THE APPLICATION OF PSYCHOLOGICAL METHODS FOR EVALUATION OF EFFECTS OF OCCUPATIONAL EXPOSURE TO NEUROTOXIC SUBSTANCES *

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Abstract. The article presents the role of psychological studies on evaluation of the effects of occupational exposure to neurotoxic substances. Psychological studies are particularly useful for detecting early (subclinical) symptoms, which may be prodromes of occupational diseases. New tendencies in application of psychological methods for occupational diseases prevention: (a) Neurobehavioral Core Test Battery (b) test batteries computerization, (c) subjective methods, (d) cognitive approach, are discussed.

INTRODUCTION

One of the tasks of an occupational health service is possibly the earliest detection of the changes in health status which show that the process of negative impact of working conditions on man has started. Early detection of such changes will make it possible to undertake effective steps leading either to the elimination or to the inhibition of the pathological process. Many authors (1,5,6,8,12) are of the opinion that the earliest information on the negative effect of work on man can be provided by psychological methods because they enable registration of changes on the functional (behavioral) level, before development of structural changes in the organism. The second kind of change frequently does not recede in spite of the removal a man from the impact of the

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noxious agent. In the case of changes of the first type, such an action can prove to be a sufficient procedure. This supports a statement that psychological methods make feasible the organization of more effective prevention.

Psychological methods for detecting early symptoms of adverse effect of working conditions

First information on the occurrence of changes in the mental functions resulting from occupational exposure to chemical compounds came from examinations carried out by clinical psychologists diagnosing workers hospitalized due to occupational poisoning, either ascertained or suspected. The most prevalent were poisonings with organic solvents, heavy metals, carbon monoxide and pesticides. The psychological changes in persons poisoned with the mentioned chemical compounds were evident and pointed to central nervous system damage. Hence, the question arises whether occupational exposure to chemical compounds at level not-inducing poisonings evokes some changes in mental functions. The occurrence of such changes could be treated as a prodrome of poisoning, and preventive action started at that stage could prevent severe health impairment. In order to explore this question, studies were undertaken — independently in several institutes — aimed at finding out the effects on the mental functions, including the central nervous system of acute and long term exposure to chemical compounds at low concentrations. The first type of investigation was carried out in toxicological chambers on animals and on men-volunteers. The characteristic features of these studies were: (a) precise measurement and determination of the exposure level as well as precise measurement of tasks performance, which were indicators of the changes in mental functions; (b) relatively short period of exposure (up to several hours); (c) the use of homogeneous pure chemical compounds. Examples of investigations of that kind on the effect of solvents on the psychonervous system are the investigations of Salvini (16) and Steward (18). Studies of that type are continued although they are most frequently aimed at finding out the combined effect of chemical compounds e.g. a solvent and an alcohol which approximated the experimental conditions to the real ones (11).

The weak point of the experimenst carried out in toxicological chambers was the short period of exposure to the relatively low cencentrations of chemical compounds which evoked some slight changes in the mental functions lasting for a short time. This was not helpful in obtaining univocal results. Hence, there was a need to undertake investigations on the long-term effect of exposure to chemical compounds in the work-

ing environment. The procedure of these investigations was similar and consisted in a comparison of the rules of testing the persons exposed to a given chemical agent with the results of the unexposed persons, or comparing the results of persons whose level of occupational exposure was different (level of exposure x duration of exposure). Attention was paid to the selection of individuals for the compared groups to make them comparable with regard to some socio-demographic variables such as age, sex and education.

The detected differences in performing the used tests were considered to be a proof of impairment of the mental function measured by particular tests. Next, the single tests were combined into a test battery and used for screening examinations of persons working under the determined, noxious conditions. A considerable number of psychological investigations on long-term occupational exposure to various neurotoxic substances were carried out. As an example here, consider studies carried out by Z. Makowska (13,14) who, tested impairment of psychomotor efficiency in persons occupationally exposed to carbon disulfide.

Concentration on the sphere of the psyche resulted from the fact that there is a relatively small number of reports on the effect of CS_2 on psychomotor efficiency. In addition, it is known that the results of psychomotor tests depend, to a significant degree, on the level of some mental functions and attention concentration, i.e. those elements which are subject to particular disturbances under the influence of CS_2. The study covered two groups of persons: 126 workers exposed to CS_2 and 126 unexposed individuals. Both groups were comparable as the pairs were selected according to sex, age and education. All persons were examined with a set of tests which enabled evaluation of the following psychomotor skills: eye-hand coordination, coordination of two hands, precision of palm movements, sped of tapping, manual dexterity, finger dexterity and simple and choice reaction time.

