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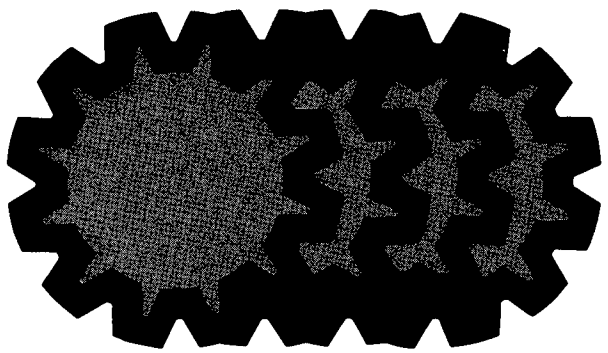
TECHNICAL INFORMATION

BEHAVIORAL AND NEUROLOGICAL EFFECTS OF CARBON DISULFIDE



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16. Abstracts A behavioral/neurological battery of tests was applied to a sample of workers occupationally exposed to carbon disulfide, together with neurological examination, and medical evaluation. Workers were also given psychometric tests of reaction time, coordination, visual search, short-term memory, and visual acuity. One hundred workers engaged in the manufacture of viscose rayon constituted the carbon disulfide-exposed group. Since ambient air levels of carbon disulfide could not be obtained within the viscose rayon plant, estimates of workers' exposure to carbon disulfide were based on detailed work history interviews with participants and results from an iodine azide test for urine metabolites of carbon disulfide. According to the total neurologic score for assessment of peripheral neuropathy, 13% of the carbon disulfide-exposed workers showed a probable or definite polyneuropathy. After correcting for age effects, neurologic indicators or ulnar nerve damage correlated significantly with indices of carbon disulfide-exposure, as did behavioral tests of reaction time, dexterity, rate of visual search, and perceptual organization.

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BEHAVIORAL AND NEUROLOGICAL EVALUATION OF WORKERS EXPOSED TO CARBON DISULFIDE (CS_2)

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ABSTRACT

The purpose of this investigation was to develop and apply a behavioral/neurological battery of tests to a sample of workers occupationally exposed to carbon disulfide (CS_2). The neurological component of the investigation consisted of electro-diagnostic examinations of electromyograms, nerve conduction velocities, and a medical evaluation by a neurologist. Workers were also given psychometric tests of reaction time, coordination, visual search, short-term memory, and visual acuity. One hundred workers engaged in the manufacture of viscose rayon constituted the CS_2-exposed group. Fifty workers engaged in similar work, but not occupationally exposed to CS_2, served as a control group.

Since ambient air levels of CS_2 could not be obtained within the viscose rayon plant, estimates of workers' exposure to CS_2 were based on 1) detailed work history interviews with participants and 2) results from an iodine azide test for urine metabolites of CS_2. Based upon application of Allen's procedure of using a total neurologic score for assessment of peripheral neuropathy, 13 percent of the CS_2-exposed workers showed a probable or definite polyneuropathy. After correcting for age effects, neurologic indicators of ulnar nerve damage were found to significantly correlate with indices of CS_2 exposure, as did behavioral tests of reaction time, dexterity, rate of visual search, and perceptual organization.

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INTRODUCTION

The recognition of workplace hazards has been steadily increasing in recent years. A number of factors have contributed to this development: 1) the passage of the 1970 Occupational Safety and Health Act, 2) increased pressure exerted by labor unions, 3) the increased educational level of the American worker, and 4) more prominent media coverage of workplace hazards. One category of workplace hazards, toxic substances, has come under increasing scrutiny due to recent discoveries of various occupational diseases that are directly or indirectly related to chemical toxicity. Such chemical hazards seem especially villainous due to their usually delayed effects. Some health impairments are detected only after many years of repeated exposure to the toxic agent and after frank clinical signs or permanent functional impairment are observed.

Among chemical hazards found at the workplace are a class of toxic agents called neurotoxins, chemicals known to cause damage to the nervous system. Included are some pesticides, heavy metals, and solvents. Each substance is developed, manufactured, and sold to serve one or a variety of purposes in industry. Despite the considerable efforts of government regulatory agencies and chemical manufacturers, sufficient information on possible long-term toxic effects of these substances on workers who may be exposed is rarely available prior to use of the substance in the workplace. The establishment of allowable safe exposure levels must be based on the best available information, however incomplete. This often means reliance on animal studies of relatively short duration. Once the substance is in use in industry, on-the-job health effects are monitored, if at all, by simple clinical tests and worker reports of symptoms. Unfortunately, these procedures may not be sensitive to effects at the early, reversible stages. The lack of sensitivity of these clinical approaches was demonstrated in a recent study which detected behavioral changes in workers who had been exposed to a toxic agent but were not identifiable as clinically poisoned (Hanninen, 1971). This evidence suggests that it may be possible through the use of other means, e.g., standardized behavioral tests, to develop "early warning indicators" of worker health problems resulting from toxic exposure.

This study was stimulated, in large part, by Hanninen's findings. In particular, the stimulus was provided by her finding that some workers chronically exposed to a neurotoxic solvent, carbon disulfide, at levels below the current United States Threshold Limit Value (T.L.V.) showed both subjective

symptoms and performance impairment, but were not diagnosed as clinically intoxicated. This finding casts doubt on the sensitivity of standard clinical procedures for detecting health impairment resulting from occupational exposure to neurotoxins such as carbon disulfide. Recognizing this need, the National Institute for Occupational Safety and Health contracted for this study in an effort to further document the behavioral and neurological effects of chronic low level exposure to carbon disulfide, and to investigate the utility of behavioral tests for detecting early, reversible, functional changes in exposed workers. The specific objectives of the study were to: (1) review the scientific literature regarding the known effects of exposure to carbon disulfide; (2) select a behavioral/neurological test battery that would be sensitive to these known and "presumed" effects; (3) administer the test battery to workers exposed to levels below, at, and possibly above the current T.L.V.; and (4) investigate relationships between the behavioral/neurological measurements, exposure indices, and medical data.

REVIEW

Carbon disulfide (or bisulfide, CS_2) is a colorless, transparent, volatile liquid which in its pure state smells like ether or chloroform. In its commercial grade, the product has an offensive odor that resembles decaying cabbage. The liquid boils at 46.25 degrees C., auto-ignites at 100 degrees C., and its vapors, when mixed with twenty parts by volume of atmospheric air, are highly explosive, having a vapor pressure of 400 mm Hg. at 28 degrees C. The density of the vapor is more than 2.5 times that of air.

Carbon disulfide is harmful both as a liquid and as a vapor. Absorption can occur through intact skin. Carbon disulfide vapor is rapidly absorbed when inhaled, producing an equilibrium between blood and inhaled vapor within 1 to 2 hours. Approximately 70% of the absorbed carbon disulfide is excreted from the body or metabolized in a few hours (Gosselin, Hodge, Smith, and Gleason, 1976). Opinions vary, however, regarding the exact percentage metabolized, excreted in the expired air, urine, or as urinary metabolites.

The existing Occupational Safety and Health Administration (OSHA) standard governing occupational exposure to carbon disulfide establishes a maximum allowable 8-hour time weighted average of 20 ppm (60 mg/M^3). During an 8-hour work shift, peak exposures of up to 100 ppm are permitted if the duration of exposures does not exceed 30 minutes. In order to achieve an 8-hour time weighted average (T.W.A.) of 20 ppm, however, these peak exposures would have to be offset by periods of exposure below 20 ppm.

The use of carbon disulfide in industry has been primarily due to its exceptional characteristic as a solvent for fats. Its primary use in the United States is in the production of viscose rayon. Other uses include the production of xanthates, plywood adhesives, flotation agents, thiocyanates, cellophane, optical glass, coal gas, tar distillation products, transparent film, and as an ingredient in lacquers and thinners.

The known effects of exposure to CS_2 were the topic of a review of the scientific literature conducted in the first phase of the present study (Tuttle, Reed, and Grether, 1973). This review focused primarily on research literature published since 1965, although earlier critical articles were also reviewed. The topics treated were (1) effects of exposure - emphasizing behavioral and neurological effects; (2) adequacy of techniques for assessing behavioral and neurological effects;

and (3) the adequacy of techniques for assessing "body burden" and ambient exposure levels.

Historical View[1]

Three periods were identified within which to characterize the literature pertaining to the effects of carbon disulfide exposure (Vigliani and Pernis, 1954). These periods are (1) from 1856 to World War I, (2) from World War I to the end of World War II, and (3) from World War II to the present. During the first period, CS_2 was used primarily in the vulcanization of rubber. During this period, regulations regarding levels of exposure to CS_2 were not well established. Consequently, it was not uncommon for workers to be exposed to very high concentrations. The high concentrations led to serious health problems among workers and caused Vigliani and Pernis (1954) to label this first period the "period of acute and subacute psychoses (Brieger, 1961, p. 302)."

During the second period, the hazards of CS_2 became widely recognized, and maximum acceptable concentrations were established. Nevertheless, numerous cases of CS_2 poisoning still existed. In Europe, this situation was attributable to occupational conditions created by the war. Individuals were required to work long hours in improperly ventilated work areas often made worse by war damage and poorly planned "makeshift" work environments. The most frequently reported symptom of CS_2 exposure was polyneuritis, usually localized in the lower limbs (Vigliani and Pernis, 1954). Similar findings were reported for workers in Japan (Kubota, 1967) and in Germany (Paluch, 1947).

During this period, the first major investigation of occupational exposure to carbon disulfide was undertaken in the United States. Dr. Alice Hamilton was commissioned by the U.S. Department of Labor to direct a comprehensive study of the hazards associated with exposure to carbon disulfide. This became a landmark study, which spurred further research and aided understanding of the health hazards within the viscose rayon industry (Penn. Department of Labor and Industry, 1938).

During the early part of the most recent historical period, Vigliani and Pernis report that cases of CS_2 poisoning were increasingly characterized by "vascular diffused encephalopathy with or without focal lesions (1954, p. 237)." More recent research has presented evidence linking CS_2 exposure to

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[1] This section is excerpted directly from the review by Tuttle, et al.(1973).

atherosclerosis (the deposition of fatty substances in, and fibrosis of, the inner layer of the arteries) and coronary artery disease (Tiller, Schilling and Morris, 1968; Hernberg, Partanen, Nordman and Sunari, 1970). The emphasis placed on the effects of CS_2 exposure on the cardiovascular system seems to be the main theme of this third period.

From the available evidence, it would seem that a fourth period in the history of CS_2 research is just beginning. Recent research by Hanninen (1971) and her associates suggests that behavioral changes are perhaps the first signs of CS_2 intoxication. This finding has important implications for the early detection of CS_2 poisoning. The development and validation of a battery of behavioral/neurological tests to detect preclinical behavioral changes resulting from CS_2 exposure would provide a valuable diagnostic tool. Such early diagnosis would permit exposed workers to be removed from exposure prior to the onset of definitive clinical symptoms or irreversible health impairment.

Conclusions from the Literature Review

Based on this extensive literature review, a number of conclusions were drawn with regard to the effects of CS_2 exposure and the methods used to study these effects. These conclusions are listed below.

1. Psychological/behavioral effects seem to be the earliest manifestations of chronic CS_2 poisoning. These early effects include: headache, fatigue, insomnia, rapid mood changes, slight psychomotor impairment, and intellectual impairment.

2. Standardized psychological/behavioral tests appear to have potential utility for discriminating between those having latent CS_2 poisoning and those who are unaffected. A test battery including a wide variety of psychological dimensions is preferable to one measuring only one or a few dimensions.

3. Slowed peripheral nerve conduction velocity and abnormal electromyographic (EMG) tracings can be observed prior to the onset of other clinical symptoms of neurological damage.

4. More advanced stages of chronic CS_2 poisoning produce abnormalities in reflex actions. These changes, however, are not as useful to early diagnosis and are not as reliable as EMG or conduction velocity measures.

5. During the period covered by this review, the effects of chronic CS_2 exposure on cardiovascular functioning were preliminarily established. These effects include high diastolic and systolic blood pressure, atherosclerosis, and an increased likelihood of death from coronary disease.

6. The effects of CS_2 exposure on hepatic functioning remain complex and unclear. Chronic exposure seems to lead to liver enlargement and a disturbance of liver antitoxic functions. Evidence from acute studies suggests that liver damage may also result from interaction of CS_2 with other factors such as diet or drugs.

7. Chronic exposure has been shown to produce significant effects on the visual system. The most consistent effects are increased retinal arterial pressure and retinal microaneurysms. These effects seem to increase in severity with the increase in the number of years of CS_2 exposure.

8. Chronic CS_2 exposure produces disturbances in metabolic and enzymatic reactions in the spleen, kidney, and gonads. Effects have been demonstrated in both human and animal studies.

9. The evidence with regard to effects of CS_2 exposure on auditory function is unclear. There is a suggestion that chronic exposure over a period of years leads to decreased sensitivity to high frequency tones.

10. The Iodine Azide Test (IAT) provides the most feasible and sensitive biochemical measure of CS_2 exposure.

11. The most accurate and generally accepted method for analyzing CS_2 vapor concentrations in the air is the diethylamine photometric procedure.

In-Plant Case Study

Following the completion of this review,a case study of particular significance was published which summarized the results of a NIOSH investigation of carbon disulfide exposure conditions in a viscose rayon plant (Occupational Health Case Report No. 1, 1974). The investigation focused on the spinning and cutting areas of the plant which are two areas having the

highest exposure to CS_2. At the time of the investigation there were approximately 27 spinnermen and 28 cuttermen employed at the plant, all of whom participated in the urinalysis screening and medical interviews. Exposure data was monitored for a sample of six spinnermen and eight cuttermen.

The results showed that cuttermen were exposed to Time-Weighted Average (T.W.A.) concentrations ranging from 9.5 ppm to 129 ppm, while the T.W.A.'s for spinnermen ranged from 4.3 to 11.1. The iodine azide test, an index of exposure based on an analysis of urinary metabolites, revealed abnormal scores for 10 of 28 cutterman and 2 of 27 spinnermen. None of the 6 chargehands or the 20 control group members had abnormal scores. Medical interviews revealed that 71 percent (20 of 28) of the cuttermen and 48 percent (13 of 27) of the spinnermen expressed symptoms characteristic of those normally associated with CS_2 exposure (e.g., headaches and dizziness). These percentages can be contrasted with those for chargehands (33% - 2 out of 6) and for controls (5% - 1 out of 20).

As a result of this investigation, the following conclusions were drawn:

1. Exposure to carbon disulfide in this work environment is toxic to cuttermen, chargehands, and others working in the cutter area.

2. Spinnermen are exposed to levels of carbon disulfide below the standard specified by the Department of Labor which is necessary to protect the worker's health. "However, because of evidence of symptomatic spinnermen and borderline abnormal iodine test results, spinnermen, N-10 men, patrolmen, filtermen, and pump-testers may on occasion be exposed to levels of carbon disulfide potentially toxic to them" (Occupational Health Case Report - No. 1, 1974, p. 29).

3. A serious safety hazard also exists with respect to any worker who is overexposed to carbon disulfide because of the dizziness which may result from exposure.

This in-plant investigation provides some indication of the effects of occupational exposure to carbon disulfide. As the authors mention, this investigation was intended to be only a limited medical investigation of those currently exposed. Since the investigation was initiated by workers in the cutting and spinning areas, the investigators were restricted to those areas. Therefore the investigation could not deal with workers who had previously worked in the spinning and cutting areas but who now worked in other areas of the plant. Nor did it include workers exposed to CS_2 in other areas of the plant.

METHOD

Selection of Behavioral/Neurological Test Battery

The selection of an experimental test battery to screen workers for the effects of a toxic substance should be guided by two principles. First, the battery should include tests that measure functions related to the known effects of the substance. Particularly important would be the inclusion of any tests that have a proven utility for the substance. Secondly, the battery should possess content validity. As noted by Hanninen (1971), the battery of tests should be heterogeneous enough to cover a variety of functions. This second principle is important in view of the fact that the full range of behavioral/neurological effects of a substance are rarely known. If tests are only selected to measure functions that are known to be affected, some potentially important effects are likely to remain unknown.

The first step in selecting tests according to these principles involved the use of consultants with expertise in the area of human performance measurement. Three psychologists were asked to read the CS_2 literature review (Tuttle et al. 1973) and make suggestions for measures to be included in a potential test battery. In addition to consultant recommendations, project staff made recommendations based on their expertise and pertinent previous research in behavioral toxicology and human performance measurement.

Recommendations by consultants and project staff were then evaluated in terms of the following criteria.

What is measured. The test should measure functions that are known to be, or hypothesized to be, affected by exposure to carbon disulfide.

Precision of measurement. Based on reported research evidence, the test should have adequate reliability. Of primary concern for the present application is test-retest reliability.

Administration requirements. In order to be practical for industry use, the tests should be able to be administered by technicians and not require expensive apparatus.

Time requirements. The length of time required to take the test was important not only from industry's viewpoint, but as a practical consideration of the research project.

Both the constraints of industry and individual cooperation in the research, as well as the practical considerations for a screening battery, demand that the time requirements be kept at a minimum.

Cost. It was considered desirable to develop a test battery that would be available for general industry use at a reasonable cost. Although no absolute cost ceiling was imposed, this criterion ruled out consideration of tests requiring elaborate apparatus (e.g., computer controlled testing devices, etc.).

Scoring. Tests which yielded objective, quantitative scores were preferred to those requiring subjective judgment and interpretation to score (e.g., projective personality measures, etc.). Related considerations were time required for scoring and the existence of normative data.

Freedom from the effects of fatigue or practice. The confounding effects of fatigue and practice can compromise the utility of a test in many instances, especially when the test is administered to the same individual on several occasions, as would be the case in an industry screening program. Therefore, tests less susceptible to these effects were favored.

Practical Considerations. A number of factors such as the size and portability of the apparatus required, the number of pieces of equipment, and space requirements were considered. These were important for the purposes of the research study as well as for industry acceptance.

On the basis of these criteria, the following tests were chosen to comprise the experimental test battery.

Feeling Tone Checklist
Wechsler Digit Span
Wechsler Digit Symbol
Wechsler Block Design
Neisser Letter Search
Critical Flicker/Fusion Frequency
Santa Ana Dexterity Test
Simple Reaction Time
Choice Reaction Time
Drop Reaction Time
Farnsworth Dichotomous Test of Color Vision

Feeling Tone Checklist. Developed by Pearson and Byers (1957), the Feeling Tone Checklist (Appendix A) provides a quantified measure of fatigue by having subjects indicate whether they feel "better than," "the same as," or "worse than" ten descriptive phrases (e.g., very lively, about to drop, etc.). The

Feeling Tone Checklist was included in the battery since fatigue has been one of the most consistently reported symptoms of exposure to neurotoxins such as carbon disulfide. In addition, the checklist can be self-administered, requiring a minimum amount of time (approximately two minutes). It can be scored by machine or hand. Developed and utilized by the Air Force, the checklist has an internal consistency reliability of 0.92.

Digit Span. This test from the Wechsler Adult Intelligence Scale (WAIS) provides a measure of memory for digits presented both forward and backward. It must be individually administered to workers and requires a verbal response from the testee, to be recorded by the test administrator. The Digit Span was included largely because of previous research (Braceland, 1938; Lilis, 1973) reporting memory impairment in workers exposed to specific neurotoxins. In addition, Hanninen (1971) found this WAIS sub-test to differentiate significantly between unexposed controls and exposed with no symptoms. Though intended to be administered by a trained psychologist, the test can be easily administered by a trained technician. Requiring less than five minutes, it is inexpensive and easily scored. The reported reliability of the digit span for three age groups ranges from 0.66 to 0.71 and is based on a correlation of the digits forward with the digits backward scores (Wechsler, 1955). Although this is somewhat lower than desirable, it is not too surprising, since the digits forward and digits backward probably represent somewhat different abilities.

Digit Symbol. This test (also from the WAIS) measures the individual's ability to code symbols with numbers using a predetermined code. Since the individual must write the symbol, psychomotor impairment as well as increased information processing time will decrease the score. This test was also shown by Hanninen (1971) to be sensitive to the effects of a neurotoxin, carbon disulfide (CS_2). In addition, the test involves simple instructions, can be administered to several individuals simultaneously, requires approximately three minutes to give, is inexpensive, and easily scored using a key provided in the WAIS test kit. The estimated alternate form reliability of the Digit Symbol test is 0.92 (Wechsler, 1955).

Block Design. A measure of perceptual organization, this WAIS subtest was also used in the Hanninen (1971) test battery, and successfully differentiated the exposed and unexposed groups. The worker is presented with a set of colored cubes (Figure 1). Two sides of each cube are red, two sides are white, and two sides are half red and half white. The task involves arranging

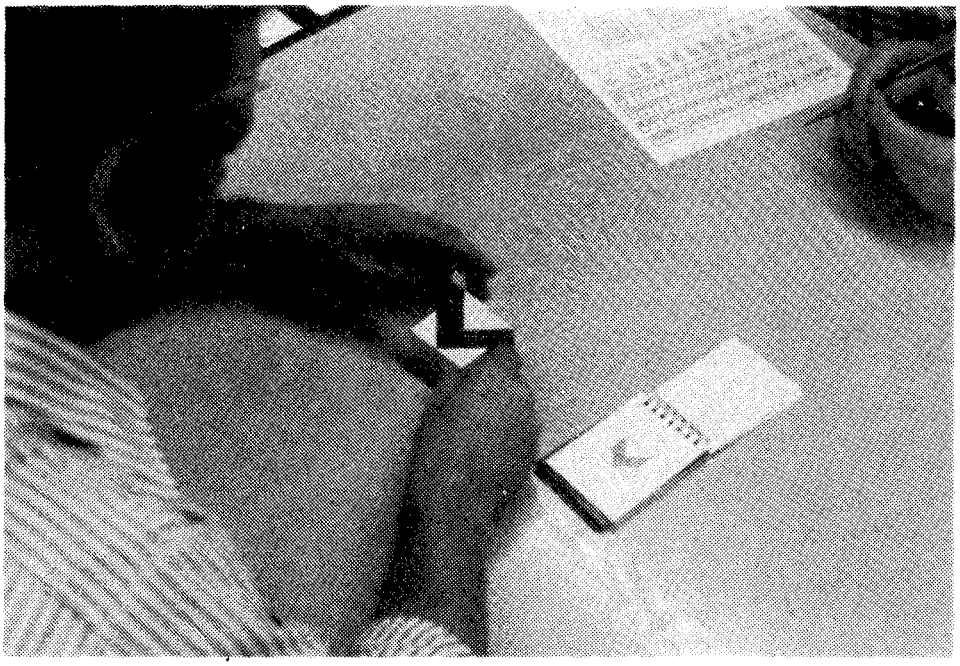

Figure 1. Block Design Test

the blocks or cubes in such a way that the top surfaces reproduce a design that is displayed for the worker by the experimenter. In the first six trials, four colored blocks are used, and for the last four trials, nine blocks are required to reproduce the design. The score is based on the number of designs correctly reproduced as well as the speed with which the task is completed. Published odd-even split half reliability coefficients for the Block Design test range from 0.82 to 0.85 for three different age groups of adults (Wechsler, 1955).

Neisser Letter Search. A "vigilance" performance test, the Neisser measures speed of visual search. Clusters of letters are presented to the subject with instructions to identify and mark the predetermined letter or letters from the visual array. The Neisser was included as a result of studies which showed difficulty in concentration and restlessness to be associated with exposure to some solvents. As a test requiring selective attention, the Neisser seems an appropriate measure of these effects. In addition, the Neisser can be administered to a number of subjects simultaneously, requires approximately five minutes, and is inexpensive. The scoring system is simple, but requires diligence on the part of the scorer. By allowing two trials with each target, some allowance is made for practice effects. In addition, the test has an acceptable test-retest reliability ($r = 0.78$) (Rose, 1974).

Critical Flicker/Fusion Frequency. This is a measure of visual/neurological performance requiring a flicker control unit (Figure 2) and a viewing chamber (Figure 3). The test involves determining the Critical Flicker Frequency - the frequency at which a steady light source with a controlled intensity begins to flicker (method of descending frequencies), or the Critical Fusion Frequency - the frequency at which the flickering light source fuses into a steady light (method of ascending frequencies). This test has been included as a result of studies which have shown that neurotoxins affect visual functioning. Investigations have also shown that the CFF performance is impaired when an individual's capacity for mental or physical performance is impaired or fatigued.

Critical Flicker/Fusion Frequency can be scored quantitatively and easily. Testing time is brief, only three to four minutes are needed per subject. The cost of the CFF equipment represents a considerable portion of total test battery cost, but is not prohibitive. The inclusion of this instrument is necessary since it improves the content validity of the battery by measuring visual functioning. Further exploration of the sensitivity of CFF to the effects of exposure to toxic substances in general is important from an exploratory research view.

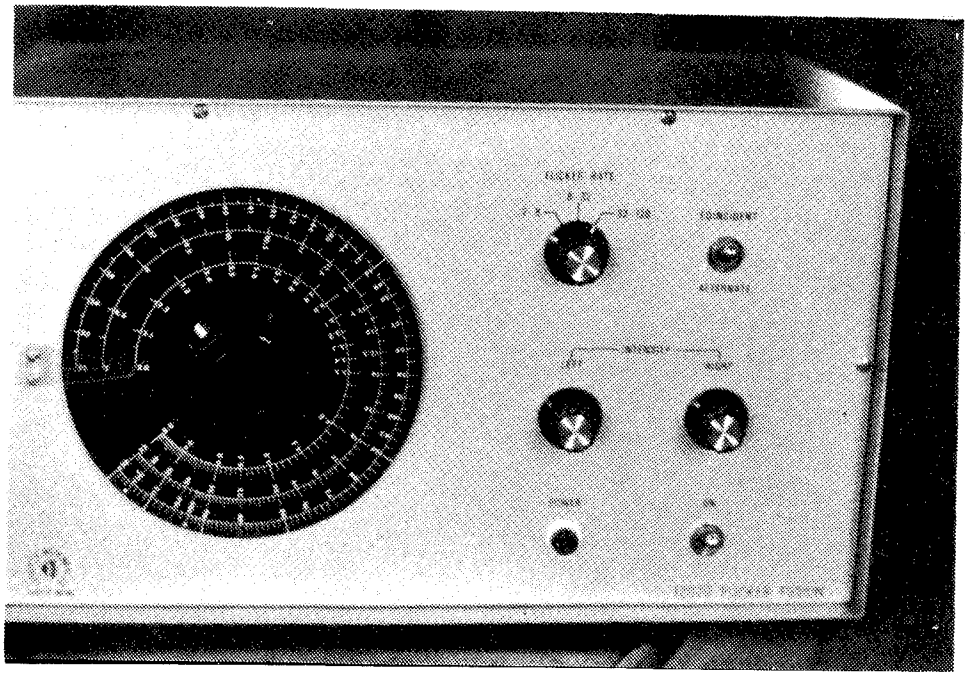

Figure 2. Flicker Control Unit

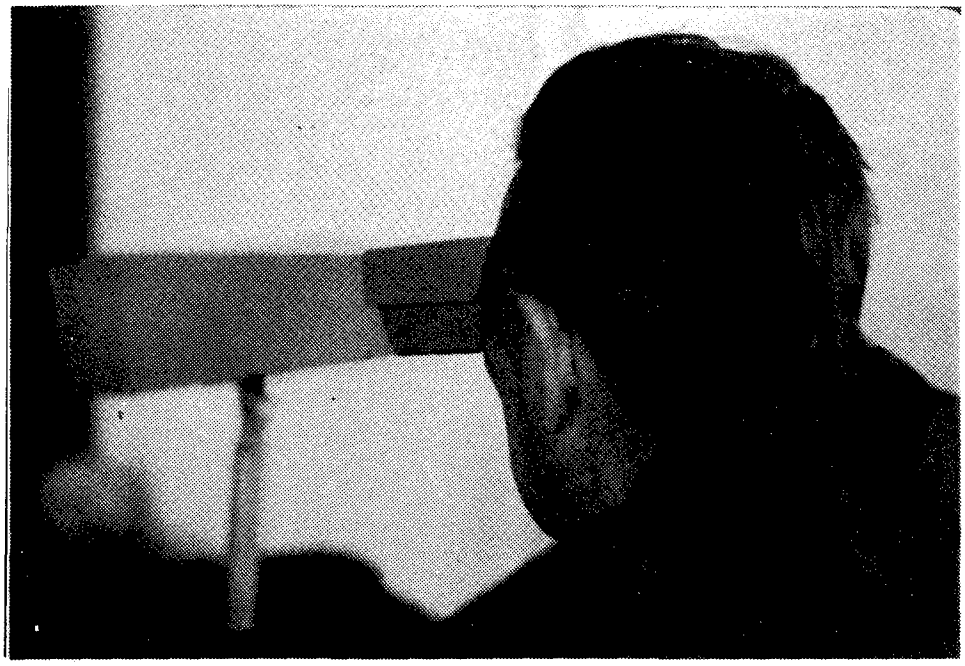

Figure 3. Viewing Chamber

Santa Ana Dexterity Test. The Santa Ana is a measure of finger dexterity that requires workers to remove, rotate, and replace pegs into holes on a board. Scores are obtained by counting the number of pegs correctly turned in a given time period with the right hand (Figure 4), left hand (Figure 5), and both hands simultaneously (Figure 6). Hanninen (1971) found this to be the most sensitive single measure of the effects of carbon disulfide exposure.

