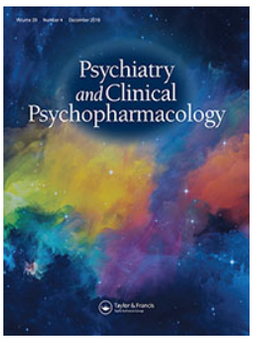

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Examination of attention and memory processes of workers exposed to solvent for a long time

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ABSTRACT

PURPOSE: This study was planned to assess the attention and memory-based performances of workers who used solvent as part of their job and therefore who had been exposed to this substance for a long time.

METHOD: The participants of the study are 31 workers who were diagnosed with solvent exposure in the occupational diseases polyclinic of Istanbul Occupational Diseases Hospital and who were treated as inpatient treatment. These 31 participants were individuals who worked for at least 1 year in solvent use, and who did not have any physical, neurological, or psychiatric diseases prior to the study. Beside the aforementioned study group, 30 healthy volunteers also participated in the study as the control group. The verbal memory processes test (VMPT), cancellation test (CT) and Stroop test TBAG form (STP) were applied to all participants.

FINDINGS: The data revealed no significant difference between the study and control groups in terms of their short-term memory scores based on the VMPT scores of the participants. However, long-term memory scores, learning achievement scores and the highest learning achievement scores of the study group were found to be significantly lower than the control group. Comparing the two groups on CT and its sub-sections, the scores of the study group were found to be significantly higher than the control group. These findings present that the study group needed more time to complete the mentioned test. It was also revealed that the study group particularly completed the fifth sub-section of STP, which focuses on selective attention, in significantly longer amount of time than the control group.

CONCLUSION: Long-term solvent exposure affects attention and memory processes negatively.

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KEYWORDS
Solvent exposure; attention; memory; verbal memory processes test; cancellation test; stroop test

Introduction

The term solvent which has a wide range of uses in the industry is the general name of liquid chemical substances which are used as very good resolvent and dissolver for materials without changing their original structure. Exposure to more than 200 types of solvents is often due to occupational causes and is very common [1–4].

Solvents can easily enter into the human body through the respiratory, oral, and skin routes due to their volatility and degreaser properties. The way in which the solvent is exposed, at what density, and for how long have effects on health. Excess exposure time and solvent concentration, the presence of chemicals other than solvents, individual sensitivity, and individual habits also change the severity of the effects [1].

Exposure to the solvent regularly and in relatively small quantities over a long period of time will not immediately affect the health. When the effects occur, it leads to health disorders that impair the quality of life at an advanced level, long-term or life-time, and sometimes shortens the life span. Due to long exposure, many health problems can arise including damage in lungs and kidney, male and female infertility, skin problems, personality changes, restlessness, sleep disorders, memory disorders, attention problems, dementia, peripheral neuropathy, concentration disorders, headache, vision problems, loss of interest/decrease in psychomotor speed, decrease in mental flexibility, changes in mood, increase in nervousness, increase in depression and anger, weakness in hand-eye and foot-eye coordination, deceleration in perceptual speed, and information processing speed [3,5,6].

In recent years, working conditions with the widespread use of solvents without sufficient precautions have become an increasingly severe public health problem in young adults worldwide as a result of developments in petrochemicals and related industries. Hundred and sixty million workers become sick, and over 1.2 million workers die from occupational diseases

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or work accidents annually due to unhealthy situations and contact with harmful substances in the workplace.

The main purpose of this research study is to examine the memory and attention-related performances of workers who use solvent as part of their job and therefore who have been exposed to this substance for a long time. The study also aimed to explore whether solvent has an influence on attention and memory processes, to draw attention to the adverse effects of solvent on cognitive functions and to contribute to the body of literature in our country through neuropsychological tests. To our knowledge, there is no study conducted in this area in the literature of our country. It is believed that the current research study will be beneficial in the regulation of preventive and remedial activities in the field of employee health and safety.

Method

The study was approved with the protocol code of 09.2017.426 by Marmara University Medical Faculty Clinical Research Ethics Committee.

The solvent substances that we check in our hospital in urine analysis and the reference ranges of these substances with reference to the Ministry of Health, Occupational Diseases Hospitals Biological Monitoring of the Exposure to Solvent and the Management of Health Risks Protocol are presented below. Solvent substances in urine are evaluated with the gas chromatography method.