The obtained results are presented in Table 1. In the case of 9 from among 12 variables it was found that persons from the group exposed to CS_2 obtained statistically significant lower results (longer performance time, more mistakes, lower performance efficiency).

As psychomotoric efficiency decreases together with the process of aging (15), rate of the weakening of this efficiency was compared in the exposed and controlled groups, in order to compare the effect of exposure to CS_2 with the effect of aging. The obtained results are presented in figures from 1 to 9. On the X-axis the age intervals are laid out and on the Y-axis — the parameters of test performance: seconds, the number of movements, etc. "B" stands for the coefficient of the regression line slope. The presented diagrams explicitly show that ex-

TABLE 1. Comparison of the Level of Results Obtained in Psychomotor Test in a Group of Persons Exposed to CS_2 and in the Control Group

Kind of task	Mean values		Differences in %
	CS_2	Control	
1. Manual dexterity test (performance time in sec)	87.8	77.6***	13.0
2. Finger dexterity test (number of filled holes — efficiency of work)	34.5	38.5*	10.3
3. Simple reaction time (msec)	357.5	283.4***	26.2
4. Choice reaction time (msec)	563.8	446.0***	26.4
5. One-plate tapping — efficiency of work (number of tappings)	172.8	191.7***	9.9
6. Two-plate tapping — work performance — (number of tappings)	127.1	142.4***	10.7
7. Tremor (number of errors)	76.4	69.8	9.4
8. Eye — hand coordination test (performance time — sec)	116.4	100.4***	19.5
9. Eye — hand coordination test (number of errors)	3.1	3.0	6.4
10. Turner test for independent movement of two hands (performance time in sec)	348.3	352.8	6.9
11. Turner test for independent movement of two hands (number of errors)	24.7	14.1***	75.5
12. Turner test for independent movement of two hands (error time in sec)	43.9	23.9***	83.3

* $p < 0.05$
*** $p < 0.001$

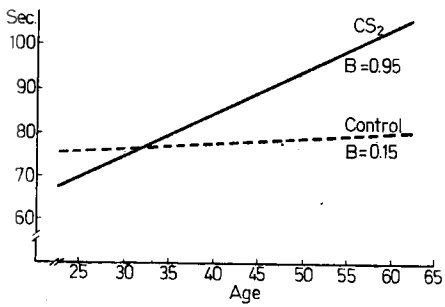


Fig. 1. Manual dexterity test (performance time in sec.).

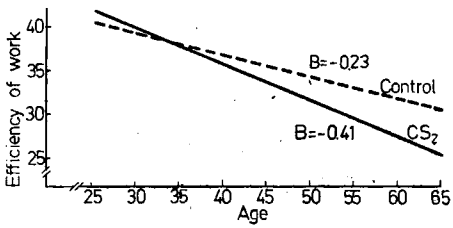


Fig. 2. Finger dexterity test (number of filled holes — efficiency of work).

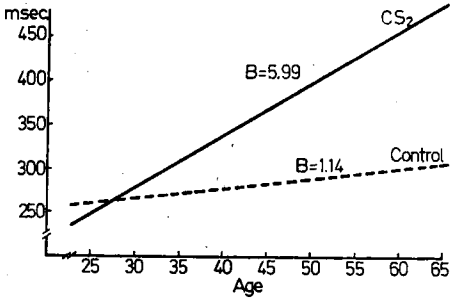


Fig. 3. Simple reaction time (msec.).

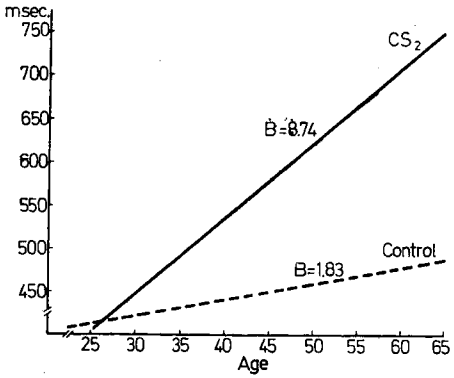


Fig. 4. Choice reaction time (msec.).

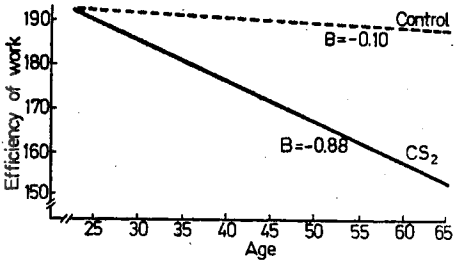


Fig. 5. One-plate tapping-efficiency of work (number of tappings).

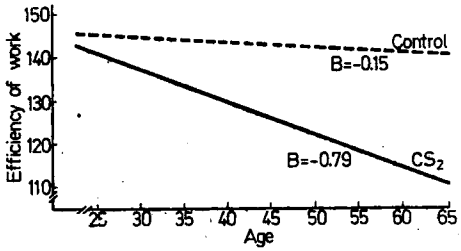


Fig. 6. Two-plate tapping-work performance — (number of tappings).

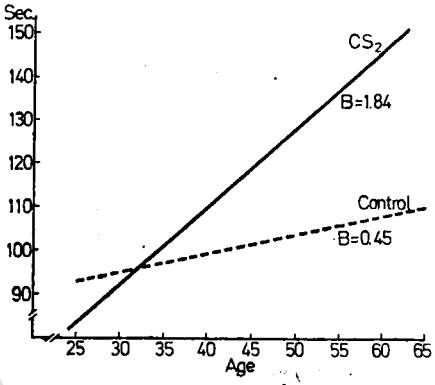


Fig. 7. Eye-hand coordination test (performance time — sec.).

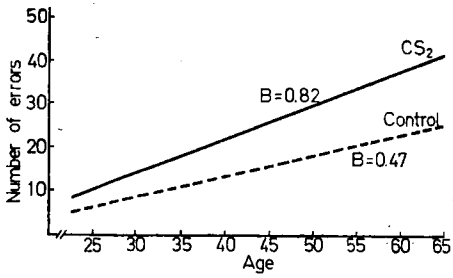


Fig. 8. Turner test for independent movement of two hands (number of errors).

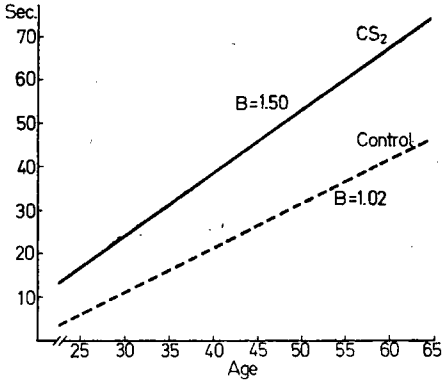


Fig. 9. Turner test for independent movement of two hands (error time in sec.).

posure to CS_2 impairs psychomotoric efficiency to a much larger extent than the process of aging.

The presented studies of Makowska are an example not only of typical research procedures used with regard to these problems, but also of typical, i.e. the most frequently met, analysis of results.

Analysis of psychological studies of persons exposed to neurotoxic substances

As I have already mentioned, many investigations have been made in which psychological methods were applied for the evaluation of the effects of exposure to chemical agents (6). The analysis of these studies enables us to distinguish three features characteristic of them.

(a) Most of them are made within the psychometric paradigm based on the behavioristic S-R conception according to which the examined person is shown a task (S-stimulus), and the task performance (R-reaction) is registered, i.e. measured. Next, the level of task performance by the designated groups of persons is compared. If there is a difference in the level of performance, attempts are made to find the reason for it, referring to the variables discriminating the compared persons. In this paradigm, the intermediary processes between stimulus and reaction, between the task and task performance, are ignored. For instance, many stages of information processing, which must take place if a given stimulus is to be followed by a given reaction, are not taken into consideration. Maximum objectivization of the investigation is the result of car-

rying on research according to the psychometric paradigm. This arises from the fact that both the stimulus (task) and reaction (performance) can be measured operationally. On the other hand, learning the mechanism which binds stimulus with reaction is abandoned. For behaviorists, this was the famous "black box" into which a scientist should not look. In our opinion, this paradigm is sufficient for the realization of some scientific aims. For most of the examinations the aim of which was to obtain an answer to the question whether exposure to agent X has an effect on man it was enough to determine the differences in test performance. Not much can be said, however, on the problem of the mechanism of e.g.: task performance deterioration. If a scientist is interested in such a mechanism, he should rather change the paradigm and plan such examinations according to the cognitive approach. This problem will be dealt with further on in this paper.