The test can be administered in approximately ten minutes, and it is possible to test at least two subjects at once (cutting the time per subject in half) if two boards are available. Practice pegs and multiple trials compensate for practice effects. The test is quite reliable, having a split half reliability of .91. Unfortunately, the boards are not available commercially at this time. For the purposes of the present project, the boards were manufactured to the same specifications by the same individual who constructed the boards used in the Hanninen experiment.

Simple and Choice Reaction Time. This measure of reaction time involves measuring the amount of time required by workers to respond to a light signal by pressing a button which turns off the light. A standard commercially available choice reaction time device with four differently colored lights was used. The apparatus involved three components: a control device used by the experimenter to control the occurrence of the light signal, a timer which displayed response time digitally in hundredths of a second (both shown in Figure 7), and a response device (Figure 8). Both simple (worker knows which light signal to expect) and choice (worker does not know which of four signals to expect) reaction trials were given.

Considerable research suggests that some neurotoxins (e.g., carbon disulfide) slow nerve conduction velocity. Slowed nerve conduction velocity would be expected to lead to slowed movement time, one of the components of reaction time.

This particular procedure offers the possibility of obtaining three separate measures which could be affected by general neurological impairment: (1) simple reaction time, (2) choice reaction time, and (3) decision time. The testing procedure requires approximately ten minutes. However, through a modification of the equipment, it was possible to test two workers at one time, thereby reducing the testing time.

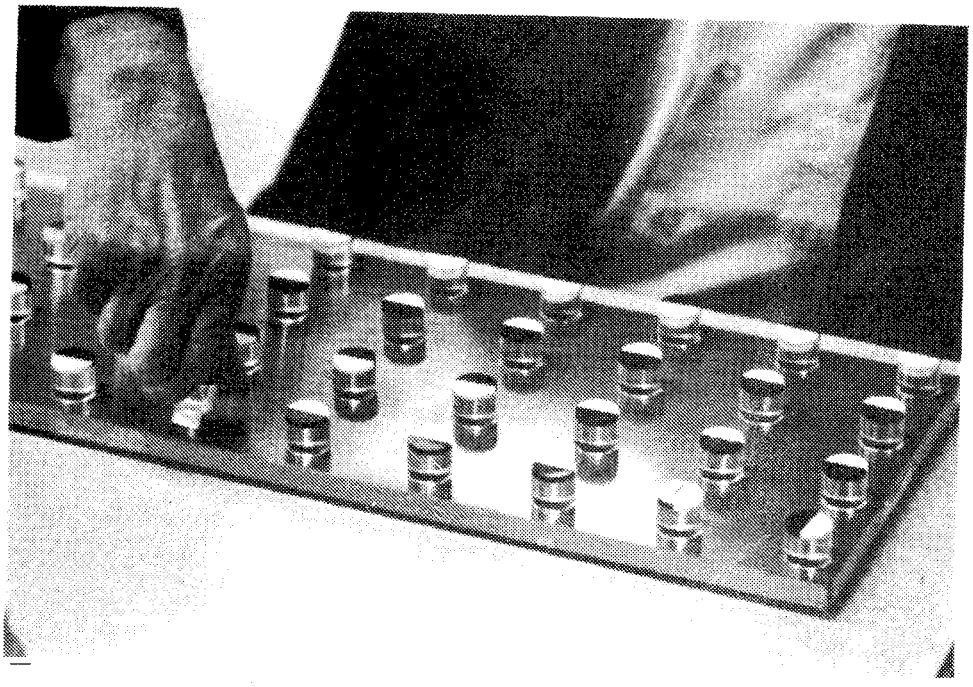

Figure 4. Santa Ana - Right Hand

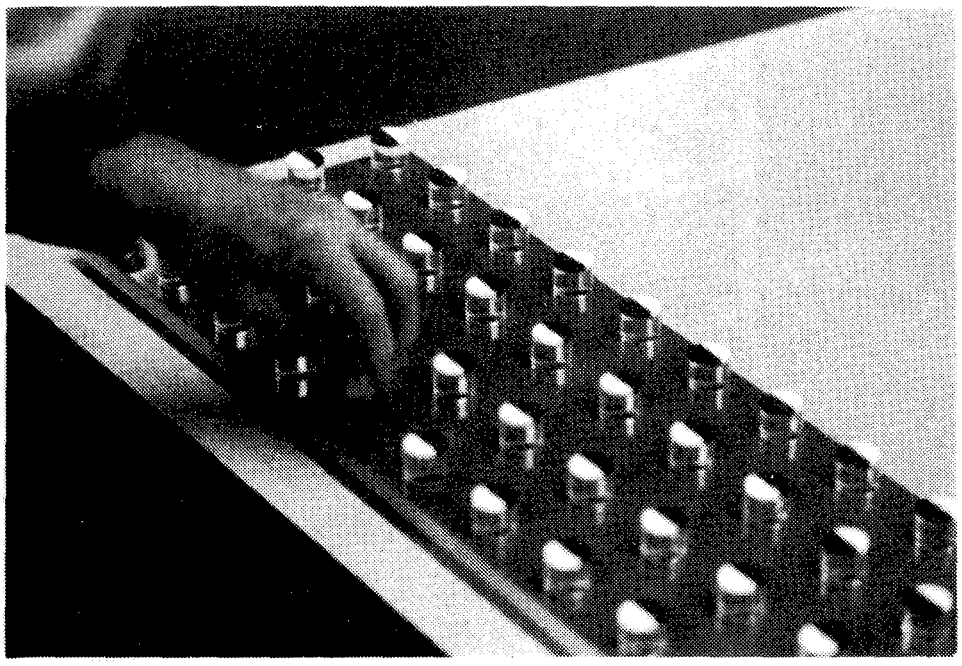

Figure 5. Santa Ana - Left Hand

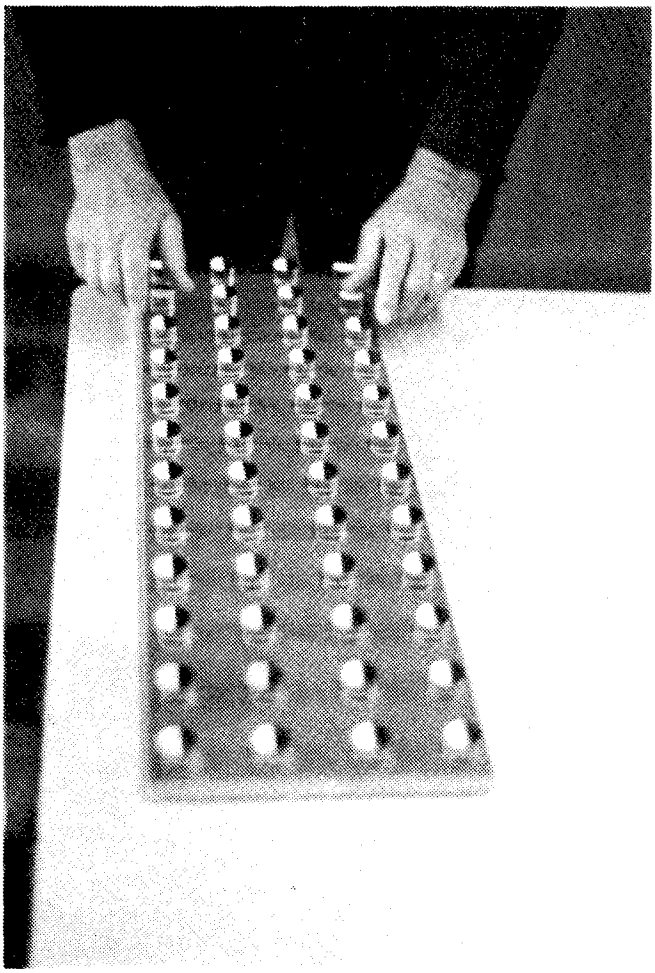

Figure 6. Santa Ana - Both Hands

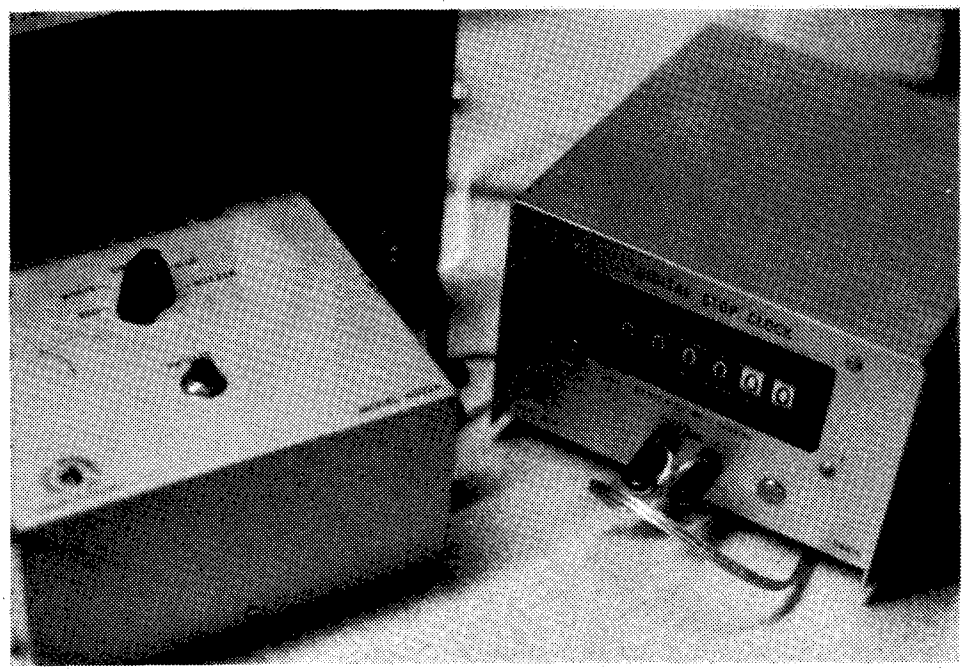

Figure 7. Experimenter's Control Panel and Timer

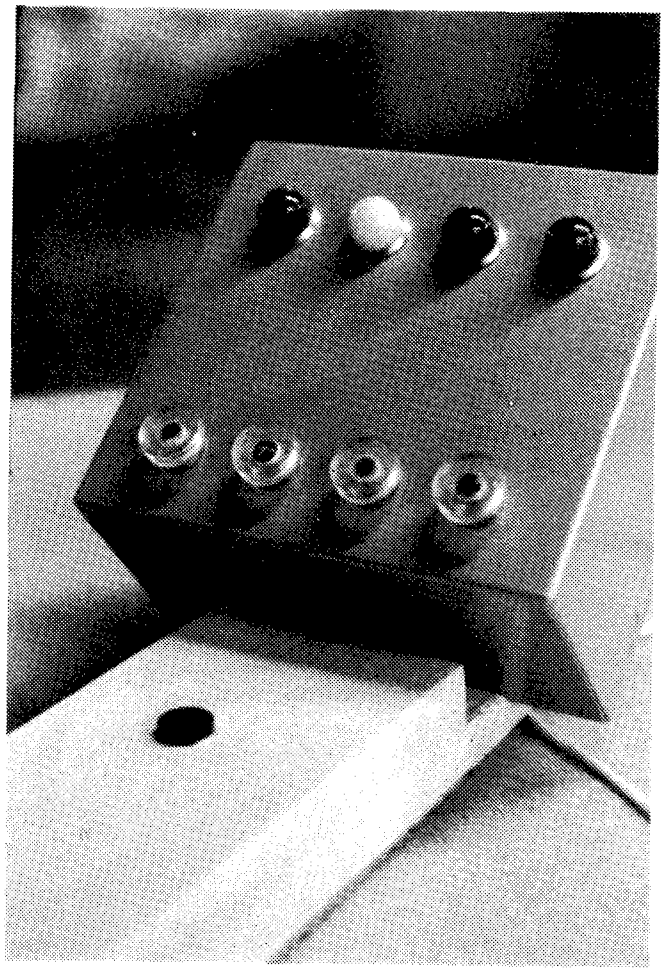

Figure 8. Response Device Used by Participant

Drop Reaction Time. A fairly new and quite simple technique for assessing reaction time, this test was included both to provide further information on its utility and to provide a second measure of simple reaction time. The apparatus consists of a board or "track" which is attached to the wall and a "ruler" calibrated in milliseconds (Figure 9). The worker is instructed to place the thumb of his/her preferred hand over the track, while the experimenter drops the ruler. As soon as the worker perceives movement, he/she is to stop the ruler's fall with the thumb. The experimenter can then read the reaction time directly from the graduations on the ruler.

Although this procedure has little research support, its simplicity, portability, and low cost make it attractive. Administration time is about four minutes or less.

Color Vision. In order to screen for adverse effects of carbon disulfide exposure on color vision, the Farnsworth Dichotomous Test for Color Blindness was included in the test battery. In this test the worker is asked to arrange a set of 15 buttons according to color (Figure 10). The test is scored by referring to numbers on the back of the buttons which correspond to the correct order. PASS-FAIL determinations are made by plotting the response pattern on a standard answer sheet and by referring to scoring criteria. Test-retest reliability data indicates extremely high stability in the pass-fail judgment across testing sessions.

Selection of Worker Population

The selection of the worker population involved a number of steps. The first involved selection of a manufacturing plant. It was desirable, from a practical point of view, to select a plant or plants in reasonably close proximity to the Washington, D.C. area in order to minimize travel costs associated with field data collection. With this objective in mind, efforts were made to locate viscose rayon plants in the Middle Atlantic states. A suitable plant was selected on the basis of geographical considerations and accessibility, and contacts were made with the corporate headquarters of the parent company and the international headquarters of the union which represented the workers. Meetings were held with both company and union officials to seek their cooperation in the project. These meetings were successful insofar as union support was concerned, however, the company declined to endorse the project. The existence of union support and, in particular, the existence of strong union support at the local level, meant that there was a good chance of getting worker cooperation. Worker cooperation was essential in order to guarantee sufficient volunteers for the behavioral and neurological screening phases of the project. The lack of company support meant that no in-plant air monitoring would be possible. Although this would create

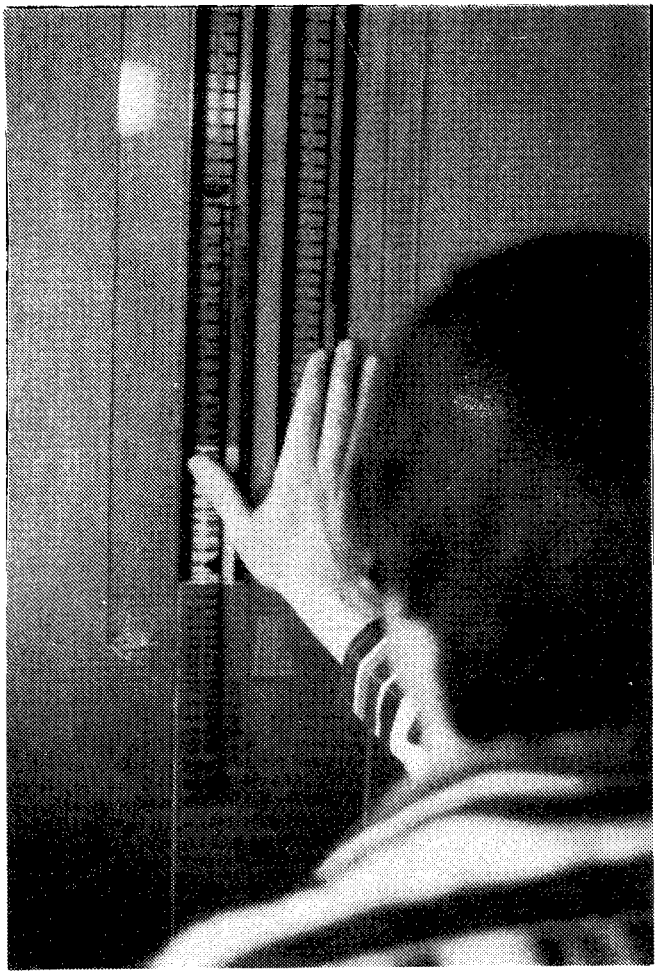

Figure 9. Drop Reaction Time Apparatus

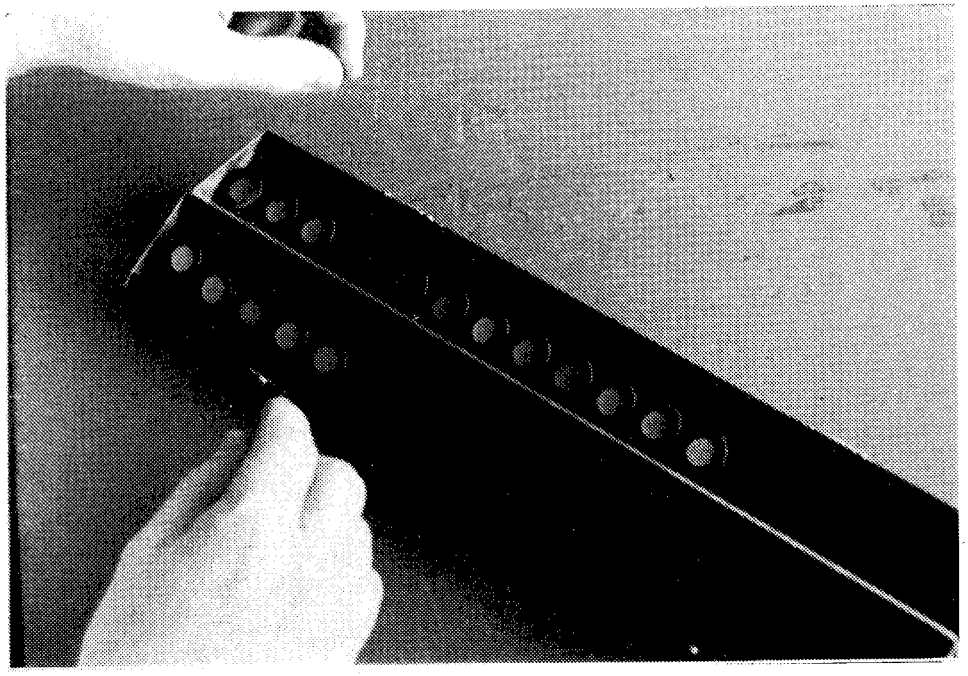

Figure 10. Color Vision Test Apparatus

problems for any attempt to quantify the exposure of individual workers, the problem was partially offset by the existence of published data for this particular plant. The results of a NIOSH investigation of CS_2 exposure levels in two jobs, cutting and spinning, could be used to determine relative levels of exposure in the two jobs where exposure is greatest. However, the absolute levels reported are less useful since there is no assurance that they reflect either current or past conditions. Nevertheless, the decision was made to conduct the study in this plant despite the lack of company cooperation.

Once the plant was selected and union cooperation obtained, there was a delay of approximately 9 months due to the procedures required for obtaining clearance of the test procedures. When the necessary clearances were obtained, efforts were initiated to obtain volunteers from the workers at the plant. This process was hampered by the fact that during the delay period, awaiting OMB clearance, there had been wide scale layoffs in the selected plant which reduced the target population available to the study. However, it was not feasible at this point to switch locations or to increase the scope of the study by adding a second plant. Therefore the decision was made to continue the project in the selected plant as planned and to initiate efforts to obtain as many participants as possible.

The recruiting of participants was handled directly by local union representatives using guidelines prepared by the project staff. Appendix B presents the guidelines that were developed for selecting participants. As shown in these guidelines,the highest priority was to obtain the participation of those workers currently working in jobs where there is daily exposure to carbon disulfide. Next priority was given to those who were recently exposed (had been transferred from the exposed jobs within 1-6 months or who had retired during that period).

In addition to the exposed population,the study design required that a group of workers be obtained who were not currently exposed and had never been exposed. Initially, efforts were begun to obtain these workers from the same plant from which the exposed group was obtained, the idea being to insure that the unexposed group were similar in every respect to the exposed group except exposure. After some time, however, it became obvious that due to the job progression pattern in the plant, it is rare to find an individual who is totally unexposed.

Normally, an individual who is hired will be placed first in the staple department in a relatively low exposure job. However, after a few weeks he will be assigned to work as a cutterman. Most will remain in this job until they have acquired sufficient seniority to bid off the cutters to some other job. However, the first 6-12 months of an employee's time is usually spent in areas in which there is at least some exposure to carbon disulfide. Because of this situation, efforts were initiated to obtain an additional control population. These efforts centered on a local carpenters' union. Contacts were initiated with the Business Agent of the local. He presented the project to the membership at a union meeting and the decision was made to participate. Thus the unexposed group was comprised of two separate subgroups, those plant employees who had never been exposed to CS_2 and carpenters who agreed to participate.

A final group of participants was drawn from the ranks of plant management. As the data collection phase was nearing completion, it became obvious that the sample size desired for the project would not be met by volunteers from the two groups thus far mentioned, i.e.,union members and carpenters. Also at this time, following changes in management and medical staff, the company had revealed a more cooperative attitude toward the project and had permitted the researchers to tour the plant and to post a notice advertising the project to workers. With this combination of circumstances it seemed appropriate to seek the participation of management personnel, particularly foremen and supervisors. Most of them were former union members who had been promoted to management and had worked or currently worked in exposed areas of the plant. The company agreed to this request and management volunteers were solicited from those areas of the plant (both exposed and unexposed) from which workers had been obtained.

A breakdown of the obtained sample is shown in Table 1.

Table 1

Composition of Sample

	No. Exposed	No. Unexposed	?	Total
Union	89	5	1	95
Carpenters	2	14	0	16
Management	23	6	1	30
	114	25	2	141

Although there were altogether a total of 150 volunteers, nine were eliminated due to either medical history information or on the basis of the neurological examination. The primary reasons for elimination were previous history of diabetes or a diagnosed neurological condition that was known to be due to causes other than exposure to CS_2. Of those union members listed as being exposed, twelve were currently working as either cuttermen or spinnermen, while 63 out of 89 had at some time worked in either or both jobs. With regard to the management personnel, eight of the exposed had previously worked as cuttermen or spinnermen. It can also be noted in Table 1 that all the carpenters cannot be considered to be unexposed. Two carpenters had previously worked in exposed jobs in the plant prior to becoming carpenters.

Medical Evaluation

Volunteers for the project were first given a set of clearance forms (Appendix C) which informed them of the purposes of the project and provided a space for individuals to sign, thereby indicating their willingness to participate. The forms also gave participants the opportunity to designate a physician to receive the report of his medical examination, and the opportunity to indicate whether or not he wished to have his individual results forwarded to the National Institute for Occupational Safety and Health for review and possible follow-up.

Individuals who signed the consent form and agreed to participate in the project were then given a medical history questionnaire to complete (Appendix D). Once this questionnaire was completed, the individual was scheduled for the neurological examination and electrodiagnostic examination. The protocols used in these examinations are provided in Appendix E.

Following the examination, each physician completed rating forms which summarized, quantitatively, the results. These rating forms are presented in Appendix F. The format of the rating scale was developed for this study, however, the rating factors and weights were taken from previous research (Allen, Mendell, Billmaier, Fontaine, and O'Neill, 1975). Four scores resulted from the ratings: symptoms, neurological, electrodiagnostic, and total. The symptoms score and the neurological score resulted from ratings made by the neurologist while the electrodiagnostic score resulted from ratings made by the electromyographer. These three scores were summed to yield a Total Neurological Score for the worker. Allen (undated manuscript) suggests that the score ranges for the Total Neurological Score can be interpreted as follows:

0 - 3	Normal
4 - 5	Abnormal but not definite neuropathy
6 - 8	Probable neuropathy
9 or over	Neuropathy

This procedure was adopted for the present study since it provided a method for quantifying the results of the neurological evaluations.

Field Data Collection

The field data collection phase of the project had three objectives: (1) collection of behavioral test data, (2) obtaining detailed work history information required to determine length of CS_2 exposure, and (3) obtaining urine samples to permit a biological determination of exposure using the iodine-azide procedure.

Behavioral Testing

Behavioral testing was conducted at the union hall for viscose rayon workers and carpenters, and in a plant conference room for management personnel. The scheduling of workers for testing was done by the union office in the case of union workers and carpenters, and by plant management in the case of the management personnel. Most workers were tested either just before or just after work. Since most participants were shift workers, this meant that testing sessions were held throughout the work day and into the evening. Midnight shift workers were tested just prior to going to work at 10:00 P.M., evening shift workers were tested prior to work at 2:00 P.M., and day shift workers were normally tested just after work at 4:00 P.M. Sessions were held at other times during the morning and afternoon for retired workers or those who had a "day off." For management personnel, since company cooperation had been obtained, testing was conducted during the employee's normal work shift.

The procedures followed in the behavioral testing are described in detail in Appendix G.

Work History Interviews

Interviews were conducted with each participant at the time of behavioral testing to determine the individual's job progression in the plant, and to assess the extent to which

the individual had been exposed to other chemical substances which might bias the study results. Each individual was asked to describe each position held in the plant and to give the number of months or years spent in each position. This information was used to determine the number of years of exposure and to obtain an estimate of the degree of exposure. Each individual was also asked to provide an estimate of the total number of years he had been exposed to carbon disulfide.

Urine Samples

According to Djuric (1967), the most acceptable biological method for estimating the degree of CS_2 exposure is the iodine azide test. This procedure involves the analysis of metabolites of CS_2 excreted in the urine and permits the calculation of an exposure coefficient. This exposure coefficient bears a linear relationship with previous exposure level. However, Djuric points out certain limitations of the method. First, it is not reliable for exposure below 50mg/m^3, a value slightly below the United States T.L.V. of 20 ppm. A second limitation is that the urine should not be too diluted (creatinine value less than 1.25 mg/ml) or the test is indeterminate.

