Polish Journal of Occupational Medicine Vol. 3, No. 1, 117-127 1990

THE PSYCHOLOGICAL EFFECTS OF CHRONIC EXPOSURE TO WHITE SPIRIT IN RUBBER INDUSTRY WORKERS

BARBARA BAZYLEWICZ-WALCZAK, MAGDALENA MARSZAL-WIŚNIEWSKA and ALEKSANDRA SIUDA

Department of Work Psychology, The Nofer Institute of Occupationl Medicine, Lodz, Poland

Key words: Organic solvents, Psychological functions, Cross section study, Occupational long-term exposure

Abstract. The aim of the study was to determine the effects of chronic occupational exposure to white spirit on the efficiency of workers' intellectual and psychomotor functions. The exposed group consisted of 226 rubber industry workers while the control group comprised 102 hosiery plant workers. The analysis of results was aimed at the determination of exposure effects depending on the duration of exposure and age of persons examined. It has been revealed that chronic exposure to white spirit, at a concentration close to the hygienic standard, induces the deterioration of some intellectual and psychomotor functions in the exposed persons, depending on the duration of exposure and age of the exposed subjects.
Among the variables presented in the study, several individual functions including: perception and reproduction of visual material; projection of spatial relationships; concentration; time of simple and choice reaction; speed and coordination of hand movements, were found the most effective in contrasting the exposed group from the control.

INTRODUCTION

Nervous tissue, due to its biochemical structure, is selectively sensitive to the effect of organic solvents. Intoxication may result in demyelination both in the central and peripheral structures of the nervous system (1). Symptomatology of the neurotoxic effect of organic solvents considerably precedes damage to the hematopoietic system and parenchymatous organs. It is thus to be expected that changes within psychical functions will be the earliest detectable effects of intoxication. Moreover, as previous studies have shown (8), psychological techniques more easily detect early CNS disturbances due to solvents than tradi-

Address reprint requests to Barbara Bazylewicz-Walczak, Department of Work Psychology, The Nofer Institute of Occupational Medicine, P.O. Box 199, 90-950 Lodz, Poland

tional medical examinations. Hence, the role of psychological tests in the evaluation of the effects on health of chronic occupational exposure to organic solvents seems to be particularly significant.

White spririt is one of the most widely used organic solvents (e.g.: as a component of glues, varnishes and paints). Medical studies dominate among the papers on white spirit toxic effects while psychological studies refer mainly to the effects of toxic mixtures with white spirit as one of the components. Most of these studies were carried on in the 1970s and 1980s in the Scandinavian countries (3, 4, 5, 6, 7, 9, 10, 11).

This study deals with the evaluation of the psychological effects of chronic exposure to white spirit contained in the glue used for rubber footwear production.

The investigations presented were aimed at determining the effect of the solvent mentioned on selected mental and psychomotor functions of exposed workers, and were carried out at the Nofer Institute of Occupational Medicine, Lodz within a research programme concerning the evaluation of the state of health of exposed workers.

MATERIALS AND METHODS

In accordance with the aim of the studies, a group of persons chronically exposed to white spirit was compared with a control group. The exposed group consisted of workers — most of them women — employed in belt-system production of rubber footwear, continuously performing one activity (gluing footwear elements) in a sitting position during the whole of each shift. As could be seen from the plant's documentation, the white spirit concentrations in this department have been close to the Polish hygienic standard value (500 mg/m^3) for 13 years. It was assumed that potential disturbances of behaviour, being the symptoms of chronic intoxication, should be expected only after a few years' exposure. Therefore, the basic criterion of choice was at least 5-years' occupational exposure. Measurements of exposure were carried out by team of chemists from the Nofer Institute of Occupational Medicine, on the basic of air samples collected during one shift. The analysis of the white spirit concentration in the air was made by means of gas chromatography with a flame ionization detector. Detectability of this method amounts to 25 mg/m^3 for white spirit. The results of the measurement confirmed that white spirit concentrations in the workers' respiratory zone remained at Maximal Acceptable Concentration level. Chemical analysis of the gue used, showed that white spirit was its only toxic component. The exposed group comprised 226 persons: 202 women

and 24 men. The control group consisted of workers unexposed to chemical substances. These were the employees of hosiery plants (seamstresses and knitters), performing work of a similar level of difficulty and complexity as the exposed group. The selection criterion here was the compatibility of these worker's sex, age, education level and duration of employment with those of the exposed workers. The group comprised 102 individuals: 91 women and 11 men.