Solvent substance	The reference range
Acetone	0–50 mcg/ml
Diethyl ketone	0–1 mg/l
Dichloromethane	0–300 mg/l
Phenyl glyoxylic acid	0–264 mg/l
Phenol	0–20 mg/l
Hexandion	0–5 mg/gc
Hydroxypyran	0–2 ng/gcre
Hippuric acid	0–1600 mg/l
Mandelic acid	0–880 mg/l
Methanol	Detection limit (LOD) 5 mg/dl, toxic level > 20 mg/dl
Methyl ethyl ketone	0.10–2 mcg/ml
Methyl hippuric acid	0–1.5 g/gcre
Methyl iso butyl ketone	0–1 mg/l
O-cresol	0–0.5 mg/l
Trans-trans muconic acid	0–0.3 mg/gc
Trichloroacetic acid (TCA)	0–15 mg/l
Trichlorethylene (TCE)	0–10 mg/l

Thirty-one workers who were diagnosed with solvent exposure in the occupational diseases polyclinic of Istanbul Occupational Diseases Hospital and who were treated as inpatient treatment were the participants in the study group of this study. The study group consisted of the aforementioned workers who worked for at least one year in solvent use, who did not have any physical, neurological, or psychiatric diseases, and who were not on any medication prior to the study. Thirty healthy individuals, who had similar demographic characteristics such as age and sex as the study group members, participated in the study in the control group. The participants in the control group did not have solvent exposure, any physical, neurological, or psychiatric diseases and were not on any type of medication prior to the study. Individuals who had been on psychoactive drugs/substances and or who had had mental deficiencies were not included in the study. Thirty-one patients in the study group and the 30 healthy participants in the control group were administered the tests that were planned by the psychologist.

Data collection tools

Socio-demographic data form: A form which included clinical data such as socio-demographic data including age, gender, education level, marital status, working status, and psychoactive substance use and disease history was used considering the aims of the study.

Verbal memory processes test (VMPT): The test, developed by Öktem [7], is a test designed to investigate verbal learning and memory in a multi-factorial manner.

Cancellation test (CT): CT, which was developed by Weintraub and Mesulam [8], conducted was an attention test, is a test measuring visual screening, response rate, inhibition of urgent reactions, visual-motor speed, and compliance. The CT Turkish Form consists of four different forms. The psychometric properties of CT in the Turkish sample were examined on the basis of the standardization of the BİLNOT battery [9].

Stroop test TBAG form (STP): This test assesses the ability to process attention stimuli and unintentional stimuli in a parallel fashion, the ability to manipulate the speed of information processing, the perceptual set-up of a person in the direction of changing demands and in particular under a "disturbing effect," the ability to suppress a conventional behavioural pattern and to perform an unusual behaviour, was first developed by Stroop [10]. The psychometric properties of Stroop TBAG in the Turkish sample were examined based on the standardization of the BİLNOT battery [9]. STP sub-tests include: reading names written in black (STP1), reading colour names written in different colours (STP2), telling colours of printed colourful circles (STP3), telling colours of the neutral words (STP4) and telling the printing colour of the names of the colours written in different colours (STP5). In the Stroop test, STP1 and STP2 are used to control the reading speed, while STP3 and STP4 are used to control the speed of colour recognition. The part that measures fulfilling another task under distorting effect (reading) is STP5.

Statistical analysis

The data of the study were analysed with "SPSS 9.0 for Windows" package program. Independent *t*-test was conducted to analyse the demographic characteristics of the study group and the control group whilst the non-parametric Mann–Whitney *U*-test was used to evaluate the differences in the neuropsychological test results between the two groups. The Pearson correlation analysis was used to determine whether there was a significant relationship between the scores of the study group in the neuropsychological tests and the age, education, and duration of work with solvent of these participants. $p < .05$ was considered to be statistically significant.

Findings

Thirty-one male workers who were diagnosed with solvent exposure constituted the study group, and 30 male participants whose job did not require solvent use were included in the study as the control group. The mean values of age and education durations of the study and control groups are shown in Table 1. As is presented in the table, there is no significant difference between the groups in terms of age and educational status.