In the present study, when possible, urine samples were obtained from workers both before and after their work shift. Not being located in the plant, however, meant that the samples were not obtained immediately after the work shift. Usually 20-30 minutes elapsed from the time the worker came from the plant to the union hall. Perhaps more importantly, the sample obtained was often diluted since workers would normally void before leaving the plant. As a result, a number of the tests were indeterminate.

When valid, the end of shift exposure coefficient provides an indication of the average exposure level for the shift. The beginning of shift exposure coefficient provides an indication of the extent to which the individual has residual effects from his previous shift. To the extent that the beginning of shift exposure coefficient fails to return to a normal indication, this can be taken as evidence of CS_2 poisoning.

Summary of Variables

The variables which resulted from the various data collection efforts can be summarized under the following categories:

1. Work/Medical History
2. Medical/Neurological
3. Electrodiagnostic
4. Exposure
5. Behavioral Test Scores

The individual variables in each of these categories are discussed or listed below.

Work/Medical History (180 variables). The variables in this group consist of responses to the Work/Medical History Questionnaire. The variables can be grouped in the following categories:

Personal Data
Work History
Beverage History
Medical History
Symptoms

For a detailed listing of individual variables see Appendix D.

Medical/Neurological (13 variables). The variables in this group are those resulting from the neurological examination and the associated laboratory and visual tests.

1. GLU - Random glucose at time of Neurological examination (non-fasting)
2. HCT - Hematocrit at time of Neurological examination
3. Visual Acuity - right eye } 1 = below normal, 2 = normal,
4. Visual Acuity - left eye } 3 = better than normal
5. Visual Field in Degrees, Right Eye Vertical Plane
6. Visual Field in Degrees, Right Eye Horizontal Plane
7. Visual Field in Degrees, Left Eye Vertical Plane
8. Visual Field in Degrees, Left Eye Horizontal Plane
9. Systolic Blood Pressure
10. Diastolic Blood Pressure
11. Age
12. Rating of Symptoms (per rating form in Appendix E)
13. Rating of Neurological Status (per rating form in Appendix F)

Electrodiagnostic (11 variables). This set of variables includes those obtained from the electrodiagnostic examination conducted by an electromyographer.

1. Ulnar Distal Motor Latency
2. Ulnar Nerve Conduction Velocity
3. Ulnar Slow Fibers Delay
4. Ulnar Slow Fibers Refractory Period
5. Ulnar Slow Fibers Resultant
6. Ulnar Slow Fibers Distance
7. Ulnar Slow Fibers Conduction Velocity
8. Peroneal Distal Motor Latency
9. Peroneal Nerve Conduction Velocity
10. Drop Reaction Time (administered at time of electrodiagnostic examination)
11. Edgscore - Electrodiagnostic rating score (per rating form in Appendix F)

Exposure (18 variables). The exposure variables were based on detailed work history interviews with participants. Also included are variables resulting from the iodine azide tests.

1. Yrs. Cutting - No. of years as cutterman
2. Yrs. Spinning - No. of years as spinnerman
3. Yrs. Acid - No. of years in acid department
4. Yrs. Churn/Mix - No. of years as churn/mix operator
5. Yrs. Staple - No. of years in staple department jobs other than cutting or spinning
6. Yrs. Other Viscose - No. of years in other viscose department jobs (other than churn/mix)
7. Yrs. Other - No. of years in other jobs in the plant outside staple and viscose
8. Yrs. Away from Cutting/Spinning - No. of years since last worked as cutterman or spinnerman
9. Yrs. of CS_2 exposure - No. of years exposed to CS_2
10. Yrs. Away from CS_2 exposure - No. of years since last worked in exposed job
11. Pre Coefficient - Pre shift exposure coefficient from Iodine Azide Test
12. Post Coefficient - Post shift exposure coefficient from Iodine Azide Test

    1 = Over 5 hours to decoloration
    2 = E = 6.5 or greater
    3 = E < 6.5

From the above variables, six additional exposure indices were derived by weighting variables 1 - 10. These are presented below along with the rationale for the variables.

13. EXP_1 = 40 * Yrs. Cutting + 3 * Yrs. Spinning + 2 * Yrs. Acid + 2 * Yrs. Churn/mix + Yrs. Staple + Yrs. Other Viscose.

    This variable is a weighted sum of the number of years in exposed jobs. The weights were selected to approximate the relative exposure levels in various sections of the plant.

14. EXP_2 = Yrs. Cutting + Yrs. Spinning

    This variable is simply the number of years the worker has spent in either Cutterman or Spinnerman jobs with the two weighted equally.

15. EXP_3 = 5 * Yrs. Cutting + 4 * Yrs. Spinning + 3 Yrs. Acid + 2 * Yrs. Churn/Mix + Yrs. Staple + Yrs. Other Viscose.

    This variable is a weighted sum of the number of years worked in exposed jobs. The weights reflect the ranks that would be assigned if the jobs/departments were rank ordered in terms of exposure level.

16. EXP_4 = 5 * Yrs. Cutting + 4 * Yrs. Spinning + 3 * Yrs. Acid + 2 * Yrs. Churn/mix.

    This variable is the same as variable 15 except that Other Staple and Other Viscose are dropped out of the calculation.

17. EXP_5 = Yrs. Cutting + Yrs. Spinning + Yrs. Acid + Yrs. Churn/mix + Yrs. Staple.

    This variable is a sum of the number of years spent in the five categories where exposure is likely to occur. This variable is the best estimate of the individual's number of years exposed (unweighted by level).

18. EXP_6 = EXP_2/Yrs. Away from Cutting/Spinning.

    This variable represents the ratio of years spent in Cutting or Spinning (EXP_2) to the number of years the worker has been out of Cutting and Spinning. This variable represents an attempt to take into account the hypothesis that one's condition may improve when removed from exposure, or at least when exposure level is reduced. Yrs. Away from Cutting/Spinning was assigned a value of 1 if the individual had been away from Cutting or Spinning for 1 year or less. Values of the variable range from 0 to N where N = the number of years exposed to CS_2.

Behavioral Test Scores (15 Variables). The variables in this group resulted from administration of the behavioral test battery.

1. SRT - Simple reaction time
2. CRT - - Choice reaction time
3. DECTIME - Decision time defined as (CRT-SRT)
4. DRT - Drop reaction time
5. CLRVIS - Color Vision (1 = fail, 0 = pass)
6. SAR - Santa Ana right hand score
7. SAL - Santa Ana left hand score
8. SAB - Santa Ana both hands score
9. NEIS - Neisser letter search score
10. DSP - Digit span
11. DSY - Digit symbol
12. CFFD - Critical flicker frequency - method of descending frequencies
13. CFFA - Critical fusion frequency - method of ascending frequencies
14. CFFM - Critical flicker/fusion frequency - mean of #12 and #13
15. BD - Block design
16. FTC - Feeling tone checklist

RESULTS

Analyses of the obtained data can be grouped into five major categories. The first, summary statistics, is concerned primarily with analyses within various subsets of variables (e.g., behavioral, neurological, exposure, etc.). The second, third, and fourth involve investigations of relationships between subgroups of variables. These analyses are concerned with relationships between: (1) CS_2 exposure indices and neurological findings; (2) CS_2 exposure indices and behavioral test scores; and (3) behavioral test scores and neurological variables. The fifth category includes analyses similar to those reported by Hanninen (1971). The results of each of these types of analyses are presented below.

Summary Statistics

The sample of participants included 150 volunteers drawn from three distinct subgroups: (1) Union workers in the rayon plant (N=102); (2) carpenters (N=16); and (3) management personnel from the viscose rayon plant (N=32). The first stage in the data analysis consisted of identifying and eliminating from further analysis those individuals who had a neurological problem stemming from some known cause other than CS_2 exposure, and also those individuals who had a condition which might have produced neurological signs similar to those produced by CS_2. This data summary led to the elimination of data for 9 participants. The condition leading most frequently to the dropping out of data was diabetes. However, data was also dropped out due to gout, transverse myelitis, circulatory problems in the lower limbs, and disc problems.

The remaining sample (N=141) is characterized on selected variables in Table 2 . The groups are very similar in terms of average age, with the union group slightly younger. In terms of years of education, the management group is somewhat higher than either the union or carpenter group, however, the difference is not statistically significant. Exposure indices reveal that the union group is highest in terms of all exposure variables except years spent in "other viscose." This category includes viscose department jobs other than churn/mixing where exposure is probably very slight. Examination of the exposure data for carpenters reveals that the group is not totally unexposed. One carpenter worked 16 years in the churn/mixing operation and another worked one year in a job in the "other viscose" category. Of the union participants, 63 of 95 (66%) have worked in either the cutting or spinning operation, or both. Twelve union participants were currently working on spinners or cutters. In the management group, 8 out of 30 (27%) have worked in the past as spinning or cutting machine operators.

Table 3 presents the six exposure indices derived from the data obtained in the work history interviews. Also shown is the participant's estimate of the total number of years he has been exposed to CS_2. This variable, yrs. exposed, is the result of participants' answers to a direct question concerning length of exposure.

Table 2

Description of the Sample

Variables	Carpenters (N=16) Mean	S.D.	Union (N=94) Mean	S.D.	Management (N=29) Mean	S.D.
Age	40.6	15.0	38.8[2]	14.5	41.7	10.6
No. Yrs. Education[1]	11.2	2.5	11.1	1.9	13.7	2.3
No. Yrs. Worked in:						
Cutting	0.0	0.0	1.2	3.1	0.5	1.3
Spinning	0.0	0.0	2.2	5.4	0.5	1.2
Acid	0.0	0.0	1.1	3.9	0.8	3.0
Churn/mix	1.0	4.0	1.1	4.7	0.0	0.0
Other Staple	0.0	0.0	4.2	7.3	2.0	3.3
Other Viscose	.2	.5	1.2	4.6	3.2	8.0
Other Non-exposed	0.0	0.0	2.0	5.6	9.8	11.2

[1]This data came from the medical history questionnaire which some participants failed to complete. The N's for this variable are Carpenters (N=12), Management (N=20), Union (N=73).

[2]N for this variable = 92

Table 3

Mean and Standard Deviation of Exposure Variables by Job Status

Variable	Carpenter			Union			Management		
	N	M	S.D	N	M	S.D	N	M	S.D
1. Yrs. Exposed	16	1.1	3.9	75	9.0	10.7	14	13.6	9.9
2. Exp_1	16	2.1	8.4	94	65.2	125.8	29	28.7	56.1
3. Exp_2	16	0.0	0.0	94	3.4	6.2	29	0.9	2.0
4. Exp_3	16	2.1	8.4	94	25.8	30.7	29	12.0	16.8
5. Exp_4	16	2.0	8.0	94	20.4	31.0	29	6.7	16.4
6. Exp_5	16	1.0	4.0	94	9.7	10.3	29	3.7	5.4
7. Exp_6	16	0.0	0.0	94	1.8	4.4	29	0.1	0.4

An idea of the interrelationships among exposure indices can be derived from an examination of Table 4 . This data is based on the total sample. Of particular interest are the correlations of the derived exposure indices with the various component scores. For example, the correlation of EXP_1 with Yrs. Cutting is .98,which indicates that EXP_1 is primarily weighted toward the amount of time spent working on the cutters. On the other hand, EXP_3, EXP_4, and EXP_5 all correlate moderately with variables 1-4,indicating that they reflect the influence of exposure in cutting, spinning, acid, and churn/mixing operations. These four areas are the areas presumed to have the highest CS_2 exposure in the plant. It can also be observed from Table 4 that there is a less than perfect relationship (r=.71) between Yrs. Exposure (variable #8) as reported directly by participants and EXP_5 (years of exposure derived from work history interviews). This is due,in part,to participants' varying frames of reference with regard to the concept of "exposure." To some participants, time spent in any job in the plant was included in their estimate of the number of years exposed, while to others,only time spent on spinners or cutters was included. As a result,there is considerable error variance associated with this variable,making it quite unreliable. EXP_5 is a more accurate estimate of the total number of years exposed.

Neurological Status. The most comprehensive single index of neurological status obtained in the present study is the Total Neurological Score. This value combines results of the neurological and electrodiagnostic evaluations. Table 5 presents frequency distributions of this index for carpenters, management, and union groups. These results show that two of the carpenters, 10 union personnel, and none of the management personnel have (according to the criteria proposed by Allen et al., 1975) either a probable or definite polyneuropathy. The differences in frequency between the groups are not statistically significant (chi square = 11.47, df = 8, $p > .20$).

Perhaps the most objective indication of neurological status is provided by the results of the electrodiagnostic examination. A frequency distribution of these findings is presented as Table 6. The differences between subgroups for the overall distributions,as shown are not statistically significant (chi square = 8.71, df = 6, $p = .10$). However, when the distribution is dichotomized between those with positive signs (1 or greater) and those with no positive signs (0), the chi square across groups is significant ($p < .05$).

An overall view of the neurological/electrodiagnostic data can be obtained from the means and standard deviations presented in Table 7. The differences in N's on the variables in Table 7 resulted from the fact that some participants did not complete both aspects of the neurological/electrodiagnostic evaluation.

Table 4

Intercorrelations Among Exposure Indices[1]

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Yrs. cutting															
2. Yrs. spinning	.06														
3. Yrs. acid	.22	.06													
4. Yrs. churn-mix	-.06	-.04	-.05												
5. Yrs. other staple	.02	.00	-.08	-.10											
6. Yrs. other viscose	-.09	-.08	-.07	.07	-.14										
7. Yrs. other unexposed	-.11	-.12	-.09	-.06	-.06	-.00									
8. Yrs. Exposed	.26	.35	.33	.29	.30	.21	.11								
9. Exp-1	.98	.18	.27	.00	.06	-.06	-.13	.37							
10. Exp-2	.54	.87	.16	-.07	.01	-.12	-.15	.43	.63						
11. Exp-3	.57	.68	.47	.20	.15	.04	-.20	.68	.69	.85					
12. Exp-4	.58	.70	.51	.21	.15	-.11	-.19	.58	.69	.87	.96				
13. Exp-5	.37	.50	.37	.30	-.04	-.15	-.19	.71	.50	.60	.84	.74			
14. Exp-6	.16	.82	-.04	-.06	.59	-.09	-.13	.29	.24	.77	.56	.58	.38		
15. Age	.16	.23	.13	.25	.31	.26	.31	.62	.24	.27	.48	.36	.52	.16	

[1] N = 139 for all variables except yrs. exposed where N = 111.

Table 5

Frequency Distributions of Total Neurological Scores by Sample Sub-Groups

	Carpenter[1]		Union		Management	
	N	%	N	%	N	%
TNS = 0	7	54	41	52	15	79
TNS = 1, 2 or 3	4	31	23	29	2	10.5
TNS = 4 or 5	0	0	5	6	2	10.5
TNS = 6, 7 or 8	2	15	4	5	0	0
TNS = 9 or greater	0	0	6	8	0	0
Total	13	100	79	100	19	100

[1]Data for two exposed carpenters dropped from this analysis.

TNS for these individuals were 5 and 4

Table 6

Frequency Distributions of Electrodiagnostic Scores by Sample Subgroups

	Carpenter		Union		Management	
Electrodiagnostic score	N	%	N	%	N	%
0	13	93	74	78	29	97
1, 2, or 3	0	0	10	11	0	0
4 or 5	0	0	3	3	1	3
6 or greater	1	7	8	8	0	0
Total	14	100	95	100	30	100

Table 7

Means and Standard Deviations for Neurological/Electrodiagnostic Data

	Carpenter[1]			Union			Management		
Variables	N	M	S.D.	N	M	S.D.	N	M	S.D.
EDG Score	14	0.6	2.1	92	1.2	2.5	26	0.2	0.8
Ulnar distal latency	14	3.1	0.5	92	3.0	0.4	26	2.9	0.5
Ulnar N.C.V.	14	55.3	4.0	92	54.9	4.2	26	55.7	4.0
Ulnar slow fibers delay	14	7.0	0.6	92	7.4	0.6	26	7.2	0.7
Ulnar slow fibers refract	14	1.0	0.1	92	1.1	0.2	26	1.0	0.1
Ulnar slow fibers C.V.	14	48.5	5.0	92	45.8	4.9	26	48.0	3.7
Peroneal distal latency	14	5.2	0.8	92	5.3	1.0	26	5.3	0.8
Peroneal N.C.V.	14	47.3	4.7	92	46.9	4.9	26	47.8	3.1
Neurological score	13	0.9	1.93	80	0.6	1.5	22	0.9	1.8
Symptoms score	13	0.0	0.0	79	0.2	0.5	22	0.0	0.0
Total Neurological score	13	1.5	2.7	79	2.1	3.7	19	0.7	1.5

[1]Data for two exposed carpenters dropped from this analysis

Behavioral Test Scores. Table 8 presents means and standard deviations of the behavioral test scores according to the three sample subgroups. Subjective reactions of participants to the behavioral testing were, virtually without exception, positive. This is indicated by responses from the post test questionnaire such as "Very good test," "It's a dandy," "Enjoyed the test very much," and "Block test was hard and fun." The only negative remark on the questionnaire related to some distractions that one participant felt interfered with his performance on the digit span test.

As is the case with most measures of human performance, the behavioral tests overlap to some degree in terms of what is measured. This degree of overlap can be evaluated by referring to Table 9 which presents, for the total sample, intercorrelations among behavioral test scores. The patterns of relationships among behavioral tests is further examined in the factor analyses reported in a later part of this section.

An important consideration with regard to behavioral testing is the extent to which the results obtained from a test are consistent over time. This consistency in psychometric terminology is referred to as the reliability of the test. The reliabilities of the tests used in the present test battery were investigated in different ways, depending on the test. Table 10 presents the results of three types of reliability analyses. Internal consistency reliability estimates provide an indication of the consistency with which the various items in a test are measuring some performance dimension. All of the tests, except digit span, show acceptable internal consistency reliability. The coefficient for digit span should be interpreted cautiously, since this reflects the correlation between two memory tasks, digits forward and digits backward. Since these two halves undoubtedly involve somewhat different processes, the differences help account for this relatively low value. Test-retest coefficients reflect the stability of the test scores over time. Such coefficients are reduced by any "real" changes in the performance dimension that is measured at two points in time, as well as differences in testing conditions, etc. The present study did not permit retesting except for drop reaction time, so the test-retest results in Table 10 are based on an earlier study (Tuttle, Wood, & Grether, 1976) and, due to the relatively small N, may be an underestimate. For the coefficient reported, the delay between test and retest is one day.

Acceptable test-retest stability is demonstrated by the Santa-Ana, Digit Symbol, Digit Span, Neisser, and CFF-descending frequencies method. The reaction time tests showed marginal

Table 8

Means and Standard Deviations of Behavioral Test Scores by Sample Subgroups

Variable	Carpenters N	Carpenters M	Carpenters S.D.	Union N	Union M	Union S.D.	Management N	Management M	Management S.D.
Simple reaction time	16	41.7	8.9	93	44.4	11.0	30	38.4	5.4
Choice reaction time	16	49.8	8.1	93	50.8	10.5	30	46.5	4.9
Decision time	16	8.1	3.1	93	6.5	4.7	30	8.1	4.6
Drop reaction time	16	195.5	15.3	90	199.3	16.9	30	178.3	14.5
Santa Ana-R	16	23.4	4.1	90	22.0	4.4	30	24.4	3.3
Santa Ana-L	16	22.9	3.7	90	21.5	4.0	30	23.3	3.4
Santa Ana-B	16	27.1	6.3	92	24.9	7.0	30	27.3	7.0
Neisser	16	1.3	0.4	88	1.3	0.4	30	1.1	0.2
Digit Span	16	9.9	1.5	91	9.7	1.6	30	11.6	1.7
Digit Symbol	16	42.7	15.0	90	43.7	15.1	30	54.9	10.7
CFF-descending	16	48.2	2.7	90	50.1	5.8	30	50.7	5.2
CFF-ascending	16	45.4	3.4	90	46.9	5.1	30	46.4	5.3
CFF-mean	16	46.8	2.8	90	48.5	4.5	30	48.5	4.6
Block Design	16	32.9	10.7	88	29.3	9.3	30	35.1	8.1
Feeling Tone C-List	15	12.4	3.4	87	12.0	4.3	28	11.8	2.5
Color Vision	14	0.0	0.0	84	0.1	0.3	26	0.0	0.0

Table 9

Intercorrelations Among Behavioral Test Scores (Total Group)[1]

	SRT	CRT	DECTime	DRT	SAR	SAL	SAB	NEIS	DSP	DSY	CFFD	CFFA	CFFM	BD	FTC
SRT															
CRT	.89														
DECTime	-.36	.10													
DRT	.57	.56	-.09												
SAR	-.71	-.68	.18	-.46											
SAL	-.65	-.63	.16	-.36	.77										
SAB	-.51	-.47	.19	-.32	.64	.61									
NEIS	.69	.67	-.17	.42	-.64	-.58	-.51								
DSP	-.28	-.30	.01	-.36	.36	.37	.26	-.38							
DSY	-.68	-.68	.13	-.49	.69	.64	.54	-.74	.49						
CFFD	-.27	-.25	.09	-.18	.25	.23	.16	-.19	.11	.19					
CFFA	-.32	-.31	.08	-.17	.33	.20	.29	-.26	.00	.32	.44				
CFFM	-.35	-.33	.11	-.21	.35	.26	.26	-.26	.07	.30	.86	.84			
BD	-.48	-.49	.07	-.33	.62	.52	.59	-.43	.36	.57	.13	.19	.19		
FTC	-.25	-.27	.00	-.04	.24	.14	.16	-.18	-.03	.17	.21	.22	.26	.03	
CLRVIS	.08	.02	-.16	.05	.00	-.06	.00	-.03	.02	-.06	.03	.08	.07	-.02	-.04

[1]N's for correlations range from 116 to 139

Table 10

Reliabilities of Behavioral Test Scores

	Internal Consistency	Test-Retest[3]	Communality Estimates
Simple Reaction Time	.97[1]	.60	.78
Choice Reaction Time	.96[1]	.56	.77
Drop Reaction Time	.95[1]	.65[4]	.73
Santa Ana-R	.88[1]	.78	.77
Santa Ana-L	.91[1]	.88	.73
Santa Ana-B	--	.78	.67
Neisser	.93[1]	.74	.61
Digit Span	.58[2]	.76	.58
Digit Symbol	--	.95	.73
CFF-Descending	--	.86	.58
CFF-Ascending	--	.46	--
CFF-Mean	--	.84	--
Block Design	--	--	.62

[1]Split half corrected by Spearman Brown formula
[2]Correlation of digits forward with digits backward
[3]All coefficients except DRT based on previous results (Tuttle et al., 1976)
[4]Correlation between DRT administered at time of behavioral testing with DRT administered during electrodiagnostic examinations

test-retest reliabilities. The third set of estimates is based on communality estimates derived from factor analyses of the behavioral test scores. Communalities represent the proportion of variance in a test that it has in common with other tests in a battery. As such it can be taken as a lower limit of the reliability of a test. Communality estimates represent an extremely conservative estimate of test reliability.

Relationships Between CS_2 Exposure and Medical/Neurological Findings

Correlational analyses were conducted to investigate relationships between CS_2 exposure and medical/neurological results. Two sets of correlation coefficients were computed. The first group, Table 11, consists of Pearson-product moment correlations between the six derived exposure indices and nine neurological variables. The second half of the table presents partial correlation coefficients for the same variables with the effects of age removed. The partial correlation analyses were conducted in order to investigate the issue of whether relationships between length of exposure and neurological status were simply due to the known relationship between age and neurological status.

The correlations in Table 11 show consistent relationships between all six exposure indices and electrodiagnostic scores, ulnar slow fibers conduction velocity, and peroneal nerve conduction velocity. Slightly less consistent relationships (for five of six exposure indices) are obtained for ulnar nerve conduction velocity and total neurological score. No significant relationships are found for the ulnar and peroneal distal latencies, or for symptoms or neurological scores.

Examination of the partial correlation coefficients reveals that, indeed, some of the above correlation is due to the effect of age. However, with the effect of age removed (or more precisely held constant), significant relationships remain between two exposure indices, EXP_1 and EXP_2, and electrodiagnostic score, ulnar nerve conduction velocity, ulnar slow fibers conduction velocity, and peroneal nerve conduction velocity. Significant partial conditions are also obtained between EXP_4 and the two ulnar conduction velocity scores and between EXP_6 and both ulnar and peroneal conduction velocities.

Multiple Regression Analyses. In order to determine the amount of variance in neurological rating scores that can be explained with knowledge of exposure, a series of multiple regression analyses were conducted. Following up the previous analyses, regression

Table 11

Correlations and Partial Correlations Between Exposure and Neurological Variables[1]

	Correlations						Partial Correlations - Age Removed					
	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5	Exp-6	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5	Exp-6
Electrodiagnostic Score	.42**	.32**	.31**	.29**	.23**	.21*	.36**	.23**	.12	.16	.01	.15
Ulnar-Distal Latency	.14	.12	.07	.10	.00	.11	.10	.08	-.01	.05	.11	.09
Ulnar-N.C.V.	-.34**	-.38**	-.33**	-.31**	-.22	-.33**	-.28**	-.32**	-.21*	-.22**	-.07	-.30**
Ulnar-Slow Fibers C.V.	-.29**	-.28**	-.36**	-.32**	-.33**	-.18*	-.21*	-.19*	-.21*	-.21*	-.15	-.12
Peroneal Distal Latency	.07	.06	.05	.07	.02	.08	.08	.07	.07	.08	.03	.08
Peroneal-N.C.V.	-.29**	-.33**	-.36**	-.32**	-.31**	-.26**	-.21*	-.23*	-.17	-.17	-.09	-.20*
Symptoms	.06	.14	.18	.15	.19	.10	.01	.09	.11	.09	.11	.07
Neurological Score	-.08	-.04	-.05	.02	.05	.00	-.19	-.16	-.15	-.12	-.17	-.07
Total Neuorological Score	.28**	.23*	.27**	.24**	.22*	.16	.17	.10	.03	.06	-.08	.09

[1] N=129 for Exposure with electrodiagnostic variables and N-111 for symptoms, neurological score and Total Neurological score

* $P < .05$
** $P < .01$

analyses were conducted only with electrodiagnostic scores and total neurological scores. The results are summarized in Table 12. A significant proportion of the variance in both the electrodiagnostic score and total neurological score was explained by exposure information. The single best predictor was EXP_1. This value weighs very heavily the amount of time worked on the cutters.

Iodine Azide Results. Relationships between iodine azide results and neurological variables were investigated using correlational techniques. As discussed previously, coded values were used for various ranges of the exposure coefficient.[1] The correlations, Table 13, were completed between these coded Iodine Azide values and the neurological variables. The only correlation reaching statistical significance ($p < .05$) is between the post shift exposure coefficient and the neurological rating score ($r = .31$).

Medical History Data. Responses to the medical history questionnaire were analyzed separately for each of the three subgroups: carpenters, union, and management. These results are presented in Appendix H. These three subgroups can be considered to reflect different average lengths and levels of CS_2 exposure. As such, differences between the groups can, to some degree at least, be attributed to differences in exposure.

The items which significantly differentiated (chi square $p<.05$) the three groups are listed in Table 14. By chance, out of 157 chi square tests, one would expect to have tests on approximately 8 items reach levels required for statistical significance. Table 14 reports that 24 significant items were found. The types of symptoms indicate those that have been associated with CS_2 exposure in previous studies (e.g., visual symptoms, cardiovascular symptoms, muscle pain, irritability, depression, headaches) as well as some that have not previously been reported as linked to CS_2 exposure (e.g., gassy stomach, pain or discomfort in the stomach, etc.).

