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The Long Term Effects of Ethylene Dichloride Exposure on Memory Functioning

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ABSTRACT

The current study examined a group of individuals exposed to ethylene dichloride (EDC) and compared them to a control group on memory functioning as measured by the Wechsler Memory Scale, III. The study also collected a follow-up evaluation from exposed participants to examine long-term effects of EDC upon memory performance. The results of the neuropsychological evaluations suggest exposure to EDC had a significant and permanent adverse influence on memory functioning at more than six years post exposure. A follow-up evaluation conducted 10 years post exposure supported this original observation. The researchers discuss limitations of this study and the need for further research concerning other aspects of functioning in addition to memory processes.

INTRODUCTION

Overview of Ethylene Dichloride

Ethylene Dichloride (EDC), more properly described as 1,2-dichloroethane, is an organic solvent used in the manufacture of pesticides, fumigants, paints and plastics (NIOSH, 1978). Its importance to the chemical industry cannot be underestimated as 2.8 billion pounds were produced in 1994 (Agency for Toxic Substances and Disease Registry [ATSDR], 2001).

EDC has been classified as a hazardous material. The Environmental Protection Agency

(EPA), National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) has set exposure limits between one part per million (ppm) and fifty ppm per work day (ATSDR, 2001; NIOSH, 1995). The management of EDC is a matter of concern as it is a carcinogen (Bahlman et al., 1978), a neurotoxin (ATSDR, 2001) and a suspected DNA mutating agent (Baertsch, Lutz, &Schlatter, 1991; Kramers, Mout, Bissumbhar, & Mulder, 1991).

Physiological Effects of EDC

EDC also adversely affects other body systems. Rao et al. (1980) noted the teratogenicity of EDC on reproduction activity of rats. Mergler, Bowler, and Cone (1990) documented color vision loss in workers), while others documented abnormal liver functions in industrial workers (Cheng, Huang, You, Du, & Chau, 1999)

Memory

General concerns. The assessment of memory is an ideal conduit to assess the long term effects of toxic substances. Memory often proves to be the thermostat of higher cortical functioning. Deficiencies, some of which can be subtle, can be first detected by a thorough assessment of memory because it is diffuse and bilateral (Banich, 2004). In this study memory is defined as an internal record or representation of some prior event or experience (Gordon, 1989).

Memory impairments secondary to toxic exposure. A number of individuals have evaluated memory dysfunction in the course of investigating cognitive impairments related to toxic exposure. For example, Morrow, Robin, Hodgson, and Kamis (1992) compared 40 individuals with 40 controls and found exposed individuals possessed memory deficits which were partially attributed to impairments in attention and concentration due to an inability to deal effectively with an increase in processing load.

Bowler, Mergler, Rauch, Harrison, and Cone (1991) investigated the effects of exposure to multiple organic solvents in the microelectronics industry and found slightly lower performance on measure of memory, as measured by the California Neuropsychological Screening Battery – Revised. Although some measures were within normal limits, the pattern of impairment was regarded as being consistent with solvent toxicity.

Deficiencies in somatic memory were discovered by Milanovic et al. (1990). Their study examined 23 individuals exposed to mixed organic solvents at a plant in Yugoslavia. It was concluded that exposure affected immediate and recent memory on measures of digit span, complex figure reproduction and word memory tests.

Current Study

The current study examined a group of individuals exposed to EDC and compared them to a control group on memory functioning as measured by the Wechsler Memory Scale, III. The study also collected a follow-up evaluation from exposed participants to examine long-term effects of EDC related to memory. The hypotheses of this study included significantly lower

memory scores for the exposed group relative to the control group, and for their long-term effects to show their impaired memory scores to remain relatively stable.

METHOD

Participants

Exposed. Sixty-one individuals (59 men and 2 women, with a mean age of 40.03 and a mean for years of education of 11.44) were evaluated 6.5 years post exposure at a private clinic. The follow-up group consisted of 12 individual from the original group. At the time of the follow-up evaluation, these individual had a mean age of 44.58. This group attested to 21.52 years of experience and an average of 96 days working directly with EDC during the clean-up. One participant could not recall the amount of days spent working directly with EDC.

Non-exposed. Forty-eight individuals (46 men and 2 women, with a mean age of 29.6 and a mean for years of education of 13.35) were evaluated at a private clinic in central Louisiana. The group, as a whole, consisted of blue collar workers, from a similar cultural background, but from a community without any petrochemical industry. Participants were prescreened for neurological or prior toxic exposure. Each was compensated $50 for their time.

Equipment

The original version of the Wechsler Memory Scale (WMS) was published in 1945 and comprised seven subtests. The 1997 edition, known as the WMS-III, contains eleven primary subtests, which produce eight primary index scores. The primary scales are auditory immediate, visual immediate, immediate memory, auditory delayed, visual delayed, auditory recognition delayed, general memory and working memory. The resulting index scores possess a mean of 100 with a standard deviation of 15.

