THE EFFECTS OF A 'SICK BUILDING' ON NEUROPSYCHOLOGICAL FUNCTIONING

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Abstract

THE EFFECTS OF A 'SICK BUILDING' ON NEUROPSYCHOLOGICAL FUNCTIONING

LAUREN R. MARSH-KNICKLE

The purpose of the present study was to investigate systematically a suggested decline in neuropsychological functioning among workers of Camp Hill Medical Centre (CHMC) who participated in a previous neuropsychological study (Hayes, 1992). Specifically, it was to determine whether or not CHMC staff volunteers who had reported Sick Building Illness (SBI) related health complaints would perform more poorly on psychometric testing than would a control group. The latter group was obtained from a rural hospital which had natural ventilation (openable windows) and subjects who had no related health complaints. Whether or not affected employees from CHMC show signs of recovery from cognitive impairment after they have been out of the work environment had not been addressed. Hence, this study

compared the test scores of CHMC staff volunteers who had been on sick leave for at least three months (previously exposed), to CHMC subjects who were either still working or off for no greater than six weeks (recently exposed). All three groups were similar in age, education, gender proportion and sample size. Each group containing 20 volunteer participants (18 females and 2 males) were administered a battery of neuropsychological tests. Test-retest correlation coefficients reached significance ($p < .05$) for the Solvent Questionnaire, the Cognitive Failure Questionnaire, Picture Arrangement (WAIS-R subscale), Performance Intelligence Quotient, Logical Memory I and II (WMS-R subscale), delay version of the Rey Osterrieth Complex Figure and all three subtests of the Stroop Colour Word Test. Premorbid Performance Intelligence was estimated using a reading test and no differences were found between the three groups. Mean trends suggested poorer overall performance by the exposed groups; and poorer performance by the previously exposed group compared to the recently exposed group. However, the self-report questionnaires were the only measures which showed differences between the two exposed groups and the control group when adopting a stringent alpha (.0025). Both CHMC groups endorsed a higher number of complaints on two of the self-report questionnaires (Solvent Questionnaire and Cognitive Failure Questionnaire) than the control group. The previously exposed group reported a greater number of depressive complaints than the control group. Further group differences were determined at .05 significance level. There was no difference between the three groups on their current Performance Intelligence. However, when the differences were calculated between their premorbid and current Performance Intelligence, CHMC staff members who were previously exposed had a larger mean difference than did the controls. Differences between these two groups were also found on the Digit Symbol subscale of the WAIS-R, Visual Memory Span (WMS-R subscale) and all three subtests of the Stroop Colour-Word Test. The recently exposed group recalled a fewer number of digit-symbol pairs (WAIS-R NI subscale) than did the controls. Interpretation of these results at this less conservative significance level must be made cautiously. However, what is noteworthy is that the tests which have shown a difference at this level all involve visually presented material. The two exposed groups were not significantly different from one another on any test measure. Several of the test measures were found to significantly correlate with other test measures, hence, many were eliminated from the discriminant analysis. This final analysis indicated that the Cognitive Failure Questionnaire was the only measure sensitive enough to predict group membership between the CHMC groups and the control group.

The Effects of a 'Sick Building' on Neuropsychological Functioning

The purpose of this study was to examine memory processes and cognitive functioning of occupants working in a "sick building". The following review provides current background information on Camp Hill Medical Centres' air quality problems and resulting health problems reported by its employees. Sick Building Illness is then outlined, including its effects on occupants, and potential contributing factors to the illness (i.e., Mass Psychogenic Illness and the role of ventilation systems and solvent exposure). Studies involving neuropsychological investigations of solvent exposures are reviewed. Finally, a recent staff assessment at Camp Hill Medical Centre, in response to the air quality problems, is presented with an emphasis on the neuropsychological assessment.

Background

Camp Hill Medical Centre, which operates in Halifax, Nova Scotia, is made up of four buildings, the Halifax Infirmary, the "Main" Building, the Abbie J Lane Building, and the newest addition, the Veteran's Memorial Building (VMB). The latter three buildings are connected via walkways, while the Halifax Infirmary is geographically separated. The main building and the Abbie J Lane were constructed in 1916 and 1969, respectively (Ross, Johnson & Rea, 1993). The VMB was completed in 1987. This date is noteworthy as construction standards were modified in the 1970's to make buildings air tight in response to the energy crisis of that decade (Jones, 1992). It was shortly after completion of this building that kitchen staff located in the basement of the VMB complained of headaches, skin and eye irritation (Ross et al., 1993). In 1989, sodium hydroxide from dishwasher exhaust was discovered to be re-entering the building through the air intake (Robb, 1993). This was initially thought to be the cause of the staff's complaints; however, in 1990 kitchen staff reported an outbreak of skin rashes. Investigations into these complaints turned up a new source of irritation - sulphuric and hydrochloric acid had been poured into the air intake (Robb, 1993) which was supposed to be providing fresh air into that area (Jones, 1992). Health related complaints appeared at this time in other areas of the three attached buildings due to ventilated air which was shared by all occupants (Marchant, Figley, Hayes, King, & Saunders, 1992). Harmful levels of phenol and formaldehyde were found in the hospitals cleaning solutions. Air flow problems were also detected, workers were being exposed to unclean air (Marchant et al., 1992, & Robb, 1993). To date, about 600 out of approximately 1100 employees at these sites have adverse health complaints attributed to working in this building complex. (Chisholm & Doyle Driedger, 1993)

Sick Building Illness

A sick building is one in which complaints of ill health in employee occupants are more common than reasonably expected (Finnegan, Pickering, & Burge, 1984). Sick Building Illness (SBI) is classified as a work-place related disorder (Ryan & Morrow, 1992). It is a set of nonspecific complaints with an unknown or unconfirmed etiology (Hodgson & Morey, 1989). The Ontario Ministry of Health referred to it as, 'a chronic multisystem disorder, in which patients reacted adversely to some chemicals and to environmental agents at levels generally tolerated by the majority' (Simon, Katon & Sparks, 1990, pp. 901). Investigations into the cause of mucous membrane irritation often result in the diagnosis of SBI only after all other obvious irritants are eliminated. Kreiss (1989), referred to it as a diagnosis by exclusion.

To date the actual prevalence and incidence rates of SBI are unknown (Wood, 1989). Woods (1989) suggested that if 20 to 30 percent of the buildings in the United States had air-quality problems, than approximately 30 to 70 million people would be ill. SBI could account for at least two-thirds of these illnesses, while the remainder could be explained by Building Related Illness (i.e., humidifier fever, Legionnaires Disease). However, current estimates, if accurate, suggest the occurrence of SBI to be a problem of significant proportions, with an enormous cost to both employers and employees

Although the originator of the term 'Sick Building Syndrome' appears to be unknown, the earliest citation is credited to Berglund, Berglund and Engen (1983; cited in Travis, McLean & Ribar, 1989). Prior to this, the condition was commonly referred to as 'Tight Building Syndrome' (Hodgson & Morey, 1989) as the cause of building related health complaints was thought to be solely related to inadequate ventilation systems. With increasing evidence for the role of other contributing factors, the popularity of this term has faded and "Sick Building Syndrome" has gained acceptance. However, reference to the illness as a syndrome (a set of symptoms) is, in fact, a misnomer, since it is characterized as having variable nonspecific symptoms. Hence, the term Sick Building Illness (SBI) would be a more suitable label for this phenomenon and will be used throughout this thesis.

Effects of Sick Building Illness

The scope of SBI effects can be categorized under three 10 classifications, namely, physiological effects, psychological effects and neuropsychological effects (Ryan & Morrow, 1992). Physiological effects include, mucous membrane irritation (eye, nose and throat), skin irritation, (Finnegan et al., 1984, Morrow, Robin, Hodgson, & Kamis, 1992; Robertson et al., 1985), upper respiratory problems, dizziness (Ryan & Morrow, 1992; Health Protection Branch, 1991), and unpleasant odour and taste perceptions (Ryan & Morrow, 1992). The Health Protection Branch (1991) of Health and Welfare Canada also added palpitations, tremors and sweating, muscle and chest pains, and tingling in the extremities. Headaches were also commonly reported (Finnegan et al., 1984; Ryan & Morrow, 1992; Robertson et al., 1985) as well as nausea (Morrow et al., 1992).

There are very few references to psychological effects in studies of SBI. In a recent study, however, occupants of problem buildings reported an increase in psychological distress (Bauer et al., 1992). Specifically, they showed higher levels of defensiveness, distrust of authority, anxiety and confusion, as measured by psychological questionnaires. Bauer et al. (1992) attributed the distress to several factors, such as, working in a building that is known to have air quality problems, and the perceived lack of solutions to these problems. As well, when occupants are confronted with skepticism due to their unobservable symptoms (i.e. they don't look sick so others believe their complaints to be "all in their heads") feelings of distress may result.

Neuropsychological effects include mental fatigue, (Finnegan et al., 1984; Ryan & Morrow, 1992), and mental confusion (Ryan & Morrow, 1992). Difficulties in concentrating, short-term memory, mental efficiency and visual/spatial functioning have also been associated with SBI (Hodgson, 1989).

Molhave (1986; cited in Hodgson, 1989) proposed a classification system of SBI symptoms, based on a definition provided by World Health Organization (WHO). It was listed as follows:

1 Sensory irritation in the eyes, nose or throat

dryness
stinging, smarting, irritation
hoarseness, changed voice

2 Skin irritation

reddening of the skin
stinging, smarting, irritation
dry skin

3. Neurotoxic symptoms

   mental fatigue
   reduced memory
   lethargy, drowsiness
   reduced power of concentration
   headache
   dizziness, intoxication
   nausea

4. Nonspecific reaction

   running nose and eyes
   asthma-like symptoms in asthmatics
   chest sounds

5. Odour and taste complaints

   changed sensitivity
   unpleasant odour or taste

Although these symptoms may be characteristic of other disorders, "when they occur as a consequence of SBI, they are reported to be excessive, are associated with specific buildings or locations within a building, and diminish upon leaving the building (e.g., weekends)" (Morrow et al., 1992). Skov, Valbjorn & Pederson (1990), in their description of SBI, stated that, "Symptoms are experienced as work-related as they typically grow worse during the workday in the building and disappear or diminish after the person has left the building". This reduction in symptoms was also used in the description of SBI by Ryan and Morrow (1992) and Finnegan et al. (1984). In fact, the latter group assessed symptoms as being work related only if they occurred in the work place and improved over weekends or holidays, or both (Finnegan et al., 1984).

Although complaints generally abate when the individual leaves the offending environment, this is not always the case (Ryan & Morrow, 1992). Psychological distress, exacerbated by situations surrounding the illness (e.g., skepticism of others of the existence of the disorder; working in a "sick" building), may serve as an interference factor in the alleviation of symptoms (Ryan & Morrow, 1992). An alternative explanation for residual effects, if the illness is a result of solvent exposure, is the concept of 'hypersensitivity' (Ross et al., 1993) or the "hypersusceptible individual" (Miller & Ashford, 1993). Individuals who have had a singular episode of intense exposure or low level exposure of a long duration to solvents or chemicals may develop a heightened sensitivity to odors they come in contact with daily. Thus, they have developed a chemical allergy (Ross et al., 1993) and complaints may continue after leaving the offending environment or after the causative agent or agents are removed.

Investigations into the etiology of SBI, although inconclusive, usually focus on psychogenic factors (Ryan & Morrow, 1992), the role of heating, ventilation and air-conditioning (HVAC) systems (Finnegan et al., 1984) and/or possible solvent exposures (Norback, Michel & Widstrom, 1990).

<u>Mass Psychogenic Illness</u>

The characterization of SBI as having variable nonspecific complaints with an unknown etiology has resulted in ongoing skeptism regarding its existence (Bauer et al., 1992). Black, Rathe, and Goldstein, (1990), stated that skeptism is evident within the medical community which has criticized the role of clinical ecologists and their testing practices. The credibility of SBI has been undermined by the myriad of symptoms, the lack of laboratory findings in SBI patients, and diagnostic methods and treatment programs that have not been validated.

When physical cause cannot be easily ascertained, physicians often turn to psychogenic explanations (Ryan & Morrow, 1992). In the case of a group of people who are presenting with similar complaints, the diagnosis of exclusion is often Mass Psychogenic Illness (MPI), also referred to as Contagious Psychogenic Illness (CPI; Ryan and Morrow, 1992). CPI was defined by Colligan and Murphy, (1979; cited in Bauer et al., 1992, p.214) as "the collective occurrence of a set of physical symptoms and related belief among two or more individuals in the absence of an identifiable pathogen".

The prevalence of lingering skeptism regarding SBI and the bias towards MPI is evident in the review of the literature. Statements regarding the elimination of MPI as a causal agent are frequently added as a defence against expected skeptism. For example, Robertson et al. (1985) described the symptomatology of mass hysteria as usually vague, often neurological, and often associated with nausea, dizziness and fainting, and the possibility of hyperventilation They further described the symptoms as being mostly transient and resolving rapidly. They concluded that these symptoms were not reported by subjects in their study who had complaints related to SBI

Bauer et al. (1992), tested the theory that SBI symptoms were a result of psychogenic cause or mass hysteria. Their study contained three groups; the first group involved 27 subjects who worked in the problem building and reported having three key complaints, headaches, fatigue and eye irritation. The second group consisted of 58 subjects who worked in the problem building and reported at least two of these complaints. The third group consisted of 26 subjects who did not work in the problem building and did not have any complaints related to SBI All subjects were administered the Minnesota Multiphasic Personality Inventory (MMPI; Dahlstrom, Welsh, & Dahlstrom, 1975), the Symptom Check List 90-revised (SCL-90-R; Derogatis, 1983), Inhouse Neurobehavioral Symptom Check-list (Bauer et al., 1992), and Cohen et al.'s Perceived Stress scale (cited in Bauer et al., 1992). The results on these measures did not differ among the three groups as they should have if the Mass Psychogenic Illness theory were correct. Bauer et al. (1992) concluded that psychological factors may be a consequence of SBI but not a causative agent or agents.