Relationships Between CS_2 Exposure and Behavioral Test Scores

In order for behavioral test scores to be useful for detecting behavioral changes resulting from exposure to CS_2, one requirement would be that test scores should vary as a function of exposure. Other things being equal, individuals exposed for longer periods of time and at higher levels should score less well than individuals having less contact with the toxic substance. To investigate relationships between exposure indices and behavioral scores, correlations and partial correlations (age held constant) were computed. These results are presented in Table 15.

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[1] 1=E value indicating negligible exposure; 2=E value 6.5 or greater; 3=E < 6.5.

Table 12

Summary of Regression Analyses to Predict Electrodiagnostic Score and Total Neurological Score from Exposure Indices

Predictors in the Equation			Criterion	R^2	R	Df
EXP_1			Electrodiagnostic Score	.177**	.42	1, 127
EXP_1	EXP_6		Electrodiagnostic Score	.188**	.43	2, 126
EXP_1	EXP_4	EXP_6	Electrodiagnostic Score	.195**	.44	3, 125
EXP_1			Total Neurological Score	.077**	.28	1, 109
EXP_1	EXP_3		Total Neurological Score	.088**	.29	2, 108
EXP_1	EXP_3	EXP_4	Total Neurological Score	.098**	.31	3, 107

* $p < .05$

** $p < .01$

Table 13

Correlations Between Iodine Azide Exposure Coefficients and Neurological Variables[1]

	Pre Shift Exposure Coef.	Post Shift Exposure Coef.
Electrodiagnostic Score	-.04	-.07
Symptoms Score	.21	-.02
Neurological Score	-.15	.31*
Total Neurological Score	-.05	.00

[1]n ranges from 44 to 58.

* $p < .05$

Table 14

Percentage of Subgroup Members Expressing the Following Symptoms

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %
35.	Blurred vision	13	15	73	53	21	9
36.	Pain in your eyes	13	15	73	56	21	4
39.	Ringing and buzzing in your ears	13	7	72	54	21	19
41.	Pain in chest	13	7	73	67	21	19
42.	Have you ever noticed your heart beating abnormally or irregularly	13	30	74	51	21	19
43.	Shortness of breath with only minor exertion	13	15	74	58	21	23
44.	Waking up at night short of breath	13	0	72	22	21	0
45.	A desire to increase the number of pillows you sleep on	13	7	73	36	21	9
49.	Repeated pain/pressure or tightness of your chest	13	0	73	39	21	4
53.	Any pain or discomfort in your stomach in recent months	13	30	72	52	21	14
57.	Being bothered by gassy stomach	13	38	73	64	21	42
68.	Pain in your muscles after only slight exertion	13	7	74	29	21	0
70.	Lost sensation, numbness,or tingling feeling	13	7	72	40	21	23
76.	Trouble sleeping	13	15	71	50	21	19
86.	Being depressed easily or having crying spells	13	0	73	32	21	0

Table 14 (cont'd)

Percentage of Subgroup Members Expressing the Following Symptoms

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %
88.	Getting irritable easily	13	0	74	55	20	20
89.	Unpleasant odor resulting from chemicals in your work environment	13	0	72	69	21	28
110.	Nerve disorders	13	30	73	39	20	5
112.	Have no headaches	13	38	73	18	21	28
119.	Have throbbing headaches	13	0	73	40	21	4
128.	Weakness - on the job	12	8	73	46	21	23
131.	Tired feelings - on the job	12	8	73	64	21	42
132.	Headaches - on the job	13	38	73	61	21	42
138.	Depression - on the job	12	8	73	39	21	9

Table 15

Correlations and Partial Correlations Between Exposure and Test Scores[1]

	Correlations						Partial Correlations - Age Removed					
	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5	Exp-6	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5	Exp-6
Simple Reaction Time	.26**	.36**	.55**	.48**	.62**	.27**	.14	.25**	.35**	.35**	.42**	.23*
Choice Reaction Time	.27**	.33**	.53**	.45**	.60**	.25**	.16	.21**	.31**	.30**	.39**	.20*
Drop Reaction Time	.27**	.31**	.41**	.39**	.47**	.19*	.21*	.25*	.29**	.30**	.36**	.15
Santa Ana - Right	-.31**	-.29**	-.47**	-.40**	-.53**	-.23*	-.21*	-.15	-.22*	-.23*	-.26**	-.17
Santa Ana - Left	-.25**	-.23*	-.38**	-.31**	-.41**	-.21*	-.14	-.09	-.15	-.13	-.15	-.15
Santa Ana - Both	-.26**	-.24*	-.35**	-.29**	-.36**	-.19*	-.16	-.11	-.09	-.11	-.07	-.13
Neisser	.26**	.43**	.56**	.50**	.58**	.30**	.15	.35**	.37**	.38**	.36**	.27**
Digit Span	-.13	-.19	-.21*	-.16	-.23*	-.18	-.09	-.14	-.14	-.10	-.16	-.16
Digit Symbol	-.35**	-.34**	-.54**	-.46**	-.58**	-.18	-.27**	-.23*	-.32**	-.32**	-.33**	-.11
Critical Flicker Freq.	.01	-.09	-.16	-.12	-.19*	-.09*	.07	-.02	-.05	-.03	-.08	-.06
Critical Fusion Freq.	-.12	-.21*	-.26**	-.24*	-.27**	-.16	-.03	-.12	-.08	-.10	-.07	-.11
CFF - Mean	-.07	-.18	-.25**	-.21*	-.28**	-.15	.02	-.09	-.08	-.08	-.09	-.10
Block Design	.24*	-.21*	-.41**	-.36**	-.46**	-.16	-.14	-.09	-.19*	-.20*	-.23	-.09
Feeling Tone	-.16	-.19*	-.21*	-.19*	-.19	-.21*	-.11	-.14	-.11	-.12	-.07	-.19

[1] n = 110

* p<.05

** p<.01

The correlations presented in Table 15 indicate that all the behavioral tests correlate significantly with two or more exposure indices. The first seven tests in the table correlate significantly with all exposure indices. However, judging from the correlations alone,it is not possible to determine if the correlations are actually due to the exposure-test score relationship or whether they actually reflect the influence of a third variable - age. The partial correlations control for age by indicating the correlation between exposure and test scores with age held constant. The results indicate that age does contribute to the obtained relationships,but that there are significant relationships between certain tests and exposure, independent of age. The tests exhibiting the most consistent relationships with age held constant are Simple and Choice Reaction Time, Drop Reaction Time, Santa-Ana Right, Neisser,and Digit Symbol.

Relationships Between Behavioral Tests and Neurological Status.

The previous section investigated one prerequisite for establishing the utility of behavioral test scores as health screening tools - relationships with exposure. This section describes the results of analyses conducted to investigate a second prerequisite - relationships with neurological variables. Correlations and partial correlations with the effects of age removed were computed between behavioral test scores and ten neurological variables. These results are presented in Tables 16 and 17. All tests except Digit Span and CFF have significant relationships with total neurological score. All except Digit Span, CFF, and the Feeling Tone Checklist have significant relationships with electrodiagnostic score. For neurological score, significant correlations were obtained for Simple and Choice Reaction Time, Santa-Ana Right, Left and Both, Digit Symbol, Block Design,and the Feeling Tone Checklist. Among the scores resulting from the electrodiagnostic examination, the one correlating most consistently with behavioral test scores is peroneal nerve conduction velocity. This variable correlates significantly with all tests except Digit Span, Critical Flicker Frequency, Block Design, and the Feeling Tone Checklist. All three conduction velocity scores correlate significantly with Santa Ana Right.

When the analyses were conducted with the effects of age held constant, there was a drop in the number of correlations reaching statistical significance. The partial correlations, Table 17,

Table 16

Correlations Between Test Scores and Neurological Variables[1]

	E.D.S.	UDML	UNCV	USFCV	PDML	PNCV	SYMPT	N.SCORE	TNUSCORE
Simple Reaction Time	.33**	.11	-.13	-.26	.02	-.33**	.34**	.42**	.29**
Choice Reaction Time	.39**	.09	-.97	-.26**	.10	-.27**	.41**	.41**	.54**
Drop Reaction Time	.40**	.10	-.01	-.14	.08	-.35**	.16	.13	.37**
Santa Ana - Right	-.44**	-.21*	.34**	.38**	.14	.37**	-.35	-.35**	-.52**
Santa Ana - Left	-.35**	-.18	.35**	.34**	-.07	.32**	-.25*	-.41**	-.27**
Santa Ana - Both	-.26**	-.17	.35**	.34**	-.12	.23**	-.20	-.27	-.34**
Neisser	.31**	.03	-.13	-.22*	-.04	-.25**	.17	.32**	.18
Digit Span	-.14	-.10	.12	.21*	-.06	.11	-.18	-.10	-.18
Digit Symbol	-.39**	-.14	.20*	.38**	.05	.38**	-.30**	-.29**	-.45**
Critical Flicker Freq.	.01	-.09	.04	-.02	.05	.14	-.06	-.06	-.01
Critical Fusion Freq.	-.13	-.11	.08	.03	.03	.23*	-.13	-.22	-.20
CFF - Mean	-.07	-.12	.07	.01	.04	.22*	-.11	-.16	.12
Block Design	-.36**	.22*	.27**	.38**	-.08	.28	-.27**	-.34**	.46**
Feeling Tone Checklist	-.04	-.16	.09	.09	.00	.05	-.24*	-.31**	-.22*

[1]N = 110 for electrodiagnostic variables, and N = 95 for symptoms, neurological score, and total neurological score.

* $p<.05$

** $p<.01$

Table 17

Partial Correlations Between Test Scores and Neurological Variables - Age Removed[1]

	E.D.S.	UDML	UNCV	USFCV	PDML	PNCV	SYMPT	N.SCORE	TNUSCORE
Simple Reaction Time	.08	.00	.08	-.01**	.07	-.05	.28*	.08	.14
Choice Reaction Time	.16	-.03	.13	-.01	-.10	.04	.38**	.24*	.33**
Drop Reaction Time	.12	-.05	.06	.00	-.26**	.14	.09	.01	.23*
Santa Ana - Right	-.23*	-.14	.22	.19	-.22*	.12	-.28**	-.15	-.30**
Santa Ana - Left	-.15	-.11	.24**	.16	-.11	.09	-.16	-.08	-.18
Santa Ana - Both	-.02	-.10	.25**	.16	-.18	-.03	-.10	-.08	-.06
Neisser	.06	-.10	.06	.03	-.02	.05	.04	-.09	-.02
Digit Span	-.09	-.08	.08	.16	-.06	.05	-.16	-.05	-.12
Digit Symbol	-.16	-.03	.02	.18	.03	.12	-.21*	-.06	-.17
Critical Flicker Freq.	.13	-.05	-.03	.13	.04	.03	-.01	.03	.12
Critical Fusion Freq.	.05	-.05	-.04	-.15	.02	.06	-.05	-.10	-.01
CFF - Mean	.11	-.06	-.04	-.16	.03	.05	-.04	-.04	-.06
Block Design	-.19	-.16	.16	.24**	.12	.07	-.18	-.20	-.27**
Feeling Tone Checklist	.08	-.12	.03	-.01	-.01	-.07	-.19	-.24*	-.11

[1]N = 110 for electrodiagnostic variables, and N = 95 for symptoms, neurological score and total neurological score.

* $p<.05$

** $p<.01$

revealed significant relationships between total neurological score and four tests: Choice Reaction Time, Drop Reaction Time, Santa Ana-right, and Block Design. Two tests, Choice Reaction Time and the Feeling Tone Checklist, had significant partial correlations with neurological score. The tests having significant partial correlations with electrodiagnostic score were Drop Reaction Time, Santa Ana-Right, and Block Design. The most consistent relationships between a behavioral measure and neurological variables were obtained with the Santa Ana-Right.

Regression Analyses. To further investigate relationships between test scores and neurological variables, a series of regression analyses were conducted. These involved predicting total neurological score and electrodiagnostic score using behavioral test scores alone and behavioral test scores along with age. Table 18 presents results of regression analyses for the total sample, using only test scores as predictors. Multiple R's of 0.63 and 0.51 were obtained for total neurological score and electrodiagnostic score respectively. When Age is added to the system as a predictor, Table 19, the prediction of total neurological score is unchanged while prediction of electrodiagnostic score improves slightly. Finally, when management personnel are dropped from the sample, Table 20, prediction of both criteria improves slightly. The improvement is greater for the total neurological score criterion than for electrodiagnostic score.

Regression analysis is a powerful statistical technique which maximizes the relationship between a set of predictor variables and some criterion. In so doing, the technique capitalizes on "chance" variation in the particular sample at hand to improve prediction. Since this "chance" variation, i.e., factors that are peculiar to the particular set of data being analyzed, will not be present in subsequent samples in the same pattern, there will always be some shrinkage, or loss of prediction, when the regression equation developed on one sample is applied to another sample. To investigate the degree of shrinkage, two options are open to the researcher. One is to use a standard formula to estimate the degree of shrinkage that would be expected in subsequent applications of the regression equation. A second involves a procedure known as cross validation. For these analyses the shrinkage formula was used.

The shrinkage formula (McNemar, 1969) provides an estimate of the degree of shrinkage based on the original R^2, sample size, and the number of predictors. The original and shrunken R^2's are presented in Table 21. Since the ratio of the number of predictors to the sample size is very small, the estimated shrinkage is quite small.

Table 18

Test Scores as Predictors of Neurological Variables - Total Sample

Equation No.	Variables in the Equation	Criterion	R^2	R	df
1-1	CRT	Total Neurological Score	.30**	.55**	1, 93
1-2	CRT BD	Total Neurological Score	.33**	.57**	2, 92
1-3	CRT BD SRT	Total Neurological Score	.36**	.60**	3, 91
1-4	CRT BD SRT SAR	Total Neurological Score	.39**	.62**	4, 90
1-5	CRT BD SRT SAR NEIS	Total Neurological Score	.40**	.63**	5, 89
2-1	SAR	Electrodiagnostic Score	.19**	.44**	1, 108
2-2	SAR DRT	Electrodiagnostic Score	.24**	.49**	2, 107
2-3	SAR DRT CFFD	Electrodiagnostic Score	.26**	.51**	3, 106

** $p < .01$

Table 19

Age and Test Scores as Predictors of Neurological Variables - Total Sample

Equation No.	Variables in the Equation					Criterion	R^2	R	df
3-1	CRT					Total Neurological Score	.30**	.55**	1, 93
3-2	CRT	BD				Total Neurological Score	.33**	.57**	2, 92
3-3	CRT	BD	SRT			Total Neurological Score	.36**	.60**	3, 91
3-4	CRT	BD	SRT	SAR		Total Neurological Score	.39**	.62**	4, 90
3-5	CRT	BD	SRT	SAR	NEIS	Total Neurological Score	.40**	.63**	5, 89
4-1	SAR					Electrodiagnostic Score	.19**	.44**	1, 108
4-2	SAR	DRT				Electrodiagnostic Score	.24**	.49**	2, 107
4-3	SAR	DRT	AGE			Electrodiagnostic Score	.27**	.52**	3, 106
4-4	SAR	DRT	AGE	CFFD		Electrodiagnostic Score	.29**	.54**	4, 105
4-5	SAR	DRT	AGE	CFFD	SRT	Electrodiagnostic Score	.31**	.56**	5, 104

** $p < .01$

Table 20

Age and Test Scores as Predictors of Neurological Variables - Management Deleted

Equation No.	Variables in the Equation					Criterion	R^2	R	df
5-1	CRT					Total Neurological Score	.32**	.57**	1, 74
5-2	CRT	SAR				Total Neurological Score	.36**	.60**	2, 73
5-3	CRT	SAR	SRT			Total Neurological Score	.41**	.64**	3, 72
5-4	CRT	SAR	SRT	NEIS		Total Neurological Score	.44**	.66**	4, 71
5-5	CRT	SAR	SRT	NEIS	AGE	Total Neurological Score	.49**	.70**	5, 70
6-1	AGE					Electrodiagnostic Score	.21**	.46**	1, 83
6-2	AGE	DRT				Electrodiagnostic Score	.26**	.51**	2, 82
6-3	AGE	DRT	CFFD			Electrodiagnostic Score	.29**	.54**	3, 81
6-4	AGE	DRT	CFFD	SAL		Electrodiagnostic Score	.30**	.55**	4, 80
6-5	AGE	DRT	CFFD	SAL	SRT	Electrodiagnostic Score	.33**	.57**	5, 79

** $p < .01$

Table 21

Estimates of Shrinkage for Behavioral Tests as Predictors of Neurological Findings

Equation No.	Original R^2	Shrunken R^2	Shrinkage
1-5	.40	.37	.03
2-3	.26	.24	.02
3-5	.40	.37	.03
4-5	.31	.29	.02
5-5	.49	.46	.03
6-5	.33	.29	.04

In an applied setting, behavioral tests would not be used in isolation to screen for neurological status. These scores would be combined with other information to yield the best possible prediction. An obvious additional set of variables to be included would be exposure indices. In order to determine the extent to which exposure information increases prediction, an additional set of regression analyses was conducted.

For this set of regression analyses, the cross validation approach was taken to empirically test for shrinkage in addition to use of the shrinkage formula. In order to permit cross validation, the sample was divided into two halves. The basis for splitting was participant identification numbers. Odd numbers were placed in one half (Data Set A) and even numbers in the second half (Data Set B). Regression equations were completed separately for the two halves. These results are summarized in Table 22.

It can be seen that prediction for Data Set A is substantially greater than for Data Set B. One reason for this difference is that the two halves are not equal in terms of the distributions of criterion scores. Both for total neurological score and electrodiagnostic score, the variation is less in Data Set B than in Set A, for example, the variance for total neurological scores is 14.31 for A and 7.38 for B. This restriction in range, created by the chance splitting of the data, probably accounts for the rather large differences in predictability between the two sets of data. Nevertheless, at least for Data Set A, it can be seen that the addition of EXP_1 to the predictor set improves prediction over that obtained without exposure information. The R^2 for predicting total neurological score without exposure was 0.40 (equation 3-5) while with one exposure variable the R^2 increased to 0.58 for Data Set A. A similar increase is noted for predicting electrodiagnostic score, from 0.31 (equation 4-5) to 0.51, for Data Set A.

Some evidence of the stability of these equations can be gained from the results of cross-validation presented in Table 23. When the equation developed on Data Set B to predict total neurological score was applied to Data Set A, the multiple correlation coefficient dropped very slightly (0.45 to 0.43). However, when the equation developed on Data Set A was applied to Data Set B, the multiple R dropped from 0.76 to 0.16. Similar results were obtained in the prediction of the electrodiagnostic score criterion. When the equation developed on Data Set B was applied to Data Set A, the multiple R "shrank" from 0.63 to 0.50. However, when the equation developed on A was applied to B, the multiple R dropped from 0.71 to 0.23.

Table 22

Test Scores and Exposure as Predictors of

Total Neurological Score and Electrodiagnostic Score

Data Set	Variables in the Equation					Criterion	R^2	R	df
A	SRT	CRT	SAR	EXP_1	AGE	Total Neurological Score	.58**	.76**	5, 56
B	SRT	CRT	SAR	EXP_1	AGE	Total Neurological Score	.21	.45	5, 41
A	SAR	DRT	AGE	EXP_1	EXP_5	Electrodiagnostic Score	.51**	.71**	5, 61
B	SAR	DRT	AGE	EXP_1	EXP_5	Electrodiagnostic Score	.40**	.63**	5, 51

** $p < .01$

Table 23

Results of the Double Cross-Validation Analysis

Data Set	Variables in the Equation					Criterion	R^2	R	df
B weights on A	SRT	CRT	SAR	EXP_1	AGE	Total Neurological Score	.18**	.43**	5, 58
A weights on B	SRT	CRT	SAR	EXP_1	AGE	Total Neurological Score	.02	.16	5, 45
B weights on A	SAR	DRT	AGE	EXP_1	EXP_5	Electrodiagnostic Score	.25**	.50**	5, 66
A weights on B	SAR	DRT	AGE	EXP_1	EXP_5	Electrodiagnostic Score	.05	.23	5, 58

** $p < .01$

These results are largely explained by the previous statements that Data Sets A and B were not equivalent in terms of the variation of criterion scores. Thus the shrinkage obtained in going from A to B is an overestimate of the true shrinkage, and the estimate obtained in going from B to A is probably something of an underestimate. Using the shrinkage formula, for example, the estimate of shrinkage for predicting Total Neurological Score based on the equation developed for Data Set A would be a drop from 0.76 to 0.74, a high degree of stability.

Cross Validation Using Regression Equation from PCE Study. A major concern with regard to the utility of behavioral tests as screening devices is the stability of the relationships demonstrated from situation to situation. In particular, it would be highly desirable if a single set of tests and a single prediction equation could be developed to screen for the effects of several different toxic substances that might lead to similar effects (e.g., peripheral neuropathy). The present study provides the possibility of examining the feasibility of this approach. In a previous study under this same contract (Tuttle et al, 1976), a test battery very similar to the present one was administered to a group of 30 workers, 20 of which were exposed to a dry cleaning solvent, perchloroethylene. Using procedures identical to those previously described, two regression equations were derived for weighing test scores to predict total neurological score. The criterion, total neurological score, was derived in the same way as in the present study, except that different neurologists and a different electromyographer were involved. In the PCE study, separate regression equations were derived for tests administered in morning testing sessions and in afternoon testing sessions. The predictor variables in each case were based on mean test scores across four or five testing sessions (both A.M. and P.M.). Thus, they were very reliable scores, despite the fact that the sample was small (N=30) and heterogeneous with regard to sex and race.

The regression equations and the results obtained from the PCE study and the cross-validated results obtained from the present data are shown in Table 24. The A.M. equation yields a cross-validated multiple correlation coefficient of 0.53 when applied to the CS_2 data and the P.M. equation leads to a cross-validated multiple correlation coefficient of 0.32. Both are highly significant ($p < .01$). This finding is strong evidence to support the notion that a single screening formula can be developed for behavioral tests and applied across situations even when different chemicals are involved. The relationships between behavioral tests and neurological status is highly stable.

Table 24

Cross-Validation Using PCE Equations on CS_2 Data

	Equations	Multiple R with Total Neurological Score: PCE Study	Multiple R with Total Neurological Score: CS_2 Study
(A.M.)	TNUscore = 49.310 - .211 * SRT - .838 * SAR - 8.148 * NEIS + .990 * DSP - .317 * DSY	.73**	.53**
(P.M.)	TNUscore = 48.256 - .360 * CRT - .642 * SAR - .299 * SAB + .514 * DSP - .110 * DSP	.73**	.32**

** $p < .01$

Hanninen-type Analyses

One of the purposes of this study was to determine if the findings of Hanninen (1971) in Finland could be replicated with American workers. Hanninen compared test scores for three groups of workers, those with CS_2 poisoning, those who were exposed but had no clinical signs, and those who were unexposed. She found that psychological tests could successfully differentiate among the three groups. This finding was significant since it suggested that behavioral tests could be used to detect impairment at an earlier stage than traditional clinical screening procedures.

In order to provide further information concerning the generality of these results, the present study attempted similar analyses. With the sample of workers obtained in the present study, it was not possible to duplicate Hanninen's groups. In the present study, four groups of workers were formed. The groups are described as follows:

Group 1 - Exposed with Total Neurological Score > 3;
Group 2 - Exposed with Total Neurological Score of 1-3;
Group 3 - Exposed with Total Neurological Score = 0;
Group 4 - Unexposed with Total Neurological Score = 0.

A more complete description of these four groups is presented in Table 25. The primary difference of significance for the present analyses is that Group 1 is considerably older as a group than Groups 2-4.

Analysis of Variance. Analyses of Variance were conducted to compare mean test scores across the four groups. These analyses are summarized in Table 26. As shown, there are significant differences between the four groups in terms of reaction time (SRT, CRT, DRT), finger dexterity (SAR, SAL, SAB), visual scanning speed (Neisser), symbol coding (DSY), Critical Flicker Frequency (CFFD), and perceptual organization (BD). Analyses of the sample with management deleted, Table 27, yielded essentially identical results.

Individual comparisons were made to compare the means of Groups 1 and 2 individually with the "control" group, Groups 3 and 4 combined. These results are also shown in Table 26. The significant differences are due to differences between Group 1 and the control (Groups 3 and 4). There are no significant differences in individual comparisons of Group 2 with the average of Groups 3 and 4.