Procedure

2001 initial evaluation. Individuals were solicited through attending physicians, agencies, attorneys, and acquaintances. Each was contacted by telephone and assigned an appointment. After completing releases and consents, individuals were assessed in a cool, quiet room by a licensed clinical neuropsychologist and a trained technician under supervision.

2005 follow up evaluation. Sixty-two individuals were contacted by phone and requested to retake the WMS-III. Of those contacted only 25 accepted and later during initial interviews, all but 12 were eliminated due to self-medication with alcohol or noncompliance with treatment regimens. Many individuals declined to be reevaluated due to adverse job consequences or fear it might interfere with their disability status. Three said they were too impaired to participate. Evaluations were conducted at a private clinic and followed the same procedures as described in the 2001 study.

RESULTS

Correlations

Each scale of the WMS-III was strongly correlated with each other scale with *r* values ranging from .57 to .89 and $p < .001$ in all cases. Age and education were also correlated with the WMS-III scales. However, these correlations were typically weak. Table 1 indicates the weakest correlations are between educational level and the scales.

To initially test the hypothesis, the groups were initially coded. A zero was assigned to each participant in the control group and a one was assigned to each participant in the experimental group. A Pearson correlation was conducted to examine if there was a relationship between group and WMS-III scores. Each scale of the WMS-III was significantly correlated with group. These results are reported in Table 2, with *r* values ranging from .56 to .72, and they indicated a need for further examination of the group differences.

Group Differences

Exposed vs. Control Group. An independent-samples *t*-test was conducted to examine any significant differences between the exposed and the control group at the initial evaluation. There were significant differences between the exposed and control groups on all scales of the memory test; however, there were also significant differences in the groups' age and education level. This initial *t*-test is shown in Table 3. It is clear the exposed group is significantly lower on all WMS-III scales.

Due to the age and education differences, the researcher conducted a partial correlation controlling for age and education. Using the groups coded as "0" and "1" again, this correlation indicated a significant relationship between the WMS-III scale scores and group. With these factors being controlled, the correlation remained strong. Table 4 indicates significant relationships between group and each WMS-III scale. These results further support the study's hypothesis.

To further strengthen the results, the researchers ran another *t*-test, this time holding education constant at 12 years of education with only those individuals having 12 years of education included in the analysis. Table 5 shows the results of this analysis. With education constant at 12 years, age was no longer a significant difference between the groups. This allowed the researchers to have more confidence in the findings reported in Table 5, indicating the control group scoring significantly higher than the exposed group on all WMS-III scales.

Initial vs. Follow-up Evaluation for Exposed Group

A *t*-test indicated few differences between the initial and follow-up evaluations for the exposed group. The individuals scored significantly higher in Auditory Delayed Memory at follow-up ($M = 94.58$, $SD = 11.97$) than at the initial evaluation ($M = 0.08$, $SD = 10.63$), $t(22) = -3.138$, $p = .005$. There was also a trend towards higher scores in Visual Delayed Memory at follow-up ($M = 89.17$, $SD = 19.95$) than at the initial evaluation ($M = 73.75$, $SD = 17.46$), $t(22) =$

-2.014, $p = .056$. All other WMS-III scales had not significantly changed since the initial evaluation.

DISCUSSION

The results of the 2001 neuropsychological evaluations suggest exposure to EDC had a significant and permanent adverse influence on memory functioning at more than six years post exposure. A follow-up evaluation conducted 10 years post exposure supported this original observation. Although there were some memory improvements in functioning, notably in auditory delayed memory, their overall memory capability was still impaired as compared to controls. Given the time since exposure further improvements in functioning appear unlikely. There was a trend toward improvement in visual delayed memory and other realms of memory functioning, such as general memory and working memory were not showing signs of further deterioration.

All of the individuals evaluated complained of a deficiency in overall, or general memory, but the end complaint may be consequence of multiple factors rather than the single cause of an impairment in memory functioning. Each complained of issues related to chronic pain, depression, marital discord, unemployment or job stress, as well as a variety of physical problems, such as transitory skin rash; a classic feature of chronic EDC exposure. Overall, it is not surprising that such physical, social and psychological stressors would result in an exacerbation of memory complaints.

As in any study there are limitations which should be noted. Foremost among these is the fact that the population involved was not random but pre-selected by the nature of being exposed and expressing a willingness to be evaluated. An evaluation of all clients would have been ideal but some declined due to employment considerations while others pleased poor health. It is a sad commentary that several declined for fear of retaliation.