(b) The great variety of applied scientific methods is another feature of the analysed studies. Cassitto (1) compared test batteries applied in various centres and revealed the differences between them. Some centres used batteries consisting of four tests, others applied 14 test-batteries. In each centre, different test batteries were used, though some applied tests were the same (e.g.: Wechsler Digit Symbol, Simple Reaction Time). The diversity of test batteries results from tradition and attachment to some methods, from more experience in their application. This variety results in the possibility of checking the usefulness of a larger number of tests, on the one hand, and in difficulties in comparing the obtained results on the other. It is not known whether various tests which are to measure the same psychical functions really measure them.

(c) Most of the studies in the fields we are interested in are of the cross-sectional type and deal with the state of mental functions of a group of persons at a given moment comparing it with the state of functions of another group, also measuered at a given moment of time. The changes which result from the lengthening of the time of exposure to a neurotoxic agent, are not observed. The reason why cross-sectional examinations outnumber follow-up ones is that it is easier to organize studies of the first type. The weakness of cross-sectional examinations is that they do not give answers to very important questions, e.g.: when the first symptoms of occupational disease occur, what the consequences of the earlier registered changes in mental functions are, after what time and with what probability functional disturbances lead to organic changes. These questions can be answered only by making studies of the follow-up type.

New tendencies

Psychological studies on the effects of exposure to various neurotoxic compounds are developing rapidly. This results from the fact that in the continuously increasing number of centres dealing with the protection of workers' health, scientists have become aware of the advantages to be derived from these studies. The quantitative development of studies, new technical possibilities and the asking and setting up of more and more precise questions and aims have led to some qualitative changes. They can be formulated in the following points:

(a) Neurobehavioral Core Test Battery

In order to improve the possibility of comparing the results of the examinations, the group of experts (acting on the initiative of WHO) suggested that in all centres dealing with the health effects of exposure to neurotoxic compounds, a uniform test battery should be used. This suggestion does not hamper the application of freely chosen tests in particular centres. We recommend administration of the Neurobehavioral Core Test Battery (as presented in Table 2) among any other tests used. This will facilitate comparison of results as well as accumulation of data on health effects of exposure to chemicals.

The tests within the battery have been selected according to the following criteria: the test battery should be short, testing should cover the range of mental functions, the tests should be easy to apply, the results should not be affected by any cultural factors. In our opinion the test battery proposed satisfies all these requirements. We intend to administer the battery for psychological examinations at the Institute of Occupational Medicine in Lodz. We hope that WHO assistance on the activities devoted to the development of the Neurobehavioral Core Test Battery will soon contribute to its wide dissemination.

TABLE 2. WHO Neurobehavioral Core Test Battery (NCTB)

Test	Function domain tested
Profile of Mood States	Affect
Simple Reaction Time	Attention (Response Speed)
Digit Span	Auditory Memory
Santa Ana dexterity test (Helsinki Version)	Manual Dexterity
Digit Symbol	Perceptual-Motor Speed
Benton Visual Retention (Recognition Form)	Visual Perception/Memory
Aiming (Pursuit Aiming II)	Motor steadiness

(b) Microcomputer test batteries

Technological advancement as regards data processing has facilitated the development of automatic systems for presenting stimulus tasks and recording respective reactions. Microcomputer test batteries of various kind have been utilized in many centres (10). Several such batteries were presented at the Second International Symposium on Neurobehavioral Methods in Occupational and Environmental Health, Copenhagen, 1985. As evidenced by our experience, however, some psychologists fear that handling computer tests evokes stress in the subjects who are not familiar with electronic data processing techniques. This stress, in turn, may adversely affect results obtained. Although, in principle, we do agree that this factor has to be taken into account, we presume the fears are exaggerated. Simply using a pencil or a ballpen may also be stressful for some people. This problem, we believe, can be solved by means of proper test administration which would eliminate or lessen undesirable emotions during testing.

Introduction of computer data processing to psychology brings about numerous benefits including maximum standardization of testing procedures, accuracy of results, computing the indicators which could not be obtained by means of traditional testing, rapid and precise computation of results, easy and economical data collection. It is expected that the benefits presented above will outweigh the fears of some psychologists. At the same time, we do realize that some testing, especially as regards clinical psychology, should not and will never be subject to computerization.

(c) Subjective methods

These methods have become more and more often used in test batteries. Subjective methods make it possible for the subject to express his/her subjective feelings, moods and emotions (3,7,9). The test usually takes the form of a symptomatological questionnaire or a scale of adjectives denoting various emotions. At present, aliments and mood changes are assumed to be the earliest symptoms of somatic disturbances.