According to the aim of the study, the selected mental and psychomotor functions of workers belonging to the groups distinguished, were examined. Within intellectual functions the following were examined:

— visual analysis and synthesis processes
— verbal memory
— sensory-motor speed and coordination
— concentration span
— mental capacity (speed and correctness of intellectual operations)
— spatial imagination (projection of spatial relationships)
— correctness of perception and reproduction of visual material.

These functions were examined by means of Block Design, Digit Span, Digit Symbol from the Wechsler Adult Intelligence Scale, the Toulouse-Pieron Test (12), the Kraepelin Test (12), the Dots Location Test from Test for Mechanical Ability T.W. MacQuarry (2) and the Bender Test (13).

Within psychomotor functions the reaction times (the speed and correctnes of responses to simple and complex light stimuli) and manual dexterity were examined. Three methods were employed here: Visual Reaction Time, Pegboard (14), One-and Two-Plate Tapping. Apart from these, a questionnaire was used which aimed at gathering supplementary information on smoking, alcohol consumption, taking medicines and verifying the proper allocation of persons to the groups examined.

STATISTICAL METHODS

Statistical analysis included: determination of the level of significance of the differences between particular variables — mean values with Student's t-test for 2 independent samples and discriminant analysis.

RESULTS

According to the procedure applied, each person examined was characterized by means of a set of variables, the numerical indices of which were constituted by the results obtained by the examinee in

particular tests. In Tables 1 and 2 mean values of particular variables in the exposed and control group were compared, taking the age sub-groups into consideration.

Results in Table 1 show that of the intellectual variables examined, the following variables most strongly differentiated both groups (the whole groups and the age subgroups):

— correctness of perception and reproduction of visual material (Bender Test)

— correctness of projecting spatial relationships (Dots Location Test), as well as

— mental efficiency and long-lasting attention concentration (Kraepelin Test).

In addition, some significant differences in associational memory, sensory-motor speed and coordination (Digit Symbol) as well as in visual analysis and synthesis (Bloc Design) were found between the exposed and unexposed individuals aged 46—60 years.

The results presented in Table 2 indicate that among the considered psychomotor variables the highest diversity (between whole groups and age sub-groups) occurred in the speed and correctness of responses to light stimuli (simple and complex reaction). Moreover, some differences were found in manual dexterity, speed and coordination of hand movements (One- and Two-Plate Tapping) between the tested groups including individuals aged 46—60 years.

In order to determine the dynamics of all the variables studied in the exposed individuals, they were divided into three sub-groups according to the period of work under conditions of exposure (5—10 years, 11—15 years, 16—30 years). The comparisons between these sub-groups showed (Table 3) that there were no statistically significant differences in the results such as: efficiency and errors in Toulouse-Pieron Test, efficiency in Dots Location Test, One-Plate Tapping and Pegboard. However, a statistically significant deterioration of performance was found in such variables as: Kreapelin Test or simple and complex reaction time, proportional to exposure duration.

Discriminant analysis made it possible to separate a set of variables which most strongly discriminated between both groups: the group of persons chronically exposed to white spirit and the control. The results presented in Table 4 indicate that the set of 11 variables is the best for the discrimination of the tested groups. This set also includes personality variables which are not, however, taken into consideration in this study, but they haven been included in a more comprehensive study (unpublished data).

DISCUSSION

The studies carried out have proved that long-term exposure to white spirit, at concentrations close to MAC, brings about the deterioration of workers' intellectual and psychomotor functions. There are some functions which deteriorate even in workers exposed for the shortest period of time, i.e. from 5 to 10 years. As far as intellectual functions are concerned this refers to the correctness of perception and reproduction of visual material, projection of spatial relationships, mental capacity and long-term concentration, while within psychomotor functions — the speed and correctness of reactions to light stimuli. It should be stressed that the correctness of perception and reproduction of visual material, measured with the Bender Test and expressed in standardized units "Z", amounted to 98 — in the exposed group, which is almost pathological according to the clinical standards mandatory in Poland, and reached 64 in the control group, which remains within the standard limits. The results of the Kraepelin Test: a higher coefficient of errors and worse test performance efficiency, suggest fatigability of exposed group when compared with the control one. Thus, the ability to perform work requiring long-term concentration is significantly decreased in the exposed group.

