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Memory sequelae of solvent intoxication

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STOLLERY BT, FLINDT MLH. Memory sequelae of solvent intoxication. *Scand J Work Environ Health* 14 (1988) 45–48. A retrospective study on a small group of female workers accidentally intoxicated by organic solvents (toluene and aliphatic hydrocarbons) evaluated complaints of residual memory impairment. Memory testing was first performed two months after the intoxication with a follow-up six months later to assess recovery. The workers showed normal patterns of performance on tests of learning and short-term and longer-term memory, but marked difficulties were observed when attention had to be allocated between two resource-competing tasks. As there was no evidence of recovery by the follow-up session, the results indicate that solvent intoxication can cause neuropsychological sequelae lasting for over eight months.

Key terms: aliphatic hydrocarbons, attention, depression, memory impairment, neurotoxic effects, occupational exposure, toluene.

The extensive use of organic solvents in industrial processes has led to an increasing interest in evaluating the possible neurotoxic effects of occupational exposure (1, 13). The present paper describes an investigation of the memory sequelae for a small group of women accidentally intoxicated by organic solvents from adhesives used in the manufacture of tennis balls. The solvents were toluene and SBP 7 [a proprietary aliphatic petroleum solvent, being a mixture of paraffin hydrocarbons in the C6 to C9 range (hexane, heptane, octane, and nonane)]. The intoxications occurred over a period of 3 d, after a change in work practices, several women experiencing loss of consciousness or faintness, nausea, vomiting, and headache. They subsequently complained of impaired memory, personality changes with depression, and loss of confidence. These symptoms were still present eight months later.

The workers had received no further solvent exposure between the time of the acute incident and the beginning of the investigation, some two months later. The overall investigation of the problem will be described elsewhere (Flindt, in preparation). The present investigation concentrated solely on memory function, as impaired memory had been a major residual complaint. The tasks assessing memory function had a well-established theoretical background (5) and were selected so that the nature of memory difficulties could be addressed.

Subjects and methods

Subjects

The subjects were female employees of a tennis-ball factory. Of the 12 solvent-exposed workers who were clinically identified as the most severely affected by the accident, nine agreed to participate in the memory study (acute group). Then solvent-exposed workers who were not affected by the accident (chronic group) and ten workers unexposed to solvents (reference group), from the packing department, were selected from volunteers whose age and duration of employment at the factory were comparable to that of the acute group.

The subjects were tested twice. The first session was two months after the accident. In that session, the subjects had a short practice on the memory tests, to acquaint them with procedures, and the main session followed after a short break. A short break was also given after each memory task. The second session was six months later. The subjects were tested individually in a session lasting 1 h. The testing took place at work, during normal workhours, in a quiet room.

Two subjects from the acute group and two subjects from the chronic group declined to be retested at the time of the follow-up, and only the results from those who participated in both sessions are reported. Table 1 summarizes the group matching achieved and omits the four refusals.

Table 1. Summary of group matching for the acute, chronic, and reference groups.

Group	Age (years)		Employment (years)		Depression score ^a	
	Mean	SD	Mean	SD	Mean	SD
Acute (N = 7)	32.1	9.6	4.7	3.3	17.6	13.6
Chronic (N = 8)	33.7	7.2	5.3	2.4	3.5	2.5
Reference (N = 10)	36.6	9.0	7.5	4.7	5.6	3.4

^a Score from the Beck (2) depression inventory.

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Memory tasks

Three memory tasks were used. Memory materials were high frequency AA and A words (11). Different words were used in each task and in each testing session. The Beck depression inventory (2) was also administered in the second session.

Paired-associate task. In each trial the subjects heard six pairs of unrelated words (eg, house-paper). The presentation rate was one word pair every 2 s, with a 2-s pause between the word pairs. At the end of each trial, the subjects attempted to recall the first word of each pair (eg, house) given the second word (eg, paper) as a cue; they were not corrected if they gave the wrong answer. This procedure was repeated eight times or until correct recall of all word pairs was achieved in two consecutive trials, whichever was sooner. Each paired associate was presented and tested in a new random order in each trial. The task lasted about 15 min.

Serial-position task. In each trial the subjects heard a list of 15 words (one word every 2 s) and immediately afterwards recalled as many words as possible (4, 9). Twenty different lists were presented in a test lasting about 30 min.

Brown-Peterson task. In each trial the subjects heard three words (one every 2 s) and attempted to recall them either immediately (0 s) or after an interval of 5, 10, 15, or 30 s of backward counting in threes (3,

10). Ten trials were given for each time interval — counterbalanced to control for task learning and proactive interference effects. The task lasted about 20 min.

Statistical analysis

The scores were analyzed with a repeated measures analysis of variance with covariance (6). The between-subject factor was the three groups (acute, chronic, and reference), and the within-subject factors were the task variables. The scores from the depression inventory, together with the subjects' age and duration of employment at the factory, were designated as covariates in order to control for their possible effects on memory performance.

Results

The acute group rated themselves as more depressed than the other groups [F-ratio: $F(2,22) = 7.5$, $P = 0.003$]. The depression scores of the chronic and reference groups did not differ significantly (table 1). The groups did not differ with respect to their age ($P = 0.58$) or duration of employment ($P = 0.25$).

Paired-associate learning task

The number of word pairs correctly learned increased over successive trials [$F(7,154) = 38.5$, $P < 0.001$], and, as learning progressed, there was a decline in the number of omission [$F(7,154) = 41.8$, $P < 0.001$] and intrusion [$F(7,154) = 6.5$, $P < 0.001$] errors. Table 2 shows that the acute group tended to learn fewer word pairs than the other groups [$F(2,22) = 2.8$, $P = 0.08$]. This poorer performance was due to a higher omission ($P = 0.05$), rather than intrusion ($P = 0.25$), error rate. The rate at which word pairs were correctly learned, however, did not differ for the three groups ($P = 0.50$). This pattern of findings was present for both sessions.

Serial position task

The proportion of words correctly recalled at each serial position (figure 1) was higher for words at the end of each list [$F(14,308) = 136.7$, $P < 0.001$]. The acute group recalled fewer words than the chronic and reference groups [$F(2,22) = 3.4$, $P = 0.05$], but the interaction between serial position and groups was not significant ($P = 0.48$). There was no evidence to suggest that the acute group's poorer recall was specific to the primacy, asymptote, or recency component of the serial position curve. The enhanced recency effect on the follow-up session [$F(14,308) = 3.58$, $P < 0.001$] was identical for the three groups ($P = 0.73$).

The presence of proactive interference (ie, interference from earlier lists) was demonstrated by the poorer recall of words from lists presented later in the task [$F(19,418) = 3.6$, $P < 0.001$]. The interaction between list position and groups ($P = 0.04$) derived simply from improved recall by the acute group from the first to

Table 2. Mean number of paired-associates correctly learned over successive trials. The scores are the average of both sessions.

Group	Number of acquisition trials							
	1	2	3	4	5	6	7	8
Acute	1.4	1.6	2.4	2.4	2.6	3.1	3.4	3.8
Chronic	1.8	2.4	2.9	3.1	4.0	3.9	3.9	4.6
Reference	2.0	3.1	4.0	4.2	4.4	4.7	4.8	5.1

Figure 1. Mean proportion of words correctly recalled as a function of serial position, averaged over both sessions.

second list ($P = 0.02$). There was no evidence to support the contention that the acute group was more prone to proactive interference.

The number of prior-list intrusions (words from a previous list) and extra-list intrusion (words not on any list presented) increased with age ($P = 0.007$ and $P = 0.015$, respectively). The acute group tended to produce fewer prior-list intrusions [$F(2,21) = 2.96$, $P = 0.07$], but extra-list intrusions did not differ for the three groups ($P = 0.16$). In the follow-up session, the prior-list intrusion rate was lower [$F(1,22) = 22.5$, $P < 0.001$], and the extra-list intrusion rate was higher [$F(1,22) = 4.1$, $P = 0.05$]. This pattern was identical for all the groups.

Brown-Peterson task

Figure 2 shows that the proportion of words correctly recalled in the Brown-Peterson task declined as the period of backward counting increased [$F(4,88) = 177.7$, $P < 0.001$]. The generally poorer recall by the acute group [$F(2,22) = 7.9$, $P = 0.003$] interacted with the delay before recall [$F(8,88) = 3.9$, $P < 0.001$]. Although the counting task induced marginally less forgetting in the second session ($P = 0.06$), the interaction with groups was not significant ($P = 0.87$).

A second analysis, of all counting intervals except the zero interval, confirmed that the acute group's impairment was restricted to the first 5 s of backward counting. Forgetting was substantial from 5 to 30 s [$F(3,66) = 34.3$, $P < 0.001$], the acute group recalled fewer words [$F(2,22) = 7.9$, $P = 0.002$], but the interaction between groups and duration of counting was not significant ($P = 0.57$). Thus the forgetting rate was equivalent for the three groups after 5 s of counting. This pattern of results was observed in both sessions.

The initial decline in recall from 0 to 5 s was not correlated with either age ($P = 0.55$) or the depression scores ($P = 0.33$). The correlation between the duration of solvent exposure and the initial decline was barely significant in the chronic group ($P = 0.07$), but was not significant in the acute group ($P = 0.27$).

The acute group's inferior retention was reflected in errors of omission. Such errors increased in all the groups with longer intervals of backward counting [$F(4,88) = 90.7$, $P < 0.001$], the increase being disproportionately great in the acute group [$F(8,88) = 5.25$, $P < 0.001$]. Prior-list intrusion and extra-list intrusion errors increased after 5 s of backward counting (both $P < 0.001$) and then remained constant. The same pattern was observed for all the groups. Finally, older subjects tended to produce more prior-list ($P = 0.05$) and extra-list ($P = 0.07$) intrusion errors.

Discussion

The present study evaluated complaints of impaired memory by female solvent-exposed workers following

Figure 2. Mean proportion of words correctly recalled in the Brown-Peterson task as a function of the delay before recall, averaged over both sessions.

acute exposure to toluene and aliphatic hydrocarbons. The clearest evidence of impairment following the intoxication was observed in the Brown-Peterson task. Overall levels of performance in the serial position and paired-associate tasks were, however, also slightly impaired. A six-month follow-up showed no relative recovery.

Free-recall in the serial position task conformed to the classic pattern found for normal subjects (5, 9). Recall was good for the first word (primary effect) and last few words (recency effect) of each list and uniformly poor for middle-list items (the asymptote). The recency effect reflects recall from a limited capacity, highly accessible, labile short-term memory system, while the asymptote reflects recall from a longer-term memory system. Although the level of performance by the acute group was inferior, the form of the serial position curve was identical for the acute, chronic, and reference groups. It can be concluded, therefore, that neither short-term (primary) nor longer-term (secondary) memory systems were specifically implicated in the inferior recall. Similarly, although the acute group recalled fewer paired associates, they learned the associates at the same rate as the chronic and reference groups.

By contrast, in the Brown-Peterson task, the acute group showed impaired resistance to the competing influence of a distractor task. While this finding provides some support for the intoxicated workers' complaints of impaired memory, two aspects of the data implied that the more rapid loss of information from short-term memory was not the result of simple decay. First, after the initial disruption, forgetting was substantial but equivalent for the three groups. Second, there was no reduced recency effect in the serial position task. Thus other task factors were implicated in the impaired Brown-Peterson performance. These factors are considered in the following discussion.

In addition to simple decay (3), vulnerability to proactive and retroactive interference (7,12), and the allocation of processing resources between memory and interval tasks (8), can also influence forgetting rates in short-term memory tasks. Interference from previous trials (proactive interference) is a known source of forgetting in Brown-Peterson tasks and was, therefore, specifically equated at each delay condition. The data from the serial position task allowed examination of proactive interference effects, but the acute group was not more susceptible to proactive interference.

In the Brown-Peterson task, interference from material processed after learning (retroactive interference) derives from the interval task (backward counting). However, because the forgetting rates of the acute, chronic, and reference groups were equivalent after the initial disruption, it can be concluded that the acute group was not more susceptible to retroactive interference.

From the preceding discussion, it can be concluded that the specific difficulty of the intoxicated workers appears to be one of initially allocating processing resources to both memory and counting tasks — that is, the acute group was more easily disrupted by another attention demanding task. Because the processing requirements of the interval task have a substantial effect on forgetting rates (8), it is important to note that there was no evidence that the acute group found the counting task more difficult. In connection with the effects of interval task difficulty on Brown-Peterson recall, Morris (8) has described several techniques for studying central processing reductions of the kind found in the present study.

Depression and reduced “freedom from distractibility” have often been described as symptoms of organic solvent exposure (1, 13), and the present findings support this possibility for the intoxicated workers. The magnitude of the memory sequelae was not correlated with the depression scores, a finding suggesting that cognitive impairment may occur independently of mood change. The possibility that preexisting group differences confounded this interpretation was considered unlikely. First, although the acute group comprised solvent workers severely affected in the accident, selection was based on case history and clinical criteria, not psychological criteria. Second, the possibility that workers with initially “poorer memory” were disproportionately represented in the acute group also seems unlikely given that the patterns of memory performance were identical for the acute, chronic, and reference groups — with the exception of the specific impairment found in the Brown-Peterson task.

In summary, the present study found that the memory sequelae of solvent intoxication reflected difficulty with initially allocating central processing resources, a difficulty which was still apparent some eight months after the intoxication. The extent to which poor recall in the paired-associate and serial position tasks was also

due to a general restriction in central processing capacity, however, remains unknown.

These findings go some way towards clarifying the clinical picture of solvent intoxication and, because information retention in situations which prevent immediate rehearsal captures a common memory experience, it is suggested that difficulties in resource allocation may also be the basis of memory complaints of other occupationally exposed populations. The poor prognosis for the intoxicated workers should be treated with caution when recovery from other solvent intoxications is being estimated because the contribution of chronic solvent exposure to the nature of the memory sequelae could not be adequately explored in such a small population of industrially intoxicated workers. Finally, it is suggested that memory tasks covering a similar range of functions should prove useful in identifying memory impairment in other occupationally exposed groups, not the least because they help to specify the nature of memory difficulties.

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