A BEHAVIORAL AND NEUROLOGICAL EVALUATION OF DRY CLEANERS EXPOSED TO PERCHLOROETHYLENE

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Part 2 of
Contract No. HSM 99-73-35

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Biomedical and Behavioral Science
Cincinnati, Ohio
June 1977

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DHEW (NIOSH) Publication No. 77-214

NIOSH Project Officer: Charles Xintaras

PREFACE

The contents of this report represent the second half of effort performed under NIOSH contract HSM-99-73-35. The results from the first half of the contract were previously published as NIOSH Technical Information report 77-128.

ABSTRACT

The possible adverse effects of perchloroethylene (PCE), a solvent widely used in dry cleaning, on workers' neurologic status and behavioral performance were examined. Twenty-seven volunteers who worked in various dry cleaning jobs constituted the sample. Of this number, 18 were exposed daily by nature of their job to various levels of PCE. These 18 PCE-exposed workers were found to have a mean 8-hour time-weighted average (TWA) exposure of 18 ppm over the 5 days of testing. The 9 males within the PCE-exposed group, however, were found to have a mean TWA exposure of 32 ppm PCE. Neurological examinations of all study participants showed a statistically significant ($p < 0.10$) difference between neurological ratings for PCE-exposed workers versus controls. However, multiple regression analyses suggest the neurological deficits to be related ($p < 0.02$) to workers' prior exposure to Stoddard's Solvent, not PCE. The effects of acute PCE exposure were examined by giving workers behavioral performance tests both prior to work and following work over a 5-day period. Although statistically significant differences in performance of some perception and psychomotor tests were found, multiple regression analysis showed the post-shift performance decrements to be significantly ($p < 0.05$) correlated with a measure of fatigue, not with PCE exposure that occurred during the workshift. In summary, no evidence was found of deleterious effects of PCE on workers' neurologic health or behavioral performance. However, findings strongly suggest the involvement of Stoddard's Solvent as a factor accounting for an increased incidence of abnormally large neurologic scores.

BIBLIOGRAPHIC DATA SHEET	1. Report No. NIOSH-77-214	2.	3. Recipient's Accession No. PB 271 924
4. Title and Subtitle A BEHAVIORAL AND NEUROLOGICAL EVALUATION OF DRY CLEANERS EXPOSED TO PERCHLOROETHYLENE			5. Report Date June 1966 6.
7. Author(s) Thomas C. Tuttle, G. David Wood, Craig B. Crether, Barry L. Johnson, and Charles Xintaras			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Westinghouse Electric Corporation Westinghouse Behavioral Services Center Columbia, Maryland 21044			10. Project/Task/Work Unit No. 11. Contract/Grant No. HSM-99-73-35
12. Sponsoring Organization Name and Address National Institute for Occupational Safety and Health 4676 Columbia Parkway Cincinnati, Ohio, 45226			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts The adverse effects of perchloroethylene (PCE) on workers' neurologic and behavioral performance were examined in 27 volunteers who worked in various dry cleaning jobs, including 18 who were exposed daily to a mean 8-hour time-weighed average (TWA) exposure of 18 ppm; 8 of the 18 had a mean TWA exposure of 32 ppm. Neurological examination showed a significant difference between neurological ratings for exposed workers versus controls, but multiple regression analyses suggest the neurological deficits to be related to prior exposure to Stoddard's solvent, not PCE. The effects of acute PCE exposure were examined by giving workers behavioral performance tests both prior to work and following work. Although significant differences were recorded in performance of some perception and psychomotor tests, multiple regression analysis showed the post-shift performance decrements to be correlated with fatigue, not with PCE exposure. In summary, no evidence was found of deleterious effects of PCE on workers' neurologic health or behavioral performance. However, findings strongly suggest the involvement of Stoddard's solvent as a factor accounting for an increased incidence of abnormally large neurologic scores.

17. Key Words and Document Analysis. 17a. Descriptors

Environmental surveys
Toxicology
Industrial atmospheres
Industrial hygiene
Air pollution
Nervous system disorders
Chlorohydrocarbons
Tetrachloroethylene
Dry cleaning
Behavior disorders
Naphthas
Stoddard solvent

17b. Identifiers/Open-Ended Terms

Air quality measurement
Neurotoxicity
Chlorinated ethylenes

17c. COSATI Field/Group 06/J

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	
Release unlimited	20. Security Class (This Page) UNCLASSIFIED	22. Price PC A05-A01

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ACKNOWLEDGMENTS

The authors wish to express their gratitude to the International Fabricare Institute for its cooperation and support in all phases of this project. Dr. Manfred Wentz, Research Director of the Institute at the time this study was initiated, assisted greatly in the literature review, and in locating dry cleaning plant owners who were willing to participate in the project. Mr. William F. Fisher, Administrator of the IFI Research Division, also greatly assisted the coordination of efforts with dry cleaning plant managers, provided considerable technical information concerning air sampling methods and dry cleaning operations. Mr. Michael Keller assisted substantially in field data collection efforts, and Mr. Ivan Andrasik also participated in the field portions of the study.

A number of individuals provided valuable technical inputs at various projects tages. These included Dr. Jack Peterson, University of Wisconsin Medical School in Milwaukee, and representatives of Dow Chemical Corporation, Steve Brown, Steve Keil, and Dr. Ted Torkleson.

The medical portions of the study required the cooperation of staff members from the Departments of Neurology and Physical Medicine at Georgetown University Hospital. Their Cooperation in scheduling patients and in re-scheduling patients is greatly appreciated.

Special thanks are due to the participants who gave their own time to participate in the testing sessions and medical evaluation procedures. Their cooperation, enthusiasm, and expectations for the project were an inspiration to the researchers.

Other Westinghouse full and part-time staff who deserve special thanks are Mr. Dennis Reed, who worked extensively on the project during the literature review and test battery selection phases as well as planning efforts for the field data collection. Special thanks go to Ms. Wilma Bell, who provided clerical support throughout the project and who typed the manuscript.

INTRODUCTION

The recognition of workplace hazards has been steadily increasing in recent years. A number of factors have contributed to this development: passage of the 1970 Occupational Safety and Health Act, increased pressure exerted by labor unions, increased educational level of the American worker, and 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 illnesses 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 such chemical hazards are a class of toxic agents called neurotoxins, i.e., substances known to cause damage to the nervous system. Known neurotoxins are such chemicals as pesticides, 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 the long-term effects of these substances on workers who may be exposed is rarely available prior to the substance's use 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 always 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 being 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 represents an attempt to further investigate such screening techniques and to test their utility for detecting changes in workers exposed to a widely-used industrial solvent, perchloroethylene (PCE or tetrachloroethylene). More specifically, the purposes of this investigation are to:

1. Review the scientific literature regarding the known effects of exposure to perchloroethylene.

2) Select a behavioral/neurological test battery for the detection of neurologic effects of exposure to perchloroethylene.

3) Administer the test battery to workers exposed to levels below, at, and above the current Threshold Limit Value (TLV).

4) Investigate relationships between the behavioral/neurological measures, exposure indices, and medical data.

REVIEW

Perchloroethylene (Tetrachloroethylene or PCE) is a colorless, nonflammable liquid used as a solvent for oils, fats, resins, and cellulose acetate. The substance has a distinctive odor somewhat resembling that of ether. The substance is sold under a variety of trade names in the United States. Production has risen from 300 million pounds in the early sixties to 740 million pounds in 1973, and is expected to exceed 980 million pounds in 1977. Its principal uses in industry are as a dry cleaning solvent (75%), a vapor degreaser (7%), and as a chemical intermediate in the production of flurocarbons (8%).

A review of the scientific literature was conducted in the first phase of the present investigation to determine the known effects of perchloroethylene exposure (Tuttle, Killian, Reed, and Grether, 1973). Relatively little published research was uncovered dealing with the effects of perchloroethylene exposure on humans. Data was particularly lacking concerning the long term (i.e., chronic) effects. The research literature was of three basic types: animal experiments, human experiments concerning short-term effects, and non-experimental case studies. Listed below are the major conclusions derived from the preceding literature review.

1. Subjective psychological behavioral effects seem to be among the earliest manifestations of acute PCE poisoning. These effects include dizziness, headaches, loss of inhibitions, lack of coordination, and central nervous system depression.

2. Little research has been conducted concerning the chronic behavioral/neurological effects of PCE exposure, particularly at low concentration levels. Case study evidence suggests that chronic exposure to high levels produces memory impairment and fatigue.

3. Based on very limited and unsystematic use, psychological/behavioral tests showed no significant differences between acutely exposed and unexposed groups. The recurrence of subjective behavioral symptoms in exposed individuals, however, suggests that a carefully selected test/battery covering a wide range of psychological functions might provide a useful technique for early diagnosis of chronically exposed workers.

4. Several of the effects of PCE exposure have important implications for worker safety. Most important among these effects are increased fatigue and impairment of memory and motor functions.

5. The earliest objective indication of PCE intoxication demonstrated in the studies reviewed is abnormal performance on the modified Romberg test.

6. Acute exposure to high levels of PCE was shown to produce liver damage in animals.

7. Expired air analysis, in conjunction with gas chromatography, represents the most effective method for PCE body burden determination.

8. The most accurate and convenient method for analysis of PCE vapor concentrations seems to be activated charcoal absorption followed by gas chromatography.

Following the completion of this review, two additional studies of significance appeared. The first of these (Stewart, Hake, Forster, Lebrun, Peterson, and Wu, 1974) experimentally exposed nineteen human volunteers to varying concentrations of PCE for a five week period. Exposure levels ranged from 20 parts per million (ppm) to 150 ppm on a carefully controlled schedule. For males exposed to 150 ppm for five days per seek, 7 1/2 hours per day, there was an apparent drop in scores on the Flannagan coordination test. All other behavioral measures failed to show any changes related to exposure levels. For "most" subjects exposed to 100 ppm for 7 1/2 hours, EEG analyses indicated altered EEG's, (i.e., increased delta wave activity). Stewart et al. found this portion of the results to be "troublesome," and recommended further EEG studies to help clarify their role in assessing potential health problems at the current Federal Occupational Health Limit of 100 ppm. The researchers further concluded that there are apparently differential susceptibilities to PCE and that the current limit does not appear to be adequate for those who are "particularly susceptible."

The EEG findings reported by Stewart et al. (1974) have subsequently been challenged by Ts'o (1975). After reviewing the evidence reported, Ts'o concludes that the data are not sufficient to conclude that the abnormal EEG's reported by Stewart et al. (1974) are the result of PCE exposure. The behavioral test results also are questionable due to the limited sample size. Test results were analyzed on groups of two, three, and four subjects. The only finding apparently related to PCE exposure was based on a group of four subjects. The small sample sizes combined

with the limited range of functions measured (e.g., no tests measuring peripheral nerve functioning) are insufficient to permit any firm conclusions concerning the sensitivity of behavioral measures.

A second study (Schwetz, Leong, and Gehring, 1974) investigated the effects of various solvent exposures (including PCE) on pregnant rats and mice and embryo and fetus development. Groups of pregnant animals were exposed to 300 ppm of perchloroethylene for seven hours daily during days 6-15 of gestation. Exposed rats showed an increase in mean maternal body weight and an increased incidence of fetal resorptions. Exposed mice experienced an increase in the relative weight of the liver and an overall decrease in fetal body weight. Delayed ossification of the skull bones, subcutaneous edemas (fetal toxicity) and split sternebrae were found more frequently in fetuses of exposed mice than in the unexposed. Despite the above findings, the authors conclude that, overall, perchloroethylene caused no significant maternal, embryonic, or fetal toxicity. This conclusion is subject to question, particularly if attempts are made to generalize this finding to humans. More research appears to be needed in order to rule out possible adverse effects of perchloroethylene exposure to either human mothers, embryos, or fetuses.

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, especially with substances which have not been thoroughly researched.

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 PCE 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 perchloroethylene.

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. 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 as part of the experimental test battery.

Feeling Tone Checklist
Wechsler Digit Span
Wechsler Digit Symbol
Neisser Letter Search
Critical Flicker Fusion
Santa Ana Dexterity Test
Choice Reaction Time
Simple Reaction Time

DESCRIPTION OF TESTS SELECTED FOR THE EXPERIMENTAL TEST BATTERY

Feeling Tone Checklist. The Feeling Tone Checklist (Pearson & Byers, 1957) provides a quantified measure of fatigue by having subjects indicate whether they feel "better than," "the same as," or "worse than" 10 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 symtpoms of exposure to neurotoxins such as perchloroethylene. In addition, the checklist can be self-administered, requiring a minimum amount of time (approximately 2 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 subtest 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 (0.72) 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 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).