Moreover, the weakening of some functions after the longest exposure (16—30 years) has been found. These are as follows: sensory-motor speed and coordination, visual analysis and synthesis, and manual dexterity. This fact is supported by comparison of the exposed and unexposed persons in the highest age group (46—60 years) and results from the correlation between the duration of exposure and the age of workers examined ($r = 0{,}44$; $p = 0{,}001$). In the exposed persons the majority of deteriorating functions remain, at a constant level irrespective of duration of exposure. These are: mental capacity and long-term concentration, accuracy of projection of spatial relationships, correctness of reactions to light stimuli, and manual dexterity. Moreover, it has been found that such functions as the speed of reactions to simple and complex light stimuli and sensory-motor speed and coordination, deteriorate proportionately to the length of exposure. The fact that deterioration of some functions was observed only in workers exposed for the longest period of time, should also be explained. Although in these studies, the duration of exposure of examined persons is known, there are no precise data on its magnitude during the entire period of exposure. The observed magnitude of exposure, remaining within MAC limits or slightly exceeding them, may be reliable for the last 13 years, whereas previously, under other room and technical conditions within the industrial

TABLE 1. Intellectual test results (means and standard deviations) for whole groups and for age sub-groups

Test Variable	Subject in groups	Exposed group N = 226		Control group N = 102		Significance level for Student's test
		Mean	SD	Mean	SD	
Digit Symbol	Total	29.54	10.02	32.91	9.06	0.01
	I	39.27	9.01	38.84	7.45	NS
	II	31.30	9.33	33.30	7.46	NS
	III	22.29	6.41	26.03	7.18	0.02
Digit Span	Total	7.70	1.31	7.90	1.10	NS
	I	8.35	1.19	8.06	1.15	NS
	II	7.80	1.27	7.91	1.00	NS
	III	7.27	1.31	7.67	1.12	NS
Block Design	Total	19.80	6.60	21.08	6.30	NS
	I	22.05	5.10	22.34	7.22	NS
	II	20.89	6.37	20.85	6.00	NS
	III	16.52	6.40	19.94	5.18	0.01
Bender Test	Total	62.32	21.97	31.08	20.56	0.001
	I	54.80	16.19	32.22	22.99	0.001
	II	58.01	20.00	26.21	13.86	0.001
	III	74.46	23.07	34.73	22.33	0.001
Kraepelin Test						
efficiency	Total	664.70	263.38	767.53	252.48	0.001
% errors		4.19	5.42	1.9	2.21	0.001
efficiency	I	672.00	224.70	797.69	240.09	NS
% errors		2.90	3.62	1.83	1.84	NS
efficiency	II	708.93	251.21	836.15	285.92	0.01
% errors		3.03	3.20	1.63	2.33	0.02
efficiency	III	541.31	277.20	666.03	190.69	0.05
% errors		7.25	8.65	2.10	2.43	0.01
Toulouse-Pieron Test						
efficiency	Total	129.50	37.28	129.80	29.87	NS
errors		35.85	35.96	30.02	22.25	NS
efficiency	I	142.57	34.85	135.06	32.99	NS
errors		30.64	13.56	25.36	21.47	NS
efficiency	II	134.26	34.93	134.82	28.89	NS
errors		34.68	37.33	32.42	20.57	NS
efficiency	III	110.53	38.51	116.00	22.19	NS
errors		41.16	38.20	32.70	23.82	NS

Dots Location Test						
efficiency	Total	19.25	11.06	21.70	12.35	NS
errors		7.76	7.22	4.80	4.88	0.001
efficiency	I	24.43	7.83	23.25	15.23	NS
errors		7.86	6.35	4.36	4.85	0.05
efficiency	II	20.59	11.15	22.94	10.67	NS
errors		7.22	6.26	4.67	5.24	0.05
efficiency	III	13.25	9.75	18.48	9.50	0.05
errors		9.35	9.39	5.33	4.48	0.10

	exposed group	control group
I age to 30 years	n= 20	n=36
II age from 31 to 45 years	n=124	n=33
III age from 46 to 60 years	n= 64	n=33

TABLE 2. Psychomotor test results (means and standard deviations) for whole groups and for age sub-groups

