

Behavioral changes after long-term exposure to organic solvents and their mixtures

Determining factors and research results

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LINDSTRÖM K. Behavioral changes after long-term exposure to organic solvents and their mixtures: Determining factors and research results. *Scand j work environ health* 7 (1981): suppl 4, 48—53. This presentation summarizes the characteristics determining the psychological end state after long-term solvent exposure. It also presents the results of research on changes in psychological functions after long-term solvent exposure. Such factors as differential vulnerability and environmental influences other than solvent exposure at work and elsewhere affect the end state. The results of five different Finnish studies are summarized. These studies concerned workers with solvent poisoning, car painters exposed to solvent mixtures, rayon viscose workers exposed to carbon disulfide, printers exposed to toluene, and laminators exposed to styrene. Intellectual functions, short-term memory, and sensory and motor functions were inspected. Verbal intelligence was lowered only in cases of intoxication and exposure to mixtures of organic solvents. Visuoconstructive abilities were deteriorated in those groups with verbal intelligence deterioration, and also among both rayon viscose workers with solvent poisoning and car painters. The group exposed to styrene showed functional changes only in visuomotor accuracy. Lowered manual or finger dexterity was found among workers exposed to carbon disulfide, workers with solvent poisoning, and car painters. The most disturbances were accumulated among those exposed to mixtures of organic solvents.

Key terms: carbon disulfide, intelligence, sensory and motor functions, short-term memory, styrene, toluene.

In many studies behavioral changes have been related to long-term exposure to organic solvents. Epidemiologic investigations have shown an increased risk of neuropsychiatric disorders among workers exposed to organic solvents and their mixtures. According to two Scandinavian case-referent studies, the risk of neuropsychiatric diseases indicating chronic brain damage was approximately two times as high as expected among construction workers who had previously been exposed to sol-

vents and who were applying for disability pensions (2, 21). A Danish cohort study of disability pensions and deaths among painters revealed an increased risk of pre-senile dementia among painters (19). In various psychological studies, related behavioral effects have been detected among workers with occupational disease caused by solvent exposure or among occupationally active workers exposed to solvents (3, 6, 10, 13, 15).

The psychological end state after long-term exposure to organic solvents can be described in terms of experienced symptoms, changes in functions, and changes in personality and emotions. Changes in functions are the most reliably measured by psychological test methods.

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The changes in psychological functions are described in this paper in a brief presentation of the results of a series of Finnish studies dealing with long-term solvent exposure. The comparison of these research results is facilitated by the application of a standardized test battery (7). A model to describe the characteristics determining the psychological end state after long-term exposure to solvents has been constructed which also contains possible confounding and modifying factors; it is presented before the empirical results.

Model of characteristics determining the psychological end state

The psychological end state after long-term exposure to industrial solvents is multidetermined; it does not depend only on the effects of solvents on the nervous system. Fig 1 presents a model of these determining factors. The model was constructed through the application of the pathogenic factors and organic pathology determining the psychological end state after any somatic disease (18), other factors thought relevant having been taken into consideration.

Other chemical exposure occurring simultaneously with industrial exposure to solvents is possible, eg, the consumption of alcohol or the use of drugs. *Other environmental factors* at work or elsewhere can prevent or facilitate the adverse effects of solvents. *Individual vulnerability* to the adverse effects of solvents is varied. Chronological age and the process of ageing are important. Personality factors such as coping and adaptation mechanisms can influence the psychological end state. Previously existing brain damage or any systemic disease can increase individual vulnerability.

Organic pathology and its characteristics, eg, its focal or diffuse nature, the rate of change in the chemicophysical milieu of the brain, and the duration of organic pathology are reflected in the psychological picture when a worker exposed to solvents for a long time is examined (18). In the field of behavioral toxicology the importance and influence of determining factors other than solvents and age are still somewhat unknown.

Review of psychological studies on long-term functional changes

Pertinent studies

This paper refers to the psychological changes found in five different studies carried out at the Institute of Occupational Health in Helsinki (table 1). The exposed groups comprised workers with solvent poisoning, car painters, viscose rayon workers, photogravure printers, and laminators. Some comparison with studies carried out in other Scandinavian countries is also made.

The duration of exposure was somewhat varied between the groups (table 2). It was the shortest in the group exposed to styrene and the longest in the group

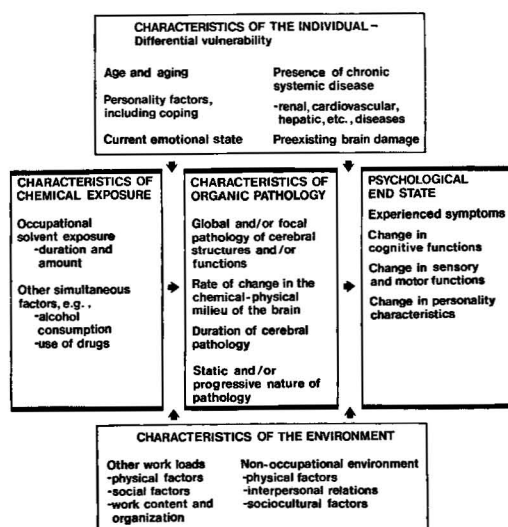


Fig 1. Determinants of the psychological end state after occupational exposure to solvents (14).