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 PCE exposure. 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 and a viewing chamber. 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 3 to 4 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.

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, left hand and both hands simultaneously. Hanninen (1971) found this to be the most sensitive single measure of the effects of carbon disulfide exposure. Since PCE is presumed to have effects possibly similar to carbon disulfide (e.g., peripheral neuropathy, etc.) it was included as a part of the test battery.

The test can be administered in approximately 10 minutes, and it is possible to test at least 2 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 0.91. Unfortunately, the boards are not available commercially at this time. For the purpose 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 visual signal by pressing a button that turns off the light. A standard commercially available choice reaction time device with four differently colored lights was used. The apparatus involved 3 components: a control device used by the experimenter to control the occurrence of the light signal, a response device, and a timer which recorded response time digitally in hundredths of a second. Both simple (worker knows which light signal to expect) and choice (worker does not know which of 4 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. Thus PCE, which is a suspected neurotoxin, would also be expected to slow movement time.

This particular procedure offers the possibility of obtaining 3 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 10 minutes. However, through a modification of the equipment, it was possible to test 2 workers at one time, thereby reducing the testing time.

PLANT AND WORKER SELECTION

Concurrent with test battery selection, efforts were conducted to obtain the cooperation of individual dry cleaners and their employees. The first step in this process involved discussions with the International Fabricare Institute - a laundry and dry cleaning trade association. The association gave its full support for the project and offered to assist in the process of identifying and obtaining the cooperation of individual dry cleaning establishments. The purposes of the project coincided with extensive efforts by the trade association to make its members more concerned with the issue of solvent exposure both from a health viewpoint and from an economic viewpoint.[1]

Through the association, arrangements were made to describe the scope and purposes of the project to a monthly meeting of dry cleaning owners and managers. After discussing the research objectives, plant representatives were asked to complete a card indicating their interest in further discussing participation. Approximately 18 plants indicated a willingness to talk further. (Further meetings were held with individual plants expressing an interest in participating. In addition, plants were inspected and consideration given to the number of employees exposed to perchloroethylene. This led to the selection of seven plants). Further contacts with these seven plants produced five in which some or all of the employees were willing to participate in the research.

A special effort was made to select plants where the dry cleaning machine operator and those individuals working nearest the machine were willing to participate. In every case, the machine operator participated and in all but two plants,all people working closest to the machines also participated. In order to obtain a control group of unexposed workers, laundry workers in one of the selected plants were asked to participate.

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[1] Solvent vapors that escape into the work environment represent a solvent loss to the operator that can amount to as much as several hundred dollars during the course of a year.

The work environment for launderers and dry cleaning workers is highly similar, except for exposure to perchloroethylene. In all, a total of 30 workers were tested at five sites. A breakdown of this total can be found in Table 1.

Table 1

Breakdown of Testing Sites and Participants

Site	No. Exposed	No. Unexposed	Total
1	1	0	1
2	5	0	5
3	7	0	7
4	5	0	5
5	2	10	12
	20	10	30

Workers who volunteered for the project were asked to complete the consent forms and the Work/Medical History Questionnaire included in Appendix A.

MEDICAL EXAMINATIONS

Prior to behavioral testing, each participant was sent to Georgetown University Hospital for a series of medical examinations. In most instances, individuals were scheduled for the medical evaluation during the week immediately preceding in-plant behavioral testing. The examination consisted of two parts: 1) a neurological examination and 2) an EMG/nerve conduction examination. The principal components of each exam appear in Appendix B. In addition, blood analyses were conducted to determine blood sugar and hematocrit levels.

Results of the examinations were summarized in two ways. Physicians provided a written examination report for each patient noting any abnormalities. In addition, each patient was rated on a rating scale provided by the experimenters. The rating scale format was developed for this study, but used rating factors and weights previously developed (Allen, Mendell, Billmaier, Fontaine, and O'Neill, 1975). The rating procedure results in three scores: 1) symptoms, 2) neurological obtained from the neurologist's ratings and 3) electro-diagnostic obtained from ratings by the electromyographer. These three scores are then summed to yield a Total Neurological Score for the worker. Allen *et al.* (1975) suggest 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 medical examinations (Appendix B).

FIELD DATA COLLECTION

The field data collection phase involved spending one week in each of four[1] dry cleaning plants selected for the project. The protocol for a typical day of data collection appears in Figure 1. Each day, the behavioral test battery was administered to workers at the beginning and end of the work day. At the time of the morning and afternoon testing session, breath samples were collected. Breath samples were also collected at approximately two hour intervals throughout the work day. Ambient samples from each employee's work stations were collected at approximately one to two hour intervals. The detailed procedures followed in the collection of PCE samples are described in Appendix C.

Analyses of ambient and breath samples led to the derivation of five exposure indices per worker for each day of testing. These measures are listed below.

1) Pre-test breath sample--taken at time of a.m. testing.
2) Post-test breath sample--taken at time of p.m. testing.
3) Mean breath sample--mean of all breath samples taken during the work day.
4) Peak exposure--highest ambient level for the day recorded.
5) Time weighted average in individual's work station--computed by the following formula:

$$TWA = (P_1)\ (W_1) + (P_2)\ (W_2)\text{----}(P_n)\ (W_n)$$

Where W_1----N = Average ambient concentrations in each of the workers N work locations and,

P_1----N = Percent of the work day each worker spends in each location.

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[1] The fifth plant was used as a pilot field test site. Since only one worker, the machine operator, agreed to participate, it was not feasible to spend a whole week in the plant. Data collection was conducted for one day in this plant to insure that all procedures were suitable for the primary data collection effort.

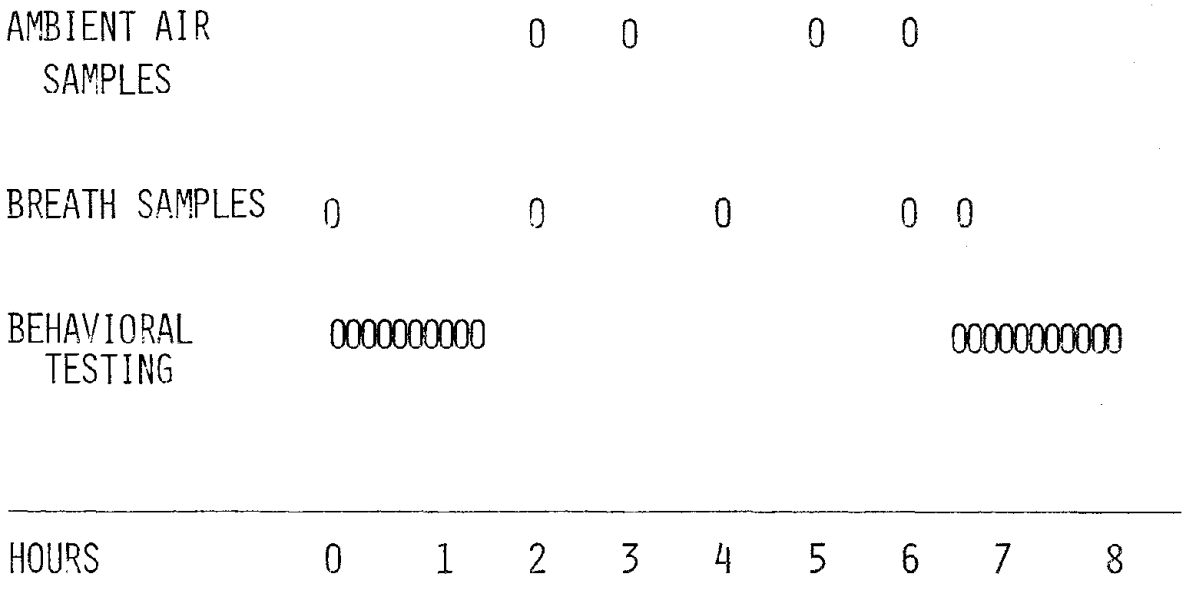

FIGURE 1 PROTOCOL FOR IN-PLANT TESTING

The behavioral testing details are described in Appendix D. The following test score variables were obtained for each testing session:

1) Simple reaction time - the average time (in hundredths of a second) to respond to 12 trials when the stimulus signal (light) was known.

2) Choice reaction time - the average time (in hundredths of a second) to respond to 12 trials when the stimulus signal (light) can be any one of four.

3) Santa Ana right - the number of pegs correctly turned in a 30 second trial with the right hand. For the first day's administration of the test, this score is the average number of pegs turned in two 30 second trials with the right hand.

4) Santa Ana left - the number of pegs correctly turned with the left hand. For the first day's administration of the test this score is the average number of pegs turned in two 30 second trials with the left hand.

5) Santa Ana both - the number of pegs correctly turned with both hands working simultaneously in a 30 second trial.

6) Neisser Letter Search - the average number of targets per second correctly marked in three trials having one, two and four target letters. Duration of trials was 20, 30, and 30 seconds respectively. On the first day's administration, the score was computed on the basis of six trials, two with each target condition.

7) Digit Span - the number of digit sequences correctly repeated. The score is a composite of digits forward and digits backward.

8) Digit Symbol - the number of correct symbols written in a 90 second trial.

9) Critical Flicker Frequency - the average (over three trials) frequency at which a steady light is perceived to begin flickering.

10) Critical Fusion Frequency - the average (over three trials) frequency at which a flickering light is perceived to stop flickering.

11) CFF Mean - the mean of #10 and #11.

12) Feeling Tone Checklist - the fatigue score using the scoring formula published for the checklist.

RESULTS

The data analyses can be grouped generally into four categories (1) Summary statistics, and investigations of relationships between (2) PCE exposure and neurological findings (3) PCE exposure and behavioral measures and (4) neurological findings and behavioral measures. The presentation of results will be organized according to these general categories.

SUMMARY STATISTICS

Although the original sample size was 30 workers, the data from 3 workers were discarded due to their limited (i.e., less than 2) days of participation in the study. The remaining 27 participants in the study can be divided into five major job categories: (1) machine operators whose primary job is to load and unload the dry cleaning machine as well as prepare garments for cleaning (e.g., spotting, etc.) (2) pressers who operate pressing machines used to press garments; (3) counter attendants who meet customers, receive and tag garments and retrieve garments from the racks when finished garments are hung; (4) other related jobs that involve combinations of the first three or auxiliary functions (e.g., seamstress) that occur in the dry cleaning shop and therefore lead to solvent exposure and (5) laundry workers who are not exposed to PCE. Table 2 presents a comparison of the exposed and control groups in terms of selected demographic variables. It should be noted that the PCE-exposed workers have been divided into 2 separate groups, PCE-exposed males and PCE-exposed females. This categorization was felt necessary due to the fact that 1) the males in the sample were primarily machine operators and as such received a much higher PCE exposure than did the females in the exposed group, and 2) the 'control' group consisted only of females with no current or prior exposure to PCE. It would have been desirable, of course, to have the control group more closely match the PCE exposure groups. This, however, was not possible, due to the limited number of dry cleaning establishments willing to participate in the study.

It can be noted from Table 2 that the range in mean ages across the 3 groups was 9 years. However, one-way analysis of variance (ANOVA1) showed that the 3 groups were not statistically significantly different ($F(2,26)=0.91$, $P > 0.10$) from each other. The 3 groups also were not significantly different in years of education ($F(2,26)=0.83$, $P > 0.10$).