The Role of Ventilation Systems in SBI

Over the last two decades increasing heating costs have resulted in the construction of air-tight buildings to maximize energy efficiency (Whorton, Larson, Gordon & Morton, 1987). Windows are installed that cannot be opened, further reducing indoor/outdoor air passage. Marchant likened this to "living in plastic bags that we push air into and out of" (cited in Jones, 1992). Logically, it is more economically feasible to maintain air at a certain temperature than it is to initially heat it or cool it to that same temperature. As a result, sealed structures using mechanical ventilation with heating and air-conditioning systems are typical of newly constructed buildings (Robertson et al., 1985). Energy shortages were further reflected when the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) lowered its standards for the minimum outdoor air per person standards for natural and mechanical ventilation.

(Hodgson & Morey, 1989). Although fresh air standards were originally set at 5 to 30 cubic feet per person, per minute, the lower limit of 5 cubic feet was "in general use throughout most of the 1970's." During this time building related complaints increased within these new structures (Hodgson & Morey, 1989).

Mechanically ventilated buildings which were constructed as sealed structures have a higher incidence of SBI than naturally ventilated buildings (Finnegan et al., 1984). Heating, ventilation and air conditioning (HVAC) systems can contribute or cause building related illnesses if they are not functioning properly (Morey & Shattuck, cited in Cone & Hodgson, 1989). HVAC systems have primary functions. The first involves maintaining temperature and humidity at a comfortable level while the second involves a supply of adequate levels of outdoor air. Problems can arise if the system is inadequate due to a poor design, if there is a breakdown in the operation of the mechanism, or if it is improperly maintained.

Robertson et al. (1985) investigated the role of ventilation systems in SBI by surveying the occupants of two separate buildings. One building was mechanically ventilated with air conditioning and humidification and the other building was naturally ventilated. They concluded that while respiratory, eye and nasal irritations were a result of ventilation systems in air conditioned buildings, headache and lethargy were not, as they were also reported in the building with natural ventilation. Finnegan et al. (1984) also reported increased symptoms by subjects in air conditioned buildings. Humidifiers and recirculated air were not contributing factors as complaints were found in a nonhumidified building and a significant number of symptoms were found in buildings with no recirculation of air.

Statistical evidence for the involvement of ventilation systems in SBI was not found by Skov and Valbjorn in their study of 3757 office workers (cited in Kreiss, 1989). This study, commonly referred to as The Danish Town Hall Study, showed a lower frequency of complaints in older buildings versus newer buildings. However, comparisons of buildings with mechanical ventilation systems and naturally ventilated buildings did not reveal any differences in complaints

Although control buildings (those with natural ventilation) were included in some of the above studies, individual subjects were not matched according to age or gender. Differences in subject characteristics between buildings (i.e., age and gender) could have influenced the studies' findings, confounding the results. Furthermore, not all HVAC systems are alike; direct comparisons between studies without first obtaining details of the designs of the systems can be misleading.

The Role of Organic Solvents in SBI

Volatile organic compounds (VOCs) have also been investigated as potential causative agents of SBI (Norback, Michel, & Widstrom, 1990; Molhave, Bach & Pedersen; cited in Hodgson et al., 1989) for two reasons (Girman, 1989). The first is a similarity between known effects of solvents and SBI symptomatology such as mucous membrane irritation, fatigue, nausea and concentration difficulties, the second is the increased levels of VOCs found in buildings (especially new buildings) compared to outdoor levels.

Hartman (1988) provided the following background on solvent effects. Toxic effects of VOCs include mucous membrane irritation, nausea, loss of appetite, vomiting and diarrhea. As well, solvents depress central nervous system functions and often result in light headedness, feelings of drunkenness and ataxia. Common physiological symptoms are: headaches, dizziness, fatigue, parathesias, pain and weakness. Neuropsychological complaints include memory impairments, concentration difficulties, general intellectual disturbances, problem solving difficulty, decreased rate of responding and decreased initiative. Affective elements include depression, anxiety, emotional lability and irritability.

Hodgson and Morey (1989, p. 407) summarized supporting evidence for the role of organic solvents in SBI as follows:

1. Formaldehyde has been shown to cause mucous membrane irritation below Occupational Safety and Health Administration standards.
2. Manipulation of the concentration of VOCs has shown a relationship between higher doses and "mucous membrane irritation, headaches, and neuropsychologic dysfunction"
3. Decreases in complaints over time that began at the onset of occupancy in one group of buildings has been related to the offgassing of volatile organic compounds. (Offgassing is the process of emission of residual solvents from new building materials and furniture; Girman, 1989)

In a study of eleven sick buildings, Norback et al. (1990), administered a questionnaire to 261 workers to obtain personal and work related information (stress, smoking status, etc.). As well, respondents indicated whether they had experienced any of 16 different symptoms. Environmental exposure levels (i.e., indoor hydrocarbon concentration, room temperature, air humidity, formaldehyde and carbon dioxide concentration) were measured following completion of the questionnaires. Pertinent information (age of building, type of ventilation system, etc.) was obtained from Occupational Health centres. Symptoms of mucous membrane irritation (eye, nose and throat), fatigue and headache increased with exposure to total indoor hydrocarbons. Norback et al. (1990) concluded that SBI is a result of exposure to a combination of hydrocarbons and not to a single compound. However, Whorton et al., (1987), did not find any evidence for the involvement of solvents as causal agents for the health complaints of employees who had recently moved to a new building. They tested for formaldehyde levels and other solvents (including volatile organics, semi-volatile organics and light hydrocarbons) as factors in the reported headaches, eye irritations, fatigue and upper respiratory complaints. Neither did they identify any other personal and work factors as causal agents.

The failure to implicate solvents by Whorton et al. (1987) may have resulted from setting inappropriate air standards or improper monitoring. Standards that are commonly used to determine acceptable or unacceptable solvent levels are often based on levels that, "induce cancer in rodents," (Ryan & Morrow, 1992) Thus, levels that may be sufficient to cause irritation may be over looked. Whorton et al.'s (1987) respondents did report a decrease in complaints over a five-week period, indicating a possible decline of offgassing from new furniture and materials. Thus, if air monitoring measures were obtained at the latter stages of the five-week period, lower levels of VOCs would be expected than those at the onset of occupancy.

Neuropsychological Investigations of Solvent Exposure

Neuropsychological tests have a higher success rate in detecting early stages of central nervous system damage caused by solvent exposure than conventional medical evaluations (Hane et al., 1977) In fact individuals exposed to low levels of solvents will often, "present with negative neurological findings" (Hartman,1988). One explanation centres on the ability of these tests to isolate behaviours which may not be used singularly during day to day activities. Often other compensatory behaviours will mask the deficit so that it is not apparent (Hartman, 1988). For instance, an inability to remember appointments may not be recognized as a problem if an individual is in the habit of using a daily planner.

A high degree of success in using assessment techniques has led to their regular use in occupational cases involving exposure to solvents (Gamberale, Kjellberg, Akerstedt, & Johannsen, 1985). The battery of tests used to assess neuropsychological functioning has varied over studies (Ryan et al., 1988; Hartman, 1988; Orbaek et al., 1985). However, the Weschler Adult Intelligence Scale - Revised - (WAIS-R) (Weschler, 1981) is a commonly used test (Hartman, 1988).

Orbaek et al. (1985), in a study of the effects of solvent exposure on 50 male workers, included neuropsychological assessment of "general intelligence (vocabulary, reasoning, and visuo-constructive intelligence), perceptual accuracy, sustained focused attention, memory and psychomotor performance." They used Synonyms and Figure Classification (Dureman & Salde, 1958; cited in Orbaek et al., 1985), measures of vocabulary and reasoning ability, respectively, as their premorbid estimates for individual performance.

There was a tendency towards lower performance on 9 of the remaining 13 tests for the exposed group, while measures of general intelligence were comparable to a reference group (matched pairwise according to age and education). When the exposed group was subdivided into groups based on levels of exposure, those with the highest level of exposure did poorly on tasks of sustained, focused attention compared to individuals with medium or low levels of exposure.

Ryan, Morrow and Hodgson (1988) administered the Pittsburgh Occupational Exposures Test Battery (Ryan et al., 1988), which included tests from the WAIS-R and the Weschler Memory Scale (WMS), to two groups of blue collar workers matched according to age and education. One group had reported cognitive and affective complaints which were attributed to solvent exposure. The second group, a control, did not have a history of solvent exposure or any other disorders which could have affected the central nervous system. The group of exposed individuals showed evidence of diffuse cognitive impairment, including learning and memory, visual/spatial skills, attention and mental flexibility, and psychomotor speed and manual dexterity. Specifically, subjects who were recently exposed to solvents (within previous 72 hours of assessment) performed more poorly on the Visual Reproduction test of the WMS and Block Design of the WAIS-R. Subjects who had a history of sudden peak exposure (less than 1 day with high level of solvent) performed more poorly on an embedded figures test and a grooved peg board test. These tasks along with Visual Reproduction (Wechsler, 1987) and Block Design (Wechsler, 1981) require visual/spatial abilities or quick response times. All are measures of non-verbal abilities.

Results similar to Ryan's study were found among house painters compared to an age matched, unexposed referent group (Hane et al., 1977). The painters' complaints included: fatigue, memory loss, decreased appetite and chest pain. A measure of verbal ability which was considered to be resistant to change was used to estimate premorbid intelligence. The exposed group had significantly lower mean scores on a figure classification test (visual-logical ability) and a rivet test (psychomotor coordination). Results showed impaired visual memory function and increased reaction time for the house painters. No effect was found in relation to number of exposure years

Ryan et al. (1988) did not establish premorbid estimates of intelligence for each subject, thus, differences may be a result of premorbid intellectual differences and not differences due to exposure While Hane et al. (1977) included a nonexposed referent group, it was matched only on the basis of age. There may have been differences between the groups (i.e, education) which could have confounded the results. Further, nonexposure criterion was met if a subject did not work in a field with known solvent exposure. However, subjects in the control group came from a wire producing industry, a printing office and a stone crusher. Nonexposure to solvents in this group may be questionable as low levels may have been undetected within these industries.

The majority of the solvent exposure studies suffer from several methodological difficulties. Because of the nature of the investigations (i.e., solvent exposure) experimental laboratory studies are not practical; therefore, the levels of solvent exposure cannot be manipulated. Cause and effect, then, cannot be inferred, and elimination of confounding variables is difficult. The control of confounding variables could be aided by the use of appropriate control groups or statistical techniques; however, this has not generally been the case. A further difficulty in interpreting or comparing results across these studies is the failure to use a consistent set of measures. It is difficult to compare results across studies when the same construct may not have been assessed. Gamberale (1985), argued that authors often refer to tests according to the mental functions the tests are thought to assess without any scientific basis for doing so. For instance, referring to a test as a "mental flexibility test" is inaccurate as there are little scientific data confirming the process at work. In fact, there may be a combination of mental functions required for that particular task.

If chemical solvents are a causative agent of SBI (as suspected in the case of Camp Hill Medical Centre [Marchant et al., 1992]), an outline of 'symptom severity and prognosis' (Morrow et al.,1992) may be useful:

Type 1 - Symptoms include fatigue, impaired concentration, and loss of initiative.

Prognosis - reversible if no longer exposed

Type 2A - Neurological soft signs (not specified) with altered affect and personality.

2B - 2A with cognitive function disturbances

Prognosis - unsure of reversibility

Type 3 - Neurobehavioral and neuroradiologic abnormalities

Prognosis - irreversible

Knowing whether or not a patient's symptoms will abate enables development of an appropriate treatment program. In a "typical" case study of the neurobehavioral effects of toxic exposure, White, Feldman and Proctor (1992, pp. 47), reported that, "Mrs. C's slow but gradual recovery of function is not unusual in solvent-exposed subjects and is sometimes observed over even longer time spans".

Camp Hill Hospital Study - Assessment of Staff Members

Recently, Marchant et al. (1992) investigated the relationship between indoor air quality and staff complaints of headaches, skin and eye irritations at CHMC. Part of their study included the assessment of staff members including control subjects on several dimensions (i.e., demographics, job satisfaction and health complaints).

The people selected for this study included all staff members that worked on the first two floors of the VMB. Volunteers (N = 134) from these floors, considered to represent the areas which contained the most affected employees, represented 96.4% of the total population. A control group (N = 57) was selected randomly from all workers in the patient care area of the Halifax Infirmary, a building which is geographically separated from the rest of CHMC. Participants from the VMB and the Halifax Infirmary had similar mean ages and group proportions of males to females. The VMB group, however, had a higher mean level of education. There were no differences in the participants home environments with respect to heating type, age, location, design and activities. As well, neither group was considered to be at risk for indoor air quality problems within their home environments. The two groups were similar in their number of life stress events, including 'death in family' and 'number of deaths of family members'.

The Cornell Medical Index, consisting of 196 items, allows for the separation of physical complaints according to their job relatedness. The two groups differed significantly on this index. Work related complaints for the VMB group consisted of: dizziness, fatigue, sleepiness, difficulty concentrating, skin dryness, rash or itching, respiratory problems, chest pain or tightness, eye irritation, and difficulty focusing their eyes. Marchant et al. (1992) considered the first four complaints to be related to the central nervous system and the last four to reflect irritation of mucous membranes. The Infirmary group reported back ache as their only complaint.

Overall, findings of the Marchant et al. (1992) study with respect to indoor air quality suggested problems with aspects of the ventilation system and a higher incidence of complaints during the periodic use of a chemical that was used in the maintenance of the ventilation system. Although cause and effect could not be established with this type of study, the VMB's ventilation system and possible chemical exposure were considered as causative factors of employees work related health complaints.

Neuropsychological Screening. The Cornell Medical Index suggested central nervous system complaints among VMB workers. As a follow-up a neuropsychological screening was administered to 20 volunteer staff members of the VMB of the Camp Hill Medical Complex in order to assess the possible cognitive impairments, (Hayes, 1992; 1993). The mean age of these volunteers was 38 years and 4 months. The first phase of the study assessed organic solvent exposure (Axelson & Hogstedt, 1988), and behaviours related to cognitive failures (Broadbent, Cooper, Fitzgerald & Parker, 1982) as reported by the volunteers and by a second questonnaire completed by a relative or a friend (Broadbent et al., 1982).

