for instance, is graded in four steps (Table 4.). The CVS status counts as the first depth or

Table 4.

Estimation of clinical CVS status. Worker.

Status	Grade
No CVS signs	1
Single signs, but irrelevant for general work ability	2
Signs that could affect workability like neurovegetative disfunctions, organic alterations of the thorax, functional heart murmurs, altered intensity of heart sounds of non-characteristic propagation	3
Signs that affect workability like vascular disorders, dyspnoea, oedema, cyanosis due to CVS, organic murmurs	4

Table 5.

Estimation of ECG signs. Worker.

ECG	Grade
Normal ECG	1
Ectopic beats, first degree AV block, PQ more than 0.28 s, right bundle branch block	2
ST depression till 1 mm, second degree AV block, left bundle branch block, ventricular hypertrophy, hypertrophy of the right atrium	3
Severe disturbances of the rhythm, ischaemic reaction, bifascicular blocks	4

Table 6.

Estimation of the maximal aerobic capacity. Worker.

Maximal aerobic capacity (MAC) ml kg^{-1}		Grade
Men	Women	
above 48	above 46	1
37–47	35–45	2
31–36	27–34	3
21–30	18–26	4
less than 21	less than 18	5

recognition (7–10). The next example, ECG, is also dealt with in four steps (Table 5). The standard and unipolar limb leads and the six chest leads at rest are taken to be the second depth of recognition. The third example is represented by evaluation of the MAC expressed in millilitres per kg^{-1} body mass (Table 6). The MAC values are valid as the second depth of recognition.

Based on the expert knowledge the compatibility between some workplace stresses and worker's capabilities is given in the synoptic Table 7. For instance »hot climate« of grade 3 is supposed to be compatible with grades 1, 2, 3 of »ECG«. In a similar way all other characteristics of stresses relevant to CVS are matched against characteristics of CVS capacities. Here four of them have been selected with the aim to show the system's algorithm.

Example. The climate at the workplace is hot, slightly above the climatic comfort. At heavy dynamic muscle work of arms and upper torso during one third of the shift duration the energy uptake is estimated to be 25 kJ /min (about 1.2 L/min oxygen). Twice a week moderate conflicts occur between the foreman and the worker (Table 8).

Table 7.

Compatibility of selected workplace stresses with worker's CVS capacities

Stresses	Grade of estimation	CVS capacities and compatible grades				
		History	Status	TA	ECG	MAC
Hot climate	0, 1	1–4	1–3	1–5	1–4	1–4
	3	1, 2	1, 2	1–4	1–3	1–3
	4	1, 2	1, 2	1–3	1, 2	1, 2
	5	1, 2	1, 2	1, 2	1	1
Energy output	0, 1	1–4	1–3	1–5	1–4	1–4
	2	1, 2	1, 2	1–4	1–3	1, 2
	3	1, 2	1, 2	1, 2	1, 2	1, 2
	4	1, 2	1, 2	1, 2	1	1
Heavy dynamic muscle activity of arms and upper torso	0, 1, 2	1–3	1–3	1–5	1–4	1–4
	3	1, 2	1, 2	1, 2	1	1–3
	4, 5	1, 2	1, 2	1, 2	1	1, 2
Interpersonal conflicts	0, 1, 2	1–4	1–3	1–5	1–3	1–5
	3	1–3	1–3	1–4	1–3	1–5
	4, 5	1, 2	1–3	1–3	1, 2	1–5

Table 8.

Four characteristics of the workplace relevant to CVS estimated in relation to the grade of the stress, certainty factor and examination depth

Characteristic	Grade	F	Depth of examination
Hot climate	3	0.7	1
Energy output	2	0.5	1
Heavy dynamic muscle activity of arms and upper torso	3	0.5	1
Interpersonal conflicts	3	0.8	1

The certainty factors of the characteristics »energy output« and »conflicts« are too low and should be measured to increase the validity of estimation. The worker at this workplace has no history of CVS signs. Some audible auscultatory ectopic beats are proved with ECG at rest as ventricular extrasystoles. Blood pressure at rest is elevated (145/100). The maximal aerobic capacity is 30 ml/kg. The certainty factors at TA and

Table 9.