Review of Table 2 shows that the PCE-exposed males had a mean exposure duration of 9.8 years, the female PCE-exposed workers for 6.7 years, and no exposure for the control workers. These figures were derived for each worker from their response to Question 15 of the Work/Medical History Questionnaire (Appendix A). The differences in

Table 2

Demographic Data for Study Groups

	PCE-Exposed Males	PCE-Exposed Females	Controls
N	9	9	9
Females	0	9	9
Mean Age (yrs.)	40.9(± 15.0)[1]	46.2(± 17.2)	37.0(± 10.9)
Mean Education (yrs.)	11.9(± 2.0)	11.3(± 1.7)	10.7(± 2.3)
Mean PCE Exposure (yrs.)	9.8(± 6.9)	6.7(± 6.1)	0.3(± 0.7)[2]
Number Previously Exposed to:			
Petroleum Solvent	4	1	0
(Mean Years)	16.5	21	
Carbon Tetrachloride	1	0	0
(Mean Years)	5		
Carbon Disulfide	1	0	0
(Mean Years)	10		
Trichloroethylene	0	0	0
Mercury	0	0	0
Hydrogen Sulfide	0	0	0
Alcohol Consumption:			
Beers/Day	1.1(± 1.5)	0.4(± 0.7)	1.2(± 2.0)
Wine/Day	0	0.2(± 0.4)	0.4(± 1.3)
Cocktails/Day	1.0(± 1.7)	0.3(± 0.5)	0.7(± 0.9)

Note:
[1] Standard Deviation
[2] One Worker with an exposure of 1 year

years of exposure to PCE are, of course, significantly different according to group ($F(2,26)=7.06$, $P < 0.01$). Dunnett's t-test shows both the PCE exposure groups to differ significantly from the control group (Dunnett's $t=2.55$ and 3.74, $df=3,24$, $P < 0.01$ for the female and male groups, respectively). However, the 2 PCE-exposed groups did not significantly differ from each other in terms of years of PCE exposure (Dunnett's $t=1.19$, $df=3,24$, $p > 0.10$). In other words, females and males did not differ in years of exposure to PCE.

The extent of workers' exposure to neurotoxic solvents other than PCE is given in Table 2. These data represent subjects' responses to Questions 13-19 on the Work History questionnaire (Appendix A). It should be noted that 5 workers reported prior exposure to a petroleum solvent (Stoddard's solvent) and 1 worker reported a prior exposure to carbon disulfide.

Since excessive alcohol consumption is known to be deleterious to the nervous system, workers were asked to report their patterns of alcohol consumption (Questions 22-27 on the Work History questionnaire). Results concerning alcohol consumption are also given in Table 2. Generally speaking, the 3 groups were similar in alcohol consumption. No single worker was identified as consuming an excess amount of alcohol, i.e., more than 6 beers/day, or 4 cocktails/day, or 6 glasses wine/day.

Table 3 contains results from PCE breath and ambient air samples. Assigning a job title to employees in small dry cleaning shops is somewhat misleading since most employees perform several operations. The categorization depicted in Table 3 and elsewhere is based on the amount of time each worker spent in various functions (e.g., machine operator, pressing, counter, outside the shop, etc.) during the week of testing. As expected, the machine operator has the highest exposure to perchloroethylene. If the machine is well maintained, his exposure is relatively low except during the transfer process when a load of garments saturated with the solvent is "transferred" manually from the washer to the dryer, or from the dryer to a buggy used to transport the garments to the pressing area. In general, the exposure level of the operators is a direct reflection of the number of transfers performed during the work day. In the plants visited, the average number performed per day ranged from 8 to 16.

The intercorrelations among various in-plant exposure indices are presented in Table 4. The highest correlations occurred between daily time weighted averages and average daily breath samples ($r = 0.90$) and between time weighted averages and daily peaks ($r = 0.90$).

Table 3

PCE Exposure Data for Dry Cleaning Jobs

	N	Mean TWA (ppm)	Mean Breath Sample (ppm)	Mean Peak (ppm)
Machine Operator	5	37.2(±24.96)	20.47(±18.21)	214.90(±179.44)
Presser	2	11.43(± 6.82)	4.48(± 0.39)	51.85(±64.56)
Counter	5	1.32(± 0.97)	0.95(± 0.62)	2.61(± 1.87)
Miscellaneous	7[1]	3.03(±2.09)	2.04(± 2.29)	27.45(±46.02)

[1] One worker who did not complete the neurological and behavioral tests is included.

Table 4

Intercorrelations Between Exposure Indices

	N	TWA	Peak	Pre BS*	Post BS	Avg. BS
TWA	125					
Peak	120	0.90				
Pre BS	96	0.74	0.76			
Post BS	84	0.85	0.84	0.87		
Avg. BS	126	0.90	0.90	0.81	0.86	

* Breath Sample

Neurological data. The neurological evaluation yielded rating scores for symptoms, neurological exam, electrodiagnostic exam, and total neurological score. In addition, quantitative scores were obtained for various elements of the electrodiagnostic examination. Table 5 presents the means and standard deviations resulting from the neurological evaluations for the exposed and unexposed groups. The only scores which significantly differentiated the 3 groups were the Electrodiagnostic Rating Score and the Total Neurological Score. For both variables, the 2 PCE-exposed groups differed significantly from the control group (Kruskal-Wallis multiple comparisons based on analysis of ranks, $P < 0.10$). In addition, for each variable the PCE males differed significantly from the PCE females.

Table 6 contains the intercorrelations among the neurological variables.

Since the PCE-exposed groups differed from the control group in terms of Electrodiagnostic Score (EDS) and Total Neurologic Score (TNS), a multiple linear regression analysis was performed on these data. Specifically, multiple stepwise regression analyses were performed for the 18 PCE-exposed workers, using TNS and EDS as separate dependent variables and sex, age, PCE time weighted average exposure (TWA), peak daily PCE exposure (PEAK), years of PCE exposure, and years of exposure to Stoddard's Solvent (PET). The results of these analyses are given in Table 7. The stepwise regression analysis procedure identifies those independent variables that have the highest partial correlation with the dependent variable.

Table 5

Group Statistics for
Neurological Data

		PCE Males		PCE Females		Controls		F^1 or H^2 value	Degrees of Freedom	P
	SCORE	Mean	SD	Mean	SD	Mean	SD			
Components of Electro-diagnostic exam	Median proximal motor latency	8.9	0.9	8.8	1.4	8.6	0.8	H=0.27	2	>0.10
	Median distal motor latency	4.0	0.6	3.6	0.5	3.9	1.2	H=1.95	2	>0.10
	Median nerve conduction velocity	56.7	6.7	56.2	5.3	57.8	3.6	F=0.19	2,23	>0.10
	Median sensory latency	3.6	0.6	3.2	0.4	3.2	0.3	H=3.26	2	>0.10
	Peroneal proximal motor latency	11.0	0.9	10.7	1.5	10.2	1.0	H=3.12	2	>0.10
	Peroneal distal motor latency	5.3	0.9	5.2	1.3	5.0	1.2	H=0.65	2	>0.10
	Peroneal nerve conduction velocity	51.5	6.9	50.3	3.7	53.4	5.8	F=0.70	2,23	>0.10
Rating Scores	EDGSCORE	4.7	3.9	2.4	3.7	1.2	2.5	H=5.21	2	<0.10
	SYMPTOMS	0.8	1.0	0.7	1.0	0.2	0.7	H=3.12	2	>0.10
	NEUSCORE	1.7	2.5	1.4	2.7	0.1	0.3	H=1.98	2	>0.10
	TNUSCORE	7.2	6.5	4.6	4.8	1.6	3.4	H=6.59	2	<0.05

Notes: 1 - One-Way ANOVA
2 - Kruskal-Wallis H value

Table 6

Intercorrelations Among Neurological Variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Median Proximal Motor Latency											
2. Median Distal Motor Latency	.32										
3. Median Nerve Conduction Velocity	-.09	.68**									
4. Median Sensory Latency	.61**	.71**	-.28								
5. Peroneal Proximal Motor Latency	.24	.29	.02	.16							
6. Peroneal Distal Motor Latency	.15	.51**	.36	.16	.79**						
7. Peroneal Nerve Conduction Velocity	-.03	.52**	.61**	.22	-.19	.36					
8. EDGSCORE	.22	.30	.05	.23	.35	.11	-.28				
9. SYMPTOMS	.43*	.37*	.10	.13	.45*	.36	-.09	.30			
10. NEUSCORE	.23	-.04	-.13	-.03	.41*	.26	-.32	.39*	.61**		
11. TNUSCORE	.31	.25	.00	.16	.48**	.24	-.33	.88**	.61**	.77**	

* P<0.05
** P<0.01

Table 7

Stepwise Regression Analysis of Neurologic Ratings

Dependent Variable	Significant Independent Variables	F-value
TNS	PET	45.8,df=1,15 P<0.001 (R^2=0.75)
EDS	PET	7.12,df=1,15 P<0.02 (R^2=0.32)

A review of Table 7 shows that the only independent variable showing a significant correlation with the two neurological scores is years of exposure to Stoddard's solvent. No relationship between PCE exposure and neurologic rating was found.

Medical history. Overall there were few differences between the exposed and unexposed groups in terms of medical history information. Table 8 presents a comparison of the percent of members in each group reporting various symptoms either on the job or away from the job. Although there are some differences (e.g., 25% of the exposed report sleepiness on the job compared to 0% of the unexposed) the differences that might be expected to result from exposure are not statistically significant using a chi square analysis. The only difference in Table 8 that is statistically significant is "conflicts or arguments" (chi-square = 6.9, 1 d.f., $p < .05$). The unexposed group reports significantly more conflicts or arguments off the job than do the exposed.

With regard to other items of medical history, there are no significant differences between the two groups in drinking problems, past or present health conditions, frequency or types of headaches, reported use of drugs, or medical history of members of the immediate family. The only significant difference in the other medical history items was in use of laxatives which the unexposed group reported using more frequently than the exposed (chi-square = 6.45, df = 1, $p < .05$). These results appear in Appendix E, which contains summary data from all 30 respondents to the questionnaire, even though only 27 completed the behavioral testing.

Table 8

Percent of Respondents with Symptoms Listed

	Exposed		Unexposed	
	During Workshift	Away From Job	During Workshift	Away From Job
Light-headedness	29	35	25	33
Dizziness	15	11	0	22
Nausea	5	5	0	0
Vomiting	0	5	0	0
Weakness	5	5	0	0
Loss of consciousness	0	0	0	0
Extreme drowsiness	11	15	0	0
Tired feelings	47	50	14	25
Headache	38	43	38	44
Irritability	33	37	14	25
Sleepiness	25	17	0	22
Change of mood	11	20	13	13
Memory impairment	11	20	0	0
Reduced concentration Capacity	15	11	0	0
Depression	5	5	14	14
Aggressiveness	5	5	0	13
Outbursts of violence	0	5	0	0
Conflicts or arguments	0	10	20	55
Fainting	0	0	0	0

Table 9

Means and Standard Deviations for Behavioral Data

	PCE-Exposed Males		PCE-Exposed Females		Controls	
	AM	PM	AM	PM	AM	PM
Santa Ana Right	24.4(4.8)*	24.8(4.5)	23.8(4.1)	25.0(4.3)	24.6(2.0)	25.1(3.0)
Santa Ana Left	24.4(4.6)	24.8(5.3)	22.7(2.7)	24.4(2.8)	21.9(2.4)	22.7(2.5)
Santa Ana Both	31.7(8.9)	33.0(9.4)	28.2(6.3)	29.6(6.2)	27.9(6.5)	29.3(6.6)
Neisser	1.1(0.2)	1.0(0.2)	1.1(0.3)	1.0(0.2)	0.9(0.2)	0.9(0.2)
Digit Span Forward	6.1(0.2)	6.0(1.2)	6.6(0.9)	6.6(0.9)	5.7(0.7)	6.0(1.1)
Digit Span Backward	4.6(1.4)	4.4(1.6)	5.1(1.5)	4.9(1.2)	3.6(0.5)	3.8(0.9)
Digit Symbol	54.4(15.1)	58.6(15.1)	58.3(14.8)	60.3(14.1)	55.6(12.7)	59.6(16.4)
Critical Flicker Frequency	48.3(6.6)	45.3(7.8)	46.4(4.6)	45.5(4.6)	45.4(3.8)	45.8(6.7)
Critical Fusion Frequency	46.3(3.9)	44.9(3.3)	46.0(5.1)	44.6(4.2)	43.6(3.7)	46.0(4.2)
CFF-Mean	50.7(8.9)	48.7(8.4)	46.2(4.6)	45.1(4.3)	44.5(2.7)	45.9(3.9)
Feeling Tone	13.8(1.8)	12.2(3.1)	14.9(2.5)	12.7(2.7)	13.9(3.4)	13.8(2.0)
Simple Reaction Time	39.1(7.1)	36.9(6.8)	44.0(8.4)	42.7(9.5)	47.2(5.9)	47.9(6.0)
Choice Reaction Time	46.6(7.7)	44.3(7.8)	51.1(8.7)	50.1(9.3)	53.1(7.1)	53.9(5.8)

*(Standard Deviation)

Table 10

Stepwise Multiple Regression Analysis for CFFD

Dependent Variable	Significant Independent Variables	F-Value
CFFD	TONE	3.67,df=1,21, P < 0.07
	SEX	3.25,df=1,21, P < 0.09 (R^2=0.24)

RELIABILITY OF BEHAVIORAL TESTS

Analyses for practice effects revealed significant improvement in performance between Day 1 and Day 5 for simple and choice reaction time, Santa Ana Right, Left and Both, Neisser and Digit Symbol. For four of these tests, simple reaction time, Santa Ana-R, Santa Ana-L, and Digit Symbol, the greatest performance increment occurs between Day 1 and Day 2. For the remaining tests, Choice Reaction Time, Santa Ana-Both, and Neisser, there was a gradual improvement through Day 3 followed by a leveling off of scores on Days 4 and 5.