Although there was some variation among subjects in the number of items they endorsed on the Solvent Questionnaire, five questions were positively endorsed by 70 percent or more of the volunteers. In rank order these were feelings of undue fatigue, the need for notes to serve as an aid for memory, experiencing headaches, trouble concentrating and perceived short term memory loss. Overall, the mean number of items endorsed as a group was 7.5 out of a total of 16 items. Employees reported a similar number of complaints in all locations of the building. Responses to the Cognitive Failures Questionnaire indicated perceived difficulties with memory, absent mindedness, irritability, decision making and noticing important details. In support of these perceived difficulties, the relative or friend responses on the Cognitive Failures Questionnaire correlated significantly with subjects responses. The item most highly endorsed on this questionnaire concerned concentration difficulties.

The second phase of the neuropsychological screening included administration of the National Adult Reading Test - (NART) (Nelson, 1982), Weschler Adult Intelligence Scale - Revised (WAIS-R), (Weschler, 1981) Weschler Memory Scale - Revised (WMS-R) (Weschler, 1987), Rey-Osterreith Complex Figure (Osterrieth, 1944) and a spontaneous drawing (Strub & Black, 1977). These measures suggested a decline in overall intellectual functioning indicative of cognitive impairment. The VMB staffs' average current Performance Intelligence Quotient was 9 points below a conservative estimate of premorbid Performance Intelligence Quotient (established by the NART). When required to recall two short stories immediately after oral presentation and again 30 minutes later, Staff Volunteers found immediate recall difficult. The range of immediate recall was between the 18th to the 97th percentile, with 25% of the staff volunteers responding below the 26th percentile. The delayed recall test results ranged between the 14th and 97th percentile. The WMS-R group mean index, however, indicated adequate verbal memory. In a test requiring Staff Volunteers to copy a complex design and then to reproduce it 30 minutes later from memory (without prior warning), group means showed adequate visual memory and poor visuo-construction abilities (i.e., four subjects' scores were greater than two standard deviations below their mean age scores). This deficit was also apparent when they were asked to draw a house freehand. The performance of nine Staff Volunteers was also impaired on a task which asked them to arrange picture cards into a sequence that made a sensible story. Thus, as a measure of executive functioning, these staff volunteers performed below expected levels.

Generalizations of these findings are limited due to the absence of a control group. A control group provides a basis for comparison for results obtained from the subjects in the group or groups to be examined. Thus, if there was a difference between the CHMC staff volunteers responses and a control groups' responses, then findings could be attributed to the differences between the groups (i.e., work site) or the conditions applied to these groups (i.e., solvent exposure). Optimally, subjects would be similar across all demographics, including histories, except for the independent variable(s) (Hartman, 1988). Obviously, this ideal control group is not always practical. Hartman

(1988) suggested that the control and treatment groups should be similar with respect to the following variables: age, education, race, gender, medical history and job classification.

Without a control group, then, these results could be attributed to different factors outside of the variables under consideration. Presently, the neuropsychological screening results of Hayes (1992; 1993) study cannot be interpreted as specific to the Camp Hill Medical Centre staff volunteers. The results may be characteristic of hospital employees in general, instead of a group of workers in that particular environment.

Recovery of Neuropsychological Effects of SBI

No studies have investigated the recovery of cognitive functions (including memory) in building occupants with SBI. Symptoms are expected to diminish when the affected individual leaves the offending environment (Ryan & Morrow, 1992; Finnegan et al., 1984). However, since neuropsychological impairments associated with SBI have not been fully investigated in previous studies, the prognosis of these symptoms remain unclear. Hence, whether complaints of this nature will diminish, persist, or show signs of further deterioration is questionnable. Citations regarding solvent exposure provide conflicting suggestions: Morrow et al. (1992) believes that symptom prognosis is based on symptom severity, while White et al. (1992) stated that recovery of function is not unusual in solvent exposed individuals. Further, hypersensitivity (Ross et al., 1992) or hypersusceptibility (Miller & Ashford, 1993) is a construct which may inhibit recovery of solvent exposed individuals. Once an individual becomes sensitized to a certain chemical, or one that is similar to it, they may develop an allergy and later react to low doses of the once tolerable chemical (Ross et al., 1993). As the number and use of chemicals continues to increase in homes, workplaces, and public buildings, the hypersusceptible individual is likely to be exposed to daily irritants. Unless allergic reactions are controlled or chemical use is reduced, their prognosis will be poor. Until recovery studies are completed, the outcome of individuals with SBI is unclear. A comparison of two groups of workers with SBI, one which has been out of the affected environment for a period of time and one which is still working in the same environment, would provide information regarding symptom recovery.

Summary

In summary, employees of CHMC have reported health complaints indicative of Sick Building Illness. This illness has been characterized as variable, nonspecific physiological and psychological symptoms with an unknown etiology. The range of complaints include physiological, psychological and neuropsychological effects. Although symptoms are thought to abate when individuals leave the affected environment, studies of neuropsychological recovery have not been carried out. Mass Psychogenic Illness, inadequate ventilation systems, and solvent exposure have been investigated as potential causes of the illness. Due to the lack of studies regarding the effects of sick buildings on neuropsychological functioning, research involving workers with known solvent exposure is referenced due to its potential involvement with the illness as a causative agent and the symptom similarity. These individuals were shown to have impaired cognitive functioning and memory processes on neuropsychological testing.

Finally, an air quality study performed recently at Camp Hill Medical Centre implicated both an inadequate ventilation system and solvent exposure as possible causes of their air quality problems. Neuropsychological findings of the hospitals staff members were in the impaired range for some measures of cognitive functioning. However, a control group was not included for comparison purposes. As well, without available recovery studies their prognosis remains unclear

Purpose of the Study

The purpose of this present study was to systematically investigate the suggested decline in neuropsychological functioning reported by Hayes (1992; 1993) in CHMC staff volunteers. The present study included two groups of volunteer staff members from the three attached buildings (the Main Building, the Abbie J. Lane Building and the VMB) of CMHC. All subjects for each CHMC group had at least three health complaints related to SBI, one of which was neuropsychological in nature. The first group, the recently exposed group, was either still working in the affected environment or had been off for less than six weeks. The latter condition was included to broaden the available subject pool. The second group, the previously exposed group, had been out of the affected environment for a minimum of three months (twelve weeks). A comparison between test scores for these two groups provides information regarding the difference in neuropsychological functioning after affected workers leave the sick building for an extended period of time. A third group, obtained from a rural hospital and who had no SBI related complaints, acted as a control group. A comparison between this group and the two CHMC groups outlines any neuropsychological impairments specific to the hospital which has been labelled as a sick building

Hypotheses

1. Volunteer staff members from CHMC, including those subjects who are still presently working or on sick leave for less than six weeks (recently exposed) and subjects who have been out of the work environment for at least twelve weeks (previously exposed) are expected to endorse more items on the Solvent Questionnaire (Axelson & Hogstedt, 1988), the Cognitive Failures Questionnaire (Broadbent et al., 1982) and the Beck Depression Inventory (Beck, 1978) than a group of volunteer subjects (with no SBI related complaints) from a rural hospital who are acting as the control group It was expected that the three groups would not differ on the results of the NART as it was used to establish each individuals' premorbid Performance Intelligence The two exposed groups are also expected to obtain lower overall results than the control group on the following measures:

A. WAIS-R (Wechsler, 1987) - Prorated version of Performance Intelligence Quotient (PIQ). Picture Completion, Picture Arrangement, Block Design, Digit Symbol, Digit Span and Digit Symbol Incidental Learning (WAIS-R NI; Kaplan, Fein, Morris and Delis, 1991).

B. WMS-R (Wechsler, 1987) - Visual Memory Span, Logical Memory I and II.

C. Rey-Osterrieth Complex Figure (Osterrieth, 1944): Copy and delay.

D. Stroop Colour-Word Test (Golden, 1978): Word, Colour and Colour-Word subtests.

E. Babcock Sentence Learning Test (Wells and Martin, 1923).

These predictions are based on the neuropsychological findings of the Hayes (1992; 1993) study, as well as studies involving solvent exposed workers (Ryan et al., 1988; Orbaek et al., 1985; Hane et al., 1977).

2. The previously exposed CHMC group (subjects who had been out of the work environment for at least three months) were expected to endorse fewer items on the three self-report questionnaires (Solvent Questionnaire, Cognitive Failure Questionnaire and Beck Depression Inventory), and obtain higher scores on the remaining test measures (as outlined in Hypothesis 1) than the recently exposed CHMC group (subjects who were still working or off for no greater than 6 weeks) This prediction is based on the suggestion by Ryan et al (1992) and Skov et al. (1990) that SBI symptoms diminish when individuals leave the affected environment.

Method

Participants

RECENTLY EXPOSED: Twenty staff members from CHMC (including the VMB, the Abbie J. Lane Building and the main building), in Halifax, Nova Scotia, volunteered to participate in this study. Subjects were obtained through the help of the Nova Scotia Nurses Union, a local support group established for Camp Hill employees who have SBI, Nova Scotia Government Employees Union, Canadian Brotherhood of Railway Transport and General Workers - Local 615, and various supervisors working within the hospital. Volunteers either contacted the experimenter expressing interest in participating as subjects or they were contacted by phone. Inclusion criteria for this group were the presence of at least three health related complaints (with at least one neuropsychological symptom) which are associated with SBI. Secondly, they had to be either presently working within the affected environment or off work for no greater than six weeks at the time of testing. Exclusion criteria consisted of any pre-existing neurological or psychological condition which could have effected the outcome of their test results.

PREVIOUSLY EXPOSED: Twenty staff members from CHMC (see locations above), in Halifax, Nova Scotia, volunteered to participate in this study. Subjects were obtained in the same manner as the recently exposed group. Members of this group had at least three health related complaints associated with SBI, with one of those complaints being neuropsychological in nature. Individuals in this group had to have been out of the affected work environment for at least twelve weeks. Once again, any pre-existing neurological or psychological condition which could have affected test results met the exclusion criteria.

CONTROLS: Twenty-two staff members from the Aberdeen Hospital in New Glasgow, Nova Scotia, volunteered to participate in this study as a control group. Access to this group was provided by the Occupational Health Department of the hospital. Inclusion criteria for this group was the absence of any health related complaints, both physical and neuropsychological, that could be related to their work environment. The results of two of the volunteers were discarded due to the presence of either neurological or psychological conditions which may have effected the outcome of their test results. At the time of this study members from this group had not been working in an environment which utilized a mechanical ventilation system.

CHMC differed from the Aberdeen Hospital in that the former hospital had a mechanical ventilation system, while the latter had windows that opened. As Table 1 illustrates, the three groups were similar in terms of sample size (n=20), gender (18 females and 2 males), age and years of education. Mean ages for each group, control (M = 39.30), recently exposed (M = 40.75) and previously exposed (M = 39.95), were equivalent, F (2,57) = .10, p = .90. As well, there were no differences, F (2,57) = .55, p = .58, between the Control group (M = 13.70), the recently exposed group (M = 14.25) or the previously exposed group (M = 14.45) on their mean years of education. Due to the limited number of volunteers available, it was not possible to control for job type over the three groups. As well, the

TABLE 1

A COMPARISON OF DEMOGRAPHIC FACTORS FOR ALL GROUPS PARTICIPATING IN THE NEUROPSYCHOLOGICAL SCREENING AND SUBSEQUENT RETESTING.

DEMOGRAPHIC FACTORS	GROUPS		
	CONTROL	RECENTLY EXPOSED	PREVIOUSLY EXPOSED
NEUROPSYCHOLOGICAL SCREENING			
Sample Size	20	20	20
Age	39.30	40.25	39.95
Years of Education	13.70	14.25	14.45
Gender Proportion	f=18 m=2	f=18 m=2	f=18 m=2
Worked in Building with Mechanical Ventilation	no	yes	yes
Worked in Building with Natural Ventilation	yes	no	no
Neuropsychological Complaints	no	yes	yes
Other SBI Related Complaints	no	yes	yes
Pre-existing Psychological Conditions	no	no	no
Pre-existing Neurological Conditions	no	no	no
RETESTING			
Sample Size	8	3	3

treatment of subjects was in accordance with the ethical standards of the ethics committee at Saint Mary's University.

Procedure

Subjects were tested individually in well lit rooms free from distraction. Administration time lasted approximately one and a half hours. Subjects sat across a desk facing the examiner. Prior to testing, each subject was given a brief description of who the examiner was and what the study was about. They were informed as to the conditions of confidentiality (see appendix), and how their results would be used in the research. As well, they were asked to consent to the use of their results for this purpose. They were also informed of the right to discontinue testing at any time should they choose to do so. Relevant background information was gathered to ensure subjects met testing criteria. Subjects then filled out the assessment questionnaires. Presentation of tests remained in the same order for all subjects in each group with the exception of the delayed version of the Rey-Osterrieth Complex Figure and Logical Memory II. These tests were administered approximately 30 minutes after they were originally presented. Thus, depending on the length of time it took for each individual to complete the preceeding tests the placement of the two delayed tests varied. Wherever possible, published, standardized testing procedures were followed, except where noted. Positive responses (i.e.; "good" or "you're doing fine") and prompting were used by the examiner infrequently. At the end of test administration, subjects were asked how they felt; any concerns were discussed. Emphasis was placed on their individual strengths. After subjects were thanked for their participation in this study, they were asked if they could be contacted in approximately three months for the purpose of retesting.

Retesting

Fourteen individuals across all three groups (recently exposed N=3, previously exposed N=3, and the control N=8) volunteered to participate in a second neuropsychological screening (Table 1). Difficulty in obtaining a greater number of subjects for retesting was based primarily on people taking vacations at the time of retesting and possible interference with future testing arranged by CHMC for environmentally affected staff members. Subjects were retested approximately three months after their initial assessment. The retesting procedure was similar to the initial assessment, including test administration order and setting. The purpose of retesting was to establish the reliability of the measures used for this particular study. The NART was omitted from subsequent testing as it was used to estimate premorbid levels of cognitive functioning - a baseline from which a current measure could be compared.