Analysis of Covariance. As pointed out earlier, Group 1 differs from the other groups in the average age of its members. Since age

Table 25

Description of Groups for Hanninen-Type Analyses

	Group 1 (N=18)		Group 2 (N=25)		Group 3 (N=67)		Group 4 (N=15)	
	M	SD	M	SD	M	SD	M	SD
Avg. Random Glucose	118.2	25.0	105.7	17.9	104.8	17.3	102.9	14.5
Ave. Hematocrit	43.9	2.9	44.2	2.7	45.0	2.3	45.7	2.8
Systolic Blood Pressure	139.4	14.7	126.2	12.3	128.0	14.1	123.8	10.6
Diastolic Blood Pressure	87.3	9.8	77.6	8.3	81.2	8.2	77.5	7.7
Age	55.3	8.4	37.3	13.9	35.4	11.9	42.8	13.2
Avg. Yrs. Cutting	2.72	6.1	1.07	2.2	0.7	1.2	0	0
Avg. Yrs. Spinning	4.91	8.9	2.59	6.1	0.8	1.9	0	0
Ave. Yrs. Acid	0.16	0.5	0.66	2.2	1.5	4.7	0	0
Avg. Yrs. Churn/Mix	2.94	7.7	0.68	2.0	0.7	4.1	0	0
Avg. Yrs. Staple	4.02	7.1	5.06	8.2	3.7	6.3	0	0
Avg. Other Viscose	3.5	7.8	1.06	4.2	1.8	5.9	0	0
Avg. Years Other Co.	4.7	8.2	1.52	2.8	2.3	5.5	7.9	12.8

TABLE 26

Means and Standard Deviations By Hanninen Groups - Total Sample

	Group 1 (N=18)		Group 2 (N=25)		Group 3 (N=67)		Group 4 (N=15)					
	M	S.D.	M	S.D.	M	S.D.	M	S.D.	F	df	1 vs. 2 vs. (3&4)	2 vs. (3&4)
SRT	53.64	11.21	43.68	9.99	40.59	8.95	41.53	7.43	9.39**	3,121	**	N.S.
CRT	60.41	11.37	50.76	10.12	47.39	7.78	48.76	6.08	10.76**	3,121	**	N.S.
DRT	206.61	20.05	199.90	16.58	190.17	17.42	193.83	17.08	4.87**	3,118	**	N.S.
SAR	17.67	4.04	23.00	3.72	23.78	3.79	23.67	3.89	12.48**	3,118	**	N.S.
SAL	17.89	3.58	22.50	3.86	22.75	3.42	22.87	4.44	8.90**	3,118	**	N.S.
SAB	19.50	4.63	25.29	5.63	27.24	7.42	25.80	6.09			**	N.S.
NEIS	1.63	0.34	1.32	0.48	1.18	0.27	1.22	0.32	8.28**	3,116	**	N.S.
DSP	9.33	1.91	9.83	1.74	10.23	1.72	10.53	2.10	1.64	3,119	--	--
DSY	28.06	11.08	45.42	15.66	49.94	13.86	46.80	12.34	11.50**	3,118	**	N.S.
CFFD	49.19	4.22	49.93	4.23	50.42	6.00	49.50	3.97	0.33	3,118	N.S.	---
CFFA	43.54	3.72	47.93	5.07	47.32	5.17	45.73	4.55	3.54*	3,118	--	--
CFFM	46.37	3.29	48.93	4.34	48.86	4.65	47.64	3.10	1.89	3,118	--	N.S.
BD	22.28	8.69	31.78	9.21	32.19	8.85	35.40	8.89	7.42**	3,116	**	---
FTC	10.13	4.53	11.63	4.86	12.35	3.34	12.71	3.17	1.66	3,113	--	--
R-VERT	130.23	18.63	129.70	21.03	131.20	20.14	142.79	10.09	1.64	3,87	--	--
R-HOR	108.69	22.37	111.81	22.15	111.52	20.80	120.79	13.03	0.96	3,88	--	--
L-VERT	129.31	19.59	133.24	19.27	133.02	15.63	145.36	9.35	2.63	3,87	--	--
L-HOR	107.15	21.88	110.10	17.14	114.88	18.43	120.64	15.11	1.57	3,87	--	--

** $p < .01$

TABLE 27

Means and Standard Deviations for Hanninen Groups - Management Deleted

	Group 1		Group 2		Group 3		Group 4			
	M	S.D.	M	S.D.	M	S.D.	M	S.D.	F	df
SRT	54.85	10.29	44.56	9.93	41.15	9.82	43.38	8.34	8.28**	3,95
CRT	61.48	10.76	51.22	10.34	47.68	8.49	49.92	7.11	9.48**	3,95
DRT	209.77	15.40	201.21	16.60	194.63	15.71	201.80	13.53	4.11**	3,92
SAR	17.18	3.57	22.73	3.65	23.47	3.92	23.90	4.20	12.26**	3,92
SAL	17.41	3.04	22.18	3.76	22.60	3.54	23.30	4.47	9.73**	3,92
SAB	19.00	4.24	25.45	5.86	26.69	7.29	26.70	6.15		
NEIS	1.65	0.33	1.34	0.49	1.21	0.28	1.25	0.35	6.27**	3,90
DSP	9.06	1.56	9.64	1.68	9.77	1.56	10.00	1.89	0.99	3,93
DSY	25.94	7.02	43.91	15.41	48.17	14.00	45.00	14.53	10.92**	3,92
CFFO	48.67	3.70	50.12	4.33	50.33	6.20	48.44	2.70	0.70	3,92
CFFA	43.09	3.29	48.06	5.16	47.50	5.04	47.33	4.51	4.33**	3,92
CFFM	45.89	2.65	49.10	4.42	48.89	4.54	47.91	3.21	2.56	3,92
BD	21.06	7.20	31.23	9.08	31.04	8.95	34.30	9.62	6.99**	3,90
FTC	10.47	4.47	11.82	5.04	12.30	3.73	13.10	3.45	1.00	3,89
R-VERT	128.17	17.84	127.89	21.40	130.45	21.55	147.11	9.91	2.19	3,68
R-HOR	106.08	21.20	110.32	22.81	109.85	22.78	123.33	13.33	1.22	3,69
L-VERT	127.17	18.81	130.95	18.82	132.41	17.47	146.00	11.36	2.20	3,68
L-HOR	103.92	19.33	109.11	17.72	114.19	19.52	123.11	9.73	2.24	3,68

is related to test scores, the question arises as to the extent to which the obtained differences are simply the result of age differences. To answer this question,a series of analyses of covariance were conducted using age as the covariate. This has the effect of adjusting the group means for the effects of age (i.e.,equating the 4 groups in terms of average age). The adjusted means and results of the covariance analyses are presented in Table 28. Significant differences ($p < .05$) between the four groups remain for five tests (all three reaction time tests, Santa Ana-Right,and Block Design). Significant differences that were apparently due only to differences in age were found for Santa-Ana Left, Santa-Ana Both, Neisser, Digit Symbol, and Critical Flicker Frequency. Interestingly, three additional measures that did not reach statistical significance in the first set of analyses, become statistically significant when the effects of age are controlled. These are three of the visual perimetry scores, Left Eye Horizontal and Vertical, and Right Eye-Vertical. In each of these variables, the visual field is measured in degrees on either the horizontal plane or the vertical plane.

Factor Analyses. In order to make comparisons of the ability structure of participants with and without clinical findings, factor analyses were conducted. The four previously discussed groups were used for these analyses. However, due to the sample sizes in the groups,the four were combined into two. Groups 1 and 2 were combined to form Factor Analysis Group 1. Groups 3 and 4 were combined to form Factor Analysis Group 2. The first group was comprised of exposed individuals having some positive clinical finding (TNUscore >0). Group 2 was composed of participants with no positive clinical findings (TNUscore=0), whether exposed or unexposed. The factor analysis results are presented in Tables 29 and 30. The method for extracting factors was principal components followed by < varimax rotation. Unities were used in communality estimates.

The solutions for the two groups each explain approximately equal amounts of variance. The solution for Group 1 contains two factors compared to the three-factor solution for Group 2. The two factors for Group 1 seem to reflect a central nervous system - peripheral nervous system dichotomy. The tests loading most heavily on Factor 1 are Simple and Choice Reaction Time, Santa Ana Right and Left, Neisser,and Digit Symbol. All these involve a considerable degree of peripheral nervous system involvement due to the motor functions involved (e.g.,pressing a button, turning pegs, rapidly checking letters, rapidly writing symbols, etc.). The tests loading most heavily on Factor 2 are Critical

Table 28

Adjusted Means and Results of Covariance Analyses - Hanninen Groups

	Groups 1	2	3	4	F[1]	df
Simple Reaction Time	46.61	44.03	42.38	39.75	2.67*	3,121
Choice Reaction Time	53.97	50.62	48.88	47.55	3.11*	3,121
Drop Reaction Time	201.40	200.05	191.42	190.70	2.66*	3,121
Santa Ana-Right	20.64	22.50	22.90	23.79	3.19*	3,121
Santa Ana-Left	20.48	21.95	22.15	22.95	1.81	3,121
Santa Ana-Both	23.88	24.67	26.23	27.15	1.37	3,121
Neisser	1.35	1.36	1.25	1.20	1.90	3,117
Digit Span	9167	9.68	10.22	10.43	1.00	3,117
Digit Symbol	39.06	43.06	46.83	47.61	2.51	3,117
Critical Flicker Frequency	51.20	49.62	49.99	49.44	0.36	3,116
Critical Fusion Frequency	45.53	47.57	46.67	46.93	0.57	3,116
CFF - mean	48.36	48.60	48.32	48.20	0.04	3,116
Block Design	26.57	30.61	30.46	35.26	3.37*	3,117
Feeling Tone Checklist	10.56	11.48	12.24	13.28	1.59	3,116
Right Eye Vertical	132.11	128.11	131.44	143.69	3.01*	3,92
Right Eye Horizontal	108.12	110.26	112.23	123.74	2.32	3,92
Left Eye Vertical	128.43	130.94	132.32	145.21	3.86*	3,92
Left Eye Horizontal	106.45	108.28	114.37	122.67	2.94*	3,92

[1]The F value is the value for the Independent Variable Group with effects of Age held constant

* $p < .05$

** $p < .01$

TABLE 29

Rotated Factor Matrix - Group 1

	1	2
CRT	.91	-.11
SRT	.94	-.10
DRT	.52	-.46
SAR	-.85	.29
SAL	-.74	.37
SAB	-.65	.43
NEIS	.82	-.12
CFFD	-.06	.71
DSP	-.21	.73
DSY	-.79	.37
BD	-.62	.44
Cum. Percent of Eigen values:	.59	.68

TABLE 30

Rotated Factor Matrix - Group 2

	1	2	3
CRT	.43	.76	.09
SRT	.45	.74	.17
DRT	-.00	.86	-.03
SAR	-.79	-.34	-.19
SAL	-.76	-.30	-.26
SAB	-.81	-.05	-.07
NEIS	.66	.42	-.07
CFFD	-.21	-.28	-.67
DSP	-.74	-.35	.58
DSY	-.66	-.47	.27
BD	-.74	-.08	.25
Cum. Percent of Eigen values:	.49	.60	.69

Flicker Frequency (CFFD) and Digit Span (DSP). Both of these tests involve primarily central nervous system activity rather than motor activity (e.g., visual performance, memory for digits).

The factor solution for the second group shows somewhat greater differentiation of abilities than that for the first group. The tests loading on Factor 1 for Group 1 comprise two factors for Group 2. The first factor is defined primarily by the Santa Ana Right, Santa Ana Left, Santa Ana Both, Digit Span, and Block Design tests. These tests measure finger dexterity (SAR, SAL), coordination (SAB), perceptual organization (BD), and memory (DSP). The second factor is a reasonably pure measure of reaction time. Perceptual speed is obviously an important component of this factor, since two other highly speeded tests, Neisser and Digit Symbol, have moderate loadings on this factor. Factor 3 is composed of the same two tests which comprise Factor 2 in the first group, Critical Flicker Frequency and Digit Span. However, the two factors are not identical since the sign of CFFD is negative in Factor 3.

DISCUSSION

The effects of carbon disulfide on workers have been well documented in the literature (Tuttle et al., 1973). One of the purposes of the present study was to determine if the current T.L.V. for carbon disulfide is adequate to protect workers from these hazards. Viscose rayon manufacturing, one of the primary users of the solvent, was selected as the setting in which the investigation would be conducted. Direct investigation of this question was not possible due to the fact that researchers were not permitted to take air samples in the plant. Thus, it was not possible to determine if the current loads for various jobs were at, above, or below the T.L.V. In an attempt to answer the question of the effects of exposure on worker health, it is necessary to consider more indirect evidence that may be relevant.

From the point of view of health problems resulting from toxic exposure, these are basically of two categories - acute and chronic. Acute problems are those resulting from a single high level exposure of short duration, and chronic problems are those which result from repeated exposure over time. Whenever workers are involved in a process that requires a toxic substance, there is the potential for acute overexposure due to machine malfunctions, spillage, etc. During the course of this study and during the medical examinations, there were a number of anecdotal reports of symptoms resulting from acute exposures. These included reports of symptoms ranging from severe headaches sufficient to cause workers to "bang their heads against concrete walls" for relief, to instances of workers "passing out," even to "nervous breakdowns" that required hospitalization. Knowledge of such examples was common for study participants, although the researchers did not attempt to document the frequency or authenticity of such reports. However, the similarity of reports from worker to worker lends support to their authenticity.

Of more central concern to the purposes of the study were instances of chronic problems. Using the criteria proposed by Allen et al. (1973), this study found 6 individuals in the union group (8%) with definite polyneuropathy, 4 individuals (5%) with probable polyneuropathy, and 5 individuals (6%) who were abnormal but did not have definite neuropathies. Of the 6 with definite neuropathy, all had been exposed to some degree, although there was considerable variation in the duration. There are others who have had presumably as high or higher levels of exposure who did not show abnormal neurological results. Thus there is apparently an interaction between duration of exposure and certain individual factors that determines whether a worker will show symptoms of CS_2 poisoning. This fragmentary evidence supports a similar speculation proposed by Hanninen (1971).

Present research evidence points to a moderate relationship between length of exposure, particularly length of exposure on the spinners and cutters, and nerve conduction speed. As length of exposure increases, nerve conduction speed decreases. The Ulnar nerve appears to reflect the effects of exposure to a greater degree than the peroneal nerve. Exposure accounts, at most, for approximately 16% of the variance in electrodiagnostic scores, and approximately 10% in nerve conduction scores, thus, obviously there are other factors operating. Among these are possibly individual differences in the capability to compensate for exposure effects.

Additional evidence regarding the effects of exposure on worker health comes from the expressed symptoms of union members compared to carpenters and management. The groups are approximately equal in terms of average age, but they differ in terms of their contact with CS_2. To this extent, differences in expressed symptoms can be assumed, at least in part, to be due to exposure. The symptoms that differentiate the two groups closely resemble past research concerning the subjective reactions to CS_2 exposure, (e.g., visual disturbance, irregular heartbeats, muscle pain and numbness, irritability, depression, insomnia, severe headaches, and unpleasant skin odors). Furthermore, based on participant responses, there is no support for competing explanations other than CS_2 for the symptoms such as differences between the groups in the use of alcohol, use of drugs, or the existence of other medical conditions.

After considering this evidence, it seems that the results of this study concur generally with previous research concerning the hazards of CS_2 exposure. However, this study cannot provide an answer to the question of the adequacy of the current T.L.V. Even if this study had been permitted to obtain exposure data, a final answer would still probably not be possible, at least with regard to the chronic effects of exposure, due to the fact that (1) current exposure levels do not reflect the level of past exposure due to variations in production level, process, and equipment; (2) some individuals wear respirators some of the time and it is difficult to accurately gauge their effectiveness; (3) mobility in the work force means that it is rare for an individual to remain in a single job, particularly cutterman, for an extended period of time; and (4) major ventilation changes have been made in the plant in the past 1-2 years. All these factors make it exceedingly difficult to characterize precisely the exposure history of an individual, which is a prerequisite to the determination of the impact of various exposure levels on health status. Because of these difficulties, the use of weighted exposure indices, such as those used in the present study, seem to be an appropriate procedure. These indices could have been more precisely derived if in-plant air monitoring had been permitted.

This would have led to more accurate weighting based on the relative time weighted averages for various jobs.

Behavioral Tests as Health Screening Techniques

A second major purpose of this study was to investigate the feasibility and utility of behavioral tests as "early warning" indicators of health impairment resulting from occupational exposure to toxic solvents. In order for tests to be useful, they must have, in psychometric terms, both construct validity and criterion related validity. Construct validity refers to the extent to which the tests "behave" as predicted from a theoretical point of view. Criterion related validity refers to the extent to which the test can be used to predict some criterion. This can be referred to as concurrent validity when the criterion data and test score (predictor data) are obtained at the same point in time, or predictive validity if the test data is collected at one point in time and the criterion information at a later point in time. Analyses were carried out to evaluate both the construct and criterion related validity of the behavioral test battery.

In order for the test battery to have construct validity, test scores should vary as a function of exposure. In other words, if the tests are to be used to detect exposure-related health impairment, then whatever the tests measure should vary as exposure varies. Previous research demonstrates that CS_2 exposure impairs rather than facilitates certain types of performance. The test battery was carefully selected to insure that the tests would measure those functions known to be affected or presumed to be affected by exposure to the solvent. Thus the prediction based on our "theory" was that test scores would reveal impaired performance as length of exposure increases. This hypothesis was supported for seven of the fourteen test variables. The functions which showed impairment as a function of length of exposure include reaction time, information processing speed, finger dexterity, visual scanning, information coding/symbol production, and perceptual organization. These are functions which are crucial to jobs that involve the operation of machinery, monitoring automated processes, and hazard detection and correction when the delay tolerance is short. Obviously not only productivity of employees but also their safety could be impaired as a result of exposure which produces such functional impairment.

The establishment of relationships between exposure and behavioral test scores satisfies one of the criteria necessary for the utilization of behavioral tests as screening devices. The second criterion is the demonstration of relationships between test scores (as predictors) and criteria of health status. The yardstick by which our society determines health status is the report

of a physician. In this study we made use of this criterion, however, we used a standard procedure for reporting the results of the medical/neurological evaluation so that all participants would be evaluated in such a way that comparisons between individuals would be possible. The neurological and electrodiagnostic rating procedures made this possible. These ratings provided the "objective" criterion against which the criterion-related validity of the behavioral tests was judged.

Investigations of the criterion related validity yielded positive results both in a concurrent validity situation and even more importantly in the predictive validity context. Concurrent validity was demonstrated through the use of multiple regression techniques to predict criterion ratings (both total neurological score and electrodiagnostic score). Tests which entered into the prediction equations were Choice Reaction Time, Simple Reaction Time, Block Design, Santa Ana-Right, and Neisser to predict Total Neurological Score (R=0.63). In predicting Electrodiagnostic score,the tests which formed the optimum prediction equation were Santa Ana-Right, Drop Reaction Time, and Critical Flicker Frequency (CFFD) with a multiple R=0.51. With the exception of CFFD, all of these variables had been shown in the previous analyses to possess construct validity.

Perhaps the most significant result from this entire study, at least with regard to the development of a health screening methodology, resulted from the cross-validation of the regression equations developed in the previous perchloroethylene study. This demonstration of predictive validity involving a prediction formula based on a group of workers exposed to one solvent, applied to workers exposed to a different solvent,is most encouraging. This result suggests that it may be possible to develop a "universal" prediction equation that would be applicable to workers exposed to all neurotoxins, or at least to the subset of neurotoxins whose earliest effects are on the peripheral functions. The advantages of such an approach are immense. It may not be necessary to conduct separate research projects for each toxic agent in this category. Once it could be determined that the substance belonged to the particular "cluster" of substances, the universal screening formula could then be used. More research would be necessary in order to test the feasibility of this approach and to develop a sufficient data base to develop such a universal equation. However, the results of this study argue strongly for this research strategy. It may well be that other clusters of toxic substances could be identified for which a single screening approach can be developed.

Accuracy of Worker Diagnosis Using the Prediction System

One question that has not been addressed sufficiently is the practical significance of these analyses. How accurately can we categorize an individual participant as "healthy" or as "abnormal" using the prediction methods? This question will be answered in two ways. One way of depicting the accuracy of the prediction methods is to construct expectancy charts. Expectancy charts for three criteria of interest are shown in Figures 11 through 13. Figure 11 presents the expectancy chart for Total Neurological Score, the overall index that combines Symptoms, Neurological Score, and Electrodiagnostic Scores. This figure shows the chances in 100 of being diagnosed as abnormal i.e., Total Neurological Score greater than 3) for various predicted score ranges. For example, by "plugging" into the regression equation values for an individual on the following variables, Simple Reaction Time, Choice Reaction Time, Santa Ana-Right, Block Design, EXP_1, and EXP_3, a predicted score would be generated. By referring this predicted score to Figure 11 it would be possible to estimate the likelihood that this individual would have a Total Neurological Score of 4 or greater, if he was given a neurological examination. The value of this procedure is that from test score information and information concerning exposure that can be gained from an interview, it is possible to predict health status. Company policy could then dictate the point at which the individual would be referred for a thorough neurological examination. However, this relatively inexpensive screening method could be used in lieu of expensive neurological examinations for the total exposed work force. Only those whose probability of abnormality is relatively high, e.g., 33% or even 50% would need to be referred for the thorough medical examination.

Similar expectancy charts are presented for Electrodiagnostic score and Neurological score (Figures 12 and 13). The regression equations by which these predictions were made are presented in Appendix I.

An alternative way of using the regression equations to predict neurological status involves creating a new dichotomous criterion variable called NHealth. This new variable has a value of 1 if the individual is "abnormal" and 0 if the individual is "normal." Normal and abnormal are defined in terms of ranges on the total neurological score variable. For example, one set of analyses was conducted to predict NHealth when abnormal was defined as a total neurological score of 6 or greater. The NHealth score for an individual was 1 if the total neurological score was 6 or greater and 0 otherwise. Regression analysis used

Chances in 100 of Receiving a Total
Neurological Score of 4 or Greater

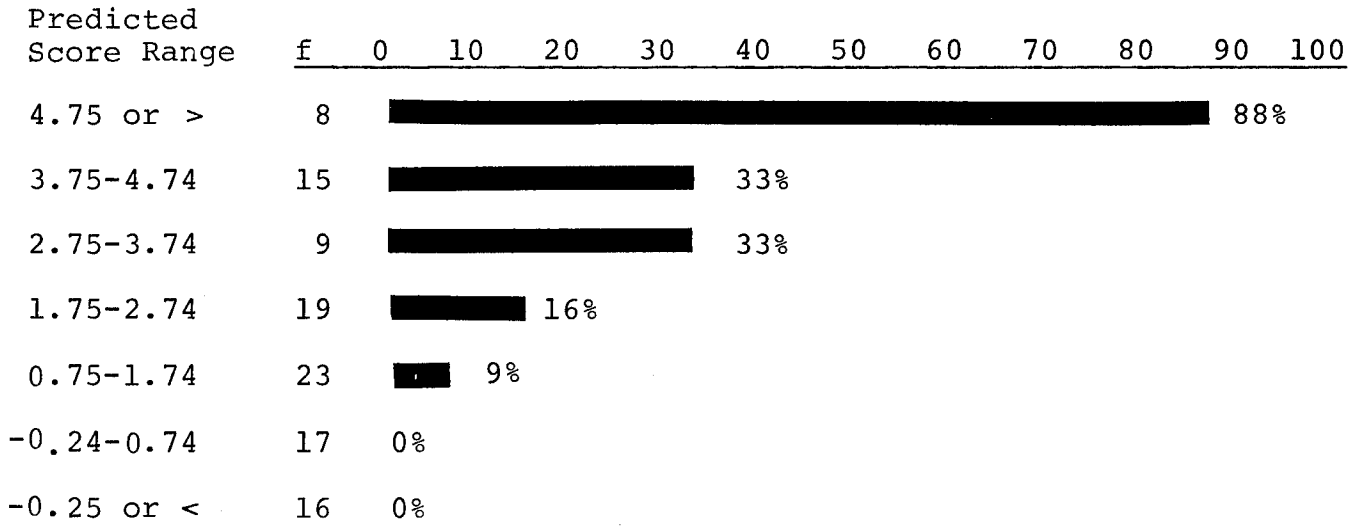

Figure 11 Expectancy Chart for Total Neurological Score

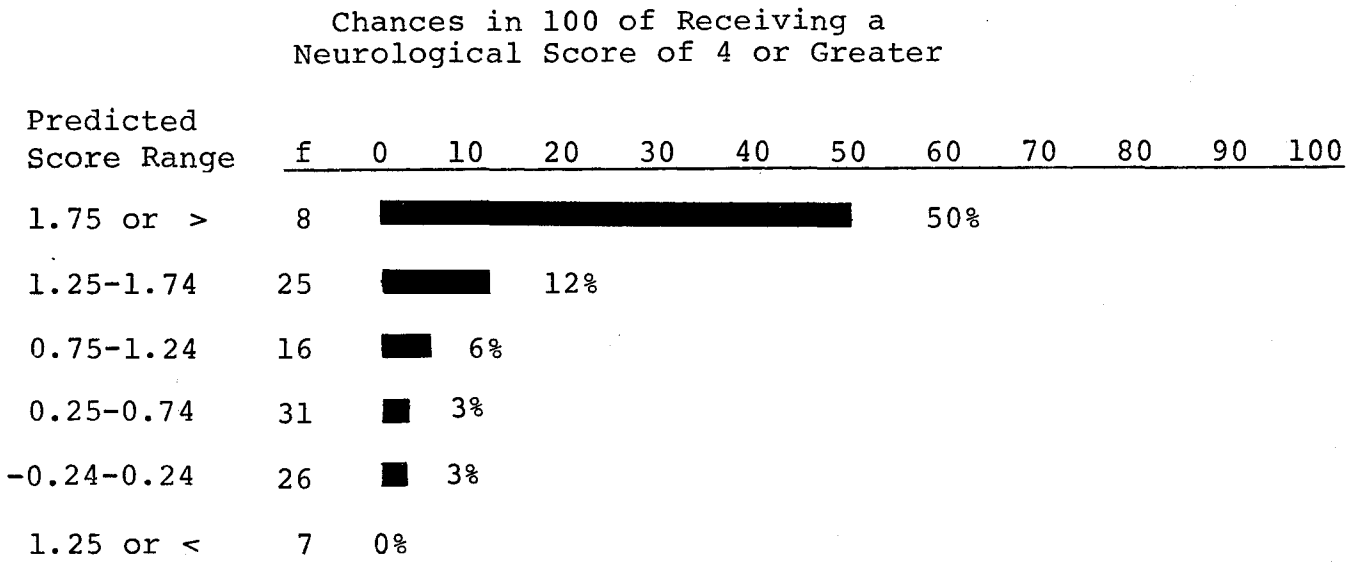

Figure 12 Expectancy Chart for Neurological Score

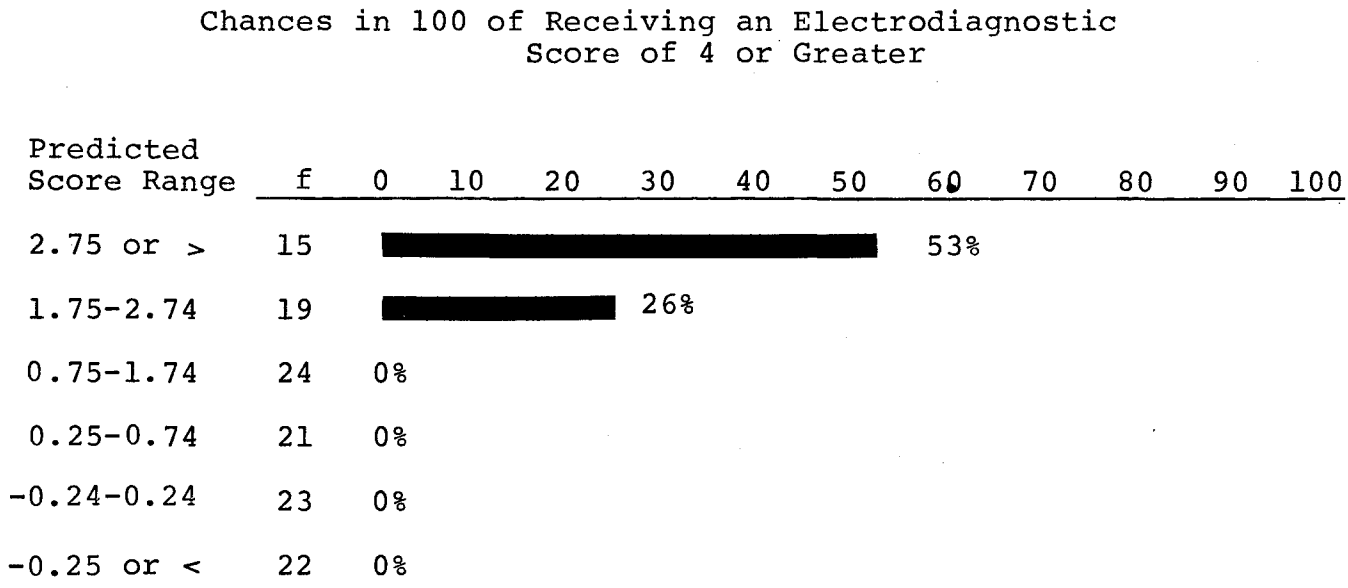

Figure 13 Expectancy Chart for Electrodiagnostic Score

in this way gives results that are analagous to a discriminant analysis of the type reported by Hanninen (1971). Table 31 presents the results of this analysis, using a cutoff on the predicted score of 0.40.

Table 31

Comparison of Neurological Status Determinations

Based on Predicted Vs. Actual Scores

(Abnormal = Total Neurological Score Greater Than 5)

		Predicted	
		Normal	Abnormal
Observed	Normal	114	0
	Abnormal	4	8

Main diagonal entries represent correct predictions, and off-diagonal entries are errors. This analysis indicates that for detecting individuals with probable or definite polyneuropathies, the accuracy of prediction is 96%. Unfortunately, the four participants not correctly categorized are abnormals who were categorized as normals. The regression equation used to make these predictions is presented in Appendix J.