There is a limited body of literature on the long-term effects of toxic substances in humans, and opportunities for future investigations abound. This study was limited to the assessment of memory functioning and did not address language usage, executive functions, interpersonal relations, depression, anxiety or other neurobehavioral issues that are related to quality of life, general adjustment or productivity. All of these topics have yet to be addressed.

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Table 1

Correlation Matrix: WMS-III Scales and other Variables

	Aud Im	Vis Imm	Imm	Aud Del	Vis Del	Aud Rec Del	Gen Mem	Work Mem	Age	Edu
Auditory Immediate (Aud Imm)										
r	-	.70	.89	.87	.73	.73	.85	*.55*	-.26	.29
p	-	< .001	< .001	< .001	< .001	< .001	< .001	< .001	.007	.002
Visual Immediate (Vis Im)										
r		-	.92	.71	.86	.65	.82	*.56*	-.41	.40
p	< .001	-	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001
Immediate (Imm)										
r	-	-	-	.84	.86	.74	.89	*.61*	-.37	.38
p	-	-	-	< .001	< .001	< .001	< .001	< .001	< .001	< .001
Auditory Delayed (Aud Del)										
r	-	-	-	-	.74	.73	.89	*.65*	-.39	.38
p	-	-	-	-	< .001	< .001	< .001	< .001	< .001	< .001
Visual Delayed (Vis Del)										
r	-	-	-	-	-	.66	.89	*.58*	-.40	.36
p	-	-	-	-	-	< .001	< .001	< .001	< .001	< .001
Auditory Recognition Delayed (AR Del)										
r	-	-	-	-	-	-	.84	.57	-.32	.36
p	-	-	-	-	-	-	< .001	< .001	< .001	< .001
General Memory (Gen Mem)										
r	-	-	-	-	-	-	-	.65	-.40	.39
p	-	-	-	-	-	-	-	< .001	< .001	< .001
Working Memory (Work Mem)										
r	-	-	-	-	-	-	-	-	-.38	.36
p	-	-	-	-	-	-	-	-	< .001	< .001
Age										
r	-	-	-	-	-	-	-	-	-	-.34
p	-	-	-	-	-	-	-	-	-	< .001

Table 2

Negative correlations for group and WMS-III scale scores

	r	*p*
Auditory Immediate Memory	-.62	<.001
Visual Immediate Memory	-.62	<.001
Immediate Memory	-.68	<.001
Auditory Delayed Memory	-.72	<.001
Visual Delayed Memory	-.68	<.001
Auditory Recognition Delayed Memory	-.56	<.001
General Memory	-.71	<.001
Working Memory	-.58	<.001

Table 3

Initial t-test of group mean differences on WMS-III scales

	Exposed (n = 61)		Control (n = 48)			
	M	*SD*	*M*	*SD*	*t*	*p*
Auditory Immediate Memory	77.15	11.99	97.67	13.92	-8.26	<.001
Visual Immediate Memory	74.38	13.27	95.60	14.08	-8.07	<.001
Immediate Memory	70.61	13.63	97.06	15.11	-9.59	<.001
Auditory Delayed Memory	76.74	11.76	102.88	13.98	-10.60	<.001
Visual Delayed Memory	72.28	13.64	97.06	13.08	-9.59	<.001
Auditory Recognition Delayed Memory	82.02	14.18	100.63	13.67	-6.91	<.001
General Memory	71.92	13.00	98.42	13.76	-10.30	<.001
Working Memory	87.87	16.59	112.31	17.95	-7.37	<.001

Table 4

Partial correlation for group and WMS-III scales

	r	*p*
Auditory Immediate Memory	-.56	<.001
Visual Immediate Memory	-.50	<.001
Immediate Memory	-.59	<.001
Auditory Delayed Memory	-.64	<.001
Visual Delayed Memory	-.59	<.001
Auditory Recognition Delayed Memory	-.45	<.001
General Memory	-.62	<.001
Working Memory	-.47	<.001

Table 5

T-test of group differences on WMS-III scales holding education constant at 12 years

	Exposed (n = 16)		Control (n = 15)			
	M	*SD*	*M*	*SD*	*t*	*p*
Auditory Immediate Memory	76.50	14.10	100.47	15.06	-4.58	<.001
Visual Immediate Memory	73.06	10.95	94.73	13.54	-4.92	<.001
Immediate Memory	69.50	13.35	94.40	15.06	-5.47	<.001
Auditory Delayed Memory	78.63	14.51	102.93	12.12	-5.05	<.001
Visual Delayed Memory	70.25	11.85	98.47	10.07	-5.59	<.001
Auditory Recognition Delayed Memory	82.81	14.49	105.00	15.00	-4.19	<.001
General Memory	72.06	13.62	101.00	12.71	-6.11	<.001
Working Memory	91.50	21.18	115.40	20.71	-3.17	<.001