Test-Retest correlation coeffients (see Table 2) were calculated for each psychometric measure, with the exclusion of the BDI. Initial BDI results were not available for all subjects participating in the retesting, thus, the questionnaire was omitted from the subsequent testing. Test-retest reliability was low for many of the measures, including the WAIS-R (Wechsler, 1988) subscales Picture Completion, Block Design, Digit Symbol, Digit Span and Digit Symbol Incidental

TABLE 2

TEST-RETEST CORRELATION COEFFICIENTS

VARIABLES	CORRELATION COEFFICIENT
Solvent Questionnaire	.71**
Cognitive Failure Questionnaire	.80**
Picture Completion	.15
Picture Arrangement	.56*
Block Design	.24
Digit Symbol	.53
Digit Symbol-Incidental Learning	.44
Performance Intelligence Quotient	.62*
Digit Span	.50
Visual Memory Span	.35*
Logical Memory I	.58*
Logical Memory II	.73**
Rey-Osterrieth-Copy	-.13
Rey-Osterrieth-Delay	.61*
Babcock Sentence Learning	.23
Stroop-Word Test	.85**
Stroop-Colour Test	.67**
Stroop-Colour/Word Test	.65*

* $p < .05$
** $p < .01$

Learning (WAIS-R NI subscale [Kaplan, 1991]). Visual Memory Span (WMS-R subscale, [Wechsler, 1987]), the copy version of the Rey-Osterrieth Complex Figure Test (Osterrieth, 1944), and the Babcock Sentence and Learning Test (Wells and Martin, 1923) were also below acceptable levels of reliability. Nonetheless, data from each measure is reported and entered into the data analysis due to the relatively small n used to obtain the test-retest reliability, the conservativeness of test-retest reliabilities, and the fact that these measures have previously demonstrated acceptable levels of reliability.

Data Analysis - All tests were scored using procedures outlined in relevant testing manuals; scoring procedures for non-standard tests are outlined with the description of the test. Mean differences on each dependent variable were examined through a series of one way analysis of variance (ANOVA) with group as the independent variable. Due to the number of Anova's carried out, a Bonferroni procedure was used to set a per comparison error rate of alpha = .0025. Given the number of tests, this alpha level ensures a family wise error rate of alpha = .05. Following each ANOVA a post hoc multiple comparison

(Scheffe test) was used to determine the direction of any differences that had been found. Correlation coefficients were also calculated between test variables. If two measures were significantly correlated ($r > .60$), the redundant measure with the lowest reliability was dropped from further analysis. The final calculation performed on the remaining data was a discriminant analysis. A direct discriminant function analysis was used to predict group membership from a subset of the study's predictors.

Assessment Materials

Tests administered as part of the neuropsychological screening included: Wechsler Adult Intelligence Scale - Revised (WAIS-R, Wechsler,1981), Wechsler Memory Scale - Revised (WMS-R, Wechsler,1987), National Adult Reading Test (NART, Nelson,1982), Rey-Osterrieth Complex Figure Test (RCFT; Osterrieth,1944), Stroop Colour-Word Test (Stroop; Golden, 1978), Babcock Sentence Learning Test (Babcock; Wells and Martin,1923), Solvent Questionnaire (SQ, Axelson & Hogstedt, 1988), Cognitive Failures Questionnaire (CFQ;

Broadbent et al.1982), and Beck Depression Inventory (BDI; Beck,1978).

The **WAIS-R**, a measure of overall intellectual functioning, is frequently used in neuropsychological evaluations to assess the presence of cognitive deficits (Spreen and Strauss,1991). It provides three intelligence quotients; Full Scale (FSIQ), Performance (PIQ) and Verbal (VIQ), and is suitable for individuals within the age range of of 16-74 years (Wechsler,1981). The WAIS-R was not administered in its entirety in this study. A PIQ was calculated using a short version of the WAIS-R which consisted of the following subtests; Picture Completion (PC), Picture Arrangement (PA), Block Design (BD), and Digit Symbol (DSYM), with the results prorated. Digit Span (DS), a verbal subscale, was also administered. Peck, Stephens, and Martelli (1987) attributed the following characteristics to the individual subtests:

> Picture Completion - is a test of visual perception and recognition that requires remote memory and judgement concerning relevance of practical and conceptual detail. This

scale is generally resilient to the effects of brain damage and is one of the best test indicators of premorbid ability (p 218 - 219)

<u>Picture Arrangement</u> - evaluates the ability to detect nonverbal social cues and to think in a logical and sequential manner. It is sensitive to brain damage and variations and performance errors may reflect particular patterns of brain dysfunction. (p.218)

<u>Block Design</u> - is a measure of visuo-spatial construction organization. Block Design performance is sensitive to brain damage in general. (p.218)

<u>Digit Span</u> - Digits forward is a measure of immediate auditory memory span and attention. Digits Backwards is a measure of active or working memory, involving both the storage and the manipulation of information. Variations from the expected pattern of Digit Span Forward/Backward are suggestive

of attention, concentration, and for sequencing problems that may reflect organic and/or emotional factors. (p.222)

Digit Symbol - is a psychomotor performance test that requires motor speed, persistence, visual-motor coordination, and sustained attention. This subtest is very sensitive to brain dysfunction. Emotional problems such as depression may also affect performance on this subtest. (p.224)

Digit-Symbol Incidental Learning (DSym Inc) is an optional subtest often used when the WAIS-R is being used as a neuropsychological instrument (Kaplan et al. 1991). Individual test results were converted from raw scores to age scaled scores with the exception of DSym Inc. For this study, test-retest reliabilities for these measures were: PIQ, r =.62; PC, r =.15; PA, r =.56; BD, r = .24; DS, r = .50; DSym, r =.53; and DSym Inc., r = .44. Average split half reliability coefficients reported in the WAIS-R manual are as follows: PIQ, r = .93; PC, r = .81; PA, r = .74; BD, r = .87; DS, r = .83; DSym, r

= .82 (Wechsler, 1987). Similar coefficients for DSym Inc. were not available.

The **WMS-R** is used in the assessment of memory function in neuropsychological and clinical evaluations (Wechsler,1987)."The functions assessed include memory for verbal and figural stimuli, meaningful and abstract material, and delayed as well as immediate recall" (Wechsler,1987, p.1). It is useful for individuals within the age range of 16-74 years. Subtests used in this assessment included, Visual Memory Span (Vis Mem), and Logical Memory I and II (Log Mem I and II). Raw scores of Vis Mem and Log Mem I and II were used in the analysis. Test-retest reliabilities in this study were as follows: Vis Mem, r =.35; Log Mem I, r = .58; and Log Mem II, r = 73 Average split half reliability coefficients reported in the WMS-R manual were as follows: Vis Mem, r = .81; Log Mem I, r = .74 and Log Mem II, r = .75 (Wechsler, 1987).

The **NART** was designed to provide a method of establishing an individual's premorbid level of intellectual functioning if cognitive decline is suspected (Nelson,1982). "Since vocabulary correlates best with overall ability level and tends to resist the dementing process better than any other intellectual attainment, the residual vocabulary of patients with dementing conditions may be the best indicator of premorbid intellectual ability" (Lezak,1983). The test is comprised of 50 irregular words which an individual must attempt to pronounce. The resulting error score is converted into a standardized estimate of a Full Scale Intelligence Quotient (NFIQ), a Verbal Intelligence Quotient (NVIQ) and a Performance Intelligence Quotient (NPIQ). In the present study, a premorbid Performance Intelligence Quotient was established for each subject, and the difference between this score and their PIQ obtained from the WAIS-R was determined (PIQ DIFF). It is reported to have high internal and test-retest reliability (Spreen and Strauss, 1991).

The **RCFT** is used to assess visuospatial construction ability and visual memory (Spreen and Strauss,1981). Raw scores from the copy (Rey Copy) and delay (Rey Delay) versions were used for analysis. In this study, test-retest reliability was -.13 for the copy version and .61 for the delay version. Using the scoring criteria outlined in Spreen and Strauss (1991), this test has a high interrater reliability (i.e. > .95)

The **Stroop** has been used to assess an individuals ability to selectively attend to less salient information while "suppressing a habitual response" (Spreen and Strauss,1991). Raw scores, for each subtest, were converted to standardized scores referred to as T-scores. T-scores were used for analysis. Test-retest reliabilites for this study were .85 for the word subtest, .67 for the colour subtest and .65 for the colour/word subtest. Reported reliabilities for the Stroop subtests ranged from .85 to .88 for the Word subtest, .79 to .82 for the Colour subtest and .69 to .73 for the Colour-word subtest (Golden, 1978)

The **Babcock** is an 18 word sentence which contains several different adjectives. It is a test of verbal memory that places importance on the 'semantic properties' of the sentence (McFie, 1975). "Attempting to learn a single sentence ... is a less arduous task [than other verbal memory tests] and also gives the patient opportunities to make frankly dysphasic as well as perseverative errors in his responses" (McFie, 1975). The scoring procedure used was developed by Mate-Kole, Major, Lenzer and Connolly (in press) and it involves a score ranging from 10-1 based on the number of trials required to correctly recall the sentence. For example, verbatim recall in one trial is equal to ten points, while recall in ten trials is equal to one point. If the subject was unable to successfully recall the sentence in ten trials they were given a score of zero. In this study, test-retest reliability was .23. Reported reliabilities could not be located.

The **SQ** is self administered and is designed to collect information regarding the effects of solvent exposure (Axelson & Hogstedt, 1988). It is comprised of 16 questions with "definitely", "no" or "not sure" as alternative responses. Test-retest reliability was .71. Reliability coefficients were not reported for this questionnaire by the authors (Axelson & Hogstedt, 1988).

The **CFQ** is a 25 item self administered questionnaire designed to elicit a subjective report of, "Failures in perception, memory and motor function" (Broadbent et al, 1982). Test-retest reliability was .80

in this present study. A previous study using this questionnaire obtained test-retest reliability ranging from .80 to .82 (Broadbent et al., 1982).

The BDI consists of 21 groups of feeling statements. The overall score, is a measure of depression ranging from no symptoms to severe. Not all subjects in this study were administered the BDI due to time constraints. Thus, 44 subjects completed this questionnaire: 20 subjects from the control group, 11 from the recently exposed group and 14 from the previously exposed group. Test-retest reliability was reported to be greater than .90 (Beck, 1970)

Results

Table 3 presents a summary of correlation coefficients between test variables. Many correlation coefficients between test variables were greater than or equal to .6, which indicated significant overlap between the variables, suggesting these variables are measuring the same construct.

TABLE 3

PEARSON r CORRELATION COEFFICIENTS: VARIABLE BY VARIABLE

VARIABLE SCORES	VARIABLE SCORES 1	2	3	4	5	6
AGE (1)						
EDUCATION (2)	-.12					
SOLVENT QUESTIONNAIRE (3)	.17	.09				
COGNITIVE FAILURE QUEST (4)	.16	-.00	.84**			
PICTURE COMPLETION (5)	.05	.05	-.15	-.19		
PICTURE ARRANGEMENT (6)	.16	.27*	.10	.05	.42**	
BLOCK DESIGN (7)	-.21	.24	-.14	-.27	.46**	.30*
DIGIT SYMBOL (8)	-.12	.30*	-.27*	-.40	.29*	.01
DIGIT SYMBOL-INC (9)	-.28	-.00	-.24	-.26	.39**	.17
DIGIT SPAN (10)	-.20	.37**	-.01	-.03	.20	.23
WAIS-R PIQ (11)	.01	.30*	-.18	.29	.76**	.61**
NART PIQ (12)	.08	.60**	.16	.09	.20	.41**
PIQ DIFFERENCE (13)	.05	.05	.19	.25	-.64**	-.35*
VISUAL MEMORY SPAN (14)	-.43**	.20	-.14	-.25	.18	-.07
LOGICAL MEMORY (15)	-.13	.31*	-.10	-.14	.48**	.35
LOGICAL MEMORY II (16)	-.14	.29*	-.07	-.13	.47**	.38**
REY OSTERRIETH COPY (17)	-.16	.13	-.24	-.10	.19	.21
REY-OSTERRIETH DELAY (18)	-.28	.25	-.21	-.29*	.28*	.30*
BABCOCK SENTENCE (19)	-.16	.37**	.15	.18	.17	.08
STROOP-WORD (20)	.02	.05	-.39**	-.43**	.19	.10
STROOP-COLOUR (21)	-.09	.04	-.35**	-.48**	.25	.11
STROOP-COLOUR/WORD (22)	-.05	.30*	-.27**	-.34*	.38**	.23

** $p \leq .01$, TWO-TAILED
* $p < .05$, TWO-TAILED

(TABLE CONTINUES)

TABLE 3

PEARSON r CORRELATION COEFFICIENTS: VARIABLE BY VARIABLE

VARIABLE SCORES	7	8	9	10	11	12
AGE (1)						
EDUCATION (2)						
SOLVENT QUESTIONNAIRE (3)						
COGNITIVE FAILURE QUEST. (4)						
PICTURE COMPLETION (5)						
PICTURE ARRANGEMENT (6)						
BLOCK DESIGN (7)						
DIGIT SYMBOL (8)	.51**					
DIGIT SYMBOL INC (9)	.27**	.29*				
DIGIT SPAN (10)	.40**	.28*	.17			
WAIS-R PIQ (11)	.77**	.63**	.37**	37**		
NART PIQ (12)	.15	.10	.03	.46**	.34*	
PIQ DIFFERENCE (13)	-.59**	-.53**	-.37**	-.07	-.73*	.26*
VISUAL MEMORY SPAN (14)	.53**	.36**	.11**	.28*	.31*	-.10
LOGICAL MEMORY I (15)	.61**	.45**	.48**	.37*	.67**	.23
LOGICAL MEMORY II (16)	.54**	.37**	.56**	.30*	.62**	.21
REY-OSTERRIETH: COPY (17)	.27*	.23	.09	.25	.33*	.07
REY-OSTERRIETH: DELAY (18)	.55**	.42**	.51**	.23	.53**	.12
BABCOCK SENTENCE (19)	.21	.12	.09	.30*	.19	.32*
STROOP-WORD (20)	.33*	.56**	.24	.06	.44*	.06
STROOP-COLOUR (21)	.39**	.61**	.34*	.04	.49*	-.04
STROOP-COLOUR/WORD (22)	.52**	.66**	.32*	.26	.66*	.26