Five characteristics of the worker relevant to CVS estimated in relation to the grade of physiological capacity, certainty factor and examination depth

Characteristic	Grade	F	Depth of examination
CVS history	1	0.8	1
CVS status	2	0.8	1
TA	2	0.7	2
ECG	2	0.6	2
MAC	3	1.0	2

ECG of 0.7 and 0.6 are too low and should be measured to increase the validity of estimation (Table 9). Measurements during ergometry are proposed. The actual results are not compatible at two points because of ectopic beats and because of MAC. The oxygen uptake at the workplace should be carefully measured and the results submitted to revision.

CONCLUSIONS

The expert system »Workplace – Worker – Environment« may serve as a tool in occupational health care, searching for accordance of work stress data and those of worker's capabilities. The same is true of the life environment. Confronted with inadequate work for disabled persons one becomes increasingly aware of ergonomic problems. The practitioner will enjoy the easy kind of planning of the contents and terms of preventive health examinations. The coded language on the other hand, demands exact formulations of items and clear, consistent relations among them instead of more fluid subjective viewpoints. The expert system has attained a certain stage of development, but it is subject to permanent evolution.

LITERATURE

1. *Mc Cormick EJ, Jeannert PR, Mecham RC.* The development and background of the Position Analysis Questionnaire (PAQ). Occupational Research Center, Purdue University, 1969, (Prepared for Office of Naval Research under contract No.1100(28), Report No 5).
2. *Mc Cormick EJ, Jeannert PR, Mecham RC.* A study of job characteristics and job dimensions as based on the Position Analysis Questionnaire (PAQ). J Appl Psychol 1972;56:347–68.
3. *Mc Cormick EJ, De Nisi AS, Shaw JB.* Use of the Position Analysis Questionnaire for establishing the job component validity of tests. J Appl Psychol 1979;64:51–6.
4. *Sušnik J, Erjavšek B, Gladež E. et al.* Ocenjevalna analiza delovnega mesta. Gospodarski vestnik 1983;1–221.

5. *Meritt D.* Building expert systems in Prolog. New York, Berlin, Heidelberg, London, Paris, Tokyo, Springer Verlag 1989;1–341.
6. *Rohmert W, Landau K.* Das arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse (AET). Bern, Stuttgart, Wien: H. Huber Verlag, 1979:1–266.
7. *Acceto B.* Osnove internistične propedevtike. Ljubljana: Medicinska fakulteta, 1987:13–26,96–125.
8. *Najdanović B, Josipović V, Lambić J. et al.* Diagnostički kriteriumi za ocenu radne sposobnosti obolelih od kardiovaskularnih obolenja. Beograd: Republička zajednica penzijskog i invalidskog osiguranja radnika, Beograd, 1972:1–272.
9. *Braunwald E. et al.* Disorders of the cardiovascular system. Part IV. In: Braunwald E, Isselbacher KJ, Petersdorf RG, Wilson JD, Martin JB, Fanci AS. eds. Morison's principles of internal medicine, 11th ed. vol. 1. New York: Mc Graw Hill, 1987:863–937.
10. *Đurđević V.* Ergometrija. Zagreb: Medicinska knjiga, 1978.

Sažetak

RADNO MJESTO – RADNIK – OKOLIŠ. EKSPERTNI SISTEM

U opisanom ekspertnom sistemu stresovi kojima je radnik izložen na radnom mjestu i u životnom okolišu prikazani su pomoću karakteristika koje se ocjenjuju brojem od 0 do 5. Na isti način vrednuju se i radnikove sposobnosti.

Algoritmom se traži kompatibilnost jednih i drugih. Dani su primjeri karakteristika, uloga faktora sigurnosti i stupnja dubine ispitivanja, s osobitim osvrtom na kardiovaskularni podsistem. Ekspertni sistem Radno mjesto – radnik – okoliš može poslužiti kao osnovno sredstvo rada u službi medicine rada.

Dispanzer za medicinu rada, Ravne na Koroškem