The mean scores and statistical comparisons of the VMPT sub-tests of both groups are given in Table 2. According to the findings, there is a statistically significant difference between long-term memory scores, learning scores and the highest learning scores between the study and control groups ($p < .001$, $p < .001$, $p < .001$, respectively). No significant difference is found between the two groups in terms of instant memory scores ($p = .085$).

The mean scores and statistical comparisons of the CT sub-tests of the study and control groups are illustrated in Table 3. As the table presents, there is a statistically significant difference between cancellation test 1, cancellation test 2, cancellation test 3, cancellation test 4 and CT total scores of the two groups ($p < .001$, $p = .001$, $p < .001$, $p < .007$, $p < .001$, respectively*). It is seen that the scores of the study group are higher when rank order means are taken into account. This finding suggests that the study group needs more time to complete the assigned tasks.

The mean scores and statistical comparisons of the STP sub-tests of the study and control groups are given in Table 4. According to the findings, there is a significant difference between the two groups in terms of STP scores only in the fifth section ($p < .05$). Although the completion times of the first, second, third, and fourth sections were longer in the solvent group than in the control group, no statistically significant difference is found between the two groups. According to these findings, the completion time of the STP fifth section is longer for the study group than that of the control group.

Discussion

To our knowledge, studies conducted in this area in our country have been limited to case reports. In this study, VMPT was used to evaluate the memory functions of the workers who experienced chronic solvent exposure and the findings revealed that the learning achievements, long-term memory processes and functions of these participants deteriorated when compared to that of the non-exposure participants in the control group. CT was used to evaluate the sustained attention of the participants, while STP was used to assess their selective attention. The findings showed that the overall attention, visual spatial perception, visual scanning skills, and selective attention of the participants in the study group decreased in comparison to that of the control group. In a study conducted with 85 patients with long-term occupational exposure to solvents at the Occupational Diseases Hospital by Van Haut et al. [11], the rate of information processing, memory and learning of the patient group was demonstrated to be significantly worse than the control group. In another study conducted with 300 boys with solvent exposure, it was shown that a significant decrease in memory and motor skills of solvent-exposed children compared to that of working and non-working school children who were not exposed to solvents [6]. VMPT, which is used to explore memory functions in our study, is a test that evaluates learning, and short- and long-term memory functions. Consistent with the previous studies conducted, the memory test results of our study group were found to be significantly lower than the control group. The study group learned significantly fewer words. Besides, the study group was able to remember significantly fewer words in the long-term spontaneous recall process. As a result of our study, it seems that the learning and long-term memory capacities of the study group were reduced compared to that of the control group. Baker [12] drew the conclusion that solvent influenced the short-term memory upon reviewing the previous studies that had been conducted since 1985. In our study, therefore, no significant difference was found in short-term memory scores between the two groups. This condition may be related to the duration of solvent exposure.

In a study conducted with 432 workers who were exposed to solvent, there was a reduction in attention, cognitive speed, and response duration in neurocognitive tests, although the complaints of the workers about attention and memory were scarce [5].Another study in the field examined the attention periods of 84 workers who had been exposed to solvent for a long time in a paint manufacturing facility, and significant impairment in attention span of the participants in parallel with their exposure spans [13]. In parallel with these studies, CT was used to assess the continuous attention levels of the participants in our study. Based on the findings obtained from CT, it was revealed that the study group completed all the subtests of CT in significantly longer time than the control group. CT is a test that measures visual spatial perception, visual screening, continuous attention, agility, response speed and spatial neglect. In order to be

Table 1. Comparison of age and education periods of the groups.

	Study group	Control group	*p*
Age	36	33.5	<.001*
Training period (years)	8.2	8.8	<.001*

*$p < .05$ with *t*-test.

Table 2. Comparison of groups in terms of mean scores of VMPT sub-tests.

	Group	*N*	Average	*S*	Sd	*T*	*P*	*Post hoc* analysis
Instant memory	Study	31	5.4	1.4	59	1.75	.085	Study group = control group
	control	30	6.2	1.9				
Long-term memory score	Study	31	11.3	1.8	59	4.67	<.001*	Study group < control group
	control	30	13.3	1.4				
Learning score	Study	31	106	12.2	59	5.13	<.001*	Study group < control group
	control	30	124	14.8				
The highest learning	Study	31	13.5	1.2	59	4.11	<.001*	Study group < control group
	control	30	14.6	0.7				

Note: VMPT: verbal memory processes test.
*$p < .05$ with *t*-test.

Table 3. Comparison of the scores of the groups in the cancellation test.

	Group	*N*	Rank average	Rank total	*U*	*P*	*Post hoc* analysis
CT 1	Study	31	39.60	1118.00	177.00	$p < .001$*	Study group > control group
	control	30	21.40	642.00			
CT 2	Study	31	37.82	1134.50	230.50	.001*	Study group > control group
	control	30	23.18	695.50			
CT 3	Study	31	39.83	1195.00	170.00	$p < .001$*	Study group > control group
	control	30	21.17	635.00			
CT 4	Study	31	36.53	1096.00	269.00	.007*	Study group > control group
	control	30	24.47	734.00			
TOTAL	Study	31	40.70	1221.00	144.00	$p < .001$*	Study group > control group
	control	30	20.30	609.00			

Note: CT: cancellation test.
*$p < .05$ with Mann–Whitney *U*-test.

Table 4. Comparison of the STP points of the study and control groups.

	Group	*N*	Rank average	Rank total	*U*	*p*	Post hoc analysis
STP1	Study	31	35.16	1090.00	336.00	.062	Study group = control group
	Control	30	26.70	801.00			
STP2	Study	31	35.35	1096.00	330.00	.051	Study group = control group
	Control	30	26.50	795.00			
STP3	Study	31	35.08	1087.50	338.50	.067	Study group = control group
	Control	30	26.78	803.50			
STP4	Study	31	33.50	1038.50	387.50	.263	Study group = control group
	Control	30	28.42	852.50			
STP5	Study	31	36.40	1228.50	297.50	**.016***	Study group > control group
	Control	30	25.42	762.50			

Note: STP: Stroop test.
*$p < .05$ with Mann–Whitney *U*-test.

successful in visual spatial perception, attention must be constantly used, in other words, target stimuli should be distinguished from astonishing stimuli and that should be maintained throughout the task [9]. In the light of this information, the significant lengthening of the test completion time of the workers in the study group can be interpreted as their decreased continuous attention, visual–spatial perception and scanning skills. It can be suggested that completing the task takes longer time for the study group since the participants in this group have difficulty maintaining their attention. These findings also suggest that the reaction rate is reduced in the study group due to solvent exposure.

STP was used to assess selective attention levels in our study. On the basis of the STP results, it was found that the only significant difference between the study group and the control group was the completion time of the fifth sub-section. The study group completed the fifth section in a significantly longer time. STP is one of the frontal area-sensitive tests that are used to evaluate executive functions. The critical section in which the disruptive effect emerged in the test was the fifth sub-section. The type of inhibition assessed in the fifth section, the gold standard in the evaluation of the test, is concerned with the inability to suppress the usual behaviour in order to achieve an unusual behaviour. This is also related to the level of focusing of an individual's attention. According to this finding, it can be said that the study group performed a lower performance than the control group in terms of the ability/speed to change the set-up under the disturbing effect and focused attention. The fifth sub-section of CT is a section that requires more attention for selective attention to be at the forefront. Based on these findings, it can be said that the selective attention level of the study group is impaired compared to the control group.

The limitations of the study include having a small study group, not conducting solvent measurements in the research context, and not having cumulative environment measurements in our country. Cumulative solvent media measurements are particularly important to be made to provide more accurate information between being exposed and being effected. Another limitation of the study is that we do not have enough data about the attention and memory processes of the participants before they were exposed to solvent.

As a result, upon the evaluation of all the neuropsychological test results together, long-term study group was found to experience selective and constant attention problems. Attention is an important concept that affects memory processes and learning. This relationship between attention and memory is also supported by the findings of this study. It was found that the study group, who had poor performance in attention tests, also showed lower performance in the memory test in comparison to the control group.

Solvent is one of the most widely used chemical substances as a dissolver in the industrial field in the world. It also has a wide range of application in the industry of our country. Occupational exposure to solvent continues to be a major problem in labour and worker health in Turkey as well as in most countries. However, there is not enough statistical information and research about this issue. Therefore, we think that our research will contribute to the related body of literature. Likewise, workers working in these areas should be regularly examined to determine the level of their exposure, and protective measures should be reviewed.

Disclosure statement

No potential conflict of interest was reported by the authors.

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