** p ≤ .01, TWO-TAILED
* p ≤ .05, TWO-TAILED

(TABLE CONTINUES)

TABLE 3

PEARSON r CORRELATION COEFFICIENTS: VARIABLE BY VARIABLE

VARIABLE SCORES	13	14	15	16	17	18
AGE (1)						
EDUCATION (2)						
SOLVENT QUESTIONNAIRE (3)						
COGNITIVE FAILURE QUEST (4)						
PICTURE COMPLETION (5)						
PICTURE ARRANGEMENT (6)						
BLOCK DESIGN (7)						
DIGIT SYMBOL (8)						
DIGIT SYMBOL-INC (9)						
DIGIT SPAN (10)						
WAIS-R PIQ (11)						
NART PIQ (12)						
PIQ DIFFERENCE (13)						
VISUAL MEMORY SPAN (14)	-.29*					
LOGICAL MEMORY I (15)	-.44**	.41**				
LOGICAL MEMORY II (16)	-.51**	.41**	.93**			
REY-OSTERRIETH COPY (17)	-.26*	.09	.33**	.28*		
REY-OSTERRIETH DELAY (18)	-.42**	.45**	.57**	.54**	.33*	
BABCOCK SENTENCE (19)	.03	.20	.35**	.30*	.00	.24
STROOP-WORD (20)	-.31*	-.03	.31*	.24	.12	.19
STROOP-COLOUR (21)	-.41**	.12	.37**	.30*	.09	.35**
STROOP-COLOUR/WORD (22)	-.47**	.25	.47**	.43**	.20	.38**

** $p \leq .01$, TWO-TAILED
* $p \leq .05$, TWO-TAILED

(TABLE CONTINUES)

TABLE 3

PEARSON r CORRELATION COEFFICIENTS: VARIABLE BY VARIABLE

VARIABLE SCORES	19	20	21	22
AGE (1)				
EDUCATION (2)				
SOLVENT QUESTIONNAIRE (3)				
COGNITIVE FAILURE QUEST (4)				
PICTURE COMPLETION (5)				
PICTURE ARRANGEMENT (6)				
BLOCK DESIGN (7)				
DIGIT SYMBOL (8)				
DIGIT SYMBOL-INC (9)				
DIGIT SPAN (10)				
WAIS-R PIQ (11)				
NART PIQ (12)				
PIQ DIFFERENCE (13)				
VISUAL MEMORY SPAN (14)				
LOGICAL MEMORY I (15)				
LOGICAL MEMORY II (16)				
REY-OSTERRIETH: COPY (17)				
REY-OSTERRIETH: DELAY (18)				
BABCOCK SENTENCE (19)				
STROOP-WORD (20)	-.20			
STROOP-COLOUR (21)	-.02	.80**		
STROOP-COLOUR/WORD (22)	.20	.65**	.67**	

** p ≤ .01, TWO-TAILED
* p ≤ .05, TWO-TAILED

Variables which had high correlations in this study included: The Solvent Questionnaire with the Cognitive Failures Questionnaire ($r = .84$, $p \leq .01$), four of the WAIS-R Subtests (Picture Completion, Picture Arrangement, Block Design and Digit Symbol) with WAIS-R Performance Intelligence Quotient ($r = .76, .61, .77$ and $.63$ $p \leq .01$, respectively); Performance Intelligence Difference with Picture Completion, Block Design, and WAIS-R Performance Intelligence Quotient ($r = -.64, -.59$ and $-.73$, $p \leq .01$, respectively); Performance Intelligence Quotient with Logical Memory I and II, and Stroop Colour/Word ($r = .61, .66$ $p \leq .01$, respectively); and Logical Memory I with Block Design ($r = .61$, $p \leq .01$). As expected Logical Memory I and Logical Memory II were highly correlated with $r = .93$, $p \leq .01$. Finally, Stroop Word was correlated with Stroop Colour ($r = .80$, $p \leq .01$) and Stroop Colour-Word with both Stroop Word ($r = .65$, $p \leq .01$) and Stroop Colour ($r = .67$, $p \leq /01$). Some of these intercorrelations between test variables were unexpected. Logical Memory I, for instance, was correlated with Block Design. This was not predicted as the former is regarded as a measure of immediate verbal memory while the latter requires visuo-spatial abilities and does not rely on immediate memory.

It should be noted that education significantly correlated with Performance Intelligence Differences ($r = .60$, $p \leq .01$), thus, as years of education increased so did the difference between a subjects current Performance Intelligence Quotient and their estimated premorbid Performance Intelligence Quotient.

Analysis of Variance with Post Hoc Multiple Comparisons

Table 4 summarizes the means and standard deviations for each variable by each group (control, recently exposed and previously exposed). Table 5 summarizes the results from a one way analysis of variance for each variable. Although group means are significant at the $p \leq .05$ level for several of the measures (i.e., Solvent Questionnaire, Cognitive Failure Questionnaire, Digit Symbol, Digit Symbol Incidental Learning, Performance Intelligence Difference, Visual Memory Span, and all three subtests of the Stroop Colour-Word Test) only two

TABLE 4

MEANS AND STANDARD DEVIATIONS OF ALL VARIABLES BY GROUP.

CONTROLLED VARIABLES	CONTROL N=20	RECENTLY EXPOSED N=20	PREVIOUSLY EXPOSED N=20
Age	39.3 (10.36)	40.75 (11.17)	39.95 (8.63)
Education	13.7 (2.74)	14.25 (2.31)	14.45 (1.88)
DEPENDENT VARIABLES			
Solvent Questionnaire	3.15 (2.74)	8.15 (2.8)	10.10 (3.55)
Cognitive Failure Questionnaire	37.05 (13.93)	57.53 (15.54)	67.63 (15.50)
Beck Depression Inventory	6.65 (51.40)	14.82 (67.16)	20.79 (120.03)
Picture Completion	10.35 (2.23)	9.10 (2.40)	9.10 (2.38)
Picture Arrangement	9.40 (2.54)	8.45 (2.26)	9.45 (2.06)
Block Design	10.30 (2.41)	10.50 (2.72)	8.80 (2.02)
Digit Symbol	11.50 (1.85)	10.90 (2.58)	9.70 (2.00)
Digit Symbol Incidental Learning	7.15 (1.42)	5.20 (2.42)	5.50 (2.70)
WAIS-R PIQ	102.05 (11.68)	96.90 (11.34)	93.95 (8.71)

(TABLE CONTINUES)

TABLE 4

MEANS AND STANDARD DEVIATIONS OF ALL VARIABLES BY GROUP

	CONTROL N=20	RECENTLY EXPOSED N=20	PREVIOUSLY EXPOSED N=20
Nart PIQ	107.40 (5.94)	108.05 (6.55)	111.65 (5.63)
PIQ Difference	8.25 (6.85)	12.00 (9.21)	17.70 (8.76)
Digit Span	10.85 (2.30)	11.58 (2.48)	11.20 (2.14)
Visual Memory Span	15.75 (2.22)	15.00 (2.69)	13.70 (2.18)
Logical Memory I	30.50 (8.52)	28.35 (7.04)	26.60 (6.00)
Logical Memory II	26.80 (8.93)	24.25 (8.58)	23.25 (6.98)
Rey-Osterrieth-Copy	29.03 (3.00)	26.73 (4.10)	26.48 (4.37)
Rey-Osterrieth-Delay	16.48 (5.79)	13.38 (7.18)	13.18 (4.59)
Babcock Sentence Learning	6.26 (2.56)	7.15 (2.74)	7.56 (2.64)
Stroop-Word	50.40 (8.07)	47.47 (5.53)	42.11 (7.47)
Stroop-Colour	51.20 (9.16)	46.32 (5.86)	42.78 (8.41)
Stroop-Colour/Word	50.00 (11.39)	47.79 (10.79)	40.56 (10.44)

TABLE 5

ONE WAY ANALYSIS OF VARIANCE: ALL VARIABLES BY GROUP.

SOURCE OF VARIATION	SS	df	MS	F-RATIO	F-PROBABILITY
AGE					
BETWEEN	21.1	2	10.55	.10	.90
WITHIN	5822.9	57	102.16		
TOTAL	5844.0	59			
EDUCATION					
BETWEEN	6.03	2	3.02	.55	.58
WITHIN	310.90	57	5.45		
TOTAL	316.93	59			
SOLVENT QUESTIONNAIRE					
BETWEEN	514.03	2	257.02	27.59	.00
WITHIN	530.90	57	9.31		
TOTAL	1044.93	59			
COGNITIVE FAILURE QUESTIONNAIRE					
BETWEEN	9509.98	2	4754.99	21.25	.00
WITHIN	12366.11	55	224.84		
TOTAL	21876.09	57			
BECK DEPRESSION INVENTORY					
BETWEEN	1691.37	2	845.68	11.07	.00
WITHIN	3208.54	42	76.39		
TOTAL	4899.91	44			
PICTURE COMPLETION					
BETWEEN	20.83	2	10.42	1.90	.16
WITHIN	312.15	57	5.48		
TOTAL	332.98	59			
PICTURE ARRANGEMENT					
BETWEEN	12.70	2	6.35	1.20	.31
WITHIN	300.70	57	5.28		
TOTAL	313.40	59			

(TABLE CONTINUES)

TABLE 5

SOURCE OF VARIATION	SS	df	MS	F-RATIO	F-PROBABILITY
<u>BLOCK DESIGN</u>					
BETWEEN	34.53	2	17.27	3.00	.06
WITHIN	328.40	57	5.76		
TOTAL	362.93	59			
<u>DIGIT SYMBOL</u>					
BETWEEN	33.23	2	16.62	3.54	.03
WITHIN	267.75	57	4.70		
TOTAL	300.98	59			
<u>DIGIT SYMBOL INCIDENTAL LEARNING</u>					
BETWEEN	44.10	2	22.05	4.35	.02
WITHIN	288.75	57	5.07		
TOTAL	332.85	59			
<u>DIGIT SPAN</u>					
BETWEEN	5.18	2	2.59	.4859	.62
WITHIN	298.38	56	5.33		
TOTAL	303.56	58			
<u>WAIS-R: PERFORMANCE INTELLIGENCE QUOTIENT</u>					
BETWEEN	672.23	2	336.12	2.96	.06
WITHIN	6477.70	57	113.64		
TOTAL	7149.93	59			
<u>NART: PERFORMANCE INTELLIGENCE QUOTIENT</u>					
BETWEEN	209.63	2	104.82	2.8610	07
WITHIN	2088.30	57	36.64		
TOTAL	2297.93	59			
<u>PERFORMANCE INTELLIGENCE QUOTIENT DIFFERENCES</u>					
BETWEEN	905.70	2	452.85	6.52	.00
WITHIN	3961.95	57	69.51		
TOTAL	4867.65	59			
<u>VISUAL MEMORY SPAN</u>					
BETWEEN	43.00	2	21.50	3.83	.03
WITHIN	313.95	56	5.61		
TOTAL	356.95	58			

(TABLE CONTINUES)

TABLE 5

SOURCE OF VARIATION	SS	df	MS	F-RATIO	F-PROBABILITY
LOGICAL MEMORY I					
BETWEEN	152.63	2	76.32	1.45	.24
WITHIN	3006.35	57	52.74		
TOTAL	3158.98	59			
LOGICAL MEMORY II					
BETWEEN	134.03	2	67.02	1.00	.38
WITHIN	3838.70	57	67.35		
TOTAL	3972.73	59			
REY-OSTERRIETH COMPLEX FIGURE: COPY					
BETWEEN	79.03	2	39.52	2.64	.08
WITHIN	851.71	57	14.94		
TOTAL	930.74	59			
REY-OSTERRIETH COMPLEX FIGURE: DELAY					
BETWEEN	136.93	2	68.47	1.94	.45
WITHIN	2016.81	57	35.38		
TOTAL	2153.74	59			
BABCOCK SENTENCE LEARNING					
BETWEEN	16.30	2	8.15	1.16	.32
WITHIN	378.68	54	7.01		
TOTAL	394.98	56			
STROOP COLOUR-WORD TEST: WORD					
BETWEEN	663.56	2	331.78	6.55	.00
WITHIN	2735.31	54	50.65		
TOTAL	3398.87	56			
STROOP COLOUR-WORD TEST: COLOUR					
BETWEEN	682.15	2	341.07	5.39	.01
WITHIN	3414.42	54	63.23		
TOTAL	4096.57	56			
STROOP COLOUR-WORD- TEST: COLOUR/WORD					
BETWEEN	909.91	2	454.95	3.83	.03
WITHIN	6413.60	54	118.77		
TOTAL	7323.51	56			

Bonferroni correction, $p < .0025$

measures, the Solvent Questionnaire and the Cognitive Failure Questionnaire, reached significance at the more stringent level of $p < .0025$. The Stroop-Word test and PIQ approached significance at this level ($p = .003$).

Table 6 summarizes the results of the post hoc multiple comparison on those measures that reached significance at the .05 level and the more stringent level of .0025. Differences significant at the .05 level were predominantly between the control group and the previously exposed group (Digit Symbol, Performance Intelligence Difference, Visual Memory Span and the three subtests of the Stroop Test) with one difference between the control group and the recently exposed group (Digit Symbol Incidental Learning). Group means for the Solvent Questionnaire and the Cognitive Failure Questionnaire were significantly different between the control group and the two exposed groups at both significance levels (.05 and .0025). The results for each dependent measure follow.

TABLE 6

POST HOC MULTIPLE COMPARISONS (SCHEFFE TEST) OF DEPENDENT VARIABLES WITH F-RATIO ≥ F-CRITICAL.