From the point of view of early detection,it is desirable to detect individuals as abnormal prior to the time they have probable or definite neuropathy. In order to investigate the accuracy of prediction at this earlier stage the criterion for abnormality was lowered from 6 or greater to 4 or greater. A regression analysis was conducted to predict NHealth with this lower cutoff score (i.e., NHealth = 1 if total neurological score equals 4 or greater,and NHealth = 0 otherwise). The results are shown in Table 32 . Accurate predictions were made for 113 out of 129 participants for an accuracy of 87.5%.

Table 32

Comparison of Neurological Status Determinations

Based on Predicted Vs. Actual Scores

(Abnormal = Total Neurological Score Greater Than 3)

		Predicted	
		Normal	Abnormal
Observed	Normal	98	9
	Abnormal	7	15

The 16 errors were approximately evenly split between false positives and false negatives. Seven abnormals were categorized as normals based on predicted scores, and nine normals were predicted to be abnormal. The equation used to make these predictions is also shown in Appendix J.

These results support the findings of Hanninen that behavioral tests, especially when augmented by information concerning Age and exposure, can, with reasonable accuracy, be used to differentiate among exposed workers who show signs of CS_2 poisoning. This finding argues strongly for the inclusion of behavioral tests in regular,in-plant health screening programs. The methods are reliable, valid, relatively easy to administer,and relatively inexpensive when compared to the alternative of complete medical examinations for all exposed employees.

Comparison with Hanninen Results

The worker sample in the present study was less seriously afflicted than the sample in the Hanninen study (1971). Therefore, it was not possible to replicate Hanninen's groups exactly. None of the workers in the present study had been diagnosed prior to the study as "poisoned." However, it seems likely that some of the participants belong in this category. Others, who have Total Neurological Scores less than 9 but greater than 3, probably more

closely resemble Hanninen's Group 2 - Latent Poisoning. Thus, Group 1 in the present study is probably a combination of Hanninen's Groups 1 (Poisoned) and 2 (Exposed). A comparison of the relationship between Hanninen's groups and groups in the present study is depicted in Figure 14.

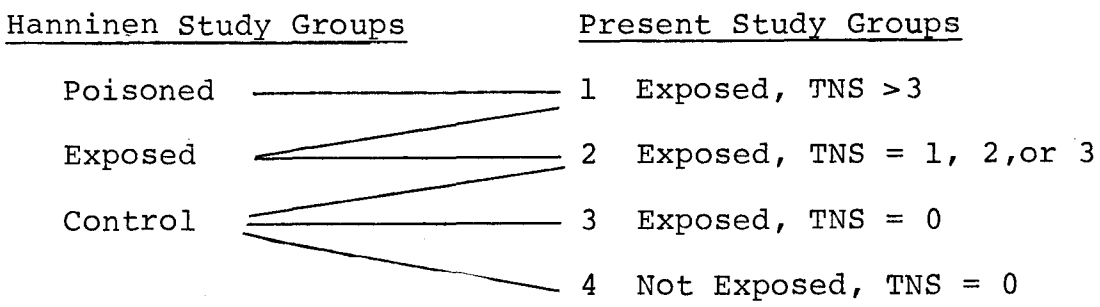

Figure 14. Comparison of Hanninen Groups with Groups in the Present Study

Hanninen found that both the poisoned and exposed groups could be discriminated with psychological tests. In order for the present study to replicate this result,it would require the establishment of differences between Groups 1 and Groups 3 and 4 combined. If differences could be demonstrated between Group 2 and Groups 3 and 4 combined, this would go beyond the Hanninen results in terms of sensitivity,since some of the members of Group 2 would presumably have been in Hanninen's control group.

The obtained results in the present study show that Group 1 can be differentiated from 3 and 4 with selected test variables. However, Group 2 cannot be successfully discriminated from 3 and 4. Thus,a reasonable conclusion is that the present results substantiate,but do not go beyond,Hanninen's findings.

Since some of the same tests were included in the present battery,as were included in the Hanninen test battery, it is interesting to compare results for these tests.[1] In the Hanninen study,significant differences were obtained between the

[1]The apparatus for the Santa Ana test used in the present study was built by the same craftsman in Finland who built the apparatus used by Hanninen.

"Poisoned" and "Control" groups on Digit Symbol, Santa Ana-Right, Santa Ana-Left. For the Exposed vs. Control comparisons, significant results were obtained for these same tests plus Digit Span, Block Design, and the Santa Ana-Both measures. In the present study with U. S. viscose rayon workers, significant differences between Group 1 and Groups 3 and 4 were obtained for all these same tests except for Digit Span. However, when the present data was analyzed with age held constant, only Santa Ana-Right and Block Design of the Hanninen tests discriminated between the groups.

Another finding in the Hanninen study,which was substantiated in the present study,was her observation that there are qualitative as well as quantitative differences between exposed/poisoned groups and control groups. The factor analysis data in the present study demonstrated different factor structures for individuals with clinical signs and those without clinical signs. It appears that exposure not only depresses certain functions, but changes the nature of the abilities themselves.

Auxiliary Issues

In addition to the primary purposes for which this study was conducted,there are some other topics which the results have addressed either directly or indirectly. The evidence from this study,pertaining to these topics,is discussed briefly below.

Utility of the Iodine Azide Test as a Screening Technique. The iodine azide test is currently the best available biological screening method for estimating previous CS_2 exposure levels. However, Djuric points out two limitations to its use. First, the test is not sensitive to exposure levels below the current T.L.V. of 20 ppm. Secondly, the test is indeterminate when urine samples are too dilute (i.e.,creatinine value less than 1.25 mg /m l). Both are serious weaknesses for research use of the procedure under conditions similar to those in the present study. The most severe limitation for the present use was the second one. Approximately 42% (81 out of 193) of the tests conducted in the present study were indeterminate,due to low creatinine levels. Creatinine levels are low when the interval between urinations is relatively short. Since this data collection was not conducted in the plant, it was not possible to obtain samples immediately following the work shift. In most cases workers voided just prior to leaving the plant for the testing session. Workers tested prior to work would ordinarily void prior to leaving home for testing. Thus,in both cases, diluted samples would be obtained during the testing session. The difficulty of communication with participants prior to testing made it impractical to notify them of this problem. Any future research using this procedure should anticipate this problem.

Comparison of the C.V.S.F. and Standard Methods for Nerve Conduction Studies. The conduction velocity of the slow fibers (C.V.S.F.) is a technique proposed by Seppalainen and Hernberg (1972) as a subclinical screening technique that is more sensitive than the traditional nerve conduction methods for detecting damage resulting from toxic exposure. Both the C.V.S.F. and traditional methods were used in the present study. Overall, the two procedures yielded similar results. The C.V.S.F. score correlated 0.51 with the ulnar maximal conduction velocity, indicating that the two variables are similar but not identical. Both scores correlate with exposure indices to the same degree. The C.V.S.F. measure had a slightly higher relationship with age (-.38 vs. -.30 for ulnar MCV) indicating that age differences may confound C.V.S.F. scores to a somewhat greater degree. There seems to be little basis from this study to recommend the additional time and expense to conduct the C.V.S.F. Perhaps the reason that Seppalainen found the test to be more sensitive with lead workers is due to differences in the way the two substances, lead and CS_2, affect the peripheral nervous system. For CS_2 exposed workers, the C.V.S.F. did not add appreciably to the effectiveness of the electrodiagnostic screening.

One other point worth mentioning regarding the C.V.S.F. is the subjective reaction of participants. Although no systematic evaluation of worker reaction was done, a number of workers stated a dislike for the electrical stimulation. The C.V.S.F. procedure requires repeated "shocks" to the patient's arm and is therefore more offensive than the more traditional conduction velocity techniques. Since the C.V.S.F. procedure seemed to add little information of value in the present study, it does not seem advisable to subject participants to the additional discomfort.

Neurological Rating Procedure. This study provided an opportunity to assess, to some degree, potential biases in the neurological rating procedure. A total of four neurologists participated in the clinical examinations, however, three of the four examined the majority of patients. Although there was no attempt to randomly assign patients to physicians, there was no systematic procedure for assigning patients. Approximately 15-20 patients were seen each night that examinations were given and patients were assigned to the physicians on a "first-come" basis. Thus it seemed reasonable to assume that the group of patients assigned to physicians did not differ significantly in terms of age, exposure history, or health status. This assumption was supported by analyses which indicated no differences between the groups in age, years of exposure, or electrodiagnostic scores.

Analyses were then conducted to investigate differences in neurological ratings and symptoms ratings. Because the distribution of rating scores is positively skewed (many zeros and fewer

non-zero ratings), analyses were performed using both raw scores and scores transformed using both arcsin and square root transformations. Significant differences, $p < 0.05$, were obtained for all three analyses (raw scores and both transformed scores) for the symptoms score. Significant differences ($p < .05$) were found in the neurological score ratings for the scores transformed by the square root transformation, but not for raw scores or transformed scores using the arcsin transformation. Thus, it appears that the three neurologists clearly used different rating criteria for assigning symptoms scores and probably even in the neurological examination itself. However, since the neurological examination rating criteria are more clearly specified and probably more objectively verifiable, the differences in ratings did not appear to be as great as in the symptoms rating.

The importance of this result is that it suggests that subsequent studies employing the Allen et al. rating procedure in a situation where a team of physicians is conducting examinations, might do well to conduct a brief training program in the use of the rating procedure. This would allow neurologists the chance to discuss among themselves the criteria to be used in assigning ratings. This should be done for the symptoms ratings in particular, as well as neurological score ratings, and even the electrodiagnostic procedures if more than one electromyographer is involved.

Disappearance of Symptoms When Exposure is Terminated. One final issue of importance for which some very tentative comments can be made is the issue of whether or not signs and symptoms improve or disappear when exposure is terminated. Any satisfactory answer to this question would require a longitudinal study design that would examine patients during periods of exposure and at designated time intervals thereafter. However, some information on this topic can be obtained from analyses which made use of a variable which reflected the "number of years individuals had been away from cutting and spinning." The general pattern of work progression finds workers leaving spinning and cutting and moving to areas of lessened exposure. Therefore, if neurological status improved with length of time away from exposure, one would expect to find a negative relationship between neurological variables and years away from cutting and spinning. Correlations between the four neurological status rating variables and years away from cutting and spinning are .12 (neurological score), -0.08 (symptoms), 0.04 (electrodiagnostic score), and 0.06 (total neurological score), all non-significantly different from zero. Analyses of variance show significant differences between groups formed on the basis of years away from cutting and spinning for electrodiagnostic score and total neurological score. However, the differences are in the

opposite direction than would be predicted. The longer people have been away, the higher the score. This finding might be explained by a combination of factors, e.g., contaminating effects of age, the fact that those who have been away longest were exposed a number of years ago when exposure levels may have been higher, etc. In any event there is no evidence to suggest that symptoms or neurological signs disappear when exposure is decreased or terminated. However, the present data should only be viewed as a very tentative answer to this question and it certainly does not rule out the possibility that there is improvement when exposure is decreased or stopped altogether. More research will be required to adequately answer this question.

CONCLUSIONS AND RECOMMENDATIONS

1. Significant statistical relationships exist between chronic CS_2 exposure and indices of neurological health. The strongest relationships, independent of age, were demonstrated between exposure indices and electrodiagnostic variables.

   Recommendation 1. Electrodiagnostic methods can be used to screen CS_2 exposed workers for nerve damage.

2. Significant statistical relationships exist between chronic CS_2 exposure and behavioral tests which measure simple reaction time, choice reaction time, visual scanning, finger dexterity, symbol coding, and perceptual organization.

3. Significant statistical relationships exist between behavioral test scores and indices of neurological health. Behavioral tests coupled with other information, such as age and length of exposure, predict neurological status with considerable accuracy (multiple R = .64).

   Recommendation 2. Behavioral tests should be used as a part of regular, in-plant monitoring of the health status of CS_2 exposed workers to help identify those who should receive more extensive medical examinations.

4. The pattern of results in the present study lend support to the conclusions drawn by Hanninen regarding the value of behavioral tests for differentiating among exposed workers with and without clinical signs.

5. The use of the iodine azide test in studies such as this, which do not have direct access to workers in the plant, has limited usefulness.

6. The C.V.S.F. procedures (conduction velocity of the slower nerve fibers in the ulnar nerve) did not increase the sensitivity of the electrodiagnostic methods in this study.

   Recommendation 3. Additional research with workers exposed to other neurotoxins should be conducted to adequately evaluate the usefulness of these C.V.S.F. procedures.

7. Rating biases may influence the usefulness of the neurological rating scores when more than one physician is involved.

   Recommendation 4. Whenever more than one physician will be involved in conducting examinations and using the rating procedure to summarize results, a brief training session should be conducted to make sure that the physicians involved use the same criteria for evaluating patients and making ratings. This is particularly important for the Symptoms rating.

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Appendices

Appendix A

Feeling Tone Checklist

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FEELING TONE CHECKLIST

INSTRUCTIONS: Below are listed ten statements that might be used by a person to describe how he feels. Read each of the statements and indicate in the space provided whether you feel Better Than, the Same As, or Worse Than the statement.

EXAMPLE: As an example, assume that at the present time you feel a little tired. You might answer the items below as follows:

	Better Than	Same As	Worse Than
A) extremely fresh	( )	( )	(X)
B) slightly tired	( )	(X)	( )
C) completely exhausted	(X)	( )	( )

Now, in the space provided below, indicate whether at this moment you feel Better Than, the Same As, or Worse Than each of the statements, by putting an "X" in the proper column.

No.	Statement	Better Than	Same As	Worse Than
1.	very lively	( )	( )	( )
2.	extremely tired	( )	( )	( )
3.	quite fresh	( )	( )	( )
4.	slightly pooped	( )	( )	( )
5.	extremely peppy	( )	( )	( )
6.	somewhat fresh	( )	( )	( )
7.	petered out	( )	( )	( )
8.	very refreshed	( )	( )	( )
9.	fairly well pooped	( )	( )	( )
10.	ready to drop	( )	( )	( )

Appendix B

Guidelines for Selecting Union Participants

Category I - Currently Exposed

Insofar as possible participants should be selected who are currently being exposed to carbon disulfide. Thus, in order of priority, jobs are as follows:

(1) Cuttermen
(2) Spinnermen
(3) Other jobs which require individuals to work in the cutterhouse or spinning area for a considerable period of time everyday (e.g., filtermen, pump testers, patrolmen, etc.)

Category II - Recently Exposed (1-6 months)

Next in order of priority are individuals who have worked recently (past 1-6 months) in the above jobs where they were regularly exposed to carbon disulfide, but are not currently exposed due to retirement, transfer, etc.

Category III - Recently Exposed (7-24 months)

Next in order of priority are individuals who have worked regularly in the above jobs within the past 7-12 months, but who are not currently exposed due to retirement, transfer, etc.

Category IV

Individuals who are not currently exposed and who have never been exposed. These individuals should be as similar to the exposed group as possible in terms of age spread, level of education, sex, etc.

The target number of participants is approximately 150 exposed and 45 unexposed. The exact number will be determined at a later date. Ideally all exposed will be drawn from the Category I - Currently Exposed Group. However, it is recognized that some will have to be selected from the Category II or Category III groups. Hopefully, no more than 20-25 will have to be drawn from Categories II or III.

All 45 unexposed will come from Category IV.

Appendix C

Participant Consent and Release Forms

OMB No. 68-S75062
Approval Expires 7/31/76

NIOSH PARTICIPANT DOCUMENT - (CS_2 Study)

I. Project Title and Number: "Behavioral and Neurological Evaluation of Workers Exposed to Industrial Solvents: Carbon Disulfide and Perchloroethylene"; Contract Number HSM 99-73-35.

Project Sponsor and Director: National Institute for Occupational Safety & Health; Craig B. Grether, Ph.D., Thomas C. Tuttle, Ph.D.

Project Purpose: To study the behavioral effects on workers exposed to carbon disulfide and perchloroethylene.

II. Consent

I, _____, hereby voluntarily agree to cooperate in the above-named study and to undergo the tests listed in this Part II. The study has been discussed with me; I have been furnished a copy of this form; and I understand the following:

1. The following conditions apply to each participant in the CS_2 Study:

   a. A Medical History Questionnaire will be completed and returned to Westinghouse Behavioral/Safety Center prior to testing.

   b. A medical examination, including a neurological component, will be given by a qualified physician at no cost to the participant.

   c. Examinations of muscle and nerve activity of the forearm and lower leg will be performed at the Charleston Area Medical Center by qualified medical personnel. One element of this exam, electromyography (EMG), is to be performed on two muscles; the extensor digitorum communis (forearm) and the tibialis anterior (lower leg). Maximal conduction velocity (MCV) will be performed on the ulnar (forearm) and peroneal (leg) nerves, and conduction velocity of slower fibers (CVSF) will be done on the ulnar nerve. Slight discomfort, similar to a pin prick, may be experienced during these procedures. These will be performed at no cost to the participant.

d. A behavioral test battery, approximately 70 minutes in length, will be given. It will consist of the following tests: Santa Ana dexterity; reaction time; Wechsler block design, digit span, digit symbol; feeling tone checklist; Neisser letter search; and critical flicker fusion.

e. At specified intervals, each participant will be asked to provide urine samples.

f. Blood samples will be taken by a pin prick of the finger.

2. Attendant discomforts and risks,except as noted above,are minimal and provision has been made for any necessary medical support to cover unforeseen conditions.

3. Benefits are as indicated in the project description in Item 1.

4. If alternative procedures are available, the procedure most advantageous for me will be indicated and used or an explanation given to me as to the use of any other procedure.

5. My inquiries concerning any procedures used with me will be answered by Dr. Thomas C. Tuttle, or Mr. David Wood (301) 730-8429.

6. I am free to discontinue participation in the project at any time.

7. Confidentiality of information will be maintained as stated in Part III, which I have read and understand.

8. If my medical records are required, a separate written consent for release of the records is required. (See attached medical release form.)

9. My participation in this study will not affect my employment except as required by law for protection of health and safety.

10. There will be a questionnaire for me to answer, and, although I will not be given a copy of the questionnaire to keep, my inquiries concerning the questionnaire will be answered by Dr. Thomas C. Tuttle (301) 730-8429.

Signature _____ Date _____

Signature _____ Date _____
(Parent or Guardian)

III. ASSURANCE OF CONFIDENTIALITY:

Your identity and your relationship to any information (1) disclosed by you in completing any project questionnaire and (2) reported by you or derived from you during your participation in the above named project shall be kept confidential in accordance with Public Health Service regulations (42 Code of Federal Regulations Part 1) and Department of Health, Education, and Welfare regulations (45 CFR, Part 5), and will not be disclosed without your written consent except as required by law and except that such information will be used for statistical and research purposes in such a manner that no individual can be identified.

IV. REQUEST AND AUTHORIZATION FOR RELEASE OF INFORMATION

I, _____, hereby request and authorize the Project Director to inform the following physicians whose names and addresses I have entered below of any significant findings from the above named study concerning me. (Do not leave blank. Write "No" in any block for which no name and address is to be given.)

(1) My personal physician:
Dr. _____
Street: _____
City: _____

(2) Company Physician:
Dr. _____
Street: _____
City: _____

(3) Other physician:
Dr. _____
Street: _____
City: _____

Signature _____ Date _____

OMB No. 68-S75-62
Approval Expires 7/31/76

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

REQUEST FOR AUTHORIZATION FOR RELEASE OF INFORMATION

I, _____, hereby request and authorize _____
(Name and Address)

_____

to release to the National Institute for Occupational Safety & Health such of my safety or medical records as are requested by the National Institute for Occupational Safety & Health.

Signature _____ Date _____

Address _____

Appendix D

Questionnaires Used in Data Collection

OMB No. 68-S75062
Approval Expires 7/31/76

WORK/MEDICAL HISTORY QUESTIONNAIRE

Instructions:

The purpose of this Work/Medical History Survey is to obtain information that will supplement the medical examination as well as to assist us in the evaluation of your scores on the test battery to be administered at a later date.

This survey deals with a number of categories including:

I Personal Data
II Work History
III Beverage History
IV Medical History
V Symptoms

Items such as those regarding smoking and beverage history are especially important because we are studying relationships between these activities and exposure to industrial solvents. The information you provide in this regard and all other information which we receive will be kept strictly confidential.

To accomplish the purposes of this research project, it is important that each person complete the entire survey. We will appreciate your efforts in providing all of the necessary information.

Please print all your answers in the spaces provided and follow the instructions printed on the survey form. If you have any questions, call the Westinghouse Behavioral/Safety Center, Columbia, Maryland, collect for David Wood or Tom Tuttle -- 9:00 a.m. to 5:30 p.m. at: (301) 730-8429.

ASSURANCE OF CONFIDENTIALITY:

Your identity and your relationship to any information (1) disclosed by you in completing any project questionnaire and (2) reported by you or derived from you during your participation in the above named project shall be kept confidential in accordance with Public Health Service regulations (42 Code of Federal Regulations Part 1) and Department of Health, Education,and Welfare regulations (45 CFR, Part 5), and will not be disclosed without your written consent except as required by law and except that such information will be used for statistical and research purposes in such a manner that no individual can be identified.

I. PERSONAL DATA

Name:_____ Social Security #_____
Address:_____ Date of Birth _____

Height: _____ft. _____ in. Weight: _____ Sex: M_____ F_____
1 0 (10)

Circle highest grade completed:
1 2 3 4 5 6 7 8 — Pre-high school
9 10 11 12 — High School
13 14 15 16 — College (11-12)

II. WORK HISTORY

1. Job title: _____
2. List the specific processes in which you are involved.
_____
_____
3. When did you start work in this job? _____ (13-16)
(Month) (Year)
4. What shift do you presently work? (17)
1st shift _____ 1
2nd shift _____ 2
3rd shift _____ 3
Not working _____ 4
5. Are you involved in shift rotation? Yes_____ No_____ (18)
If "No", skip to Item 7.

6. If "Yes", does your shift rotate: (19)
weekly _____ 1
every two weeks _____ 2
monthly _____ 3
quarterly _____ 4
other _____

7. How many hours do you work per week (average)?_____(20-21)

8. List previous jobs starting with the most recent. (Do not include present job.)

Number of years worked	Name of Plant	Job Title or description
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____
_____	_____	_____
	_____	_____

9. Do you expect to be working for the same company five years from now? Yes _____ (1) No _____ (0) (22)

10. Do you expect to be doing the same type of work five years from now? Yes _____ (1) No _____ (0) (23)

11. Have you ever worn a respirator on the job? (24)

No	0
Yes, for 1-6 months	1
Yes, for 6-months-1 year	2
Yes, for 1-2 years	3
Yes, for 3-4 years	4
Yes, for over 4 years	5

12. Do you wear a respirator now on your job? (25)

No	0
Only when performing certain duties	1
Most of the time	2
Always	3

Have you ever had a job which exposed you to any of the following?

		No (0)	Don't know	Yes (1)	If yes, for how many years?	
13.	Petroleum solvent (Stoddard Solvent)	___	___	___	____	(26,27-28)
14.	Carbon tet (carbon tetrachloride	___	___	___	____	(29,30-31)
15.	Perc (PCE, perchloroethylene)	___	___	___	____	(32,33-34)
16.	Carbon Disulfide (CS_2)	___	___	___	____	(35,36-37)
17.	Trichloroethylene	___	___	___	____	(38,39-40)
18.	Mercury Vapor	___	___	___	____	(41,42-43)
19.	Hydrogen Sulfide	___	___	___	____	(44,45-46)

20. Other chemical substances (specify)

_____ ____

_____ ____

III. Beverage History

21. Do you now or have you ever drunk alcoholic beverages? (47)
Yes_____1_____ No_____0_____
(If "No" skip to Part IV, Medical History

22. On the average, how many beers do you drink per day? (48)
1 _____ None
2 _____ less than 1
3 _____ 1-2
4 _____ 3-5
5 _____ 6 or more

23. On the average, how many glasses of wine do you drink per day? (49)
1 _____ None
2 _____ less than 1
3 _____ 1-2
4 _____ 3-5
5 _____ 6 or more

24. On the average, how many cocktails or drinks of liquor do you have per day? (50)
1 _____ None
2 _____ less than 1
3 _____ 1-2
4 _____ 3-5
5 _____ 6 or more

25. At what age did you start drinking alcoholic beverages? (51-52)
Age _____

26. On the average, how frequently do you drink alcoholic beverages just before going to work? (53)
1 _____ Never
2 _____ Less than 1 time per week
3 _____ 1 or 2 times per week
4 _____ 3 times per week
5 _____ 4 or 5 times per week

27. On the average, how frequently do you drink alcoholic beverages during the workday (including breaks, lunch, etc.)? (54)
1 _____ Never
2 _____ Less than 1 time per week
3 _____ 1 or 2 times per week
4 _____ 3 times per week
5 _____ 4 or 5 times per week

28. How frequently do you drink alcoholic beverages immediately after work? (55)

1 _____ Never
2 _____ Less than 1 time per week
3 _____ 1 or 2 times per week
4 _____ 3 times per week
5 _____ 4 or 5 times per week

29. How has your drinking pattern changed over the past years?

1 _____ Increased considerably (56)
2 _____ Increased slightly
3 _____ Remained the same
4 _____ Decreased slightly
5 _____ Decreased considerably

30. How much of your drinking is done in the company of other people? (57)

4 _____ All
3 _____ Most
2 _____ Little
1 _____ Hardly any or none

31. Have you ever been hospitalized or treated for an alcohol-related illness? (58)

Yes_____ No_____
1 0

IV. MEDICAL HISTORY

Check the appropriate column "No" or "Yes" regarding whether or not you have ever experienced the following symptoms.

		No 0	Yes 1	
32.	Being knocked unconscious.....	____	____	(59)
33.	Eye or vision trouble	____	____	(60)
34.	Attacks of temporary vision loss	____	____	(61)
35.	Blurred vision	____	____	(62)
36.	Pain in your eyes	____	____	(63)
37.	Difficulty in hearing	____	____	(64)
38.	Any constant draining or discharge from either ear, other than wax	____	____	(65)
39.	Ringing and buzzing in your ears	____	____	(66)
40.	Pain in your ears	____	____	(67)
41.	Pain in chest	____	____	(68)
42.	Have you ever noticed your heart beating abnormally or irregularly?.....	____	____	(69)
43.	Shortness of breath with only minor exertion .	____	____	(70)
44.	Waking up at night short of breath	____	____	(71)
45.	A desire to increase the number of pillows you sleep on	____	____	(72)
46.	Swelling of your legs	____	____	(2:1)
47.	Frequent leg cramps or pain after walking	____	____	(2)
48.	Hands or feet turning blue	____	____	(3)
49.	Repeated pain, pressure,or tightness of your chest	____	____	(4)
50.	A need to avoid certain foods	____	____	(5)
51.	Frequent bloating or swelling	____	____	(6)
52.	Taking milk or antacid for stomach aches	____	____	(7)
53.	Any pain or discomfort in your stomach in recent months	____	____	(8)
54.	Frequent diarrhea or constipation.....	____	____	(9)
55.	A need to take laxatives frequtly	____	____	(10)
56.	Any change in color or form in your stools in the past six months	____	____	(11)

		No 0	Yes 1	
57.	Being bothered by gassy stomach	____	____	(12)
58.	Pain or a burning sensation when you urinate.	____	____	(13)
59.	Urination four or more times a day	____	____	(14)
60.	Urination three or less times a day	____	____	(15)
61.	Smoky, cloudy, or bloody urine	____	____	(16)
62.	Passing a kidney stone	____	____	(17)
63.	Painful swelling or any other problems with the testicles or penis (male sex organs) -- male respondents only --	____	____	(18)
64.	Increased sensitivity to heat	____	____	(19)
65.	Increased sensitivity to cold	____	____	(20)
66.	Sexual desire less than you think it should be	____	____	(21)
67.	Trouble with your muscles like frequent cramps, pain,or swelling	____	____	(22)
68.	Pain in your muscles after only slight exertion	____	____	(23)
69.	Tremors, twitching, or incoordination of your muscles	____	____	(24)
70.	Lost sensation, numbness, or tingling feeling.	____	____	(25)
71.	"Shooting" pains in your arms or legs	____	____	(26)
72.	Decreased strength in your arms, forearms or hands	____	____	(27)
73.	Frequent or constant coughing	____	____	(28)
74.	Coughing up blood	____	____	(29)
75.	Wheezing or whistling sound when you breathe.	____	____	(30)
76.	Trouble sleeping	____	____	(31)
77.	Coldness of body parts	____	____	(32)
78.	Numbness of body parts	____	____	(33)
79.	Changes in walking speed or gait	____	____	(34)
80.	Fatigue while walking	____	____	(35)
81.	Loss of appetite	____	____	(36)
82.	Unusually large weight loss	____	____	(37)
83.	Rheumatism	____	____	(38)
84.	Arthritis	____	____	(39)
85.	Have you ever been hospitalized for a work-related illness or injury?	____	____	(40)
86.	Being depressed easily or having crying spells	____	____	(41)

		No 0	Yes 1	
87.	Having problems with severe anxiety	____	____	(42)
88.	Getting irritable easily	____	____	(43)
89.	Having emotional problems you would like to discuss with the doctor	____	____	(44)
90.	Frequently having unpleasant dreams	____	____	(45)
91.	Unpleasant odor resulting from chemicals in your present work environment	____	____	(46)
92.	Frequent nausea or vomiting	____	____	(47)

Check the appropriate column "No" or "Yes" regarding whether or not you have ever been told that you have the following signs.