Table 1. Groups studied at the Institute of Occupational Health in Helsinki — Number of subjects in the groups, their mean ages, and the standard deviations in ages.

Group	N	Age (a)	
		Mean	SD
Patients with solvent poisoning (13)	56	38.8	10.9
Car painters (7)	100	35.5	11.0
Viscose rayon workers (9)	206	49.3	8.9
Printers (6)	26	39.5	6.8
Laminators (15)	98	29.5	7.4

Table 2. Main agents of exposure, duration of exposure, and estimation of the level of exposure in the groups studied.

Group	Main agents of exposure	Duration of exposure (a)		Level of exposure
		Mean	SD	
Solvent patients	Mixture of organic solvents or various aromatic and halogenated hydrocarbons	9.1	8.3	3 low level, 26 moderate level, 27 high level (close to the Finnish threshold limit value)
Car painters	Mixture of organic solvents, mainly aromatic hydrocarbons	14.8	8.5	31.8 % of the Finnish threshold limit value
Rayon viscose workers	Carbon disulfide	15.0	(range 1—27)	Very varied, earlier many times over 20 ppm
Printers	Toluene	19.7	6.2	60—200 ppm
Laminators	Styrene	4.9	3.2	7—4,715 mg/l (0.05—33.2 mmol) mean mandelic acid concentration in urine [median 808 mg/l (5.7 mmol)]

Table 3. The psychological functions studied and test methods used in the measurements.

Function	Test method ^a
Intellectual functions	
Verbal ability	Similarities (WAIS), Vocabulary (WAIS)
Visuoconstructive ability	Block Design (WAIS), Picture Completion (WAIS)
Short-term memory	
Concentration	Digit Span (WAIS), Digit Symbol (WAIS)
Visual memory	Visual Reproduction (WMS), Benton Test
Verbal memory	Logical Memory (WMS), Associative Learning (WMS)
Sensory and motor functions	
Perceptual speed and accuracy	Bourdon Wiersma Test, Symmetry Drawing
Manual and finger dexterity	Santa Ana Dexterity Test, Finger tapping, Mira Test

^a WAIS = Wechsler Adult Intelligence Scale, WMS = Wechsler Memory Scale.

exposed to toluene. The car painters were exposed to a low level of mixtures of organic solvents, about a third of the respective Finnish threshold limit values (TLVs). The mean exposure of the workers exposed to styrene was also clearly well below the applied hygienic limit value. The exposure of the patients with solvent poisoning was estimated to be very close to the actual TLVs in one-half of the cases and below these values in the other half. The exposure level of the printers was also estimated to be below the applied hygienic limit value of 200 ppm. The exposure levels of the workers exposed to carbon disulfide have been very varied; the level had previously exceeded 20 ppm many times, but during the last 10 a the level has usually been below 20 ppm.

The cognitive functions and the sensory and motor functions of the workers were measured with the psychological test battery used at the Institute of Occupational Health in Helsinki (7). The functions measured and the tests used are presented in table 3. One or two of the tests mentioned in each functional category were used to measure possible functional changes.

Intellectual functions

Cognitive functions can be divided into two types, intellectual functions and memory functions. The intellectual functions include both verbal and visuoconstructive abilities. Two subtests of the Wechsler Adult Intelligence Scale (WAIS) — Similarities and Vocabulary — were used as

measures of verbal intelligence. The WAIS verbal subtests can be considered "hold tests"; in other words, a person's ability to perform these tests does not easily deteriorate with the diffuse brain damage possible with solvent poisoning (11). Only severe cases of occupational disease (12) or house painters with dementia (1) have shown decrement in verbal intelligence, although car painters exposed to a mixture of organic solvents did show a slight tendency towards lowered verbal ability.

The visuoconstructive abilities have been shown to be more vulnerable in the event of all kinds of brain damage (22). Long-term solvent exposure has usually been related to these changes. The selection of tests for this functional area has usually included the Block Design and Picture Completion subtests of WAIS. In our studies patients with solvent poisoning, car painters, and workers exposed to carbon disulfide showed decrement in these visuoconstructive functions (6, 8, 12). Two Swedish studies of house and car painters confirmed these findings (3, 10).

Short-term memory

Short-term memory is assessed mostly by means of the Wechsler Memory Scale (WMS) subtests and the Benton Visual Retention Test. Both verbal and visual subtests are usually included. The Digit Span and Digit Symbol subtests of WAIS, including memory tasks, are considered better measures of attention and concentration than memory itself (20). Lowered scores for both Digit Span and Digit Symbol were found among solvent-poisoned workers and car painters exposed to mixtures of solvents, while workers exposed to carbon disulfide showed decrement only on the Digit Symbol subtest (6, 8, 13).