DEPENDENT MEASURES	CONTROL	GROUP MEAN RECENTLY EXPOSED	PREVIOUSLY EXPOSED	GROUPS WHICH DIFFER
Solvent Questionnaire	3.15	8.15	10.10	Control from 2 & 3*
Cognitive Failure Questionnaire	37.05	57.53	67.63	Control from 2 & 3*
Beck Depression Inventory	6.65	14.82	20.79	Control from 3*
Digit Symbol	11.50	10.90	9.70	Control from 3**
Digit Symbol Incidental Learning	7.15	5.20	5.50	Control from 2**
P.I.Q. Difference	8.25	12.00	17.70	Control from 3**
Visual Memory Span	15.75	15.00	13.70	Control from 3**
Stroop-Word	50.40	47.47	42.11	Control from 3**
Stroop-Colour	51.20	46.32	42.78	Control from 3**
Stroop-Colour/Word	50.00	47.79	40.56	Control from 3**

* Bonferroni correction $p < .0025$

** $p < .05$

Solvent Questionnaire - Subjects in the three groups responded differently to the SQ ($F(2,57) = 27.59$, $p < .001$). Scheffe's post hoc test showed that those in both the recently exposed group ($M = 8.15$) and the previously exposed group ($M = 10.10$) reported significantly more symptoms than the control subjects ($M = 3.15$).

Cognitive Failures Questionnaire - As in the SQ, subjects in the three groups responded differently to the CFQ, $F(2, 55) = 21.15$, $p < .001$. Scheffe's post hoc test showed that those in both the recently exposed group ($M = 57.53$) and the previously exposed group ($M = 67.63$) reported significantly more symptoms than the control subjects ($M = 37.05$).

Picture Completion - The control group ($M = 10.35$) was able to perceive missing details better than both exposed groups who had similar means ($M = 9.10$). However, the mean differences were not significant at either the .0025 or .05 level, $F(2,57) = 1.90$, $p = .16$

Picture Arrangement - The previously exposed group (M = 9.45) arranged cartoon-like cards to make sensible stories as well as the control group (M = 9.40) while the recently exposed group (M = 8.45) did not. Group means were not significantly different at either the .0025 or .05 level, F(2,57) = 1.20, p = .31.

Block Design - The recently exposed group (M = 10.50) and the control group (m = 10.30) had similar test results while the previously exposed group (M = 8.80) was less able to arrange blocks to match a presented design. Once again, means were not different at the .0025 or .05 significance level F(2,57) = 3.00, p = .06.

Digit Symbol - While the recently exposed group (M = 10.90) scored higher than the previously exposed group (M = 9.70) both exposed groups completed fewer digit-symbol pairs than the control group (m = 11.50). The means were not different at .0025 significance level, F (2,57) = 3.54, p = .04. There was a mean difference, however, between the previously exposed group and the control group at .05 level, as determined by Scheffe's post hoc analysis.

Digit Symbol Incidental Learning - Subjects from both the recently exposed group (M = 5.20) and the previously exposed group (M = 5.50), who had similar scores, recalled fewer digit-symbol pairs than did the control group (M = 7.15). Mean differences were not found at the .0025 significance level, $F(2,57) = 4.35$, $p = .02$. However, at the .05 level Scheffe's post hoc revealed differences between the recently exposed group and the control group.

Digit Span - Both the recently exposed group (M = 11.58) and the previously exposed group (M = 11.20) recalled longer strings of digits, forwards and backwards, than the control group (M = 10.05). The means were not significantly different at either the .0025 or the .05 level, $F(2,56) = .49$, $p = .62$.

WAIS - R Performance Intelligence Quotient - The control group (M = 102.05) had a higher current PIQ than the recently exposed group (M = 90.90) and the previously exposed group (M = 93.95). The means were not statistically different at either significance level (.0025 or .05), $F(2,57) = 2.96$, $p = .06$.

NART <u>Performance Intelligence Quotient</u> - The previously exposed group (M = 111.65) had a slightly higher premorbid PIQ than the recently exposed group (M = 108.05) and the control group (M = 107.40) These differences were not significant at either the .0025 or the 05 level, $F(2,57) = 2.86$, $p = .07$

<u>Performance Intelligence Quotient Difference</u> - The previously exposed group's (M = 17.70) difference was more than twice the difference of the control group (M = 8.25). The recently exposed group's (M = 12.00) difference fell in between the other two groups. Although mean differences were not significant at the .0025 level, they were at the .05 level, $F(2,57) = 6.52$, $p = .003$. Scheffe's post hoc test showed this difference to be between the previously exposed group and the control group.

Visual <u>Memory Span</u> - The control group (M = 15.75) recalled more forward and backward sequences than both of the exposed groups. The recently exposed group (M = 15.0C) scored higher than the previously exposed group (M = 13.70). No differences were found between the means at the .0025 level, however at the .05 level Scheffe's post hoc test showed a difference between the previously exposed group and the control group, $F(2, 56) = 3.83$, $p = .03$

Logical Memory I - The control group (M = 30.50) recalled more details than the recently exposed group (m = 28.35) and the previously exposed group (M = 26.60). These differences were not significant at the .0025 or .05 level, $F(2,57) = 1.4$, $p = .24$.

Logical Memory II - Once again, the control group (M = 26.80) recalled more details than the recently exposed group (M= 24.25) and the previously exposed group (M = 23.25). However, the mean differences were not significant at either alpha level (.0025. 05) $F(2,57) = 1.00$, $p = .38$.

Rey-Osterrieth Complex Figure: Copy - The control group (M = 29.03) had higher mean scores than the recently exposed group (M = 26.73) and the previously exposed group (M = 26.48). No difference was found between the means at either the .0025 level of the .05 level, $F(2,57) = 2.64$, $p = .08$.

Rey-Osterrieth Complex Figure: Delay - The recently exposed group ($M = 13.38$) recalled a similar number of details as the previously exposed group ($M = 13.18$). Both exposed groups performed more poorly than the control group ($M = 16.48$). The differences between the means were not significant at either the .0025 level or the .05 level, $F(2,57) = 1.94$, $p = .15$.

Babcock Sentence Learning Test - Both the recently exposed group ($M = 7.15$) and the previously exposed group ($M = 7.56$) recalled the sentence in fewer trials than the control group ($M = 6.26$). There was no difference between the means at the .0025 level or the .05 level, $F(2,54) = 1.16$, $p = .32$.

Stroop Colour-Word Test: Word - The control group ($M = 50.40$) read more colour words in 45 seconds than either the recently exposed group ($M = 47.47$) or the previously exposed group ($M = 42.11$).

These mean differences are not significant at the 0025 level However at the .05 level Scheffe's post hoc test showed a difference between the previously exposed group and the control group

Stroop Colour-Word Test: Colour - The control group (M = 51 20) named more colours than the recently exposed group (M = 46 32) and the previously exposed group (M = 42.78). Mean differences were not significant at the .0025 level. At the .05 level, differences were determined by Scheffe's post hoc test to be between the previously Exposed group and the control group, $F(2,54) = 5.39$, $p = 01$

Stroop Colour-Word Test: Colour/Word - The control group (M = 50 00) was able to name more colours (instead of reading the words) than the recently exposed group (M = 47.79) and the previously exposed group (M = 40.56). Mean differences were not significant at the 0025 level However, Scheffe's post hoc test showed a difference between the previously exposed group and the control group at the 05 level

The control group had higher mean scores on over 50% of the measures as compared to the exposed groups as expected. Of particular interest was the lower mean results on the Performance Intelligence Difference. This outcome was expected as this difference is used as a measure of cognitive impairment, and the underlying assumption of a control group (in this study) was that they are free from impairment. Considering only the mean scores, the previously exposed group did not perform as well as the recently exposed group. In fact, the latter group scored higher on over 50% of the test measures than did the previously exposed group. Further, the previously exposed group had a greater overall Performance Intelligence Difference indicating an increased possibility of cognitive impairment, than the recently exposed group.

Discriminant Analysis

A direct discriminant function analysis was used to predict group membership from a subset of the study's predictors. Several dependent measures were eliminated from this analysis due to their high intercorrelation(s) ($r > .60$) with other variables.

The discriminant analysis used the following variables as predictors of group membership: age, gender, CFQ, PC, PA, BD, DSym, DSymInc, DS, VISMEM, LOGMEM II and StroopW. The groups were the three groups defined above.

Of the original 60 cases, six were not used in the discriminant analyses phase as they contained at least one missing predictor variable. All 60 cases were included in the classification phase as the six cases were assigned a group mean score in place of their missing variable. No outliers were detected in any of the three groups.

Two discriminant functions were calculated, with a combined $X^2(30) = 58.69$, $p<.01$. Removal of the first function resulted in a non-significant association between groups and predictors $x^2(14) = 10.24$, $p=.74$ (TABLE 7). The two discriminant functions accounted for 88% and 11.5%, respectively, of the between-group variability. The first discriminant function separated the control group from the exposed groups while the second discriminant function separated the recently exposed group from the previously exposed group.

TABLE 7

CANONICAL DISCRIMINANT FUNCTIONS FOR DISCRIMINATING VARIABLES AND STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS.

FUNCTION	EIGEN VALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	: AFTER : FUNCTION	WILK'S LAMDA	CHI-SQUARED	DF	SIGNIFICANCE LEVEL
1*	2.01	88.46	88.46	.82	: 0	.26	58.69	30	.00
2*	.26	11.54	100.00	.46	: 1	.79	10.24	14	.74

* MARKS THE 2 CANONICAL DISCRMINANT FUNCTIONS REMAINING IN THE ANALYSIS.

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNCTION 1	FUNCTION 2
AGE	0.27498	0.19746
GENDER	-0.13127	0.05352
COGNITIVE FAILURE QUESTIONNAIRE	-0.88174	0.18123
PICTURE COMPLETION	0.20479	-0.00932
PICTURE ARRANGEMENT	0.13489	-0.52015
BLOCK DESIGN	-0.34076	0.64621
DIGIT SYMBOL	-0.40583	0.02925
DIGIT SYMBOL-INCIDENTAL LEARNING	0.20042	-0.39816
DIGIT SPAN	-0.43199	0.06248
VISUAL MEMORY SPAN	0.86035	0.35827
LOGICAL MEMORY II	-0.37321	0.13471
STROOP-WORD	0.64673	0.47065
BABCOCK SENTENCE LEARNING	0.06346	0.04484
REY-OSTERRIETH: COPY	0.61599	-0.17855
REY-OSTERRIETH: DELAY	-0.09241	-0.33157

Table 8 shows that only one variable best predicts group membership for the control group from the other two groups: CFQ. This was the only loading greater than .50 for the first discriminant function. Hence, the control group members endorsed significantly fewer questions on the CFQ (mean = 37.05) than the two groups from CHMC (recently exposed, M= 57.53, previously exposed, M = 67.63). No variables had loadings greater than .50 for the second descriminant function, however, Block Design approached this cut off at .49.

The classification procedure for all 60 cases, classified 46 (76.67%) of the cases correctly (Table 9). This is better than chance alone, which would be 33% for three groups with equal n's (sample proportion). Control group members were more likely to be correctly classified (95%) than those in the recently exposed group 2 (90%) or in the previously exposed group (65%). Cases in the previously exposed group, if not predicted accurately, were classified into the recently exposed group.

TABLE 8

POOLED WITHIN-GROUP CORRELATIONS BETWEEN DISCRIMINATING VARIABLES AND CANONICAL DISCRIMINATION FUNCTIONS.

	FUNCTION 1	FUNCTION 2
Cognitive Failure Questionnaire	-0.60874*	-0.02657
Digit Symbol Incidental Learning	0.24695*	-0.22999
Rey-Osterrieth: Copy	0.20830*	-0.15434
Rey-Osterrieth: Delay	0.17120*	-0.13718
Picture Completion	0.16542*	0.03088
Babcock Sentence Learning	-0.15233*	0.07722
Age	-0.05447*	0.02346
Block Design	0.12010	0.49059*
Digit Symbol	0.19615	0.44325*
Stroop-Word	0.31604	0.38996*
Visual Memory Span	0.23111	0.35046*
Picture Arrangement	-0.00094	-0.34749*
Gender	0.00506	-0.18000*
Digit Span	-0.10423	0.13337*
Logical Memory II	0.09350	0.10290*

* Predictors that best discriminate for that particular function. Variables are ordered by size of correlation within the function.

TABLE 9

CLASSIFICATION RESULTS OF DISCRIMINATION ANALYSIS BY GROUP

ACTUAL GROUP	NUMBER OF CASES	PREDICTED GROUP MEMBERSHIP 1	2	3
Control (1)	20	19 95.0%	1 5.0%	0 0.0%
Recently Exposed (2)	20	2 10.0%	14 70.0%	4 20.0%
Previously Exposed (3)	20	0 0.0%	7 35.0%	13 65.0%

Percent of grouped cases correctly classified: 76.67%

Beck Depression Inventory (BDI)

Group means were calculated for the BDI. Unfortunately, the BDI had not been administered to all subjects during their initial screenings and was omitted during retesting. The control group (n=20) had a mean of 6.65 while the recently exposed group (n=11) and the previously exposed group (n=14) had means of 14.82 and 20.76, respectively. An analysis of variance indicated significant group differences, $F(2,42) = 111.07$ $p < .05$. Scheffe's post hoc test showed that those in the previously exposed group reported significantly more symptoms than the control subjects. Due to the small sample size and unequal n's these results must be interpreted with caution. A reported Test-retest reliability was .90 (Beck, 1970).

Discussion

The initial hypothesis predicted that exposed CHMC groups would report more solvent exposure related complaints, a higher frequency of cognitive failures and more depressive symptoms than the control group. No differences were expected to be found between premorbid estimates of Performance Intelligence for the control group or exposed groups. It was also expected that the exposed groups would perform more poorly on the remaining neuropsychological tests.

Volunteer staff members from CHMC (both the recently exposed and the previously exposed groups) did endorse a greater number of items on the Solvent Questionnaire and the Cognitive Failure Questionnaire than the control group. Only the previously exposed group endorsed significantly more items on the BDI than the control group. The fact that the control group endorsed so few items in each questionnaire suggests that they did indeed meet the criteria of a nonexposed group. These results substantiate the information provided by control group subjects during their interviews. As predicted, the three groups did not differ on the NART, thus they were equivalent in regards to their estimated premorbid Performance Intelligence. Since there was no significant difference between mean years of education for all three groups, it was expected that NART scores would be similar-which, in fact, was obtained. Group mean scores across twelve of the remaining test measures indicated a trend towards poorer overall performance by the exposed groups as opposed to controls as predicted. However, by adopting a stringent confidence level (i.e. $p<.0025$) these differences did not reach significance. When a less conservative approach is taken (i.e. $p < .05$), which increased the family-wise error rate, the control group performed significantly better on: (1) the difference calculated between estimated premorbid Performance Intelligence and current Performance Intelligence, (2) Digit Symbol, (3) Digit Symbol Incidental Learning, (4) Visual Memory Span, and (5) all three subtests of the Stroop Colour-Word Test, than subjects in the exposed groups. These differences were between the previously exposed group and the control group, with the exception of Digit Symbol Incidental Learning, where the differences occured between the recently exposed group and the control group.