Test Variable	Subject in groups	Exposed group N=226 Mean	SD	Control group N = 102 Mean	SD	Significance level for Student's t-test
SIMPLE REACTION	Total	25.90	3.55	26.90	0.63	0.001
TIME	I	26.80	0.68	26.97	0.16	NS
No. of correct responses	II	26.06	3.23	26.79	0.88	0.05
	III	25.27	4.52	26.82	0.62	0.01
Mean Reaction Time	Total	429.20	152.22	282.7	70.00	0.001
(ms)	I	350.35	117.42	261.00	45.00	0.01
	II	424.84	146.25	298.73	78.00	0.001
	III	463.62	163.97	284.94	76.00	0.001
COMPLEX REACTION	Total	14.94	2.74	16.01	1,35	0.001
TIME	I	14.50	3.57	16.08	1.23	0.10
No. of correct responses	II	15.13	2.50	16.15	1.13	0.001
	III	14.59	2.90	15.79	1.61	0.02
Mean Reaction time	Total	592.85	107.70	536.7	86.00	0.001
(ms)	I	539.45	87.64	434.61	51.00	0.05
	II	590.59	108.27	560.45	87.00	NS
	III	614.22	112.52	569.88	89.00	0.10
One-Plate Tapping	Total	171.40	28.90	174.72	28.37	NS
	I	179.45	24.12	172.08	31.04	NS
	II	174.65	27.90	172.45	32.29	NS
	III	161.78	30.05	179.88	18.83	0.001
Two-Plate Tapping	Total	126.90	24.58	135.66	25.24	0.01
	I	138.35	22.90	138.50	24.09	NS
	II	127.34	23.63	130.73	21.77	NS
	III	122.36	25.82	137.48	28.74	0.02
Pegboard	Total	60.41	7.92	61.63	10.32	NS
(time in s)	I	56.90	7.24	60.14	10.76	NS
	II	59.40	7.58	61.55	9.20	NS
	III	63.47	7.94	63.36	10.63	NS

	exposed group	control group
I age to 30 years	n= 20	n=36
II age from 31 to 45 years	n=142	n=33
III age from 46 to 60 years	n= 64	n=33

TABLE 3. Comparison of average scores on psychological tests between the groups of different exposure duration and the control group

Test Variable	Exposed 5—10 years n=51		Exposed 11—15 years n=103		Exposed 16—30 years n=72		Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Digit Symbol	31.9	11.7	30.9	9.7	26.0***	8.0	32.9	9.1
Digit Span	8.0	1.1	7.7	1.3	7.5*	1.4	7.9	1.1
Block Design	19.5	6.3	20.5	6.9	18.9*	6.2	21.2	6.2
Bender Test	66.6***	25.8	57.0***	19.1	66.9***	21.1	31.1	20.6
Kreapelin Test								
efficiency	653.9*	281.0	683.2*	263.2	642.3**	241.8	777.7	246.8
% errors	4.3*	5.6	4.1**	5.1	3.9*	5.9	1.9	2.3
Toulouse-Pieron Test								
efficiency	137.1	37.6	130.2	39.6	123.0	36.3	129.8	27.8
errors	32.3	19.6	38.5	41.1	33.8	35.4	30.0	22.2
Dots Location Test								
efficiency	21.1	10.8	19.6	11.6	17.4	10.7	21.7	12.3
errors	7.8**	5.2	7.1*	6.7	8.7*	9.0	4.8	4.9
Simple Reaction Time								
No. of correct responses	26.4	2.1	25.8**	3.6	25.6*	4.2	26.9	0.6
Mean reaction time (ms)	403.8***	145.4	417.9***	139.6	463.4***	166.8	282.7	68.0
Complex Reaction Time								
No. of correct responses	14.4***	3.1	15.4*	2.0	14.6***	3.2	16.0	1.3
Mean reaction time (ms)	568.9*	101.4	593.8***	109.8	608.2***	107.1	536.7	86.5
One-Plate Tapping	168.1	50.8	171.0	27.6	174.4	29.0	174.4	28.4
Two-Plate Tapping	129.5	22.8	125.7**	21.2	126.7*	26.5	135.6	25.3
Pegboard (time in s)	59.5	8.7	60.1	7.4	61.4	7.9	61.5	10.3

Significance level for Student's t-test:
* $p<0.05$
** $p<0.01$
*** $p<0.001$

plant, the concentrations of white spirit (according to the plant's information) considerably exceed the hygienic standard. Thus, workers exposed for longer than 15 years may have been subject to more severe intoxication. That is why the results obtained in this group can probably be attributed not only to exposure duration, but also to its magnitude.