However, these methods require particular attention and an observance the psychometric principles of construction and application of the subjective tests. An example which illustrates some undesirable effects of the use of subjective methods is a study carried out by Dudek and Nowacki (3). For the study, the Hänninen's symptomatological questionnaire was used in order to evaluate the effects of chronic exposure to perchloroethylene (PER) in 36 dry cleaners. The control group were 35 laundry workers. Both groups were to perform the same occupational activities.

Table 3 presents the results of this study as well as those of a similar study concerning exposure to lead which was conducted at the Institute of Occupational Health in Helsinki.

The workers exposed to lead complained more often about various ailments. As regards the Polish study, there were only two significant differences with respect to ailment reporting by the exposed and unexposed workers. Does that mean that exposure to PER produces less

TABLE 3. Mean Score in Particular Scales of SSQ in Persons Exposed to Lead and Tetrachloroethylene

Symptom category	Helsinki			Lodz	
	Referents	Lead I	Lead II	Referents	Tetrachloroethylen
Fatigue	0.1	1.2****	1.7****	2.8	2.6
Sleep disturbances	0.1	0.5	0.6***	1.0	1.4
Absent-mindedness	0.3	0.8	1.4***	1.8	2.1
Depression	0.1	0.9***	0.6***	1.3	1.4
Lability	0.4	1.0	1.0**	1.6	1.7
Neurovegetative	0.2	0.8**	1.0***	2.2	2.1
Gastrointestinal	0.0	0.4***	0.9****	1.1	0.7*
Neurological I	0.1	0.6**	1.3****	1.4	2.1**
Neurological II	0.1	0.3	0.9****	0.9	1.3

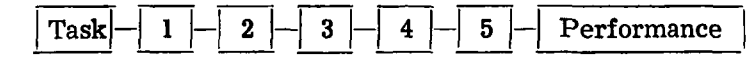
* — $p < 0.10$
** — $p < 0.05$
*** — $p < 0.01$
**** — $p < 0.001$

health impairments? Such a statement could be controversial. It should be noted that ailment reporting by workers in Poland is considerably higher than in Finland. Hence this tendency may have contributed to the fact that the symptomatological questionnaire has become a less sensitive instrument in Poland.

These results have been presented not with a view to disparaging subjective methods but rather to emphasize the necessity of developing methods which would have a discriminative power appropriate for the given cultural conditions as well as including control scales to detect simulation or dissimulation of the subjects.

(d) Cognitive approach

There have been some suggestions in the literature for the psychologists dealing in the evaluation of effects of exposure to neurotoxic agents that the psychometric paradigm should be abandoned and the methodological achievement of cognitive psychology made use of (4,8). Some reports have already appeared on the usefulness of data processing for evaluating the effects of exposure (2,17). In order to better recognize the need for the cognitive approach let us analyse the following scheme



1,2,3,4,5 — mental functions or stages of data processing

In the psychometric approach, the researcher deals only with test administration and measuring its performance. All the intermediate stages, between the task and its performance, are ignored. Let us consider a situation when the test performance declines. We cannot state which of the intermediate elements may be responsible for this. There are three different possibilities: 1) one element has become impaired, 2) more than one element have become impaired, 3) some elements may have become impaired while others may have improved. As a result, a test has been found which can be used for evaluating the effects of exposure although the underlying mechanism of the decline in test performance has not been discovered. The mechanism itself, however, may not be considered as the objective if e.g. the investigator is interested only in seeking out the workers who require more detailed examinations.

Nevertheless, if the methods of measuring the intermediate elements were available, a more sensitive method of evaluating the effects of exposure could be developed, and consequently a more accurate picture obtained of disturbances resulting from exposure to a noxious agent.

Let us now consider the situation in which no decline in test performance occurs i.e. if there are no differences between the results obtained either from the exposed or the unexposed group. The result will be ambiguous since it does not indicate the lack of differences between the groups. Several factors may have accounted for this, namely: 1) one intermediate element has become impaired, but the change is too small to be detected during the recording of task performance, i.e. the test has appeared not to be sensitive enough; 2) the impairment of one element could be compensated in the course of the intermediate process.

In the cognitve approach, the researcher attempts to measure the processes between the task itself and its performance. Thus, that approach seems to be more advantageous than the psychometric one. At the Institute of Occupational Medicine, psychological examinations are carried

out according to the cognitive approach. It seems that the activities which should be undertaken promptly and developed in an international collaboration, are an attempt to determine the prognostic value of test results, particularly when mental function disturbances cannot be regarded as the symptoms of evident and/or initial pathology.

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