Analyses of test reliability involved both internal consistency analyses and test-retest comparisons. Results of the reliability analyses are presented in Table 11.

Internal consistency analyses were computed for all tests which could be split meaningfully into two halves either using odd-even items (e.g., choice reaction time) or using successive trials (e.g., simple reaction time, Santa Ana-R, Santa Ana-L, Neisser). All internal consistency reliabilities were 0.8 or greater except for the Santa Ana-L (0.73) and the Santa Ana-R (0.45). Test re-test comparisons were made using Day 1-Day 2 morning scores for all tests except CFF which used Day 1-Day 3 comparisons. Test-retest comparisons ranged from 0.33 for the Drop Reaction Time test to 0.95 for Digit Symbol. Only the 2 Reaction Time Scores and the Critical Fusion Frequency failed to exhibit reasonable stability ($r_{tt} > 0.7$). Although the Santa-Ana scores have relatively low internal consistency, possibly due to differential practice effects among participants, the Santa Ana-R and Santa Ana-L do have acceptable test-retest reliabilities. Further relationships among test scores may be examined by referring to the intercorrelations in Appendix E.

RELATIONSHIPS BETWEEN BEHAVIORAL TEST SCORES AND NEUROLOGICAL DATA

An additional purpose of this study was to investigate the utility of behavioral tests as early warning health screening tools. In order for behavioral measures to be useful for this purpose, they must at least detect health problems that are detected in a neurological/electro-diagnostic evaluation. In order to investigate the utility of behavioral measures for this purpose, a series of analyses were conducted to determine statistical relationships between behavioral test scores and scores on the neurological evaluation.

The first set of analyses involved computing correlations between test scores and neurological variables. These results are shown in Tables 12 and 13.

Table 11

Reliabilities of Obtained Test Scores

Test	Internal Consistency	Test-Retest Reliability[3]
Simple Reaction Time	.95[2]	.60
Choice Reaction Time	.94[1]	.56
Drop Reaction Time	.90[1]	.33
Santa Ana Right	.45[2]	.78
Santa Ana Left	.73[2]	.88
Santa Ana Both		.78
Neisser Form 1	.94[2]	.74[4]
Neisser Form 2	.85[2]	
Digit Span	--	.76
Digit Symbol	--	.95
Critical Flicker Frequency	--	.86
Critical Fusion Frequency	--	.46
CFF Mean	--	.84

[1]Odd-Even split half corrected by Spearman-Brown prophecy formula

[2]Split half based on alternate trials corrected by Spearman-Brown prophecy formula

[3]Based on Morning 1 vs. Morning 2 correlations except for CFF which is Morning 1 vs. Morning 3

[4]Form 1 and Form 2 combined

Table 12

Correlations Between Neurological Scores and Behavioral Test Scores (A.M. Sessions)

	SRT	CRT	SAR	SAL	SAB	NEIS	DSY	TDSP	CFFM	FTCPRE
Median-Proximal Motor Latency	.09	.21	-.42#	-.20	-.18	.16	-.28	-.21	.12	.02
Median-Distal Motor Latency	.07	.06	-.25	-.24	-.23	.29	-.29	-.08	.11	.15
Median-Nerve Conduction Velocity	-.02	-.10	.59#	.46#	.22	-.11	.46#	.25	.26	-.11
Median-Sensory Latency	-.06	.01	-.15	-.04	-.11	.38*	-.26	-.23	.20	.10
Peroneal-Proximal Motor Latency	-.22	-.10	-.44#	-.17	-.16	-.04	-.11	-.13	.27	.21
Peroneal-Distal Motor Latency	-.19	-.12	-.28	.03	-.05	.12	-.18	-.06	.093	.19
Peroneal-Nerve Conduction Velocity	-.13	-.16	.25	.27	.30	.28	-.19	.01	-.11	-.01
EDGSCORE	.11	.16	-.53#	-.44#	-.30	.21	-.35*	-.09	-.07	-.11
SYMPTOMS	-.06	-.01	-.53#	-.208	-.31	.25	-.39*	-.13	-.01	-.10
NEUSCORE	-.02	.06	-.49#	-.33*	-.24	.26	-.36*	-.16	-.03	-.06
TNUSCORE	.05	.13	-.63#	-.47#	-.345*	.28	-.44#	-.15	-.06	-.11

* $p < 0.10$ # $p < 0.05$

Table 13

Correlations Between Neurological Scores and Behavioral Test Scores (P.M. Sessions)

	SRT	CRT	SAR	SAL	SAB	NEIS	DSY	TDSP	CFFM	FTCPRE
Median-Proximal Motor Latency	.13	.17	-.34*	-.23	-.24	.15	-.42#	-.26	.08	-.14
Median-Distal Motor Latency	.34*	.05	-.40#	-.27	-.07	.30	-.25	-.16	.10	-.10
Median-Nerve Conduction Velocity	-.01	-.14	.34*	.54#	.47#	-.20	.59#	.20	.27	.03
Median-Sensory Latency	-.06	-.04	-.22	-.06	.04	.32	-.14	-.32	.14	-.14
Peroneal-Proximal Motor Latency	.02	-.22	-.33*	-.14	.00	.06	-.44#	-.22	.19	-.04
Peroneal-Distal Motor Latency	.01	-.15	-.21	.02	.19	.24	-.27	-.15	.05	.02
Peroneal-Nerve Conduction Velocity	-.08	.02	-.12	.20	.34*	.28	.25	-.04	-.14	-.05
EDGSCORE	.22	.04	-.47#	-.45#	-.41#	.28	-.53#	-.04	-.06	-.02
SYMPTOMS	.14	-.05	-.45#	-.36*	-.40#	.36*	-.53#	-.28	-.05	-.24
NEUSCORE	.08	-.05	-.38*	-.33*	-.32	-.39#	-.49#	-.15	-.01	-.04
TNUSCORE	.20	.00	-.54#	-.49#	-.46#	.40#	-.63#	-.13	-.05	-.07

* $p < 0.10$ # $p < 0.05$

In general, the correlations were higher with p.m. scores than with a.m. scores. Tests showing significant relationships ($p < .05$) with one or more neurological variables were Santa Ana-R, Santa Ana-L, Santa Ana-B, Neisser, and Digit Symbol. Using p.m. test scores, all these tests correlated significantly ($p < .05$) with the Total Neurological Score, and using a.m. scores, all but the Neisser had significant correlations with the Total Neurological Score.

The next set of analyses were performed to determine the extent to which combinations of test scores could be used to predict the Total Neurological Score. To investigate this question, a series of stepwise multiple regression analyses were conducted using behavioral test scores as predictors and the Total Neurological Score (TNS) as a criterion. Analyses were conducted separately for a.m. and p.m. test scores. The results are summarized in Tables 14 and 15. These tables present the combination of test scores yielding the best (i.e.,highest r^2) prediction of the criterion (Total Neurological Score) with one predictor, two predictors, and so on up until addition of new predictors into the regression model no longer yields statistical significance. Results from Table 14 show that a.m. performance on the Santa Ana (right hand), simple reaction time, and digit symbol tests correlated with the TNS. However, the only predictor variable whose p.m. values showed a significant correlation with TNS was Digit Symbol (Table 15).

Finally, to evaluate the amount of prediction possible from a combination of test scores, exposure and demographic variables, and reported symptoms, these variables were combined in a series of regression analyses. The criterion variable was the total neurological score.

The results of a series of analyses conducted with the average a.m. test scores are shown in Table 16. Results with p.m. test scores are quite similar to those presented here. By combining predictors, considerably better prediction is obtained for the total neurological score criterion. Using only 5 predictors (Santa Ana-right, Choice Reaction Time, Years of Exposure to Stoddard's Solvent, Weighted Average Exposure to PCE), a multiple correlation coefficient of 0.89 with the Total Neurological Score was obtained. Undoubtedly this level of prediction is approaching the reliability of the criterion, i.e., the upper ceiling for its predictability. Obtaining multiple correlation coefficients of this magnitude with only 5 variables is highly encouraging. However, it should be emphasized that a test of the practical utility of these findings must await cross validation studies conducted on an independent sample of data.

Table 14

Predicting Total Neurological Score Using Behavioral Test Scores (A.M.)

No. of Predictors	Predictors	R^2	R	F	df
1	Santa Ana-R	0.41	0.64	15.9*	1,23
2	Santa Ana-R, Simple R.T.	0.49	0.70	10.6	2,22
3	Santa Ana-R, Simple R.T., Digit Symbol	0.56	0.75	9.1	3,21

Table 15

Predicting Total Neurological Score Using Behavioral Test Scores (P.M.)

No. of Predictors	Predictors	R^2	R	F	df
1	Digit Symbol	0.53	0.73	22.8*	1,20

* $p < 0.01$

Table 16

A.M. Performance, Exposure History, and Demographic Data as Predictors of Total Neurologic Score

Predictor Variables	R^2	R	F	df
PET (yrs of Stoddard's Solvent)	0.70	0.84	53.4*	1, 23
PET + AGE	0.75	0.87	32.7*	2, 22
PET + AGE + Santa Ana Right (SAR)	0.76	0.87	22.0*	3, 21
PET + AGE + SAR + Choice RT (CRT)	0.78	0.88	17.6*	4, 20
PET + AGE + SAR + CRT + PCE (TWA)	0.80	0.89	14.9*	5, 19

*$p < 0.001$

Regression equation:

TNS=18.1+0.34PET+0.09AGE-0.50SAR-0.14CRT+0.02TWA

DISCUSSION

The central question investigated in this study was whether or not exposure to perchloroethylene adversely affected workers' neurologic status and performance on tests of perceptual, cognitive, and psychomotor skills. The answer from this study is that no evidence was found to indicate that PCE exerted adverse effects on workers' neurologic health or performance.

Although the PCE-exposed group was found to be significantly different from the control group in terms of electrodiagnostic and neurologic rating scores, multiple regression analysis showed that workers' prior exposure to Stoddard's Solvent was probably responsible. No evidence was found of long term PCE exposure as being a factor in accounting for differences in neurological ratings between PCE-exposed workers and the control group.

Similarly, although there were A.M. to P.M. significant differences in performance tests, these differences were found with one exception to be in the direction of improved performance following completion of the workshift. An A.M. to P.M. performance decrement for exposed workers was observed on one test, Critical Flicker Frequency. Although this finding appears consistent with previously reported case study evidence regarding PCE-induced fatigue, other performance tests that should have been affected by fatigue showed no performance decrements. This study found no evidence to suggest that PCE exposures at the levels measured in the dry cleaning establishments studied exerted deleterious effects on human performance.

A second basic issue addressed by this study is the utility of a behavioral test battery for detecting health problems that do exist. The results seem to provide a more definitive answer to this question. Clearly the test battery proved useful for detecting neurological difficulties in the participants in this study. The generality of the prediction equations based on the present test battery, however, can only be tested by actually applying them to another group of workers.