The set of variables, revealed in discriminant analysis as the one best differentiating the exposed group from the unexposed should be used for diagnosing the toxic effects of chronic exposure to white spirit. This is, undoubtedly, very important for the early diagnosis of poisonings, both in periodical medical examinations and in clinical examinations for the purposes of medical certification. These variables have included the following functions: correctness of perception and reproduction of visual material with particular attention paid to spatial relationships, concentration, speed of reactions to single and complex light stimuli, and manual dexterity.

The results obtained in our study are concordant with the data from literature concerning the effect of mixtures of solvents containing white spirit. Thus, irrespective of procedures and test batteries applied, the results obtained by others (7, 10) indicate a lowering of such functions as: manual dexterity, psychomotor coordination, concentration span and time of reaction. Longer reaction times and lowered immediate memory were found in the study of Gamberale et al. (5), whereas the deterioration of learning memory and abstraction functions were found in the studies of Hänninen et al. (9), Elofasson et al. (4), Gregorsen et al. (6).

Finally, it should be stressed that the negative psychological effects of exposure to white spirit at concentrations close to MAC would suggest that the obligatory hygienic standards are not fully safe. However, this assumption calls for confirmation in the follow-up studies, ensuring higher accuracy of conclusions due to the elimination of the impact of individual differences on the obtained empirical material in the compared groups.

ACKNOWLEDGEMENTS

The authors would like to thank Ms Krystyna Wojniłłowicz for her technical assistance.

REFERENCES

1. Baker E.L., Smith T.J. and Landrigan P.J. The neurotoxicity of industrial solvents: A review of the literature. Am J Ind Med 8: 207—217. 1985.
2. Choynowski M. et al. The development, theoretical approach and work of the psychometrical laboratory. Biul Psychomet Vol 2: 205—264, 1968 (in Polish).
3. Ekberg K., Barregard L., et al. Chronic and acute effects of solvents on central nervous system functions in floorlayers. Br J Ind Med 43: 101—106, 1986.
4. Elofsson S.A. et al. Exposure to organic solvents. A cross-sectional epidemiological investigation on occupationally exposed car and industrial painters with special reference to the nervous system. Scand J Work Environ Health 6: 239—298, 1980.
5. Gamberale F., Annwall G. and Hultengren M. Exposure to white spirit. II. Psychological Functions. Scan J Work Environ Health 1: 31—39, 1975.
6. Gregerson P., Angels B., Nielson T.E., et al. Neurotoxic effects of organic solvents in Exposed workers. An occupational, neuropsychological and neurological investigation. Ann J Ind Med 5: 201—225, 1984.
7. Hane M., Axelson O., Blume J., et al. Psychological function changes among house painters. Scand J Work Environ Health 3, 1977.
8. Hänninen H.: Psychological picture of manifest and latent carbon disulphide, poisoning. Brit J Ind Med 28: 374—381, 1971.
9. Hänninen H., Ekskelinen L., et al. Behavioural effects of long-term exposure to a mixture of organic solvents. Scand J Work Environ Health 2: 240—255, 1976.
10. Knave B. et al. Long-term exposure to jet fuel II. A cross-sectional epidemiologic investigation on occupationally industrial workers with special reference to the nervous system. Scand J Work Environ Health 5: 19—45, 1978.
11. Lindström K. and Wiekström G. Psychological function changes among maintenance house painters exposed to low levels of organic solvent mixtures. Acta Psychiat Scand 67, Suppl 303: 81—91, 1983.
12. Meili R. Lehrbuch Der Psychologischen Diagnostik. Verlay Hans Huber, Bern, 1961.
13. Pascal G.R. and Suttell B.J. The Bender-Gestalt Test. Quanitification and validity for adults. Grune and Stratton, New York, 1951.
14. Tests moteur d'Heuyer et Baille, Ets. Pierre Dufour, Paris, 1973.
Received for publication: January 11, 1990
Accepted for publication: March 26, 1990