		No 0	Yes 1	
93.	Color blindness	____	____	(48)
94.	Rheumatic fever	____	____	(49)
95.	Abnormal electrocardiogram (EKG)	____	____	(50)
96.	A heart murmur	____	____	(51)
97.	An enlarged heart	____	____	(52)

98.	High blood pressure	____	____	(53)
99.	A heart attack	____	____	(54)
100.	A blood clot in your heart	____	____	(55)
101.	Are you taking any medication for your heart or blood pressure?	____	____	(56)
102.	High level cholesterol or fats	____	____	(57)

103.	Ulcers or colitis	____	____	(58)
104.	A kidney infection	____	____	(59)
105.	Diabetes	____	____	(60)
106.	Asthma	____	____	(61)
107.	Bronchitis	____	____	(62)

108.	Pneumonia	____	____	(63)
109.	Emphysema	____	____	(64)
110.	Nerve disorders	____	____	(65)

111. On the average, how often do you have headaches off the job? (66)

a.	daily	____ 5
b.	every two days	____ 4
c.	twice a week	____ 3
d.	once a week	____ 2
e.	less often than once a week	____ 1

Check the items that describe the type of headache you have on the job. (Check all that apply.)

112.	I have no headaches	_____	1	(67)
113.	Located all over head	_____	1	(68)
114.	Located mainly in front of head	_____	1	(69)
115.	Located mainly in temples	_____	1	(70)
116.	Located mainly in eyes, face,or neck	_____	1	(71)
117.	Comes and goes	_____	1	(72)
118.	Constant	_____	1	(3:1)
119.	Throbbing	_____	1	(2)
120.	Pounding	_____	1	(3)

		No	Yes	
		0	1	
121.	Do you have any impaired or missing legs, arms, fingers, etc.?	____	____	(4)

If so, indicate the impaired or missing body part _____

_____.

122. Do you require any medical aids (e.g., eye glasses, pacemaker, artificial kidney, hearing aid, etc.)?
Yes_____ No _____ (5)
1 0
If so, describe _____

_____

123. Do you have any birth related defect or condition?
Yes_____ No_____ If so, describe _____ (6)
1 0

_____

V. SYMPTOMS

Indicate whether or not you have experienced any of the following symptoms. If your response is "Yes", check the column indicating whether these symptoms occur "during your workshift", or "occur at home", or "away from the job." Check both "Yes" columns if appropriate.

	0	Yes	
	No	1 During Workshift	1 Away From Job
124. Light-headedness	____	____ (7)	____ (8)
125. Dizziness	____	____ (9)	____ (10)
126. Nausea	____	____ (11)	____ (12)
127. Vomiting	____	____ (13)	____ (14)
128. Weakness	____	____ (15)	____ (16)
129. Loss of consciousness	____	____ (17)	____ (18)
130. Extreme drowsiness	____	____ (19)	____ (20)
131. Tired feelings	____	____ (21)	____ (22)
132. Headache	____	____ (23)	____ (24)
133. Irritability	____	____ (25)	____ (26)
134. Sleepiness	____	____ (27)	____ (28)
135. Change of mood	____	____ (29)	____ (30)
136. Memory impairment	____	____ (31)	____ (32)
137. Reduced concentration capacity	____	____ (33)	____ (34)
138. Depression	____	____ (35)	____ (36)
139. Aggressiveness	____	____ (37)	____ (38)
140. Outbursts of violence	____	____ (39)	____ (40)
141. Conflicts or arguments	____	____ (41)	____ (42)
142. Fainting	____	____ (43)	____ (44)

Did parents, brothers,or sisters suffer from:

		1 Yes	0 No	Don't Know
143.	Diabetes	___	___	___
144.	High blood pressure (46)	___	___	___
145.	Stroke (47)	___	___	___
146.	Nerve disorders (48)	___	___	___
147.	Anemia (49)	___	___	___
148.	Obesity (50)	___	___	___
149.	Heart disease (angina and/or heart attack) (51)	___	___	___
150.	Circulatory disorders, lower limbs (52)	___	___	___
151.	Liver ailments (like cirrhosis of the liver) (53)	___	___	___
152.	Arthritis (54)	___	___	___

How frequently have you taken the following drugs in the past 3 months? (This information will be regarded as strictly confidential). Check the appropriate column.

Frequently .....
Moderately .....
Infrequently .....
Not at all .....

		1	2	3	4	
153.	Dexedrine	___	___	___	___	(55)
154.	Benzedrine (or other amphetamines)	___	___	___	___	(56)
155.	Marijuana	___	___	___	___	(57)
156.	Sleeping pills (Sleepeze, Compoz, etc.)	___	___	___	___	(58)
157.	LSD	___	___	___	___	(59)
158.	"Speed"	___	___	___	___	(60)
159.	"Downers" (tuinal, redbirds, etc.)	___	___	___	___	(61)

OME No. 68-S75062
Approval Expires 7/31/76

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226

Solvent Behavioral Study

CONDUCTED BY: Westinghouse Behavioral/Safety Center
Columbia, Maryland

SPONSORED BY: National Institute for
Occupational Safety and Health

CONTRACT NO: HSM 99-73-35

PRE-TEST QUESTIONNAIRE

1. Did you get your normal amount of sleep last night?
   Yes___ No____

2. Do you have any injuries or temporary physical ailments?
   Yes___ No____
   If yes, specify. _____

   _____

3. Do you have any worries or personal problems which are bothering you today? (No further inquiries are to be made regarding this question.) Yes ___ No___

4. Have you drunk any alcohol in the last 24 hours? Yes ___ No___
   If yes, do you feel any effects now? Yes ___ No ___
   How many drinks? ____
   Approximately how long ago? _____

5. Have you taken any medication in the last 24 hours?
   (including aspirin or other non-prescription medicines)
   Yes ___ No ___
   If yes, what kind? _____
   If yes, do you feel any effects now? Yes ___ No ___
   What amount did you take? _____
   Approximately how long ago? _____

6. Do you use eyeglasses, a hearing aid, or other such devices?
   Yes (specify)_____ No _____
   If yes, do you have them/it with you today?_____

OME No. 68-S75062
Approval Expires 7/31/76

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226

Solvent Behavioral Study

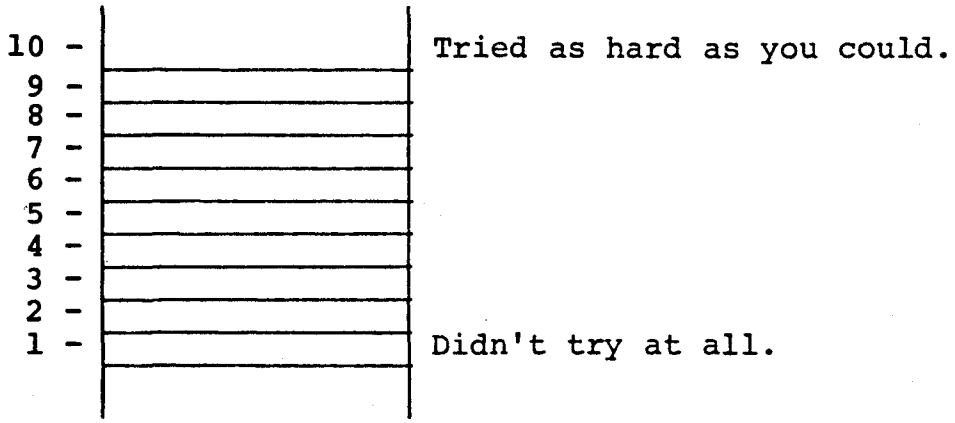
CONDUCTED BY: Westinghouse Behavioral/Safety Center
Columbia, Maryland

SPONSORED BY: National Institute for
Occupational Safety and Health

CONTRACT NO: HSM 99-73-35

POST-TEST QUESTIONNAIRE

1. Here is a ladder. Imagine that the top represents the hardest you could try and the bottom represents not trying at all. Where on the ladder would you be with regard to how hard you tried on these tests?



2. Do you have any further reactions to the testing procedure?

_____

_____

_____

_____

_____

_____

Appendix E

Protocols Used in the Neurological and Electrodiagnostic Examinations

Protocol for the Neurological Examination

1. Review and follow-up of Medical History Questionnaire.
2. Check for physical deformities.
3. Cardiovascular examination including:
   a. Peripheral circulation (pulse beat)
   b. Blood pressure
   c. Heart sounds
4. Percussion and auscultation of lungs.
5. Weber, Rinne' Tests of auditory functioning.
6. Otoscopic examination.
7. Throat examination.
8. Visual functioning.
   a. Visual acuity
   b. Perimeter measure
   c. Blind spot mapping

   > Using equipment supplied by Westinghouse

Specific neurological aspects of this medical examination include:

9. Opthalmalogic examination.
10. Mental status profile.
11. Other neurological signs, such as:
    a. Touch, pain, and temperature sensitivity in the extremities
    b. Deep tendon reflexes
    c. Muscle strength in both extensor and flexor groups
    d. Pyramidal and extra-pyramidal signs
    e. Coordination

Procedure Used for the Electrodiagnostic Examinations

Equipment

The equipment used was the Teca T-4 Electromyography System equipped with: (1) MS6 Basic Isolated Nerve Stimulator, (2) NT6 Advanced Isolated Nerve Stimulator, and (3) Direct Recording EMG (photo sensitive paper).

EMG Examination

The EMG examination was performed on a common wrist extensor and the anterior tibial muscle of the dominant side using a monopolar needle electrode. After evaluation of the insertional activity and the presence or absence of abnormal forms, the patient was asked to gradually contract the test muscle against manual resistance, noting abnormalities of the first recruited motor unit action potentials and the developing interference pattern. A record was made on maximum volition at various gains. (500 mu/cm, 1000 mc/cm, 2000 mu/cm.)

Nerve Conduction Studies

MCV, motor conduction velocity, was performed on the ulnar and peroneal (lateral popliteal) on the dominant side using surface electrodes.

Peroneal. The active electrode (different) was placed over the maximum muscle mass of the extensor digitorum brevis, the reference electrode (indifferent) 1 c.m. proximal to the base of the little toe dorsal aspect and the ground electrode over the mid dorsum of the foot. The nerve was stimulated at or 1 c.m. above the ankle and just above the medial to the fibula head with supramaximal rectangular pulse stimuli of 0.2 m.s. duration at 1 second stimulus intervals. The response was measured by Strobe unit. (Direct reading control coupled to electronic index or traces reads to nearest 0.1 m.s.) The distance was measured in centimeters between stimulus points by metal tape measure.

Ulnar. The active (different) electrode was placed over the estimated motor point at mid muscle belly of the abductor digiti quinti. (At times the point of maximum visual response to stimulus was determined for placement of active electrode). The reference electrode was placed at the base of the little finger (lateral palmar). The ground electro was placed over the hyperthenar eminence. The nerve was stimulated 1 c.m. proximal to the volar wrist crease slightly radial to the flexor carpi ulnaris tendon and 1 c.m. proximal to the medial epicondyle of the humerus.

A conduction study was performed on the ulnar nerve referred to as a conduction velocity of the slow fibers (CVSF) of the ulnar nerve developed by Seppalainen (1971) as a modification of the method first described by Hopf (1962). The technique is described by Seppalainen and Hernberg (1972). The active, reference, and ground electrode are placed as in description of MCV of the ulnar nerve. Stimuli are provided to the proximal and distal stimulus point. The proximal stimulus is sufficiently delayed to allow two successive muscle responses. The interval is then gradually shortened until the second response begins to decrease in amplitude. The delay time is measured by Strobe, 1 m.s. (the refractory period of the nerve fiber or amount determined by refractory study) is subtracted. The conduction time is then calculated by dividing the distance by the resultant.

A visual evaluation of the refractory period was performed. Templates were not prepared. The refractory period of 0.8, or 1.2 were used instead of 1 m.s. when very obvious residual alterations could be seen in the display of evoked potentials on approximation of paired stimuli.

Nerve conduction velocity is known to vary with neuromuscular temperature. The relationship is direct with a change of about 2.4 m.s. for every degree centigrade change in temperature. This factor should be considered when a moderately slow NCV is found. Notations were made for the last fifty cases examined regarding any temperature alterations distally in the lower extremities.

The results of both the EMG and Nerve Conduction Studies were recorded on the form shown in Figure 15.

Name ID.# AGE: SEX M F

DATE:

TIME: AM PM	RIGHT	LEFT
NERVE CONDUCTION STUDIES		
Ulnar Nerve Motor		
Proximal motor latency		
Distal Motor latency (4 msec.)		
Distance		
MNCV (50-65 m/sec.)		
Ulnar Nerve Slow Fiber		
Delay		
Refractory Period		
Resultant		
Distance		
C. V. (40-45 ms)		
PERONEAL NERVE MOTOR		
Proximal motor latency		
Distal motor latency		
Distance cm		
MNCV (40-60 m/s)		

ELECTROMYOGRAPHY: Monopolar

Rt.	Lt.	Anterior Tib.	Ext. Communis

Figure 15 Form used to record results of electrodiagnostic examinations.

Appendix F

Rating Forms Used to Summarize

Neurological and Electrodiagnostic Examinations

Rating Scale for Symptoms and Neurological Examination

Patient's Name _____ Exam Date _____

		Score
I. Symptoms		
None relevant to polyneuropathy	_____ (0)	
Symptoms possibly relevant but variable or uncertain	_____ (1)	
Symptoms characteristic of polyneuropathy	_____ (2)	
Highly indicative and specific symptoms	_____ (3)	
	Total Symptoms	
Please check the most appropriate blank under each major heading.		
II. Neurological Examination		
1. Fasciculations	____ No(0) ___(Yes)(1)	
2. Muscle strength (check one)		
Normal	_____ (0)	
Grade 4 strength, one muscle group	_____ (1)	
Grade 4 strength, multiple or bilateral	_____ (2)	
Grade 3 strength, one muscle group	_____ (3)	
Grade 3 strength, multiple or bilateral	_____ (4)	
Grade 2 strength or less	_____ (5)	
3. Reflexes (check one)		
Normal	_____ (0)	
One reflex diminished, unilateral or bilateral	_____ (1)	
One reflex lost, bilateral	_____ (3)	
Multiple reflexes lost	_____ (5)	
4. Sensory Exam		
a. Vibration Sense (check one)		
Normal	_____ (0)	
Vibration diminished, one area bilateral	_____ (1)	
Vibration diminished, two limbs bilateral	_____ (2)	
Vibration lost, one or more areas bilateral	_____ (3)	

		Score
b. Position Sense (check one)		
Normal	_____ (0)	
Position sense decreased, one area bilateral	_____ (1)	
Position sense decreased, two limbs bilateral	_____ (2)	
Position sense lost, bilateral	_____ (3)	
c. Other Sensory (check one)		
Normal	_____ (0)	
Impairment of pin, touch, temperature, or two point discrimination, one limb or one neurological distribution	_____ (2)	
Impairment of pin, touch, temperature, or two point discrimination, bilateral or multiple	_____ (3)	
5. Motor Exam		
Normal	_____ (0)	
Atrophy, bilateral or multiple	_____ (4)	
Total Neurological Exam		

Rating Scale for Electrodiagnostic Studies

Patient's Name _____ Exam Date _____

			Score
1. Positive Waves			
None	_____	(0)	
Positive Waves (1 + or more) in one or more muscles	_____	(1)	
2. Fasciculations			
None	_____	(0)	
Fasciculations (1 + or more) in one or more muscles	_____	(1)	
3. Fibrillations			
None	_____	(0)	
Fibrillations (1 + or more)	_____	(2)	
4. Abnormal Motor Unit Potentials			
None	_____	(0)	
Abnormal motor unit potentials (MUP's) or decreased number of potentials	_____	(3)	
5. Multiple Muscle Involvement			
None	_____	(0)	
Multiple muscle involvement with abnormalities other than positive waves	_____	(2)	
6. C. V./Latencies			
Normal C. V. and latencies	_____	(0)	
Borderline distal latency or conduction velocity	_____	(3)	
Increase in distal latency	_____	(4)	
Decrease in conduction velocity	_____	(5)	
Total Electrodiagnostic Score			

Appendix G

Description of Procedures Used in Behavioral Testing

Description of Procedures Used in Behavioral Testing

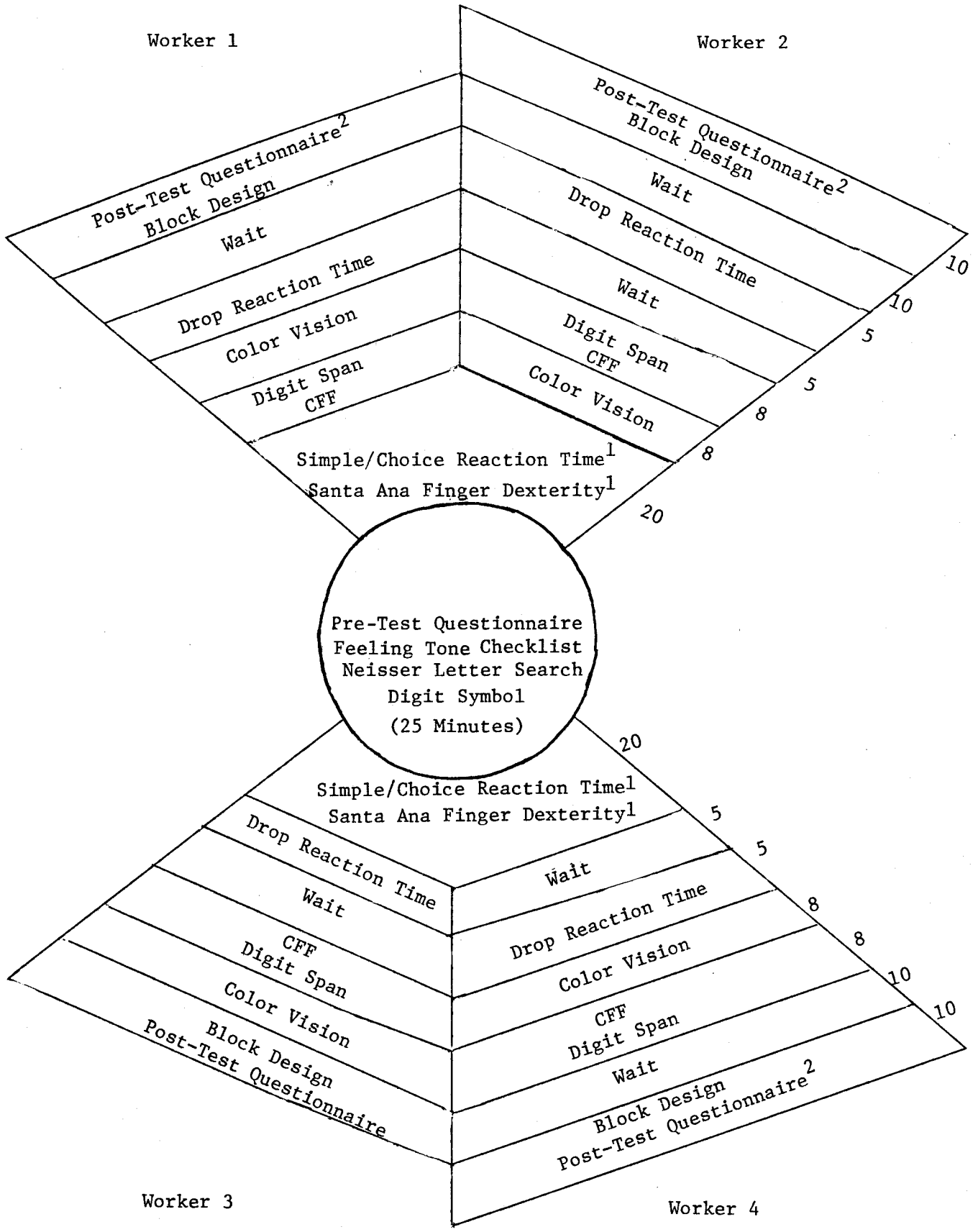
Workers were scheduled for behavioral testing during one of six two-day testing periods. The actual scheduling of subjects was carried out by either union or management personnel. Every effort was made to schedule participants at a time convenient to their normal schedule, although for all participants, other than management personnel, testing was done on the individual's own time. Individuals were not paid for participation.

Testing Procedure. Upon entering the testing facility (union hall or plant conference room), the participant was greeted by one of the researchers. He was asked to have a seat and complete a pretest questionnaire, until all participants for that session had arrived. Normally there were four participants per testing session. After all participants had arrived, an opportunity was given for anyone to ask questions concerning the purposes and procedures of the project. The most frequently asked question dealt with procedures by which participants would be notified as to the results of the study.

Once all questions were answered, the testing began. The total time required was about 90 minutes. Figure 16 depicts the usual sequence of testing when four persons were being tested. The initial period (25 minutes) was spent with those items listed in the center of Figure 16 . These were group administered by a single test administrator. After this initial group phase, two tests were administered which could be administered two at a time. For example, Administrator A would give the Santa Ana to Workers 1 and 2 while Administrator B would give the Simple and Choice Reaction time test to Workers 3 and 4. Then Administrator B would give the Santa Ana to Workers 3 and 4 while Administrator A gave the reaction time tests to Workers 1 and 2. Following this pairwise administration, the remaining tests were all individually administered. While one worker in a pair was being tested, the other would wait. Waiting time was reasonably short and this did not present any problems in terms of reactions of participants.

The test scores for each participant were recorded on the answer sheet shown in Figure 17 .

Instructions for administering individual tests are presented in the following pages.



[1]Tests that were administered to two workers at a time.

[2]Post-test Questionnaire was self-administered and required approximately two minutes to complete.

Figure 16 Format of Testing Sessions

TOXICOLOGY
RECORD FORM

NAME _____
DATE _____

Tested:
before work ☐ after work ☐
day off ☐ time _____

RT	RTc	RTn	SAr	SAl	SAb	N	Dsp	Dsy	CFFd	CFFa	BD	FTC pre	FTC post

TESTING ORDER

Reaction Time _____ Random Order

Trial	Choice	Color 4	Color 3	Color 2	Color 1	Trial
1						1
2						2
3						3
4						4
5						5
6						6
7						7
8						8
9						9
10						10
11						11
12						12
13						13
14						14
15						15
16						16
17						17
18						18
19						19
20						20

Critical Flicker Fusion	D	A
Trial 1		
Trial 2		
Trial 3		

Santa Ana	Trials 1	Trials 2
Right		
Left		
Both		

Reaction Time	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Figure 17 Toxicology Record Form

Instructions for Feeling Tone Checklist

Hand the Feeling Tone Checklist to the subject and say:

> This questionnaire is called the Feeling Tone Checklist. Look at the instructions while I read them aloud.
>
> Below are listed ten statements that might be used by a person to describe how he feels. Read each of the statements and indicate in the space provided whether you feel Better Than, the Same As, or Worse Than the statement.
>
> As an example, assume that at the present time you feel "a little tired." You might answer the items below as follows: Worse than extremely fresh, the same as slightly tired, but better than completely exhausted.
>
> Now, in the space provided below, indicate whether at this moment you feel better than, the same as, or worse than each of the statements, by putting an X in the proper column.

Instructions for Reaction Time Test

Have the S sit in the chair before the reaction time apparatus. Give the following instructions.

> This test is used to determine how quickly you can respond to a light signal. This is what you are to do. Rest the index finger of your preferred hand on the ready key in front of you. When you see a light come on, press the button under that light and return your finger to the ready key.
>
> I will always alert you before the light comes on by saying "Ready." Any questions?

Answer any questions the S may have. Make sure the S's finger is resting on the ready key. Set the indicator on "Green."

> First, we will make some trials using only the green light. Remember, try to react as quickly as you can. Ready!

Pause from 2 to 8 seconds and then activate the control switch. Record the time. Return the timer to "0." Repeat for a total of 6 trials. Now turn the indicator to "white."

> Now we will try only the white light. Remember, try to react as quickly as you can. Ready!

Proceed as above, for a total of 6 trials. Then do the same for the red and blue light. Always be sure to set the indicator on the appropriate color and return the timer to "0" after each trial.

> Now we are going to do some more trials, only I will not tell you which color is going to come on. However, I will still alert you as to when to look for a light by saying, "Ready." Any questions?

Again, answer any questions the subject may have. Check to see that the S's finger is resting on the ready key.

> Remember, try to react as quickly as you can. Ready!

Make 20 trials varying the order of colors as follows. Record the time after each trial.

Random Order 1

1 white	6 white	11 blue	16 white
2 blue	7 blue	12 red	17 green
3 white	8 green	13 white	18 green
4 red	9 green	14 red	19 red
5 blue	10 red	15 green	20 blue

Random Order 2

1 red	6 green	11 green	16 green
2 white	7 green	12 green	17 blue
3 blue	8 blue	13 white	18 red
4 red	9 red	14 blue	19 white
5 red	10 blue	15 white	20 white

Random Order 3

1 red	6 green	11 blue	16 white
2 green	7 green	12 red	17 green
3 white	8 red	13 white	18 blue
4 blue	9 red	14 white	19 blue
5 green	10 red	15 blue	20 white

Random Order 4

1 red	6 white	11 white	16 green
2 red	7 green	12 red	17 red
3 blue	8 blue	13 white	18 white
4 green	9 red	14 blue	19 blue
5 green	10 green	15 white	20 blue

Random Order 5

1 blue	6 white	11 red	16 green
2 red	7 blue	12 white	17 red
3 blue	8 green	13 red	18 blue
4 red	9 white	14 green	19 white
5 white	10 blue	15 green	20 green

Instructions for the Drop Reaction Time

Attach the reaction time device to any vertical surface with the "start" indicator slightly above eye level (approximately 44 inches above the floor). Seat the S before the device.