The relationships found between test scores and neurological data have important implications for in-plant health screening programs. With regard to neurotoxic chemicals, the earliest clinical indication of health impairment appears to come from electrodiagnostic studies. More specifically, nerve condition studies measuring conduction velocities and latencies of susceptible nerves seem to provide the earliest indication of health impairment. Their clinical studies, however, are expensive and require the services of a trained electromyographer. Behavioral tests on the other hand can be inexpensively administered and scored, require no elaborate apparatus, and can be administered by a trained technician. These characteristics make them much more suitable as in-plant screening techniques. Their practicality coupled with their sensitivity to neurological changes as demonstrated by this study, argue strongly for their implementation in industrial health screening programs. The primary

Behavioral scores: Means and standard deviations for tests in the behavioral test battery are presented in Table 9 for both the exposed and unexposed groups. The means are computed across testing session, i.e., day effects were ignored. In order to test for group and session effects, an analysis of variance with repeated measures on one variable was performed on each behavioral variable listed in Table 9. The results of these ANOVA analyses are given in Appendix F. A review of Table 9 shows that both PCE exposure groups exhibited small decrements in performance on 1) digit span, 2) critical flicker, and 3) critical fusion. Improved performance was noted in 1) Santa Ana dexterity, 2) digit symbol, 3) reaction time, 4) Neisser letter search, and 5) feeling tone. The ANOVA tables in Appendix F show the AM-PM differences to be statistically significant for the following tests:

1)	Santa Ana (right hand),	P = .022
2)	Santa Ana (left hand),	P = .008
3)	Santa Ana (both),	P = .001
4)	Neisser Letter Search,	P = .016
5)	Digit Symbol	P = .001
6)	Critical Flicker Frequency,	P = .083

As previously noted, the AM-PM significant differences for the Santa Ana, Neisser letter search, and digit symbol tests were in the direction of improved performance, i.e., subjects performed better following work than before they started their workshift. However, one performance measure, Critical Flicker Frequency (CFFD), showed AM-PM decrements. In order to assess the involvement of PCE, if any, as a factor in inducing this performance decrement, a stepwise multiple regression analysis was performed. The dependent variable in the regression models was CFFD. For each model the independent variables were age, sex, PCE exposure (TWA), PCE peak exposure, and Feeling Tone (TONE) results. The AM-PM data (i.e., dependent variables and TONE) were expressed as ratios of PM to AM performance when included in the regression analyses. Table 10 lists those independent variables identified as being statistically significant ($P < 0.10$) by stepwise regression analysis. As noted in Table 10, only independent variables SEX and TONE were significantly correlated with CFFD. It can therefore be concluded that the performance decrements observed with the Critical Flicker Frequency test were due to subjects' fatigue and sex, not to PCE exposure.

objective associated with the use of behavioral measures would be to identify those workers who are suspected of having health impairment and who could be referred to a medical facility for an in-depth medical evaluation. The behavioral evaluation could be conducted frequently (e.g., every month) thereby permitting detection of systematic trends in performance over some period of time that might indicate health problems.

The application of the behavioral tests as screening tools might involve the use of expectancy charts such as those depicted in Tables 17 and 18. Each of these charts display in graphic form the likelihood that a worker having various "predicted" total neurological scores would have an "actual" Total Neurological Score above a given cut-off score. The top part of Tables 17 and 18 is based on a Total Neurological Score cut-off of 3. According to Allen et al. (1975) scores above 3 indicate an abnormality, though not necessarily a polyneuropathy. The lower part of Tables 17 and 18 is based on a cut-off score of 5 indicating a probable polyneuropathy (Allen et al., 1975).

In practice these expectancy charts could be used as follows. Workers would be administered selected behavioral tests. Using the prediction formula for Total Neurological Score established (e.g., see Table 16) the test scores would be "plugged-into" the appropriate regression equation yielding a predicted Total Neurological Score. This predicted score would be the basis for "entering" the expectancy chart. For example, if the individual worker's predicted score were 2 or less there would be a "0" probability that the individual would be diagnosed as "abnormal" on the neurological/electrodiagnostic examination. On the other hand if the predicted score were 7 or greater, there would be a 100% chance that the individual would be diagnosed as abnormal on a neurological/electrodiagnostic examination. For in-plant screening, anyone with a predicted score of 3-6 might be referred for in-depth medical examination since they would have a 42% chance of being diagnosed as "abnormal."

It would appear from the results obtained in this preliminary study that behavioral tests offer considerable promise for in-plant health screening programs. In using such tests, there are certain operational problems that need to be overcome. One of these is practice effects. Ths study demonstrated that even with significant practice effects the tests still have considerable sensitivity, at least to chronic effects. An operational program would need to establish a testing procedure that would provide sufficient training on each test (e.g., Santa Ana) so that a stable performance plateau was reached. Increasing the number of practice trials should increase the sensitivity of the tests.

Table 17

Expectancy Charts Based on Regression Equation for A.M. Test Scores

Predicted TN Score Range	f	Chances in 100 of Receiving a Total Neurological Score of 4 or Greater
< 3	9	0%
3 - 6	12	42%
> 6	6	100%

Predicted TN Score Range	f	Chances in 100 of Receiving a Total Neurological Score of 6 or Greater
< 6	16	0%
6 - 7	5	20%
> 7	6	100%

Table 18

Expectancy Charts Based on Regression Equations for P.M. Test Scores

Predicted TN Score Range	f	Chances in 100 of Receiving a Neurological Score of 4 or Greater
< 6	17	12%
6 - 9	7	86%
> 9	3	100%

Predicted TN Score Range	f	Chances in 100 of Receiving a Neurological Score of 6 or Greater
< 6	17	0%
6 - 9	7	57%
> 9	3	100%

A second factor that would be crucial for an operational program is the motivational level of workers being tested. Virtually all performance measures are affected by varying levels of motivation. Procedures would have to be developed to insure that the motivation level of workers being screened is high. Perhaps this could best be done by fully explaining the purposes and operation of the program to all workers. Full disclosure of the purposes and results of the screening program should assist in winning worker cooperation. Attempts to hide the purposes of the program are likely to be counter productive. As an additional safeguard, psychometric checks could be developed to decide if an individual's score is valid. Such techniques may be based on the degree of variability between trials, amount of departure from a previously established baseline, and observation of the individual during testing. Faking can never be completely eliminated in any testing program, so the approach should be to rule out as many incentives for faking as possible.

With proper consideration for these factors, it should be possible to design and implement in-plant screening programs that are effective and relatively inexpensive. The benefits of such a program are many. Obviously early detection of potential health problems is beneficial for those affected. The principal objective of such a program would be to detect and reverse progressive health conditions before they become irreversible. Early detection also has benefits for employers. Although in the short run some costs may be incurred if the problems are caused by faulty equipment or procedures, in the long run there should be cost savings. The most obvious savings would be the avoidance of increased insurance premiums and workman's compensation claims. Indirectly, benefits are likely to accrue from a better maintained work place and use of more efficient work practices. Workers who do not have to work in an unhealthy environment can be expected to be more productive and to have fewer work-related accidents. Both of these factors have positive economic consequences for the employer. Thus the early detection of work place health problems using in-plant screening techniques such as those investigated in this study is one activity in which there are no losers; everyone can win from the use of such procedures.

RECOMMENDATIONS

One of the purposes of this preliminary research effort was to identify promising directions for future research. In addition, it seems appropriate to make procedural recommendations for any future research. Listed below are the major recommendations derived from the present research effort.

1. Additional research to further delineate the effects of chronic exposure to Stoddard's Solvent should be conducted. Subsequent research could profit from certain alterations in the study design. Suggested modifications include:

    a. Increasing the number of workers tested;
    b. Decreasing the data collection time per site to two days;
    c. Providing neurological examinations and electrodiagnostic examinations to as many of the workers as possible (however, if it is not possible to examine all workers, then a random sample could be drawn from the participants);
    d. Reducing the behavioral test battery by including only the following tests: Santa Ana, Simple and Choice Reaction Time, Digit Symbol, Digit Span, and the Neisser Letter Search.

A primary objective of this subsequent research should be the investigation of the stability of the prediction system developed in this initial research effort.

2. Additional research to examine acute effects does not, on the basis of the present results, appear to be a fruitful line of investigation. However, if additional research is undertaken, one modification might be attempted. This would be to take performance measures at three or more times during the work day. PCE exposure tends to be low at the beginning of the work day, increase during the workday and then decline at the end of the day as machines are shut down.

3. The neurological rating scheme used in this study provides a useful method for quantifying and intergrating the results of the neurological and electrodiagnostic examinations. Additional research should be conducted to assess the inter-rater reliability of this rating system. One approach to this line of investigation would involve comparing multiple physicians' ratings based on standard written neurological examination reports, and reports of electrodiagnostic examinations.

4. The full potential of the medical history questionnaire utilized in this study as a quantitative health screening device was not fully explored. Using standard item analysis techniques, such as those used to develop criterion referenced, weighted application blanks for job applicants, it would be possible to select items and develop scoring keys to predict some selected clinical criterion (e.g., Total Neurological Score). The development of such a weighted medical history form could be a very useful and practical tool to be included in an in-plant health-screening system.

REFERENCES

Allen, N., Mendell, J.R., Billmaier, D.J., Fontaine, R.E., & O'Neil,J. Toxic polyneuropathy due to methyl n-butyl ketone. Archives of Neurology, 1975, 32, 209-218.

Braceland, F.J. Psychiatric aspects. In Pennsylvania Department of Labor and Industry, Survey of carbon disulfide and hydrogen sulfide hazards in the viscose rayon industry, 1938, Bulletin 46.

Hanninen, H., Psychological picture of manifest and latent carbon disulfide poisoning. British journal of industrial medicine, 1971, 28, 374-381.

Lilis, R. Behavioral effects of occupational carbon disulfide exposure. In Xintaras, C., Johnson, B.L., & deGroot, I. (Eds.), Behavioral toxicology: Early detection of occupational hazards. HEW Publication No. (NIOSH) 74-126, Washington, D.C., U.S. Government Printing Office (Stock #1733-00031).

Pearson, R.G. and Byars, G.E. The development and validation of a checklist for measuring subjective fatigue. USAF Report No. 56-115, School of Aviation Medicine, Randolph Field, Texas, 1956.

Rose, A.M., Human information processing: An assessment and research battery. Unpublished doctoral disseration, University of Michigan, 1974.

Schwetz, B.A., Leong, B.K.J. & Gehring, P.J. The effect of maternally inhaled trichloroethylene, perchloroethylene, methyl chloroform and methylene chloride on embryonal and fetal development in mice and rats. Toxicology Research Laboratory, Dow Chemical Company, Midland, Michigan, 1974.

Stewart, R.D., Hake, C.L., Forster, H.V. Lebrun, A.J., Peterson, J.E., & WU, A. Tetrachloroethylene: Development of a biologic standard for the industrial worker by breath analysis. Report No. NIOSH-MCOW-ENUM-PCE-74-6, Medical College of Wisconsin: Milwaukee, Wisconsin, 1974.

Ts'o, T. Personal correspondence to the Corporate Medical Department, Dow Chemical Company, Midland, Michigan, 1975.

Tuttle, T.C., Killian, N.E., Reed, D.E., & Grether, C.B. Behavioral, neurological, and physiological effects of perchloroethylene exposure: Review and evaluation. National Institute for Occupational Safety and Health, Contract No. HSM 99-73-35, Final Report, Columbia, Maryland: Westinghouse Behavioral/Safety Center, October 1973.

Wechsler, D. Manual for the Wechsler Adult Intelligence Scale. The Psychological Corporation, New York, New York, 1955.

APPENDICES

APPENDIX A

Questionnaires Used in Data Collection

Note: Questionnaires used in the dry cleaners study were identical to those used in the carbon disulfide portion of the contract. See Appendix C of NIOSH 77-128.

APPENDIX B

Protocols for Medical Examinations

Note: Protocols for medical examinations were identical to those used in the carbon disulfide aspect of this contract. See Appendix E of NIOSH 77-128.

APPENDIX C

Description of Procedures Used in Collection of Breath and Ambient Air PCE Samples

Collecting Breath Samples

Workers were asked to inflate a 12" x 12" saran bag according to the following instructions: "Take a deep breath, hold it for about 10 seconds, and then blow up the bag." After the bag was inflated, it was corked and set aside for analysis. The sampling schedule called for breath samples to be made immediately prior to each testing session and at two hour intervals throughout the work day. Bags were analyzed as soon as possible after collection using the Miran-1 portable infrared spectrophotometer and index values were recorded on the record sheet along with the person's name, the bag number, the date and time taken. These index values were converted to ppm through use of the calibration curve for PCE. Prior to initial use and periodically during the field testing, bags were tested for leaks. Bags which had leaks were discarded.

Collecting Ambient Air Samples

The sampling schedule called for at least four samples to be taken at each work station throughout the work day. This meant samples were taken anywhere from one to two hours apart, depending on the work schedule of differing plants and employees. Extra samples were taken around the dry cleaning machine to insure measures of PCE concentration under all conditions (i.e., transfer) were obtained. Initially, (i.e., in the first two plants) 12" x 12" saran bags were inflated with a hand pump. However, this method was later dropped in favor of inflating a 12" x 24" bag with an electric pump. In either instance, samples were taken directly in the breathing area of the worker. Again, samples were analyzed with the Miran-1 as soon as possible after collection. In most cases, the analyses were done within one hour of sample collection. Index levels were recorded along with the location sampled, conditions under which sampled (if in machine area), bag number, date and time. These index values were converted to ppm using the calibration curve for PCE.

Field Analysis Procedures for Breath and Ambient Air Samples

Once breath and ambient samples had been collected, they were analyzed using the Miran I portable analyzer. The Miran I is a single beam, variable filter, spectrophotometer, scanning the infrared spectral range of 2.5 to 14.5 microns. Several steps should be taken in preparing the Miran for use.

1. Turn on the Miran approximately one hour before use.

2. The following controls should be set as indicated for detecting perchloroethylene:

-Path length (at end of column) 1M (up position)
-Slit 2MM
-Wave length 10.9 microns

3. The analyzer controls should be set as follows (see Figure 2):

-Gain switch	X10 gain
-Function switch	100%T
-Meter range	CAL (fully counter clockwise)
-Time constant	.25

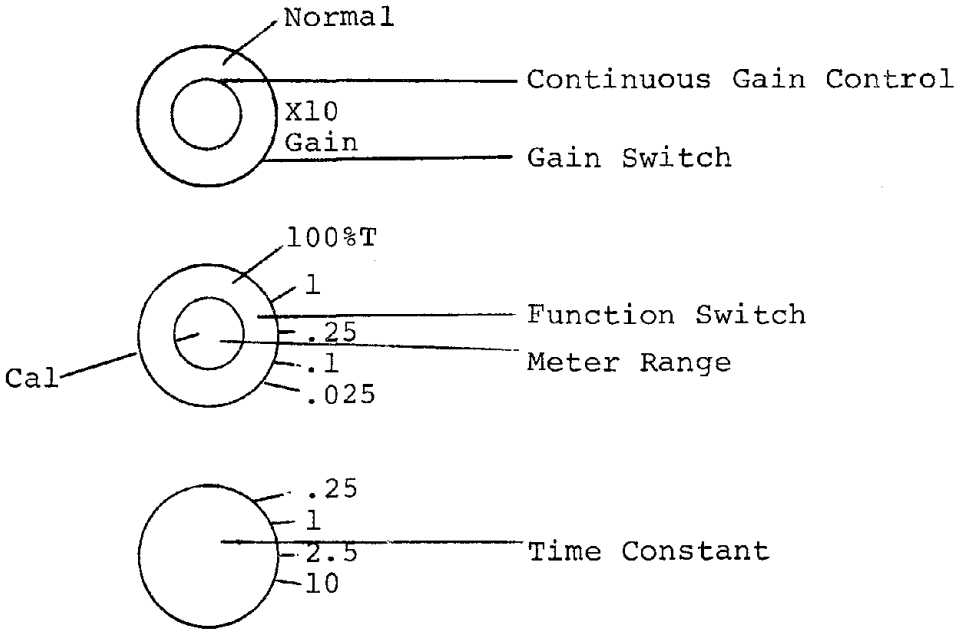

FIGURE 2 MIRAN I Analyzer Controls

4. Once all settings have been made, place the zero gas filter over the air intake near the end of the column and turn on the pump. When the meter reading is nearly constant adjust the Continuous Gain Control until a reading of 100% is obtained on the lower scale, (If this cannot be done, the column is out of alignment and instrument will have to be realigned and recalibrated.

5. Turn the Function Switch to .1 and turn off the pump. The meter should read close to 0. If it does not, adjust the Continuous Gain Control until a reading of 0 or slightly greater is obtained. (Never attempt to take a reading if the needle is set below 0). Turn the Time Constant to 2.5. The needle should remain on or slightly greater than 0.

6. To check the calibration of the equipment, analyze a bag containing a known concentration of perchloroethylene. Inflate a sample bag with fresh air and cap it. Inject one microliter of perchloroethylene into the bag by using a syringe to puncture the bag. When the syringe is withdrawn, seal the hole with Scotch tape. After a couple of minutes, place the bag stem over the air intake and turn on the pump. Turn off the pump just before the bag is empty and take a scale reading. The needle should register between .8 and 1.2 on the upper scale. Remove the bag and again attach the zero gas filter. Activate the pump to clear the system.

7. To analyze bag samples, the procedures are similar to those for calibration except that no solvent should be injected into the bag. However, the stem of the bag is attached to the air intake. The analyzer pump should then be activated until the bag is collapsed. When the bag is empty, the pump should be turned off. When the needle stabilizes, the absorbance can be read directly from the meter on the instrument. Concentrations in ppm can be determined by converting absorbance readings to ppm using a calibration curve such as that depicted in Figure 3. The curve shown is for use with the .25 range. When used with the .1 scale, ppm values shown should be divided by 2.5. The range selected depends on the sensitivity desired (e.g., 1-range for concentrations over 500 ppm, .025 scale for concentrations of 12.5 ppm or less).

A number of precautions should be exercised when analyzing samples:

- Use the heating element when running breath samples to avoid condensation.

- Only run the pump with the air intake covered.

- Use care when attaching bags to or removing them from the air intake to avoid disturbing the alignment of the 1 m. cell.

Calibration for Tetrachloroethylene

Wavelength 10.9 u Slit Width 2 mm Date 4-25-75

Pathlength 1 m Range 0 - .25 A Analyst JEZ

Minimun Dectectable Limit 1 ppm

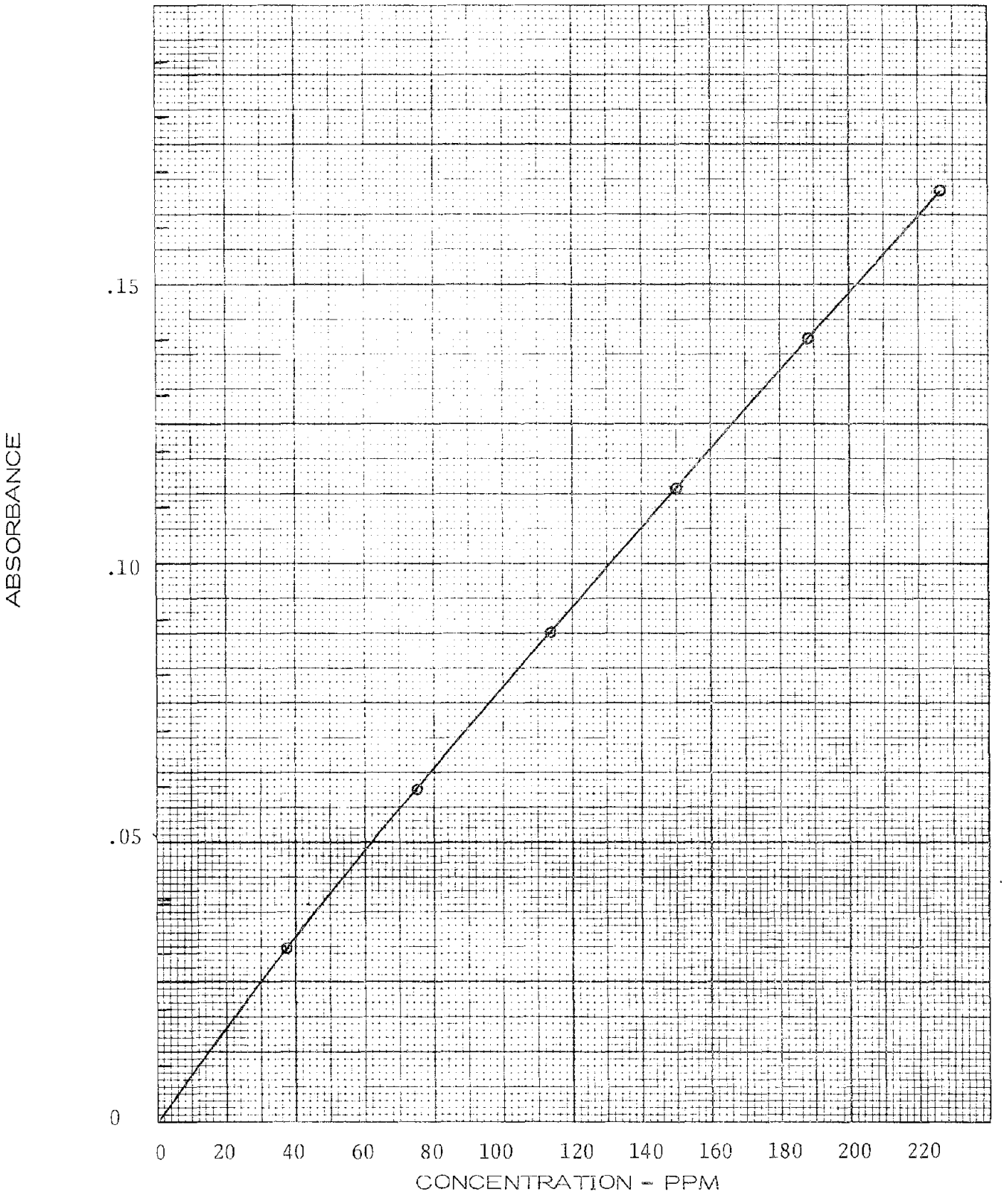

Figure 3 Calibration Curve for Miran I

APPENDIX D

Description of Procedures Used in Behavioral Testing

BEHAVIORAL TESTING

Behavioral testing was conducted at each plant twice a day, for a five day period. Sessions were held at the beginning and end of the work day. An attempt was made to test workers in the morning before any exposure to perchloroethylene and in the afternoon after exposure had ended. Adherence to these guidelines was affected by the following constraints:

1. The individual employee's cooperation.
2. The plant's workload for the day.
3. Work schedules, both the plant's and individual employee's.
4. The number of employees to be tested.

In each session, from 1 to 4 workers were tested at a time by two test administrators. When more than one person was being tested, attempts were made to "group test" as much as possible in order to reduce the time required for the employee. The testing schedule is presented in Figure 4. The order in which tests were administered was varied from day to day and testing was arranged such that no test was given exclusively by the same administrator, except for the Digit Symbol and Digit Span. The test manual calls for these tests to be given only by trained psychologists. Instructions for administering each test are presented in part 1 of this report (NIOSH publication NIOSH 77-128).

Testing time on the first day of testing when all tests were administered was about one hour. After the first day, a reduced version of the battery was given which took an average of 20-25 minutes per subject. In most instances, testing was completed without interrruption. However, due to the fact that testing had to be conducted in-plant, the potential for distraction and interference (e.g., machinery noise, bells, other employees walking by) was always present.

Test	when administered				
	Mon.	Tues.	Wed.	Thurs.	Fri.
Pretest Questionnaire*	x	x	x	x	x
Feeling Tone Checklist (Pre)	x	x	x	x	x
Digit Symbol	x		x		x
Neisser Letter Search**	x	x	x	x	x
Critical Flicker/Fusion Freq.	x	x		x	
Reaction Time	x	x	x	x	x
Drop Reaction Time	x	x	x	x	x
Santa Ana Test**	x	x	x	x	x
Feeling Tone Checklist (Post)	x	x	x	x	x
Digit Span***	x	x	x	x	x
Post Test Questionnaire****					x

*Administered only at morning sessions.
**Followed complete procedures on Mondays; omitted all second trials other days.
***Administered at Work Station.
****Administered only at last testing session.

Figure 4 Testing schedule for PCE. study.

APPENDIX E

Summary of Medical History Questionnaire Data

TABLE 19

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
32.	Being knocked unconscious	20	0.10	0.31	9	0.11	0.33
33.	Eye or vision trouble	20	0.70	0.47	9	0.33	0.50
34.	Attacks of temporary vision loss	20	0.0	0.0	8	0.0	0.0
35.	Blurred vision	20	0.30	0.47	8	0.50	0.53
36.	Pain in your eyes	20	0.10	0.31	8	0.25	0.40
37.	Difficulty in hearing	20	0.15	0.37	8	0.13	0.35
38.	Any constant draining or discharge from either ear, other than wax	20	0.5	0.22	9	0.11	0.33
39.	Ringing and buzzing in your ears	20	0.20	0.41	8	0.38	0.52
40.	Pain in your ears	20	0.5	0.22	9	0.00	0.02
41.	Pain in chest	20	0.30	0.47	9	0.11	0.33
42.	Have you ever noticed your heart beating abnormally or irregularly?	19	0.32	0.48	8	0.25	0.46
43.	Shortness of breath with only minor exertion	20	0.32	0.49	8	0.25	0.46
44.	Waking up at night short of breath	20	0.05	0.22	9	0.0	0.0
45.	A desire to increase the number of pillows you sleep on	20	0.20	0.41	9	0.33	0.50
46.	Swelling of your legs	20	0.20	0.41	9	0.22	0.44
47.	Frequent leg cramps or pain after walking	20	0.05	0.22	9	0.30	0.50
48.	Hands or feet turning blue	20	0.0	0.0	9	0.0	0.0
49.	Repeated pain, pressure or tightness of your chest	20	0.05	0.22	9	0.0	0.0
50.	A need to avoid certain foods	20	0.30	0.47	9	0.11	0.33
51.	Frequent bloating or swelling	20	0.20	0.41	9	0.11	0.33

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
52.	Taking milk or antacid for stomach aches	19	0.32	0.48	8	0.13	0.35
53.	Any pain or discomfort in your stomach in recent months	19	0.26	0.45	8	0.13	0.35
54.	Frequent diarrhea or constipation	19	0.05	0.23	9	0.44	0.53
55	A need to take laxatives frequently	19	0.0	0.0	9	0.44	0.53
56.	Any change in color or form in your stools in the past six months	19	0.0	0.0	9	0.22	0.44
57.	Being bothered by gassy stomach	20	0.25	0.44	8	0.13	0.35
58.	Pain or a burning sensation when you urinate	19	0.16	0.37	9	0.11	0.33
59.	Urination four or more times a day	20	0.70	0.47	8	0.63	0.52
60.	Urination three or less times a day	17	0.35	0.49	8	0.38	0.52
61.	Smoky, cloudy, or bloody urine	20	0.0	0.0	8	0.0	0.0
62.	Passing a kidney stone	20	0.10	0.31	9	0.0	0.0
63.	Painful swelling or any other problems with the testicles or penis (male sex organs) -male respondents only-	10	0.0	0.0	0	-	-
64.	Increased sensitivity to heat	17	0.12	0.33	7	0.14	0.38
65.	Increased sensitivity to cold	19	0.21	0.42	7	0.10	0.00
66.	Sexual desire less than you think it should be	14	0.36	0.50	7	0.42	0.53
67.	Trouble with your muscles like frequent cramps, pain or swelling	20	0.0	0.0	8	0.25	0.46

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
68.	Pain in your muscles after only slight exertion	20	0.0	0.0	6	0.17	0.41
69.	Tremors, twitching, or incoordination of your muscles	20	0.05	0.22	8	0.13	0.35
70.	Lost sensation, numbness or tingling feeling	20	0.20	0.41	6	0.17	0.41
71.	"Shooting" pains in your arms or legs	20	0.10	0.31	8	0.25	0.46
72.	Decreased strength in your arms, forearms or hands	19	0.26	0.45	9	0.22	0.44
73.	Frequent or constant coughing	18	0.17	0.38	9	0.11	0.33
74.	Coughing up blood	18	0.0	0.0	8	0.0	0.0
75.	Wheezing or whistling sound when you breathe	19	0.16	0.37	9	0.11	0.33
76.	Trouble sleeping	20	0.25	0.44	9	0.22	0.44
77.	Coldness of body parts	17	0.12	0.33	9	0.11	0.33
78.	Numbness of body parts	19	0.16	0.37	9	0.11	0.33
79.	Changes in walking speed or gait	17	0.06	0.24	8	0.25	0.46
80.	Fatigue while walking	19	0.26	0.45	8	0.25	0.46
81.	Loss of appetite	19	0.05	0.23	9	0.0	0.0
82.	Unusually large weight loss	19	0.05	0.23	9	0.0	0.0
83.	Rheumatism	19	0.05	0.23	9	0.0	0.0
84.	Arthritis	18	0.17	0.38	9	0.22	0.44
85.	Have you ever been hospitalized for a work-related illness or injury?	19	0.05	0.23	9	0.11	0.33

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
86.	Being depressed easily or having crying spells	19	0.16	0.37	8	0.25	0.46
87.	Having problems with severe anxiety	19	0.11	0.32	8	0.13	0.35
88.	Getting irritable easily	20	0.45	0.51	8	0.25	0.46
89.	Having emotional problems you would like to discuss with the doctor	19	0.11	0.32	7	0.0	0.0
90.	Frequently having unpleasant dreams	18	0.11	0.33	6	0.17	0.41
91.	Unpleasant odor resulting from chemicals in your present work environment	18	0.11	0.32	9	0.0	0.0
92.	Frequent nausea or vomiting	19	0.0	0.0	9	0.0	0.0
93.	Color blindness	20	0.05	0.22	9	0.0	0.0
94.	Rheumatic fever	20	0.0	0.0	9	0.11	0.33
95.	Abnormal electrocardiogram (EKG)	20	0.10	0.31	9	0.0	0.0
96.	A heart murmur	20	0.15	0.37	9	0.0	0.0
97.	An enlarged heart	20	0.10	0.31	9	0.0	0.0
98.	High blood pressure	20	0.30	0.47	9	0.44	0.53
99.	A heart attack	20	0.05	0.22	9	0.0	0.0
100.	A blood clot in your heart	20	0.0	0.0	9	0.0	0.0
101.	Are you taking any medication for your heart or blood pressure?	20	0.30	0.47	9	0.11	0.33
102.	High level cholesterol or fats	20	0.10	0.31	8	0.13	0.35
103.	Ulcers or colitis	20	0.15	0.37	8	0.10	0.00
104.	A kidney infection	20	0.0	0.0	8	0.13	0.35
105.	Diabetes	20	0.0	0.0	8	0.25	0.46

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
106.	Asthma	20	0.05	0.22	8	0.0	0.0
107.	Bronchitis	20	0.10	0.31	8	0.0	0.0
108.	Pneumonia	19	0.11	0.32	8	0.25	0.46
109.	Emphysema	19	0.05	0.23	8	0.0	0.0
110.	Nerve Disorders	19	0.05	0.23	7	0.14	0.38
111.	Frequency of headaches off the job	17	1.76	1.20	8	2.00	1.85
	Check the items that describe the type of headache you have on the job.						
112.	No headaches	7	1.00	0.0	3	1.00	0.0
113.	Located all over head	1	1.00	0.0	1	1.00	0.0
114.	Located mainly in front of head	7	1.00	0.0	2	1.00	0.0
115.	Located mainly in temples	3	1.00	0.0	4	1.00	0.0
116.	Located mainly in eyes, face or neck	2	1.00	0.0	1	1.00	0.0
117.	Comes and goes	4	1.00	0.0	3	1.00	0.0
118.	Constant	2	1.00	0.0	0	-	-
119.	Throbbing	3	1.00	0.0	1	1.00	0.0
120.	Pounding	2	1.00	0.0	2	1.00	0.0
121.	Do you have any impaired or missing legs, arms, fingers, etc.?	20	0.10	0.31	9	0.0	0.0
122.	Do you require any medical aids (e.g., eye glasses, pacemaker, artificial kidney, hearing aid, etc)?	20	0.65	0.49	9	0.44	0.53

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
123.	Do you have any birth related defect or condition?	20	0.10	0.31	9	0.11	0.33
	Did parents, brothers or sisters suffer from:						
124.	Diabetes	19	0.37	0.50	7	0.43	0.54
125.	High blood pressure	15	0.53	0.52	7	0.43	0.53
126.	Stroke	18	0.22	0.43	5	0.60	0.55
127.	Nerve disorders	16	0.25	0.45	5	0.60	0.55
128.	Anemia	17	0.12	0.33	4	0.25	0.50
129.	Obesity	16	0.31	0.48	4	0.25	0.50
130.	Heart disease (angina and/or heart attack)	18	0.44	0.51	6	0.50	0.55
131.	Circulatory disorders, lower limbs	13	0.15	0.38	6	0.0	0.0
132.	Liver ailments (like cirrhosis of the liver)	16	0.13	0.34	7	0.43	0.53
133.	Arthritis	15	0.40	0.51	7	0.50	0.55
	Use of Drugs						
134.	Dexedrine	18	1.06	0.24	9	0.78	0.44
135.	Benzedrine (or other amphetamines)	18	1.06	0.24	9	0.78	0.44
136.	Marijuana	18	1.22	0.73	9	1.11	0.93
137.	Sleeping pills(Sleepeze, Compoz, etc.)	18	1.00	0.0	9	0.78	0.44

TABLE 19 (cont'd)

SUMMARY OF MEDICAL HISTORY INFORMATION

Item No.	Item	Exposed Workers No.	Exposed Workers Mean	Exposed Workers Std. Dev.	Control Workers No.	Control Workers Mean	Control Workers Std. Dev.
138.	LSD	18	1.00	0.0	9	0.78	0.44
139.	"Speed"	18	1.06	0.24	9	0.78	0.44
140.	"Downers" (tuinal, redbirds, etc.)	18	1.06	0.24	9	0.78	0.44

APPENDIX F

Analysis of Variance for Performance Data (A.M.-P.M. Contrasts)

*G

S = 9 A = 3 B = 2

GROUP A(1):
  CONDITION B(1):
    30.4 24.4 23 32 17 24.4 21.7 25.8 21
  CONDITION B(2):
    31.6 26.6 22 34 17.8 24.8 19.3 25 22.4

GROUP A(2):
  CONDITION B(1):
    23.6 22.8 19.6 19.6 25.4 27.8 22 23 20.8
  CONDITION B(2):
    25 25 25.2 21.8 26.8 30 22.4 22.8 21

GROUP A(3):
  CONDITION B(1):
    18.3 19.8 24.8 22.5 21.7 25.3 23.6 21.8 19.7
  CONDITION B(2):
    22 17.8 24.3 24 24.3 24.3 24.4 23.8 19.3

MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

	A.M.	P.M.	
	B(1)	B(2)	
A(1)	24.411	24.833	(PCE-Exposed Males)
	4.627	5.327	
A(2)	22.733	24.444	(PCE-Exposed Females)
	2.681	2.814	
A(3)	21.944	22.689	(Controls)
	2.384	2.488	

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	48.0	24.0	1.00	0.386
S(A)	24	579.0	24.1		
WITHIN SUBJECTS:					
B	1	12.4	12.4	8.48	0.008
AB	2	4.0	2.0	1.38	0.270
S(A)B	24	35.1	1.5		
TOTAL	53	678.6			

*

SANTA ANA DEXTERITY (RIGHT HAND)

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         31 26.6 19.8 30.6 19.2 24.4 17.7 25.5 24.8
       CONDITION B(  2):
         31.6 26.2 22.2 30 19 24.4 18.3 25.8 26

     GROUP A(  2):
       CONDITION B(  1):
         25.2 25.3 25 17 24.6 29.6 26.6 23 17.6
       CONDITION B(  2):
         23.8 26 28.2 19 1_27.6 32.4 24.4 24.5 18.8

     GROUP A(  3):
       CONDITION B(  1):
         24.3 25.3 26 21.5 27.5 23.5 26.6 24.8 22
       CONDITION B(  2):
         24 26.5 27.7 23 28.5 25.8 27.8 24 19

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                  B(  1)      B(  2)
     A(  1)      24.400      24.833
                  4.761       4.479
     A(  2)      23.767      24.967
                  4.079       4.319
     A(  3)      24.611      25.144
                  2.018       3.002


                              ANALYSIS OF VARIANCE
     +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     +  SOURCE          DF              SS              MS          F      P      +
     +  BETWEEN SUBJECTS:                                                       +
     +  A                2             2.4             1.2       0.04   0.950  +
     +  S(A)            24           700.0            29.2                      +
     +                                                                          +
     +  WITHIN SUBJECTS:                                                       +
     +  B                1             7.0             7.0       5.88   0.022  +
     +  AB               2             1.6             0.8       0.65   0.534  +
     +  S(A)B           24            28.7             1.2                      +
     +  TOTAL           53           739.7                                      +
     +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

*
```

SANTA ANA DEXTERITY (BOTH HANDS)

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         41 36.8 24.6 44.2 19.2 31.7 25.3 38.8 23.8
       CONDITION B(  2):
         41.3 38.2 27.6 45.6 18.4 33 26 42.5 24.4

     GROUP A(  2):
       CONDITION B(  1):
         28.2 31 30.2 23.2 27.2 42 21.5 28.8 21.6
       CONDITION B(  2):
         28.8 34.8 32.6 25.6 29.8 41.4 24 29.3 20.4

     GROUP A(  3):
       CONDITION B(  1):
         24.5 17 36.8 29 25.8 34.5 34.8 23 25.7
       CONDITION B(  2):
         28 18.3 39 27.7 28 35.3 36.8 27.3 23.3

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)       31.711      33.000
                   8.868       9.422
     A(  2)       28.189      29.633
                   6.296       6.205
     A(  3)       27.900      29.300
                   6.473       6.645
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	156.4	78.2	0.72	0.502
S(A)	24	2616.0	109.0		
WITHIN SUBJECTS:					
B	1	25.6	25.6	16.60	0.001
AB	2	0.1	0.0	0.02	0.970
S(A)B	24	37.0	1.5		
TOTAL	53	2835.1			

*

NEISSER LETTER SEARCH

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         .93 1.22 1.06 .65 1.15 1.44 1.29 .91 .91
       CONDITION B(  2):
         .88 1.24 1.05 .61 1.17 1.27 1.19 .81 .89

     GROUP A(  2):
       CONDITION B(  1):
         .91 1.08 .76 1.28 .79 .90 1.51 1.3 .96
       CONDITION B(  2):
         .91 .91 .73 1.41 .81 .88 1.34 1.23 .97

     GROUP A(  3):
       CONDITION B(  1):
         .91 1.13 .72 1.06 .91 .76 .82 .79 1.25
       CONDITION B(  2):
         .79 1.07 .71 1.09 .91 .77 .82 .73 1.26

       MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                 B(  1)      B(  2)
     A(  1)       1.062       1.012
                  0.240       0.227
     A(  2)       1.054       1.021
                  0.257       0.243
     A(  3)       0.928       0.906
                  0.182       0.192


                              ANALYSIS OF VARIANCE
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+  SOURCE          DF              SS              MS          F       P      +
+  BETWEEN SUBJECTS:                                                         +
+  A                2             0.2             0.1        0.89   0.428    +
+  S(A)            24             2.4             0.1                        +
+                                                                            +
+  WITHIN SUBJECTS:                                                          +
+  B                1             0.0             0.0        6.60   0.016    +
+  AB               2             0.0             0.0        0.35   0.714    +
+  S(A)B           24             0.1             0.0                        +
+  TOTAL           53             2.6                                        +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

*
```

DIGIT SPAN (FORWARD)

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         5.4 5 5 8.4 6 6 6 6_7.5 5.3
       CONDITION B(  2):
         5 5.4 4.6 8.6 6.2 6 5.3 7.3 5.8

     GROUP A(  2):
       CONDITION B(  1):
         6.2 6.5 6.2 5 7.8 7.8 6.2 6.3 7
       CONDITION B(  2):
         6_5.6 6.8 6.4 5.4 7.6 8 6.2 6 7.7

     GROUP A(  3):
       CONDITION B(  1):
         5.5 4.3 6.7 5 5.8 5.5 6.2 6.3 6
       CONDITION B(  2):
         6 4.7 8.5 4.7 5.5 6 6.2 6.5 5.7

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)         6.067       6.022
                    1.163       1.242
     A(  2)         6.556       6.633
                    0.878       0.949
     A(  3)         5.700       5.978
                    0.728       1.132
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	5.5	2.7	1.37	0.272
S(A)	24	48.0	2.0		
WITHIN SUBJECTS:					
B	1	0.1	0.1	1.14	0.296
AB	2	0.2	0.1	0.94	0.408
S(A)B	24	3.0	0.1		
TOTAL	53	56.9			

*

DIGIT SPAN (BACKWARD)

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         4.8 3.2 3.2 7.4 3.8 4 3.7 6.3 4.8
       CONDITION B(  2):
         3.8 2.8 3.2 8 4 3 4.3 5.7 4.8

     GROUP A(  2):
       CONDITION B(  1):
         4.4 5.3 4.6 3.2 7.4 7.4 3.6 4.5 5.7
       CONDITION B(  2):
         4 5.3 4.8 2.8 6.8 6 4 4.7 6

     GROUP A(  3):
       CONDITION B(  1):
         3.5 3.3 5 3.3 3.8 3.5 3.2 3.8 3.7
       CONDITION B(  2):
         4 2.3 5.5 3.3 4.3 3.5 3.4 4 4

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)         4.578       4.400
                    1.438       1.632
     A(  2)         5.122       4.933
                    1.497       1.238
     A(  3)         3.678       3.811
                    0.543       0.867
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	14.9	7.5	2.47	0.104
S(A)	24	72.7	3.0		
WITHIN SUBJECTS:					
B	1	0.1	0.1	0.53	0.480
AB	2	0.3	0.2	0.98	0.393
S(A)B	24	3.7	0.2		
TOTAL	53	91.7			

*

DIGIT SYMBOL (WAIS)

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         64.7 38.7 47 84.7 39.7 54.4 44 66.5 50
       CONDITION B(  2):
         75 41.7 48_49.3 86.3 42.3 58.6 52_51 67.5 55.5

     GROUP A(  2):
       CONDITION B(  1):
         52 58 73.7 38 75 79 45.7 44 59
       CONDITION B(  2):
         53.3 60 63.3 40.5 74.3 87.7 48.7 53 61.5

     GROUP A(  3):
       CONDITION B(  1):
         64.5 39.7 67.5 46.3 63.3 62.5 61.3 63 32.3
       CONDITION B(  2):
         77.5 39.3 72.7 42.3 72.3 67.5 64.7 66 34

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)       54.411      58.578
                  15.064      15.086
     A(  2)       58.267      60.256
                  14.833      14.081
     A(  3)       55.600      59.589
                  12.734      16.391
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	69.9	34.9	0.08	0.913
S(A)	24	10165.6	423.6		
WITHIN SUBJECTS:					
B	1	154.4	154.4	14.07	0.001
AB	2	13.2	6.6	0.60	0.562
S(A)B	24	263.4	11.0		
TOTAL	53	10666.3			

*

CRITICAL FLICKER FREQUENCY

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         51.7 47.6 57.3 33.9 45.9 45.7 50.1 54.2 47.9
       CONDITION B(  2):
         48.7 46.3 46.7 25.1 46.1 47.3 48.8 52.2 46.3

     GROUP A(  2):
       CONDITION B(  1):
         46.7 53.5 53.8 44.4 44.1 48 43.5 43.9 40
       CONDITION B(  2):
         47.3 47.8 55.4 43.9 44 47.4 41.5 42.1 40.1

     GROUP A(  3):
       CONDITION B(  1):
         48.2 43.8 40.5 40.3 47.7 46 44.6 52.4 45.4
       CONDITION B(  2):
         50 43.4 40.1 40.2 47.2 44.4 45.8 61.2 40

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)       48.256      45.278
                   6.625       7.811
     A(  2)       46.433      45.500
                   4.647       4.632
     A(  3)       45.433      45.811
                   3.803       6.727
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	12.4	6.2	0.10	0.901
S(A)	24	1521.2	63.4		
WITHIN SUBJECTS:					
B	1	18.7	18.7	3.21	0.083
AB	2	25.7	12.9	2.21	0.130
S(A)B	24	140.1	5.8		
TOTAL	53	1718.1			

*

CRITICAL FUSION FREQUENCY

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         50.7 41.7 45.3 49.8 42.6 44 43.8 52.6 46
       CONDITION B(  2):
         48.2 41.1 42.2 50 41.2 44.3 42.9 48.4 45.4

     GROUP A(  2):
       CONDITION B(  1):
         44.8 50 56.2 47.8 47.9 44.9 40.4 41.4 40.9
       CONDITION B(  2):
         43.9 45.8 53.6 47.6 43.6 45.3 41.3 40.1 40.3

     GROUP A(  3):
       CONDITION B(  1):
         51.3 44.4 41.1 45.2 43.1 45.9 38.4 40.6 42.6
       CONDITION B(  2):
         55.7 43.7 43.9 47.7 43.5 48.9 43.2 42.5 44.5

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                    B(  1)      B(  2)
     A(  1)       46.278      44.856
                   3.853       3.338
     A(  2)       46.033      44.611
                   5.100       4.229
     A(  3)       43.622      45.956
                   3.730       4.238
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS					
A	2	5.7	2.8	0.09	0.909
S(A)	24	778.1	32.4		
WITHIN SUBJECTS:					
B	1	0.4	0.4	0.26	0.619
AB	2	42.3	21.2	14.14	0.000
S(A)B	24	35.9	1.5		
TOTAL	53	862.4			

```
*
```

AVERAGE OF CRITICAL FUSION
AND FLICKER FREQUENCIES

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         51.2 44.6 51.3 72.8 44.5 44.8 47 53.4 46.9
       CONDITION B(  2):
         48.5 43.7 44.4 70.3 43.6 45.8 45.8 50.3 45.9

     GROUP A(  2):
       CONDITION B(  1):
         45.7 51.7 55 46.1 46.1 46.4 41.9 42.7 40.4
       CONDITION B(  2):
         45.6 46.8 54.5 45.7 43.8 46.4 41.4 41.1 40.2

     GROUP A(  3):
       CONDITION B(  1):
         49.7 44 40.8 42.8 45.4 45.9 41.6 46.5 44.1
       CONDITION B(  2):
         52.9 43.6 42 44 45.3 46.7 44.5 51.8 42.3

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)       50.722      48.700
                   8.909       8.391
     A(  2)       46.222      45.056
                   4.642       4.315
     A(  3)       44.533      45.900
                   2.720       3.934


                                ANALYSIS OF VARIANCE
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+  SOURCE          DF              SS              MS          F       P      +
+  BETWEEN SUBJECTS:                                                         +
+  A                2           221.8           110.9        1.61   0.220   +
+  S(A)            24          1654.5            68.9                        +
+                                                                            +
+  WITHIN SUBJECTS:                                                          +
+  B                1             5.0             5.0        2.49   0.125   +
+  AB               2            28.0            14.0        6.97   0.004   +
+  S(A)B           24            48.1             2.0                        +
+  TOTAL           53          1957.3                                        +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

*
```

SIMPLE REACTION TIME

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         34.5 32.2 32.9 32.3 41.4 53.3 45 37.6 42.3
       CONDITION B(  2):
         32.8 30.4 32.2 27.5 38.2 45.8 44.8 37.1 44.1

     GROUP A(  2):
       CONDITION B(  1):
         41.8 36.3 42.5 47.6 35.8 31.6 51.2 50 59.4
       CONDITION B(  2):
         41.5 33.8 40.1 47.1 34.5 28.5 50.7 51.1 57.1

     GROUP A(  3):
       CONDITION B(  1):
         46 55.1 40.3 54.6 46.2 52.1 42.1 39.6 49
       CONDITION B(  2):
         46.1 51.5 42.1 51 45.2 53.7 41.2 41.8 58.4

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                    B(  1)      B(  2)
     A(  1)        39.056      36.989
                    7.138       6.751
     A(  2)        44.022      42.711
                    8.841       9.471
     A(  3)        47.222      47.889
                    5.897       6.049
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	822.0	411.0	3.81	0.036
S(A)	24	2586.7	107.8		
WITHIN SUBJECTS:					
B	1	11.0	11.0	2.66	0.112
AB	2	17.9	9.0	2.16	0.135
S(A)B	24	99.5	4.1		
TOTAL	53	3537.1			

*

FOUR-CHOICE REACTION TIME

```
*G
     S = 9      A = 3      B = 2


     GROUP A(  1):
       CONDITION B(  1):
         43.7 40 42.2 35.9 49.7 60.3 55.7 43.5 48.1
       CONDITION B(  2):
         40.1 38.1 41.1 33.2 46.3 59.3 50.4 41.6 48.5

     GROUP A(  2):
       CONDITION B(  1):
         48.2 45.5 49.1 56.8 42.3 39.1 55.7 55.8 67.5
       CONDITION B(  2):
         48.8 48.7 45.4 54.6 39.5 34.8 59.1 57.4 62.9

     GROUP A(  3):
       CONDITION B(  1):
         47.5 60.5 44.1 62.1 52.8 61.8 45 49.8 54.1
       CONDITION B(  2):
         48.2 62.8 50.7 57.5 49.7 58.4 46.1 52.2 59.4

         MEANS (TOP) AND STANDARD DEVIATIONS (BOTTOM):

                   B(  1)      B(  2)
     A(  1)      46.567      44.289
                  7.728       7.751
     A(  2)      51.111      50.133
                  8.731       9.291
     A(  3)      53.078      53.889
                  7.083       5.775
```

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	P
BETWEEN SUBJECTS:					
A	2	600.4	300.2	2.56	0.097
S(A)	24	2814.2	117.3		
WITHIN SUBJECTS:					
B	1	9.0	9.0	1.91	0.177
AB	2	21.6	10.8	2.30	0.120
S(A)B	24	112.9	4.7		
TOTAL	53	3558.1			

*

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