Short-term verbal memory, as measured with the Logical Memory and the Associative Learning subtests of the WMS, was impaired among car painters and printers exposed to toluene (5).

The tests used to measure visual memory were either the Benton Test or Visual Reproduction (WMS). Visual memory was affected among car painters after exposure to a mixture of organic solvents, among printers exposed to toluene (6), and also, in a recent study, among maintenance

house painters exposed to a low level of the solvent naphtha (17). In a Danish study, house painters with dementia showed the highest frequency of disturbances in visual memory (1).

Sensory and motor functions

Sensory and motor functions were assessed with measurements of reaction time, clerical tests, and tests of manual and finger dexterity. In Swedish studies, reaction times were impaired among car and industrial painters exposed to solvent mixtures (3) and among boatmakers exposed to styrene (4). Maintenance house painters exposed to a low level of the solvent naphtha also had slowed reaction times in a Finnish study (17).

Perceptual speed and accuracy were usually measured by tests of the Bourdon type and, in some Finnish studies, also by the Symmetry Drawing test. Workers with solvent poisoning performed slowly in perceptual tasks, while both workers exposed to carbon disulfide and those exposed to styrene showed poor perceptual accuracy (8, 13, 15). Manual dexterity measured by the Santa Ana Dexterity Test or the Mira Test was disturbed in workers with solvent poisoning and workers exposed to carbon disulfide (8, 13).

Finger dexterity had deteriorated among car painters in both a Finnish (6) and Swedish (3) study.

Sensitivity of the test methods

Multivariate analyses of the test methods were used in order to determine those test combinations which would maximally differentiate subjects exposed to solvents from subjects not exposed to solvents. Maximal discriminative power was shown for different combinations of the tests. Among solvent patients, four tests — Digit Symbol, Digit Span, Symmetry Drawing and accuracy in the Mira Test — formed this combination (13). Car painters were characterized by decline in the test combination of Block Design, Digit Span, and Associative Learning (6). In carbon disulfide exposure, disturbed manual dexterity, as measured by the Santa Ana Dexterity and Mira tests, was the most characteristic disturbance (8). Reversals in Symmetry Drawing and errors on the Bourdon

Table 4. Summary of the results of five Finnish studies of the effects of long-term exposure to solvents.

Function	Patients with solvent poisoning	Car painters	Viscose rayon workers	Printers	Laminators
Intellectual functions					
Verbal ability	(+)	(+)	—	—	—
Visuoconstructive ability	+	+	+	—	—
Short-term memory					
Concentration	+	+	—	—	—
Verbal memory	—	+	—	+	—
Visual memory	—	+	+	+	—
Sensory and motor functions					
Perceptual speed and accuracy	+	—	+	—	+
Manual and finger dexterity	+	+	+	—	—

Wiersma Test were related to high urinary mandelic acid concentration, which was used to indicate the level of styrene exposure (9).

Discussion

The most severe decreases in behavioral functions were found, as could be expected, among workers with occupational disease caused by aromatic and halogenated hydrocarbons and their mixtures (table 4). But car painters exposed to mixtures of solvents also showed widespread impairments of cognitive functions, and their motor speed was lowered. This result indicated possible synergistic effects of various components of exposure to solvents. A recently studied group of maintenance house painters exposed to the solvent naphtha showed only limited decline however. The two groups exposed to individual aromatic hydrocarbons, toluene and styrene in general, showed slighter decrements than those exposed to mixtures of solvents. The workers with exposure to carbon disulfide, in particular, had not only disturbed sensory and motor functions, but also poor visuoconstructive intelligence and poor visual memory.

These findings do not necessarily directly indicate the toxic aggressiveness of a chemical agent with respect to behavioral functions. Of course, the level and duration of exposure are also important. Among actual groups, the printers exposed to tol-

uene and the car painters exposed to mixtures of solvents represented the longest duration of exposure, while the duration of exposure among the styrene workers was quite short, the mean being only 5 a. The level of exposure in the groups of car painters and laminators was estimated to be clearly below the actual hygienic limit values applied in Finland. Even the group with solvent poisoning and the group exposed to toluene were seldom exposed to concentrations exceeding the applied hygienic limit values.

The results were based mostly on group comparisons between subjects exposed to solvents and subjects not exposed to solvents. In all the cases, the groups were matched according to age, sex, and educational level. In some cases, the preexposure intellectual level also constituted a matching criterion (6, 17). The use of alcohol was also controlled in some studies (16). The most difficult aspect to control, however, was the effects of selection which occurred in the preemployment phase and later during the work involving exposure. The influence of this selection on the psychological end state at the group level can be evaluated only by means of follow-up studies.

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