> This is a simple reaction time test to determine how quickly you can react to a visual signal. Place your preferred hand, palm flat, here with the large joint in your thumb on this thumb rest.

Assist the S in placing thumb properly if necessary. Do not allow the thumb to actually touch the ruler.

> When I drop this plastic ruler, you will stop it by placing your thumb against it as soon as you see it begin to fall. I will always alert you as to when I will drop the ruler by saying "Ready". Sometime after that, I will drop the ruler and you should press your thumb against it, to stop it as quickly as possible. We will repeat this several times. If you become tired, let me know and we'll rest. Any questions?

Answer any questions the subject may have.

> Ready!

Pause from 2 to 8 seconds before releasing the ruler. Record S's time on the record form. Run a total of twenty trials, disallowing any trials where the S reacts prematurely, allows the ruler to drop to the floor, or slows the fall of the ruler by allowing the thumb to touch it.

Have the S sit in a chair before the Santa Ana Board. The board should be on a table of normal height. Give the following instructions.

> The purpose of this test is to measure how rapidly you can rotate the pegs in this board. Your task is to turn the pegs like this.

Demonstrate the task by turning the first four pegs 180°.

> The peg must always be raised a little from the hole, because the lower part of the peg is square. You can try it by turning back the pegs that I have turned.
>
> Now, using your right hand, start in the upper left hand corner. Work across the top row, then drop down to the next row and move back across from right to left, and so on. Continue until I tell you to stop. Try to work as fast as possible since speed is important. If you drop a peg, let it be and continue with the task. Any questions?

Answer any questions the S may have, making sure he understands what he is to do.

> Begin now!

Begin the stopwatch. Allow 30 seconds for each trial. If there is a break in performance due to some general disturbance (falling of pegs, etc.) make another trial. If the S makes casual errors (i.e., turning a peg 45° or 360° instead of 180°) let it be, but if he systematically turns the pegs wrong, show him once more how to do the task and allow another trial. If the S tries to correct casual errors, tell him to let it be and continue.

After 30 seconds say:

> Stop!

Count the number of pegs correctly turned and enter this number on the record form. Return each peg to its original position.

> Now you are to do the same thing, only with your left hand. This time begin in the lower left corner. Work across the row; move up to the next row and work back to the left, and so on. Continue until I tell you to stop. Try to work as fast as possible, since speed is important. If you drop a peg, let it be and continue with the task. Any questions?

Answer any questions the S may have, making sure he understands what he is to do.

> Begin now!

Follow the same procedure as above. After 30 seconds say:

> Stop!

Count the number of pegs correctly turned and enter this number on the record form. Return each peg to its original position.

> Now once more with the right hand.

Proceed as before.

> And now with the left again.

Proceed as before.

> Now I am going to put the board in a new position because you are to turn the pegs with both hands simultaneously, like this.

Place the board in the new position where the S is looking down the length of the board. Stand at the end of the board and demonstrate the task by turning the first three pairs of pegs in the outer row. Then have the S take your place at the board.

> You can try it by turning these pegs back to the original positions.
>
> Start with the outer rows and work upwards and continue back down with the pegs in the inner rows until I tell you to stop. Try to work as fast as possible since speed is important. If you drop a peg, let it be and continue with the task. Any questions?

Answer any questions the S may have, making sure he understands what he is to do.

> You may begin now.

Allow 30 seconds, then say:

> Stop!

Count the number of pegs turned correctly and record this number in the record book.

Instructions for the Neisser Letter Search

Present the Neisser booklet to the subject. Do not allow him to open the booklet until you instruct him to do so.

> In this booklet you will see columns of groups of five letters. For this task, I want you to look for a letter that I tell you. For example, if you are told to look for the letter A, put a check next to each group that contains an A.

Demonstrate this task on sample page of booklet.

> Work down the columns as quickly as you can, without missing any target. You will have 20 seconds to search for as many targets as you can. When I say "stop", draw a line under the last item you looked at, not the last item you checked. Any questions? The target for this first trial is the letter D (M). Ready. Begin.

Begin the stopwatch. Allow 20 seconds for the trial.

> STOP!

Allow a 30 second rest period between trials.

> Now, when I say begin, turn to the next page and follow the same procedure. Only this time you will be looking for a different letter which I will tell you in a moment. Any questions? The target for this trial is M (D). Ready. Begin.

Begin the stopwatch. Allow 20 seconds.

This time, you will be looking for 2(4) different letters. Put a check next to each item that has a B or an F (P or Q; C, R, G, or Z; H, V, J, or T). No 2(4) target letters will occur in the same line. Again, work down the columns, checking each item for all targets before moving to the next item. Any questions? Ready. Turn to the next page and begin.

Follow this procedure for each of the 2-target letter trials and each of the 4-target letter trials. Allow 30 seconds for each trial and 30 seconds between trials. Be sure the subject knows which letter he is looking for and that he begins each test on a new page.

Scoring: An item is incorrect if a target was missed or an item was incorrectly checked.

Convert number correct into a time per item measure.

Instructions for Digit Span (WAIS)

Digits Forward

Start with the Trial 1 of Series 3 for all subjects.

> I am going to say some numbers. Listen carefully, and when I am through, say them right after me.

In any series, if the subject repeats Trial I correctly, proceed to the next higher series. If the subject fails Trial I, give Trial II of the same series, then proceed to the next series if he passes. The second trial of a series is given only if the first trial is failed. Discontinue after failure on both trials of a given series.

Series	Trial I	Trial II
(3)	5-8-2	6-9-4
(4)	6-4-3-9	7-2-8-6
(5)	4-2-7-3-1	7-5-8-3-6
(6)	6-1-9-4-7-3	3-9-2-4-8-7
(7)	5-9-1-7-4-2-8	4-1-7-9-3-8-6
(8)	5-8-1-9-2-6-4-7	3-8-2-9-5-1-7-4
(9)	2-7-5-8-6-2-5-8-4	7-1-3-9-4-2-5-6-8

Scoring : The score is the number of digits in the longest series repeated without error in Trial I or II.

Maximum score: 9

Digits Backward

> Now I am going to say some more numbers, but this time when I stop I want you to say them backwards. For example, if I say "7-1-9" what would you say?

If the subject responds correctly, say "Here are some others" and proceed with the test beginning with Trial I of the 3-digit Series.

If the subject does not reply correctly or fails to understand, give the right answer and another example, saying "Remember you are to say them backwards: 3-4-8." If the subject succeeds this time, proceed with the test using Trial I of the 3-digit Series. However, if he fails the second example, proceed with the test by giving Trial I of the 2-digit Series. If a subject passes an example but fails both trials of the 3-digit Series, go back and give the 2-digit Series, then discontinue the test. Discontinue after failure on both trials of a given series.

Series	Trial I	Trial II
(2)	2-4	5-8
(3)	6-2-9	4-1-5
(4)	3-2-7-9	4-9-6-8
(5)	1-5-2-8-6	6-1-8-4-3
(6)	5-3-9-4-1-8	7-2-4-8-5-6
(7)	8-1-2-9-3-6-5	4-7-3-9-1-2-8
(8)	9-4-3-7-6-2-5-8	7-2-8-1-9-6-5

Scoring: The score is the number of digits in the longest series repeated backwards without error in Trial I or II.

Maximum score: 8

Total Score for the Digit Span Test: Sum of scores on Digits Forward and Digits Backward.

Maximum score: 17

Place the test before the S and, pointing to the key and samples as appropriate, say:

> Look at these boxes. Notice that each has a number in the upper part and a mark in the lower part. Every number has a different mark. Now look here where the upper boxes have numbers but the squares beneath have no marks. You are to put in each of these squares the mark that should go there, like this. Here is a 2, so you would put in this mark. Here is a 1, so you put in this mark. Here is a 3, so you put in this mark.

Write in the first three symbols as demonstration, then provide subject with a pencil and have him complete the seven remaining items of the sample. Point to the line separating the samples from the test proper and say:

> Now you do it for these numbers as far as this line.

If subject does not grasp the task, help him with more items until the ten sample items have been completed. After the demonstration and practice, point to the first square following the samples and say:

> Now, when I tell you to begin, start here and fill in as many squares as you can without skipping any. Ready, begin!

Allow 90 seconds. Start timing when the S is told to begin. If a subject starts to omit squares or to do only one type of figure, say "Do them in order and don't skip any."

Instructions for Critical Flicker Fusion

Seat the S in the chair before the Critical Flicker Fusion apparatus. Give the following instructions.

> This test is used to determine at what point you can detect when a steady light source begins to flicker. This is what you are to do. Place your left hand on the large black dial to your left. Now, put your eyes to the viewer in front of you. You should see an illuminated spot. Now rotate the dial. What do you see? (S should see steady dot and flickering dot as he turns back and forth.) Now I am going to return the dial to zero. Now, (slowly) turn the dial until the light begins to flicker or shimmer. At the point at which the light begins to flicker, remove your hand from the dial, but keep your eyes to the viewer.

Record the "hertzs" indicated on the dial. Return the dial to the upper limit.

> Now do it again.

Return the "hertzs" indicated and return the dial to the upper limit.

> And now, again.

Now, let the S rest for a moment. Set the dial at the low end of the scale.

> Now, place your hand on the dial once again and put your eyes to the viewer. You should see the illuminated spot once again and it should be flickering. (Slowly) Turn the dial until the light stops flickering. At the point at which the light stops flickering, remove your hand from the dial, but keep your eyes to the viewer.

Record the "hertzs" indicated on the dial. Return the dial to the lower limit.

Now, do it again.

Record the "hertzs" indicated and return the dial to the lower limit.

And now, again.

Directions for Block Design (WAIS)

Start with Design 1 for all Ss. Take four blocks and say:

> You see these blocks. They are all alike. On some sides they are all red; on some, all white; and on some, half red and half white.
>
> I am going to put them together to make a design. Watch me.

Arrange the four blocks slowly into the design shown on Card 1, without exposing Card 1 to the subject. Then, leaving the model intact, give four other blocks to the subject and say:

> Now, make one just like this.

Occasionally, a subject will try to duplicate the examiner's model exactly, including the sides. When this occurs on Design 1, tell the subject that only the top needs to be duplicated. If the subject successfully completes the design within the time limit, score 4 points and proceed to Design 2.

If the subject fails to complete the design within the time limit or arranges the blocks incorrectly, pick up his blocks, leaving the examiner's model intact, and say "Watch me again."

Demonstrate a second time using subject's blocks, then mix them up, still leaving the examiner's model intact, and say:

> Now, you try it and be sure to make it just like mine.

Whether subject succeeds or fails on this trial, proceed to Design 2.

Now, remove the blocks that served as model for Design 1 and put in their place the card marked "2".

> This time we are going to put the blocks together to make them look like this picture. Watch me first.

Construct the design slowly, giving the subject the opportunity to see that it duplicates the design on Card 2. Then mix up the blocks used in the demonstration and place them before the subject.

> Now look at the picture and make one just like it with these blocks. Go ahead and tell me when you have finished.

If the subject is successful on this trial, proceed to Design 3. If he fails, demonstrate a second time, saying "Watch me again." After making the design, mix up the blocks and say "Now try it." Whether or not the subject succeeds on the second trial, proceed to Design 3.

Place the card for Design 3 before the subject and provide him with four blocks.

> Now make one like this. Tell me when you have finished.

When the subject indicates he has finished or at the end of the time limit, mix up his blocks and present Design 4.

> Now make one like this. Go ahead; let me know when you have finished.

Follow this procedure for all succeeding designs. When Design 7 is reached, take out the five other blocks.

> Now make one like this, using nine blocks. Be sure to tell me when you have finished.

Proceed with Designs 8, 9, and 10. For Design 10, do not permit the subject to rotate the card to give the design a flat base. However, give full credit if his reproduction of the design is rotated not more than 45°.

Time Limits

Designs 1-2	60 seconds (Time each trial separately)
Designs 3-6	60 seconds
Designs 7-10	120 seconds

Record time taken for the subject to complete each design if it is done correctly within the time limit; bonuses are given for rapid performances on Designs 7-10.

Discontinue

After 3 consecutive failures. Failure on both trials of either Design 1 or Design 2 is considered one failure.

Scoring

Designs 1-2: first trial, 4 points each; second trial, 2 points each
Designs 3-6: 4 points each.
Designs 7-10: 4 points for successful completion of each design; see table below for scores with time bonuses included. Scores are based on correct solutions within the time limit. No credit is given for partially correct or incomplete designs.

Maximum score: 48

Scores for Designs 7-10 with Time Bonuses Included

Design	Points with Time Bonus		
	4	5	6
7	41"-120"	31"-40"	1"-30"
8	71"-120"	46"-70"	1"-45"
9	81"-120"	61"-80"	1"-60"
10	81"-120"	61"-80"	1"-60"

Instructions for Farnsworth Dichotomous

Test of Color Blindness

Prior to administration of the test, the color caps No. 1-No. 15 should be arranged in a row in random order in the top rack. Take care that the worker does not see the numbers on the bottom of the color caps. Place the case so that the inclined tray is nearest the worker and the fixed (or reference cap) is at his left. Then say:

> The object of the test is to arrange the color caps in order according to color. Take the cap from this panel (indicate) which looks most like this cap (point to the reference cap) and place it here (indicate the space next to the reference cap). Then take the cap which looks most like the one you moved and place it next in line, and the cap that is most like that and place it third in line and so on. Continue doing this until all caps are arranged in order.

If the worker does not seem to understand the instructions, then repeat them. After each colored cap is placed, it may be necessary to say:

> Now, which of these buttons (indicate) is most like the last one (indicate)?

Individuals should be given as much time as needed to complete the task. If an individual rushes through the test he should be given a chance to review the sorting to be sure that they are "all in order." Most people will complete the test in 1-2 minutes.

To score the test close the cover, turn the can over and then reopen it. Record the scoring numbers on the bottom of each cap in order starting with the reference cap.

Interpretation of the results should be done by referring to the test manual. If all caps are in sequential order, the score is "Pass." If there are deviations from this order,the response pattern should be plotted on the standard answer sheet to determine if the errors are consequential.

Appendix H

Medical History Data by Sample Subgroup

TABLE 33

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.		Carpenter			Union			Management			X^2
		N	M	S.D.	N	M	S.D.	N	M	S.D.	$p < .05$
21.	Use of alcohol	13	.77	0.44	74	.82	0.38	21	.85	0.35	-
22.	No. beers per day	8	1.50	0.76	63	1.66	0.93	18	1.55	0.51	-
23.	No. glasses wine per day	8	1.00	0.00	63	1.06	0.39	18	1.22	0.42	-
24.	No. cocktails per day	8	1.13	0.35	62	1.16	0.41	18	1.50	0.70	-
25.	Age started drinking	7	18.71	1.25	57	18.64	4.29	18	20.38	4.64	-
26.	Freq. of pre-work drinking	8	1.00	0.00	63	1.30	0.61	18	1.00	0.00	-
27.	Freq. of drinking during day	8	1.00	0.00	63	1.33	0.71	18	1.11	0.32	-
28.	Freq. post-work drinking	8	1.75	1.38	63	1.77	1.09	18	2.05	1.10	-
29.	Change in drinking pattern	6	4.00	1.26	58	4.15	1.13	18	3.94	0.93	-
30.	Drinking alone	6	3.16	1.16	58	2.00	1.18	17	2.88	1.05	-
31.	Treated for alcohol illness	8	0.00	0.00	63	0.03	0.17	18	0.00	0.00	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 * ($p < .05$)
32.	Being knocked unconscious	13	38	73	28	21	28	-
33.	Eye or vision trouble	13	46	75	58	21	42	-
34.	Attacks of temporary vision loss	13	07	72	13	21	0	-
35.	Blurred vision	13	15	73	53	21	09	*
36.	Pain in your eyes	13	15	73	56	21	04	*
37.	Difficulty in hearing	12	16	74	41	21	33	-
38.	Any constant draining or discharge from either ear, other than wax	13	0	72	05	21	09	-
39.	Ringing and buzzing in your ears	13	07	72	54	21	19	*
40.	Pain in your ears	13	0	72	22	21	28	-
41.	Pain in chest	13	07	73	67	21	19	*
42.	Have you ever noticed your heart beating abnormally or irregularly?	13	30	74	51	21	19	*
43.	Shortness of breath with only minor exertion	13	15	74	58	21	23	*
44.	Waking up at night short of breath	13	0	72	22	21	0	*
45.	A desire to increase the number of pillows you sleep on	13	07	73	36	21	09	*
46.	Swelling of your legs	13	15	73	24	21	04	-
47.	Frequent leg cramps or pain after walking	13	07	74	37	21	28	-
48.	Hands or feet turning blue	13	07	72	05	21	0	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 * ($p < .05$)
49.	Repeated pain, pressure, or tightness of your chest	13	0	73	39	21	04	*
50.	A need to avoid certain foods	13	30	74	35	21	19	-
51.	Frequent bloating or swelling	13	15	73	20	21	09	-
52.	Taking milk or antacid for stomach aches	13	30	73	41	21	33	-
53.	Any pain or discomfort in your stomach in recent months	13	30	72	52	21	14	*
54.	Frequent diarrhea or constipation	13	07	73	30	21	04	-
55.	A need to take laxatives frequently	13	0	70	14	21	0	-
56.	Any change in color or form in your stools in the past six months	13	0	71	14	21	0	-
57.	Being bothered by gassy stomach	13	38	73	64	21	42	*
58.	Pain or a burning sensation when you urinate	13	07	73	36	21	19	-
59.	Urination four or more times a day	13	76	73	78	21	95	-
60.	Urination three or less times a day	09	33	63	25	19	10	-
61.	Smoky, cloudy, or bloody urine	13	07	72	34	21	14	-
62.	Passing a kidney stone	13	0	73	12	21	04	-
63.	Painful swelling or any other problems with the testicles or penis (male sex organs) -male respondents only-	13	23	73	20	21	0	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 *(p < .05)
64.	Increased sensitivity to heat	11	09	72	26	21	14	-
65.	Increased sensitivity to cold	11	27	71	46	21	0	-
66.	Sexual desire less than you think it should be	13	07	73	34	21	14	-
67.	Trouble with your muscles like frequent cramps, pain, or swelling	13	07	73	32	21	14	-
68.	Pain in your muscles after only slight exertion	13	07	74	29	21	0	*
69.	Tremors, twitching, or incoordination of your muscles	13	15	74	33	21	14	-
70.	Lost sensation, numbness, or tingling feeling	13	07	72	40	21	23	-
71.	"Shooting" pains in your arms or legs	13	07	73	39	21	19	-
72.	Decreased strength in your arms, forearms, or hands	13	15	73	41	21	14	-
73.	Frequent or constant coughing	13	15	73	38	21	23	-
74.	Coughing up blood	13	0	73	01	21	0	-
75.	Wheezing or whistling sound when you breathe	13	15	73	36	21	09	-
76.	Trouble sleeping	13	15	71	50	21	19	*
77.	Coldness of body parts	13	23	73	30	21	14	-
78.	Numbness of body parts	13	15	72	37	21	19	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 * ($p < .05$)
79.	Changes in walking speed or gait	13	15	72	27	21	14	-
80.	Fatigue while walking	13	07	73	36	20	25	-
81.	Loss of appetite	13	0	73	28	21	04	-
82.	Unusually large weight loss	13	0	72	09	21	0	-
83.	Rheumatism	13	15	70	10	20	0	-
84.	Arthritis	13	23	70	22	21	19	-
85.	Have you ever been hospitalized for a work-related illness or injury?	13	23	73	27	20	15	-
86.	Being depressed easily or having crying spells	13	0	73	32	21	0	*
87.	Having problems with severe anxiety	13	07	73	24	21	14	-
88.	Getting irritable easily	13	0	74	55	20	20	*
89.	Having emotional problems you would like to discuss with the doctor	13	07	73	13	21	0	-
90.	Frequently having unpleasant dreams	13	07	73	23	21	0	-
91.	Unpleasant odor resulting from chemicals in your present work environment	13	0	72	69	21	28	*
92.	Frequent nausea or vomiting	13	0	73	17	0	0	-
93.	Color blindness	13	0	73	08	21	0	-
94.	Rheumatic fever	13	0	73	0	21	04	-
95.	Abnormal electrocardiogram (EKG)	13	15	71	11	20	05	-
96.	A heart murmur	13	07	74	12	21	0	-
97.	An enlarged heart	13	07	70	01	21	04	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 *(p < .05)
98.	High blood pressure	13	15	73	27	21	14	-
99.	A heart attack	13	0	74	04	21	0	
100.	A blood clot in your heart	13	0	73	0	21	0	-
101.	Are you taking any medication for your heart or blood pressure?	13	23	74	12	21	09	-
102.	High level cholesterol or fats	13	0	71	07	21	09	-
103.	Ulcers or colitis	13	15	70	21	21	19	-
104.	A kidney infection	13	23	72	22	21	14	-
105.	Diabetes	13	0	72	0	21	04	-
106.	Asthma	13	0	72	06	21	04	-
107.	Bronchitis	13	0	72	15	21	0	-
108.	Pneumonia	13	0	74	20	21	09	-
109.	Emphysema	13	0	73	05	21	0	-
110.	Nerve Disorders	13	30	73	39	20	05	*
111.	Frequency of headaches off the job	13	1.84[1]	74	1.97[1]	21	1.14[1]	-
	Check the items that describe the type of headache you have on the job.							
112.	No headaches	13	38	74	18	21	28	*
113.	Located all over head	13	15	74	14	21	04	-
114.	Located mainly in front of head	13	23	74	42	21	38	-

[1] Mean of rating on frequency scale.

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item		Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 *(p < .05)
115.	Located mainly in temples		13	07	74	29	21	19	-
116.	Located mainly in eyes, face,or neck		13	0	74	28	21	28	-
117.	Comes and goes		13	30	74	24	21	23	-
118.	Constant		13	23	74	13	21	14	-
119.	Throbbing		13	0	74	40	21	04	*
120.	Pounding		13	0	74	09	21	0	-
121.	Do you have any impaired or missing legs, arms, fingers, etc.?		13	0	74	09	21	09	-
122.	Do you require any medical aids (e.g., eye glasses, pacemaker, artificial kidney, hearing aid, etc.)?		13	53	73	47	21	61	-
123.	Do you have any birth related defect or condition?		13	0	74	04	21	09	-
124.	Light-headedness	a[1]	13	23	74	44	21	19	-
		b[2]	13	23	71	32	21	23	-
125.	Dizziness	a	13	23	73	35	21	14	-
		b	13	30	68	27	21	19	-
126.	Nausea	a	13	23	71	25	21	14	-
		b	13	23	72	19	21	19	-
127.	Vomiting	a	13	23	69	08	21	09	-
		b	13	23	70	11	21	09	-

[1] During work

[2] Away from job

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item		Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 *($p < .05$)
128.	Weakness	a[1]	12	08	73	46	21	23	*
		b[2]	12	08	70	30	21	09	-
129.	Loss of consciouseness	a	12	08	73	06	21	0	-
		b	12	08	73	02	21	0	-
130.	Extreme drowsiness	a	12	08	72	23	21	14	-
		b	12	08	66	18	21	09	-
131.	Tired feelings	a	12	08	73	64	21	42	*
		b	12	08	68	55	21	38	-
132.	Headache	a	13	38	73	61	21	42	*
		b	13	46	71	52	21	52	-
133.	Irritability	a	12	16	74	44	20	35	-
		b	12	16	73	43	20	35	-
134.	Sleepiness	a	12	08	73	43	21	19	-
		b	12	16	70	42	21	28	-
135.	Change of mood	a	12	08	73	45	21	28	-
		b	12	08	71	43	21	23	-
136.	Memory impairment	a	12	08	74	33	21	19	-
		b	12	08	72	26	21	19	-
137.	Reduced concentration	a	12	08	72	37	21	23	-
		b	12	08	70	34	21	23	-
138.	Depression	a	12	08	73	39	21	09	*
		b	12	16	70	37	21	09	-
139.	Aggressiveness	a	12	08	74	16	20	25	-
		b	12	08	74	16	20	15	-
140.	Outbursts of violence	a	12	08	74	09	21	04	-
		b	12	08	73	15	21	04	-
141.	Conflicts or arguments	a	12	08	74	27	21	38	-
		b	12	08	74	29	21	19	-
142.	Fainting	a	12	08	73	04	21	0	-
		b	12	08	73	02	21	0	-

[1] During work

[2] Away from job

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters %	Union N	Union %	Management N	Management %	X^2 *($p < .05$)
	Did parents, brothers, or sisters suffer from:							
143.	Diabetes	12	08	71	28	20	20	-
144.	High blood pressure	11	45	71	54	16	56	-
145.	Stroke	12	16	70	27	21	14	-
146.	Nerve disorders	12	25	71	29	21	09	-
147.	Anemia	12	25	70	07	0	0	-
148.	Obesity	11	18	67	11	20	20	-
149.	Heart disease (angina and/or heart attack)	12	41	72	43	21	33	-
150.	Circulatory disorders, lower limbs	11	18	72	20	18	11	-
151.	Liver ailments (like cirrhosis of the liver)	11	09	71	05	20	0	-
152.	Arthritis	12	58	71	52	19	42	-

TABLE 33 (cont'd)

SUMMARY OF MEDICAL HISTORY RESPONSES BY SUBGROUP

Item No.	Item	Carpenters N	Carpenters M	Carpenters S.D.	Union N	Union M	Union S.D.	Management N	Management M	Management S.D.	X^2 * ($p < .05$)
Frequency of Drug Use:											
153.	Dexedrine	09	1.00	0.0	70	1.01	0.11	21	1.00	0.0	-
154.	Benzedrine (or other amphetamines)	10	1.00	0.0	70	1.02	0.16	21	1.00	0.0	-
155.	Marijuana	09	1.00	0.0	72	1.18	0.61	21	1.04	0.21	-
156.	Sleeping pills (Sleepeze, Compoz, etc.)	10	1.00	0.0	71	1.16	0.60	21	1.00	0.0	-
157.	LSD	09	1.00	0.0	71	1.00	0.0	21	1.00	0.0	-
158.	"Speed"	09	1.00	0.0	71	1.05	0.28	21	1.00	0.0	-
159.	"Downers" (tuinal, redbirds, etc.)	09	1.00	0.0	71	1.04	0.26	21	1.00	0.0	-

Appendix I

Regression Equations Used to Generate Expectancy Charts for Neurological Criteria

(1) Total Neurological Score = 4.137 -0.148 * SRT +0.245 * CRT
-0.266 * SAR -0.059 * BD +0.006 * EXP_1 -0.029 * EXP_3

(2) Electrodiagnostic Score = - 2.686 +0.026 * DRT -0.135 * SAR
+0.046 * AGE +0.008 * EXP_1 +0.162 * EXP_2
-0.054 * EXP_3

(3) Neurological Score = 1.775 -0.111 * SRT +0.140 * CRT
-0.134 * SAR -0.003 * EXP_1

Appendix J

Regression Equations Used to Generate Predictions of NHealth Criteria

(1) NHealth 1[a] = 0.109 +0.008 * CRT -0.019 * SAR -0.169
* NEIS + 0.005 * AGE +0.001 * EXP_1
-0.004 * EXP_3

(2) NHealth 2[b] = -0.089 +0.007 * CRT -0.019 * SAR +0.010
* AGE +0.001 * EXP_1 -0.015 * EXP_5
+0.027 * EXP_6

[a] NHealth 1 = 1 when Total Neurological Score 5

[b] NHealth 2 = 1 when Total Neurological Score 3

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