There are few methods available for use in neuropsychological research to estimate premorbid levels of cognitive functioning (Spreen and Strauss, 1991). While the NART is considered to be a powerful predictor of the WAIS FSIQ and VIQ, it is relatively poor at predicting PIQ (Crawford, 1992). Unfortunately there are no methods available which will explain a high percentage of the variance of the PIQ, thus the NART, like any of the other measures, must be interpreted with caution

The difference between an individuals premorbid and current Performance Intelligence is often used as a measure of cognitive decline (Spreen & Strauss, 1991). A difference between premorbid and current Performance Intelligence scores of 21 points is a conservative indicator of impairment (C. Hayes, personal communication, September 15, 1993). In the present study, the previously exposed group was 3.3 points below this cutoff (21 - 17.7), however, the difference was more than twice the magnitude of the control group's difference. The recently exposed group's mean was between those of the other two groups. The interpretation that the differences obtained by the two exposed groups represented a real decline in functioning remains likely, however, until better techniques become available for determination of premorbid Performance IQ, declines are speculative.

The previously exposed group also differed from the control group on Digit Symbol. In a previous study by the Nova Scotia Environmental Medicine Clinic and the Environmental Health Center Dallas (Ross et al., 1993), an evaluation of CHMC staff members revealed that 85 percent of the twenty-six subjects scored at or below the 50th percentile and 38 percent scored below the twentieth percentile on the Digit-Symbol Test. As well, Bowler, Sudia, Mergler, Harrison and Cone (1992) concluded that Digit Symbol is a useful measure for identifying central nervous system impairment. Although previously exposed subjects scored lower on this test than did controls, it should be noted that the former group's mean was only slightly below average (i.e. -.3) and not indicative of impairment. The second aspect of this test was the incidental recall of digit-symbol pairs Recall of less than six of the pairs, "Must raise the suspicion of some type of memory impairment" (Kaplan et al.,1991). While controls on average recalled more than six pairs, both exposed groups recalled less than six pairs, thereby suggesting impairment.

The recently exposed group performed almost as well as the control group on Visual Memory Span, while the previously exposed group performed more poorly than the controls. As a measure of visual memory, this test relies on an individual's ability to attend and concentrate (Spreen & Strauss, 1991). Hence the previously exposed subjects poor visual memory performance may have been influenced by poor attention and concentration abilities.

Finally, the previously exposed group performed more poorly on all three subtests of the Stroop Colour-Word Test than the controls. This test has a mean of 50 and a standard deviation of 10 (Golden, 1978). While the control group obtained average scores for all three subtests the previously exposed group approached almost one full standard deviation below the mean for each subtest. These scores are not indicative of impairment, however, the previously exposed group's score shows evidence of decline from the mean. The recently exposed group 's scores were more similar to the controls.

The exposed group's means did not differ from the control group's means on Picture Completion, Picture Arrangement, Block Design, Performance Intelligence Quotient, Digit Span, Logical Memory I and II, Rey-Osterrieth Complex Figure, and Babcock Sentence Learning. Results on the first three subtests (Performance subscales of the WAIS-R), each of which involve visual material, were all within or approaching an average age-scaled level of performance. However, apparent trends on both Picture Completion and Block Design indicated poorer performance by the exposed groups compared to the control group. The previously exposed group, as well as the control group, was able to arrange cartoon-like drawings to make sensible stories (Picture Arrangement), which requires adequate social judgement, (Wechsler, 1987). The recently exposed group performed at almost one age-scale point below the control group, however this difference is not indicative of decline. The control group had greater difficulty recalling strings of digits forwards and backwards than did both of the exposed groups All three groups, however, did so at average levels.

Although the three groups did not differ on mean Performance Intelligence Quotients, the trend was for the controls to perform overall at a level higher than the exposed groups. All three scores, however, were within one standard deviation of the mean - thus, they were all equivalent and were functioning in the average range.

While subjects from the exposed groups complained of memory disturbances, their overall performance on measures of immediate and delayed recall was similar to the control groups. A closer look at the means showed that the controls had a tendency to recall more information both immediately after presentation and 30 minutes later than the exposed groups. However, although not used as a dependent measure in this study, the three groups did not appear to differ in the percentage of information recalled on the second trial (i.e. Logical Memory II / Logical Memory I). At face value, all three groups recalled more than 75 percent of the information 30 minutes after they initially recalled it. Thus, when information had been encoded, none of the groups had difficulty retrieving it, and thus had no obvious indication for deteriorated memory.

The exposed groups' means were lower for the copy version of the Rey-Osterrieth Complex Figure than the control group's. As a measure of visual construction ability the two exposed groups performed below the tenth percentile while the control group performed at the tenth percentile (Lezak, 1974). This was much lower than expected for the control group which was expected to be closer to the 50th percentile (average). The three groups recalled approximately 50 percent of their initial construction after a 30 minute interval. The two exposed groups scores were below the tenth percentile, while the controls were only slightly better at the twentieth percentile. Thus, all three groups performed poorly on this task.

Finally, the previously exposed and the recently exposed groups recalled a complex sentence (Babcock Sentence Learning Test) in fewer trials than did the controls. These results are not consistent with the findings on a separate measure relying on verbal memory (Logical Memory I) where the exposed groups did not perform as well as the control group. Overall, there is no consistent evidence for impairment on tasks of verbal memory.

The second prediction of this study was that those subjects who were still working in the affected environment or who had been off work for less than six weeks (recently exposed) would have lower scores on objective measures and higher scores on subjective measures (i.e., self-report questionnaires) than those subjects who had not been working in the affected environment for 12 weeks or more (previously exposed). Skov et al. (1990) and Ryan and Morrow (1992) stated that SBI symptoms usually diminish when individuals leave the offending environment. Findings from this study did not support this hypothesis. In fact, the two exposed groups were not found to significantly differ on any of these test measures, including the self-report questionnaires, even at the .05 significance level. Furthermore, taking only the group mean scores into consideration, the previously exposed group reported a greater number of complaints related to solvent exposure, more frequent occurrences of cognitive failures, and more depressive symptoms, than did the recently exposed group. As well, mean trends suggest those individuals who had been out of the work environment for at least twelve weeks performed more poorly on tasks involving visual construction, visual-motor speed, verbal and visual memory, and attention and concentration than the recently exposed group.

Group means for the previously exposed group were lower than the recently exposed group for each subtest of the WAIS-R excluding Digit Symbol Incidental Learning and Picture Arrangement. The latter test suggests that those individuals who were out of the affected environment for at least 12 weeks were better able to pick out relevant stimuli from line drawings and sequentially arrange them using abstract reasoning and social judgement than were the previously exposed group. The group mean difference on Digit Symbol Incidental Learning was negligible. Performance on each of the WAIS-R subscales was within the average range for both groups. Both groups' premorbid Performance Intelligence estimates were in the high average range while their current levels of functioning were in the average range. The trend indicates that the previously exposed group is much closer to the cut off indicative of cognitive impairment than the other exposed group. The previously exposed group also performed more poorly on Visual Memory Span, a test which relies on attention and concentration, and recalled fewer details of a short story immediately after presentation and once again 30 minutes later. Both groups recalled approximately the same percentage of information during the second trial (Logical Memory II/ Logical Memory I). There was no apparent problem with the retrieval of verbal material. Means for both groups of the copy and delay version of the Rey-Osterrieth Complex Figure were almost identical. Hence, once again the previously exposed group did not perform as expected. Minimal improvement was noted for the previously exposed group on the number of trials it took to recall a complex sentence, however, a decline in performance was noted on all three subtests of the Stroop Colour-Word Test, in comparison to the recently exposed group. As previously noted, the previously exposed group performed at almost one standard deviation below the mean.

These results are clearly the opposite to what was expected. Using both a statistically conservative ($p < .0025$) and a less stringent ($p < .05$) criteria the two groups did not differ on their performances. However, the previously exposed group had a tendency towards reporting a greater number of complaints and performing more poorly on objective test measures than the recently exposed group

Results from the discriminant analyses indicated that the only predictor included in this analysis which was able to predict group membership between the control group and the exposed groups was the Cognitive Failure Questionnaire Hence, any CHMC staff members who endorse many of the items on the questionnaire could predictably be classified into the exposed group as opposed to the control group There were no predictors powerful enough which would enable the separation of the two exposed groups Inclusion of subjects, who had been out of the work environment for less than six weeks, into the recently exposed group may have resulted in the two exposed groups being more alike than different. The use of the CFQ as a singular predictor for classifying individuals with SBI related complaints is intuitively limited. Since it is a self-report measure the results are based on subjective perceptions of the respondent. Therefore, individuals have control over the outcome and may respond according to any underlying motivation. If, for instance, it is in the respondents best interest to appear ill, they can do so. On the other hand, if subjects are denying their symptoms, for whatever reason, their responses will likely reflect this. Thus, classification of individuals reporting SBI symptoms using only the CFQ would be foolhardy. Furthermore, inclusion of this measure into a diagnostic battery of tests is only useful if it is accompanied with knowledge of the respondents' potential secondary gain. Hence, questions regarding what type of outcome a respondent is looking for, and how test findings (negative or positive) will affect them (i.e., insurance claim) are necessary. CHMC staff members, in this study, would gain recognition of their illness if the results were negative (thus confirming their complaints). However, their physical symptoms alone would result in sick leave. They did not need neuropsychological complaints for time off work. Furthermore, the cost to these individuals of coming forward with their complaints was greater than the benefits. For example, skepticism by co-workers, family members and often from their own family physicians had to be endured. Being off from work put financial strains on themselves and their family. Many discussed the high incidence of marital discord among affected workers. Treatment programs, if followed, were paid for out of their own pockets. In light of these consequences, it appears that the cost of the illness to these individuals is as significant as any secondary gain.

In retrospect, the role of the CFQ as a dependent variable is questionable. Since the inclusion criteria for the two exposed groups included the presence of at least one neuropsychological complaint (i.e., memory disturbance, attention and concentration), these individuals were more likely to endorse a greater number of items reflecting cognitive failures than a control group which had no such complaints. This questionnaire may have been more useful as an independent variable in this study. It would have provided a means to further define the groups in lieu of a measure of solvent exposure.

Summary

Both of the CHMC exposed groups were either experiencing, or perceived themselves to be experiencing, a greater number of neuropsychological and depressive effects than subjects working in a different building. Workers who had been off for an extended period of time reported an increase in symptoms from those who were still working or who had been off for a shorter period of time. Thus, contrary to the suggestion made by Ryan and Morrow (1992) and Finnegan et al (1984), symptoms did not diminish after leaving the offending environment. This may be due to several factors. The most obvious is that the previously exposed group was in fact more affected than the recently exposed group, thus the differences would be true differences. Subjects from the recently exposed group were either still working or had only been on sick leave for less than six weeks. Since the previously exposed group had been sent off work much earlier, it is plausible that they were more affected by the air-quality problems (i.e., they had a greater number of symptoms and/or these symptoms were more severe) than those who remained working or who were put off work for a shorter period of time. Prior to test administration, neither the level of solvent exposure nor the degree to which subjects were affected (i.e. symptom severity) were measured for each group in this study. Thus, whether or not the groups differed in these respects is unknown. As awareness about the illness increased over time, it is likely that staff members would take the occurrence of related symptoms more seriously and report them to the Occupational Health Department in their earlier stages.

During the time of test administration, procedures designed to eliminate air quality problems within CHMC had already commenced. Based on this, it would be predicted that symptom severity would be much worse when air quality was poorer. Although the recently exposed group would have been working in the same general environment as the previously exposed group, prior to the air quality reparations, not all individuals are affected to the same degree. In fact, a proportion of people working in sick buildings do not experience any of the related symptoms, or at least are still able to function adequately enough on the job site. This aspect of the illness, although widely recognized, is little understood and is often the cause of controversy within the medical community.

Another phenomenon which supports this notion of a 'true' difference is the concept of 'Hypersensitivity' (Ross, 1993) or the 'Hypersusceptible Individual' (Miller & Ashford, 1993). Individuals who have had a singular episode of intense exposure or low level exposure of a long duration to solvents or chemicals may develop a heightened sensitivity to odors they may come in contact with daily. Participants from Camp Hill Medical Centre often reported that perfumes, colognes, gasoline fumes and exhaust fumes (to name a few), had become very aversive to them since the onset of their symptoms. Exposure to these noxious smells resulted in 'reactions' referred to as cascosmia (Miller & Ashford, 1993). Reactions were often characterized as headaches, dizziness, disorientation and irritability. Hence, if participants from the previously exposed group did develop hypersensitivities, then simply remaining outside of the work environment for longer periods of time than individuals in the recently exposed group would not have resulted in a recovery from symptoms as predicted.

An alternative explanation for these group differences on subjective measures may be a tendency for those subjects who were off work for longer periods of time to perceive their symptoms as being worse than they were - to cognitively justify their length of leave. Although this is a plausible argument, since the majority of these individuals expressed a desire to return to work, it is thought that the tendency would have been more likely to minimize their complaints

Finally, the issue of malingering must also be addressed. Although a test sensitive to the effects of malingering was not included, each examinee's method of responding was observed. Specifically, behaviour patterns such as self-monitoring their responses, self-correcting any recognized errors, effort applied, rate of responding (i.e., length of time they attempted a task if they could not solve it immediately), and sustained focus (i.e., staying on task at hand without interruptions, such as talking to the examiner or irrelevant self-talk), were noted. Observed behaviours were similar across subjects in all three groups. They did differ, however, on emotional responses to their performance. Participants within the control group generally referred to the testing as being interesting and challenging, and were quick to say they would be interested in doing it again. Subjects within the experimental groups generally showed higher levels of frustration, tearfulness and fatigue on completion of the testing. No one individual stood out as trying to fake bad.

No significant differences were found on remaining test items between the exposed groups and the control group at the .0025 significance level. Using a less conservative alpha level (.05) the previously exposed group performed more poorly than the control group on several measures: Digit Symbol, Visual Memory Span, all three subtests of the Stroop Colour-Word Test and on the difference calculated between participants' premorbid and current levels of Performance Intelligence. The constructs which these tests are purported to measure include: visual-motor coordination and speed, attention and concentration on tasks involving the presentation of visual material, information processing, and suppression of a common response for a less common response (which also relies on attention and concentration). As well, the discrepancy between the premorbid level and current level of Performance Intelligence was much larger for the previously exposed group as compared to the control group. Thus, the former group performed lower than expected, and approached a conservative cutoff indicative of cognitive impairment. The recently exposed group differed from the control group only on a measure of incidental learning (Digit Symbol Incidental Learning) This task involves visually presented material which may be encoded verbally

Interpretations of results found at the .05 significance level must be made cautiously. Without using a Bonferroni correction, the family wise error rate significantly increases, thus, apparent effects may result from probability alone. Effects are likely to be reported at the .05 level when in fact there are no effects (Type 1 error), however, they would be expected to occur randomly throughout the measures. That was not the case in this study. All of the measures in this study which had differences significant at this less conservative level involved material which was visually presented. This apparent clustering is noteworthy as it would not have been expected by chance alone. Furthermore, attentional impairments (Orbaek et al., 1985; Ryan and Morrow, 1988) and reduced psychomotor speed which there was a tendency for in this study have previously been reported in studies examining the effects of solvent exposure. Once again, if the results occurred due to chance alone this pattern would not have been expected.

The two exposed groups were not different on any measures; however, there was a trend towards poor performance on test measures by the previously exposed group. In fact, the previously exposed group scored lower on twelve of the remaining test measures. As well, the discrepancy between their premorbid level and current level of Performance Intelligence was five points greater than the recently exposed group.

Neuropsychological Deficits of Exposed Workers

When considering only the performance of the exposed groups, participants from the two groups met criteria indicative of cognitive impairment on some of the measures. Both groups recalled fewer than six of the digit-symbol pairs on a task of incidental learning. Kaplan et al. (1991) suggested that this may be a marker for memory impairment. The previously exposed group was approximately three points below a conservative marker for cognitive impairment, while the recently exposed group was nine points below. Both groups showed evidence of visual-construction difficulties, scoring below the tenth percentile. Subsequent recall by both groups was also below the tenth percentile.

This may be due to inadequacies within the measure used (i.e., method of scoring) as difficulties were also evident in the control group. Finally, while performance by the recently exposed group was approaching an average level of functioning on all three subtests of the Stroop Colour-Word Test, the previously exposed group was in the opposite direction. Thus, the latter group had more difficulty with information processing and on an interference task which relied on attention and concentration.

Effects of Depression on Neuropsychological Functioning

As previously noted, the exposed groups endorsed more depressive statements on the BDI than did the controls. The control group's score fell within the normal range indicating no signs of depression. The recently exposed group's score was within the range indicative of minimal depression, while the previously exposed group's score was within the moderate-to-severe range of depression. The effects of depression on neuropsychological functioning can not be overlooked. "Depressed patients have been found to show deficits on tasks that assess specific aspects of reaction time, attention, or short term learning and memory, the magnitude of which may co-vary with the severity of depressive symptomatology and diminish with clinical recovery" (Sackeim et al., 1992). At face value, there seems to be a relationship with severity of depressive symptoms and performance on subtests. The control group with no depressive symptoms performed better than the exposed groups, and inversely, the previously exposed group which had moderate-to-severe symptoms of depression had a tendency towards poorer performance. Further, the constructs which showed poorer performance in this study included psychomotor coordination, attention and concentration and learning by the exposed groups. The findings of Sackeim et al. (1992) suggest that a Performance Intelligence deficit is characteristic of depressed patients. This could explain the increased discrepancy between the previously exposed groups premorbid level and current level of Performance Intelligence. However, there was a significant difference between Sackeim et al.'s (1992) subjects and the present study's participants. The previous study was comprised of depressed inpatients who met the criteria for Major Depressive Disorders. The modal patient in Sackeim et al.'s study had at least three previous episodes of this disorder, either depression or mania and the first episode occured 15 years earlier. Participants in the present study had not previously experienced a moderate-to-severe depressive episode. Furthermore, many of them stated that their depressive feelings were not persistent since onset. Instead they described themselves as having good days and bad days. They also reported having to make many adjustments to their lifestyles in relation to SBI, hence, feelings of depression were not considered by the examiner to be an unusual outcome. Furthermore, a review of the BDI reveals many items that overlap with SBI symptoms (i.e. sleep disturbances, weight loss, concern about health). Thus, individuals with SBI related complaints would be more likely to obtain higher scores on this measure than healthy individuals. However, since the effects of depression on neuropsychological functioning were not measured, inferences regarding a relationship between the two variables is beyond the scope of this study.

Present Study Versus Previous Studies Findings

A direct comparison of scores on the Cognitive Failures Questionnaire between the present study and the Hayes (1992) study is not possible as an overall mean score was not published. A mean score of 7.5 was provided for the Solvent Questionnaire (Hayes, 1992). In comparison, both exposed groups in the present study endorsed a higher number of items. While the current Performance Intelligence (average level) and premorbid Performance Intelligence (above average level) were similar across both studies, the difference calculated between these two measures was much higher for both exposed groups in the present study than the CHMC group in the Hayes (1992) study (M=8.55). Similar to the previous study, exposed subjects in the present study showed adequate verbal memory (immediate and delayed), adequate visual memory and poor visual construction abilities. Executive functioning was measured in the previous study using Picture Arrangement, and was reported to be less than expected for nine of the subjects. Functioning on this subtest in the present study was found to be adequate (i.e. average). Overall, there were similar findings across these two studies on all measures except for Picture Arrangement.

Present findings are similar to Orbaek et al.'s (1985) findings in that few statistically significant differences were found but there was a general tendency towards "lower performance scores in the exposed group" (Orbaek et al., 1985). They suggested that when differences are marginal between exposed versus unexposed individuals, there are at least differences on tests relying on "attentive capability and not on complex, symbolic, intellectual operations" (Orbaek et al.,1985). They concluded that individuals with attentional impairments compensate by slowing down to achieve accuracy. Although results in the present study were average for both exposed groups on Digit-Symbol, the previously exposed group performed significantly more poorly than the control group. Present results also replicated the findings by Ryan and Morrow (1988). They found impaired functioning by exposed individuals on tests of psychomotor speed and manual dexterity, and attention and mental flexibility (Ryan & Morrow, 1988). The present findings are also consistent with Hane et al.'s (1977) findings. This study showed lower performances on tests of psychomotor coordination, and visual memory, by exposed subjects.

Lower performance on tasks involving psychomotor speed and attention and concentration is common to all of these studies including the present study. A comparison such as this is not as straightforward as it may appear. Each study incorporated different measures to evaluate similar constructs, thus, any comparisons must be made with caution as the measures may not be equivalent.

Methodological Issues and Limitations

One limitation of this study is sample size, which may have had an effect on results as some test items were approaching significance. As well, the present findings must be interpreted cautiously as many of the measures used in this study were found to have poor test-retest reliability. Test-retest correlation coefficients were less than .60, $p < .05$, for ten of the tests which were administered a second time. This may reflect two factors: 1) a small n and 2) that almost half of the individuals who took part in the retesting were CMHC volunteer staff members who were taking steps to improve their health and cognitive functioning. It should be noted that although test-retest reliability was low in this particular study the measures used generally have a high reliability and are used frequently in neuropsychological studies and clinical practice. As well, due to the number of measures used in this study, the family-wise error rate was high. However, it was offset by the use of a Bonferroni correction factor. The high number of tests incorporated also resulted in the occurrence of redundant measures, as several of the variables correlated with other variables.

A further limitation of this study was the lack of control over exposure levels between the two CHMC groups. The severity of symptoms was not measured for each group, hence, they may have confounded the test results.

In retrospect, the BDI should have been given to all subjects during their initial testing and retesting. A correlation between BDI results and dependent measures would have been useful in determining the effect depression has on specific variables for this population. Further limitations include the absence of a test of malingering. Although it was not suspected, it would have objectively ruled out any question of its presence. Unfortunately, due to the limited number of subjects available, equating the three groups according to job description, although attempted, was not possible. As well, the examiner was aware which group each individual belonged to at the onset of testing. This was done for practical reasons and because the design did not call for random group assignment.

Future Research

The number of published neuropsychological investigations into SBI are scant, thus the scope of research required is vast. Frequently, while listing SBI related complaints, neuropsychological deficits are often not included in the literature, and often overlooked. Longitudinal studies regarding cognitive functioning are needed to fully understand any changes that may take place over longer periods of time. Questions regarding long term recovery or further deterioration need to be addressed.

Methods of measuring language expression difficulties need to be developed. Subjects frequently reported these speech disturbances during the interview and it was often observed throughout the testing session. Measuring how subjects attempt to solve each task and their response patterns should also be addressed in future studies. Differences were observed among the groups in their approaches to problem solving, however, they were not measured in this study.

Ultimately, neuropsychological testing should be performed on individuals prior to occupation of a newly constructed building to establish their premorbid levels of functioning. Testing could then be repeated after occupation (i.e. one year later). This would eliminate errors inherent in estimations. Obviously, this type of research would incur significant costs and is therefore not economically feasible. However, studies approaching this design would provide valuable information about the effects of SBI.

Implications of the Study

Skepticism surrounding SBI is fueled by the lack of controlled research. The present study addressed this issue from a neuropsychological perspective. Questions regarding whether neuropsychological findings for CHMC staff members would improve once they are out of the affected environment for an extended period of time have not previously been investigated. Although significant differences were not found, there was a clear trend for poorer performance by individuals who have been out of the work environment for at least twelve weeks than a group of individuals who were still working or had only been out of the work environment for a short period of time. This suggests a need for incorporating measures which can establish group exposure levels prior to testing in future studies. This information would enable more meaningful interpretations.

The study's results also have implications for future test battery's used in neuropsychological investigations of SBI. As there was considerable overlap evident between test measures on correlation coefficients, many of the measures were redundant. In light of the present findings and findings from previous solvent exposure research, emphasis should be placed on tests which measure general Performance Intelligence, attention and concentration, psychomotor coordination, and visual construction abilities. Consequently, the size of test batteries used with this population can be reduced, saving both time and money. A prorated version of the WAIS-R is useful as it provides a current PIQ and involves individual subtests which appear to be sensitive to SBI related neuropsychological complaints. The only WAIS-R subtest in this study that found significant group differences was Digit Symbol (and the additional test of incidental learning), however, Picture Arrangement, Block Design and Picture Completion did show trends for group mean differences. In fact, Block Design was approaching significance. Furthermore, these subtests provide qualitative data as well as quantitative data. Valuable information obtained from observing how an individual responds (i.e., use of problem solving strategies, amount of effort applied) on these tasks is useful over and above test scores. Visual Memory Span was sensitive to effects and was not highly correlated with any other measures, thus, it's inclusion in future testing of this population is warranted. A premorbid estimate of Performance Intelligence is necessary to compare with current levels of functioning in order to detect possible declines. Since there are no methods available which reliably estimate Performance Intelligence, perhaps a combination of methods could be incorporated, backed up by information obtained from each subjects personal history (i.e., school marks). The Rey-Osterrieth Complex Figure is useful for measuring visual construction and visual memory impairments (as opposed to group differences), however, it would be interesting to see if it was sensitive to group differences using different scoring parameters. Scoring procedures outlined in Spreen and Strauss (1991) may be too strict and consequently group differences may be overlooked. Since all three subtests of the Stroop Colour-Word Test have high intercorrelations and similar test results for each group, two of the subtests could be omitted. Finally, while a measure of depression provides new information, the Solvent Questionnaire is redundant. Additional tests which have not been included in this study (i.e. measures of language expression and other constructs not yet investigated) may provide additional information.

Conclusion

Trends in the present data supported the initial hypothesis that there was a difference between CHMC exposed groups and a control group on various neuropsychological tests and self-report questionnaires. However, the only test measures which had significantly different ($p < .0025$) results were the self-report questionnaires - subjective measures. Thus, the two exposed groups reported experiencing more complaints related to solvent exposure, and cognitive failures than the control group. As well, the previously exposed group experienced a greater number of symptoms related to depression than the control group. The lack of significant differences for the remaining test measures may have been influenced by a small sample size, as a comparison of the means reflected a tendency towards poorer performance for the exposed groups versus the control group. When the significance level was reduced, ($p < .05$) which increased the statistical power to detect differences (but increased the possibility of type 1 error), differences between the exposed groups and the control group are evident. What is noteworthy about these differences is that they occurred in measures which involved visual material and showed declines in constructs which have been reported in the solvent exposure literature (Orbaek et al., 1985; Ryan & Morrow, 1988; Hane et al., 1977). Potential interactions between test results and effects of depression were not measured in this study, thus they cannot be ruled out. Contrary to the second hypothesis, the previously exposed group did not perform significantly better than the recently exposed group. In fact, mean trends suggested that they were more likely to perform more poorly on objective measures and report a greater number of related complaints. This raises the question regarding the differences in exposure levels or effects between the two CHMC groups. Further investigations controlling for these group differences are required. A comparison of test results between the Hayes (1992) study and the present study showed similar levels of functioning on neuropsychological tests by CHMC staff volunteers. As well these results were similar to findings in solvent exposure studies.

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Appendix

Issue of Confidentiality and Use of Test Results

Subjects were provided with the following information during their neuropsychological assessment:

1. Confidentiality- your name, or any other identifying characteristics, will be located only on your test protocols. The only person to have access to this information will be myself, the examiner. In the future, when the results of this study are reported, your name or any other personal characteristics which would allow the reader or audience to identify you will not be included.

2. Individual raw data will not be reported. Instead, your results will be included with the data collected from other individuals and will be presented as a group.

Example of consent provided by subjects:

I, subject's name, hereby grant permission to Lauren Marsh-Knickle to use the data from my neuropsychological screening to be used in her thesis research.

Signed:

Dated: