NEUROPSYCHOLOGICAL DYSFUNCTION ASSOCIATED WITH DENTAL OFFICE ENVIRONMENT

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

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May 1989

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Murry, Joe Mitchell, Neuropsychological Dysfunction Associated with Dental Office Environment. Master of Science (Psychology) May, 1989, 49 pp., 12 tables, references, 64 titles.

Five chemicals indigenous to the dental office environment that may cause toxic effects are formaldehyde, phenol, acrylic, mercury, and nitrous oxide. These chemicals create abnormal stress on physiological and psychological systems of the body resulting in symptomatology and pathology when the body defenses can no longer maintain homeostasis by adaptation. This study demonstrated serious behavioral consequences of chemical and heavy metal exposure. This study provided evidence that a significant percentage of dental office personnel who are exposed to the dental office chemicals show psycho-neurological dysfunction. It was concluded that these individuals suffer adverse reactions to the chemicals in their work environment. The problem areas included perceptual motor difficulty in cognitive functioning, concern with bodily functions, despondency, and interpersonal problems.

NEUROPSYCHOLOGICAL DYSFUNCTION ASSOCIATED WITH DENTAL OFFICE ENVIRONMENT

The environment in which we live requires our physiological systems to adapt continuously to maintain homeostatic balance (Selye, 1956). Radical and rapid changes place an abnormal amount of stress on our physiological systems (immune and endocrine), the results of which are medical and/or psychological symptomatology and pathology (Ader, 1981). The symptoms experienced from exposure to chemicals or other xenobiotics may vary in different individuals (Rea & Mitchell, 1982).

While there have been estimates that as many as 20,000,000 workers in various occupations serve as an early warning system of chemical toxicity for the general population (Anderson, 1982), seldom has the professional office worker been the subject of study. Clinical observations of patients who worked in a dental office environment (J. R. Butler & J. M. Murry, personal communication, 1987) suggested the possibility of individual and common behavioral toxic response patterns. It was considered that the most consistent feature in their environment was the dental office in which they worked.

A two-phase study was conceived as a pilot work for indications of (1) chemicals indigenous to the dental office and (2) indications of adverse behavioral consequences to dental office personnel.

An analysis for chemicals was made of a typical dental office, and blood studies of some personnel for presence of chemicals in the serum were reviewed (W. J. Rea, personal communication, 1988). Results showed 5 chemicals indigenous to the dental office which were of concern to this study. These chemicals are listed in Table 1.

Table 1

Five Toxic Chemicals Indigenous to the Dental Office

1. Nitrous oxide
2. Mercury
3. Formaldeyde
4. Phenol
5. Acrylic

Each of these chemicals has been found to be toxic. A summary review of the physiological and psychological effects of each chemical under study has revealed a number of serious problems associated with exposure.

Nitrous Oxide

Nitrous oxide, the chemical formula for which is N_2O, is a gas used as an anesthetic in dental surgery as well as in other medical procedures. It sometimes has an exhilarating effect when inhaled; thus the term laughing gas has come to be used for nitrous oxide (Great Encyclopedic Dictionary, 1966). Because of the ability of nitrous oxide to reduce fear and anxiety of patients undergoing dental treatment, nitrous oxide/oxygen analgesia has become widely used by the dental profession to enhance the comfort of the patient (Langa, 1968).

Physiological effects of nitrous oxide include a reversible depressing action on the brain. Pharmacodynamics of nitrous oxide are not clear but may involve combining the cellular lipoids to alter oxidative process via enzyme alteration (Langa, 1968). Anesthetic drugs appear to have a selectivity for specific neural mechanisms, altering pain perception at dosages that leave other perceptions relatively unaffected. Concomitantly, the patient experiences a feeling of remoteness from surroundings with decreased psychomotor performance and diminished ability to concentrate. When nitrous oxide is used over prolonged periods, bone marrow is depressed and white cell count is decreased (Langa, 1968).

Psychological effects are manifest in an array of feelings depending on the plane of analgesia and individual susceptibility to the drug. In the first stage, analgesia creates a feeling of detachment, an increased pain threshold, and a generally euphoric state. The second stage is different for every individual and may create delirium, excitement, and/or fear. The third stage, divided into four planes, is the surgical stage. The patient may remember and be able to give an account of the procedure when only the first or second plane is reached, but the latter planes are deep anesthesia. The fourth stage is respiratory paralysis (Guedel, 1953).

Although these stages do not accurately portray anesthesia as currently used, the psychological feelings developed in stages 1 and 2 have great potential for dentistry and medicine as well as psychology (Langa, 1968). Fear, pain, and anxiety disappear. Euphoria and feelings of warmth and comfort are described by patients, as well as tingling sensations in the fingers, toes, and tip of the tongue, probably due to psychomotor excitation. The patient may experience diaphoresis due to psychic disturbance during the altered consciousness. The patient responds to verbal commands and may experience a vibratory sensation as well as feelings of lethargy, warmth, non-caring, safety, and trust. Awareness and recall of the procedure may be enhanced, with

possible repercussions if events were not beneficial or pleasant (Guerra, 1986).

Psychological symptoms with both the use and abuse of nitrous oxide include depression, impaired memory, cloudy thinking, and illogical processing of information. Other psychological symptoms reported are headiness, drowsiness, a "two-martini feeling," throaty voice, relaxation, wandering thoughts, deep thoughts, humorous thoughts, freedom from intrusion, sexual feelings, and lack of inhibition. Fear may be present or completely abated (Silver, 1970).

Myeloneuropathy has been reported after prolonged exposure to nitrous oxide, especially by dentists. Complaints range from sensory disturbances to Lhermitte sign, loss of balance, leg weakness, gait ataxia, impotence, and sphincter disturbance. Neurological examination showed sensorimotor polyneuropathy, possibly axonal in nature. Mode of action may be a disturbance of the actions of vitamin B_{12} in the nervous system (Layzer, 1978).

Evidence exists that prolonged exposure to nitrous oxide may cause spontaneous abortion and carcinoma as well as testicular damage and sexual dysfunction. Studies under laboratory conditions showed cognitive and motor skills decreased (Whitcher, Zimmerman, Tonn, & Piziali, 1977).

Table 2 summarizes the adverse reactions and psychological symptoms attributed to nitrous oxide.

Table 2

Nitrous Oxide

Adverse Reactions	Psychological Symptoms
Myeloneuropathy	Depression
Neuropathy	Detachment
Spontaneous Abortion	Euphoria
Sexual Dysfunction	Fear
Impotence	Delirium
Sphincter Disturbance	Impaired Memory
Loss of Balance	Cloudy Thinking
Weakness	Illogical Processing of Material
Sensorimotor Polyneuropathy	Thought Dysfunction
Enzyme and Hormonal Disturbance	CNS Dysfunction

Mercury

Mercury has been the subject of numerous articles in medical and dental literature. Chronic mercury poisoning by inhalation is so common that it has earned a place in the medical dictionary (Dorland's Medical Dictionary, 1957). It is termed erythismus mercuralis, a psychical disturbance noted in persons poisoned by mercury. Characterized by tremor, fearfulness, and timidity, especially in the

presence of strangers, this disease has been enshrined in literature in Alice in Wonderland (Carroll, 1865), in which the Mad Hatter trembled and shook when the Queen of Hearts pointed her finger at him.

A review of the literature (Langan, Fan, & Hoos, 1987) cited 134 references which discussed both assertions and denials that mercury in the dental office represents a threat to the dentist and his staff members. Mercury exposure to the dental staff comes from condensation and delivery of mercury-silver amalgam restorations and from removal of old amalgam restorations from teeth. Reported physiological, psychological, and neurological problems include rash, skin reactions, neuropsychiatric symptoms, acrodynia, paresthesia, ataxia, hearing and visual changes, dysarthria, and cerebral palsy. Neuropsychiatric symptoms include catatonia, dissociation, paranoia, delusions, visual and auditory disturbances, and schizophrenic-like symptoms. Other psychological symptoms include headaches, unsteadiness, inability to read and write, tension, hyperactivity, sleepiness, and insomnia. Death has also been reported as a result of exposure to mercury. Mercury destroys brain tissue leading to sensory, motor, and non-specific functional deficits. Paresthesias in the extremities and around the mouth seem to be early symptoms in adults (Weiss, 1983).

Contact allergy to dental amalgams is frequently caused by mercury released during condensation (Catsaki & Sulica, 1978; White & Brandt, 1976). Mercury poisoning may be the etiology of erythema multiforme (Eversole, 1979), a symptom complex involving the skin and mucous membrane. Membranous neuropathy (Gluck et al., 1973; Hayslett et al., 1972) and neutropenia (Rose & Kaye, 1983) may result from mercurials which may be used as diuretics. Organs which retain mercury the longest include the brain, kidneys, and testicles. The mercury bound in these organs is not detected until autopsy.

Even in the face of these studies, the conclusions of Langan et al. (1987) imply that there is no danger from mercury contamination to dental personnel. However, many articles indicate that mercury is an extremely dangerous chemical. The safety standards as published by the Occupational Safety and Health Administration (OSHA) are certainly in question (Langan et al., 1987; Ochoa & Miller, 1983).

The ADA News ("Analysis from Mercury Testing," 1987) reports that 80 out of 1,500 dentists tested at the annual meeting of the American Dental Association in Las Vegas showed elevated concentrations of mercury in the urine. The concentrations were above 25 micrograms of mercury per liter.

Shapiro et al. (1982) found in a study of the relationship between cumulative exposure to mercury and chronic health impairment that one-third of 298 dentists tested had mercury levels above the 20 μg/g tissue as measured by x-ray fluorescence technique. Twenty-three of the dentists had high concentrations of mercury in the tissue. Of the 23, 30% had polyneuropathies and exhibited mild visuographic dysfunction and symptom distress. The findings suggest that the use of mercury as a restorative material is a health risk for dentists.

Table 3 outlines the various adverse reactions and psychological symptoms which have resulted from exposure to mercury.

Formaldehyde

Formaldehyde effect to human systems has been thoroughly surveyed and researched by government agencies, private individuals, and industry because of its widespread use in commercial products. A colorless, pungent gas with the chemical formula CH_2O, it is normally used in the form of a 37% aqueous solution as an antiseptic, preservative, and disinfectant, and as the basis of various plastics (Great Encyclopedic Dictionary, 1966). Formaldehyde in a 40% concentration is used as a disinfectant for surgical instruments and counter tops, probably killing bacteria by combining with their protein (Goth, 1972).

Table 3

Mercury

Adverse Reactions	Psychological Symptoms
Dermatological Symptoms	Memory Loss
Testicular Disease	Gait Ataxia and Tremor
Nephropathy and Glomerular Disease	Disorientation
Paresthesia	Weakness and Fatigue
Loss of Hearing and Vision	Blurred Vision and Auditory Disturbance
CNS Destruction and Cerebral Palsy	Anxiety and Depression
Dysarthrea and Ataxia	Tension
Arthralgia	Catatonia
Gastritis	Dissociation and Delusions
Cardiovascular Dysfunction	Paranoia
Neuropathy	Fearfulness
Death	Flight of Ideas

Formaldehyde is used extensively in industry in the form of building materials (Breysse, 1977; Godish, 1981, 1987), in urea foams for insulation and packing (Harris, 1981), in clothing and dyes (Bourne & Seferian, 1959), in production and utilization of hundreds of chemicals (Andersen et al., 1984), and in many foods (Imbus, 1985). Formaldehyde is found in the dental office in a variety of forms and uses, among which are dyes in the carpets and drapes, particle boards and plywood building materials, preservatives of anesthetics, cold sterilization solutions such as Cidex (glutaraldehyde), autoclave solutions, and fixatives for biopsied tissues.

OSHA has investigated many complaints of symptomatology resulting from exposure to formaldehyde and its by-products (Godish, 1983). Symptomatology includes decompensation of respiratory and immune function, neurophysiologic dysfunction (Godish, 1983), threshold alteration, eye and skin irritation, upper and lower airway irritation, edema, joint inflammation, pneumonia (Imbus, 1985; Miabach, 1983), and cancer (Swenberg, Kerns, Mitchell, Gralla, & Pavkov, 1980). Formaldehyde has been shown to trigger cardiovascular disease (Rea, 1978). Along with CNS depression, formaldehyde has produced a significantly high incidence of gynecological problems including painful menstruation and hypomenstrual syndrome. Inflammatory disease of the

reproductive system has been reported (Godish, 1983). Psychological symptoms attributed to formaldehyde include headaches (Rea, 1978), memory lapse, fatigue, drowsiness, difficulty in sleeping, irritation, ravenous hunger, compulsive eating, hyperactivity, and schizophrenic-like behavior (Stovall, 1980; Randolph, 1987; Philpott & Kalita, 1980).

The concentration of formaldehyde which can produce the above symptoms is far lower than the OSHA standards for clean air of 3 parts per million (ppm). OSHA has determined this to be an unhealthful concentration of formaldehyde and now recommends a maximum of 1 ppm (National Institute for Occupational Safety and Health, 1976; Matthews, et al., 1985; Grot, Silberstein, & Ishigars, 1985). Denmark's air quality standard is 0.10 ppm of formaldehyde, which also has been determined to be too great a concentration because it continues to cause irritating symptoms (Godish, 1983).

The above forms of formaldehyde are extrinsic forms of the chemical, and many individuals show symptoms and sensitivities to extrinsic formaldehyde. Internal forms of formaldehyde may produce adverse reactions also. This may be due to the spread of effect and as such the individual becomes sensitive to his own body chemistry. Choline is transformed to glycine by oxidation, demethylation, and transmethylation to eventually form glycine and

formaldehyde. Formaldehyde is also a by-product of the metabolism of the amino acid glycine, which is important in various physiologic functions including hemoglobin synthesis (Harper, 1959). Transmethylation of other amino acids, such as sulfur-containing amino acids methionine and cystine, produces formaldehyde as a by-product (Harper, 1959).

Adverse reactions and psychological symptoms resulting from exposure to formaldehyde are summarized in Table 4.

Phenol

Phenol is a white crystalline caustic compound, C_6H_5OH, derived from coal tar. Also known as carbolic acid, it has a characteristic odor and is used as a disinfectant, antiseptic, and germicide. Extremely poisonous, it may be any of a series of aromatic hydroxyl derivatives of benzene or its homologs. Phenolic resins are any of a large and important class of resins and plastics made from an aldehyde-phenol base. Biphenyl, a phenol derivative, is a colorless crystalline hydrocarbon, $C_6H_5 \cdot C_6H_5$, found in coal tar and used in lacquers and as a preservative of citrus fruits (Great Encyclopedic Dictionary, 1966; Dorland's Illustrated Medical Dictionary, 1988).

Phenols are used in dentistry as disinfectants. Phenolic resins are found in transformers used in the dental office equipment and other electrical equipment. The

Table 4

Formaldehyde

Adverse Reactions	Psychological Symptoms
Decompensation of Immune Function	Memory Loss
Respiratory Decompensation	Fatigue
Neurophysiological Dysfunction	Drowsiness
Cardiovascular Disease	Sleep Disruption
CNS Depression	Ravenous Hunger
Gynecological Problems	Compulsive Eating
Irritation of Eyes, Skin, and Upper and Lower Airways	Hyperactivity/Irritability
Reproductive System Disease	Schizophrenic-Like Behavior
Headaches	Mood Alteration
	Feelings of Hostility

biphenyls are used as preservatives as well as pesticides used in and around the dental office buildings.

The benzene compounds are immunotoxic and neurotoxic (Askari & Galiks, 1976). Polychlorobiphenyl (PCB) compounds apparently cause lymphocyte infiltration into the liver, kidney, small intestine, and lungs. In cattle they have created high immunological activity and susceptibility to infections, suggesting impairment of the immunological mechanisms (Cooke, Helland, Vanderweele, & Dejong, 1978). They impair host resistance, possibly by alteration of lymphoreticular organs (Loose, Silkworth, Pittman, Benitz, & Mueller, 1978). Other recent data on effects of PCBs in mammals and birds include chronic toxic effects and subacute reproductive effects (Kimbrough et al., 1978).

Polybrominated biphenyl produced loss of body weight, hepatocellular swelling, liver weight increases, and increased lipid deposition in rats and mice. Spleenic lymphocytes were reported less responsive to the T-cell mitogens phytohemagglutinin and concanavlin A. B-cell mitogen and serum immunoglobulin were depressed (Moore, Luster, & Gupta, 1978; Silkworth & Loose, 1978). Exposure to PCBs and dichlorodiphenyltrichloroethane (DDT) disturbed fetal and perinatal regulatory mechanisms (Sonntag, 1975).

Sources of human exposure to the phenolic compounds are varied, including accidental exposure during the

manufacturing process of PCBs and their derivatives, from the use of products manufactured from PCBs, and through contamination of the food chain (Reggiani & Bruppacher, 1985). Since degradation of these phenolic compounds is resisted by the human biochemical processes, PCBs are becoming an increased risk to man. Biphenyls are lipophilic, making them difficult to remove from the body and causing the individual to be chronically and periodically reexposed as lipid is broken down by body processes (Christiani, Kriebel, Fox, & Baker, 1986).

Clinical features associated with exposure, both acute and chronic, include dermatological signs, neurological symptoms, respiratory findings, and impairment of liver function. Skin lesions have been found in newborns of mothers exposed to high levels of the substances. An abnormal number and shape of teeth were observed in children born of exposed mothers. Skin and ocular manifestations have occurred. Irregular menstrual cycles have been reported. Immunological dysfunction has been accredited to exposure to the PCBs along with a threefold increase in serum triglycerides which returned to normal after five to seven years. Other manifestations include low birth weight, retarded growth, elevated bilirubin, enlargement of Meibomian glands, hypoplastic nails, and dark brown

pigmentation of the skin, gums, nails, and groin (Yushimura, 1978).

Neurophysiologic effects remain controversial, but soft neurologic signs appeared in many of the children affected by the Yusho accident, in which PCBs were dumped into Japanese waters (Reggiani & Bruppacher, 1985). Headaches, dizziness, depression, sleeplessness, nervousness, somnolence, fatigue, and memory loss were also reported. Gastrointestinal symptoms such as anorexia, weight loss, nausea, vomiting, and pain have been reported with chronic occupational exposure (Reggiani & Bruppacher, 1985).

Other psychological symptoms due to PCB exposure include irritability and difficulty in concentration. Family disruptions, alcohol intolerance, sleep disturbances, confusion, and psychosocial disturbances have also been reported (Rasmussen & Svend, 1986).

The "spinning syndrome," induced in mice by prenatal intoxication with PCBs transported across the placental barrier from the exposed mothers, may be analagous to neurologic findings in children exposed to PCBs. This exposure has been believed to cause "minimal cerebral dysfunction" and to result in hyperactivity syndrome in children (Chou, Miike, Payne, & Davis, 1979).

Table 5 shows a summary of adverse reactions and psychological symptoms attributed to exposure to phenol.

Table 5

Phenol

Adverse Reactions	Psychological Symptoms
Decompensation of Immune System	Headaches
Nervous System Dysfunction	Dizziness
Reproductive Effects	Depression
Liver Destruction	Confusion
Disturbed Fetal and Perinatal Regulatory Systems	Nervousness
Dermatological Lesions in Newborns	Somnolence
Respiratory Symptoms	Fatigue
Skin and Ocular Manifestations	Memory Loss
Irregular Menstrual Cycles	Irritability
Abnormal Number and Shape of Teeth	Difficulty in Concentration

Acrylic

Acrylic is a derivative of ethylene and contains a vinyl group in its structural formula. One series of acrylics is derived from acrylic acid, CH_2 = CHCOOH, and another from methacrylic acid, CH_2 = $C(CH_3)$COOH. Both of these compounds polymerize by addition. Esterification of these acids forms polymethacrylate, and addition of the monomer forms the acrylic plastic. Methyl methacrylate is a monomer used to dissolve the polymer, polymethyl methacrylate (acrylic), to form a plastic dough which can be packed and molded into a dense plastic, which, in dentistry, is used to form prosthetic appliances. The acrylic is used in the fabrication of esthetic composite restorations and as luting agents. Methyl methacrylate is a clear, transparent liquid at room temperature. It is highly volatile, with a melting point of -48°C and a boiling point of 100.8°C. It has a high vapor pressure and is an excellent solvent (Skinner & Phillips, 1960).

It has been found that acrylates may trigger a myriad of sensitivities which occur in association with sub-threshold and picomolar quantities of the chemical agents. Acrylated prepolymers have been incriminated as chemical incitants associated with dysfunctions ranging from mild respiratory problems to severe central nervous system (CNS) disorders (Rea & Mitchell, 1982).

Dermatological diseases in quinea pigs have been attributed to contact with acrylated inks (Bjorkner, 1981). Contact dermatitis in human beings was also reported (Bjorkner, Dahlquist, & Fregert, 1980).

Neurological dysfunction including toxic brain syndrome, loss of memory, loss of dexterity, loss of visual acuity, and loss of hearing have been reported in case studies in which dental acrylic monomer was the incitant. Exposure to acrylic monomer will create fine motor dysfunction, psychological mood swings, decreased cognitive function, and disorientation (W. J. Rea, personal communication, 1988).

Table 6 shows a summary of adverse reactions and psychological symptoms related to exposure to acrylic.

The purpose of the second phase of this study was to determine the effects, if any, the chemicals indigenous to the dental office environment might have on the behavior of the dentist or the staff members in terms of cognitive and psychomotor function and personality traits.

It was hypothesized that the practicing dentist would have a heavy mind/body burden of the above-mentioned chemicals, and that the longer the dentist was in the practice of dentistry, the more dysfunctional he would become in terms of personality and cognitive/psychomotor performance.

Table 6

Acrylic

Adverse Reactions	Psychological Symptoms
CNS Dysfunction	Mood Swings
Dexterity Loss	Cognitive Function Loss
Visual Acuity Loss	Disorientation
Hearing Loss	Irritability
Respiratory Problems	Psychomotor Dysfunction
Dermatological Diseases	Feelings of Hostility
Immunological Dysfunction	Loss of Auditory Memory
	Loss of Visual Memory
	Thought Processing Dysfunction
	Flight of Ideas

Method

Subjects

The subjects were drawn from a group of dentists and their staff members attending a dental conference. No attempt was made to control age, sex, or race.

The subjects who volunteered for the study ranged from 26 to 57 years of age. There were 22 females and 29 males. The subjects represented private dental practices from all regions of the U.S. with the exception of New England and

Hawaii. Approximately 50% were from the Rocky Mountains westward, 20% from the midwest and southwest, 20% from the east, southeast, and south, and 5% from Canada and Alaska. The years associated with private dental practice ranged from 1 1/2 to 28.

Consent forms were presented to all participants, who were informed of the intent to publish data from the tests.

Test Materials

The personality test used in the study was the Clinical Analysis Questionnaire (CAQ) (Krug & Cattell, 1980). The median test-retest coefficient across all scales is .73 reliability. Validity coefficients for the individual factors, with .30 considered important, range from .45 to .86 for personality traits and from .69 to .95 for the clinical factors. These validity coefficients are considered remarkably faithful to its hypothesized structure. The Bender Gestalt test was used to measure neurophysiological function (Bender, 1946). Gestalt function is that function of the integrated organism whereby it responds to a given constellation of stimuli as a whole. A pattern in the sensory field is a potential stimulus. Any resulting pattern is a sensory motor pattern. Interpretation of the Bender Gestalt test by the Embree-Butler Technique (Embree, 1963) measures the number and degree of errors for rotation,

omission of angles, addition of angles, distortion, tremor, overlap difficulty, embellishments, lack of closure, and angle flattening. Fine tremor shows fine motor dysfunction. Overlap difficulty, rotation, or distortion may indicate visual motor dysfunction or integration problems. Embellishment and lack of closure may indicate attention and concentration difficulty. The Harrell-Butler Intermediate Neurological Examination (H-BINE) was used to measure cognitive and psychoneurophysiological functions (Harrell & Butler, 1988). Normative data are from university undergraduates, and psychoneurophysiological information gained by the test includes immediate, intermediate, and delayed verbal and visual memory, serial learning function and cognition, neuromuscular coordination, oral apraxia and motor speed coordination, motor coordination and hemisphere communication, vigilance, attention, cognitive comprehension, ability to inhibit incoming stimuli, construction apraxia, perceptual motor ability, organization confusion, expressive speech latency, finger localization, tactile sensory function, abstract thinking, spatial manipulation, shift of set, logical thought processing, visual spatial memory, antecedent consequences, logical reasoning, decisional judgment, and comprehension.

Procedure

The neuroscreen was administered to 19 of the subjects individually, and each neuroscreen was scored according to standardized instruction. The Bender Gestalt test was administered to the entire group in a group setting. Each design was shown on a screen, and the participants were instructed to reproduce each of the nine designs as accurately as possible on a sheet of white paper. The CAQ test was self-administered in a group setting following the explicit instructions of the test booklet.

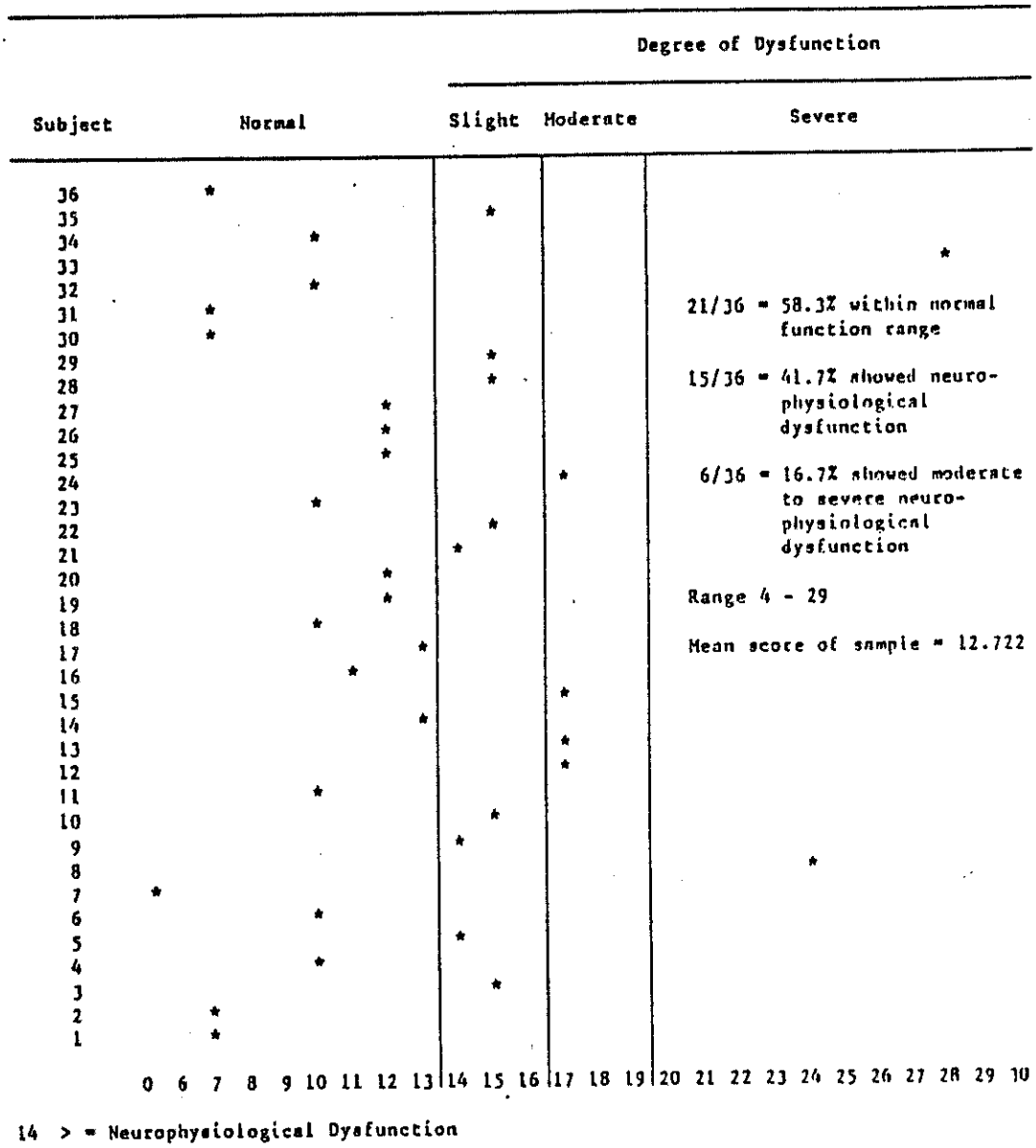
Results

The normative scores of each of the tests were used as standard scores, and the statistical data were compared to the normative scores. Generally the group as a whole scored more than one standard deviation away from the normal population in terms of psychoneurological function. It was found that more than 90% showed fine motor tremor. Approximately 41.7% showed some psychomotor dysfunction, and 16.7% showed moderate to severe psychomotor dysfunction (Table 7).

Immediate recall with interference was found to be impaired in 57.9% of the dentists sampled. Delayed auditory memory was impaired in more than 84% of those tested. Auditory immediate effortful processing and working memory was decreased in 42.1%. Visual motor function and visual memory were impaired in 52.6%. Vigilance, attention,

Table 7

Bender Gestalt Psychomotor Function by Individual Subject



14 > = Neurophysiological Dysfunction

concentration, and cognitive comprehension were decreased in 52.6%. Construction apraxia and perceptual motor dysfunction were found in 57.9%. In 52.6% there was tactile sensory dysfunction and/or inability to locate finger position. Concrete thinking was prevalent in 52.6%. Logical thinking and recall of stories was impaired in 78.9%, while spatial and visual memory was impaired in 68.4%. Ability to process antecedent consequences was a problem for 47.4% (Table 8).

Personality and behavioral traits that tended to show trends for the dental population tested were indicated by the CAQ. Scores and interpretation from the personality trait factors included interesting and disturbing information. There were 33 subjects tested. The results indicated that 72.7% of the sample dentists deviated from the norm with 39.4% greater than 1 standard deviation from the norm. In 18.2% very high scores indicated that a large portion of dentists and auxiliary personnel are successful and satisfied with their profession. They are warm-hearted and personable. However, 27.3% scored very low, indicating a history of unsatisfying interpersonal relationships. Extremely high scores may indicate an unhealthy and overriding need for approval by others.

The intelligence scale in this test is a measure of general abstract ability. In the dental sample 30.3% were

Table 8

Harrell-Butler Intermediate Neurological Examination

Questions	% of Composite Scores Missed	Interpretations	Questions Missed by Age Group			
			> 35	36-45	46-55	56 >
1	57.9	Intermediate and delayed auditory memory with interference tasks	*	*	*	*
2	89.5		*	*	*	*
3	84.2		*	*	*	*
5	42.1	Auditory immediate effortful processing and working memory	*	*		
7	52.6	Visual/motor memory	*		*	*
16	52.6	Vigilance attention cognitive comprehension		*	*	
18	57.9	Construction apraxia, perceptual/ motor activity	*	*	*	
23	52.6	Finger location and tactile sensory function	*		*	
29	52.6	Abstraction	*	*	*	
32	78.9	Logical stories	*	*	*	*
35	68.4	Spatial memory/visual recall	*	*	*	*
37	89.5	Abstract thinking	*	*	*	*
38	84.2	Abstract thinking	*	*	*	*
40	47.4	Antecedent consequence	*		*	
41	47.4	Receptive speech		*		*
42	68.4	Intermediate logical memory	*	*	*	*
Composite mean score = 29.16			29.60	27.57	28.20	36.00
Mean normal score = 20.6						
Standerd deviation = 6						

high. The scores on the emotional stability scale were 72.7% out of the norm; 48.5% were higher than the norm, indicating an individual with sufficient resources to cope with stress. Scores in 24.2% were low and in 18.2% were very low. Low scores may indicate a high level of anxiety, unstable emotions, poor coping skills, difficulty reaching goals, immature planning ability, accident proneness, and physical illness. Low scores may also indicate individuals who are more easily overwhelmed by challenges or even opportunities of the day.

The impulsivity scale indicates that the individual who scores high enjoys life and is happy-go-lucky, lively, and enthusiastic with many friends. The dental sample score was 30.3% high and 21.2% low. Low scores indicate that the individual may internalize inner conflicts. On the conformity scale, 36.4% of the scores were high. High scores indicated conscientious, persevering, duty bound individuals who follow rules and respect authority. If the scores are very high, tension, irritation, and disgust may be felt toward individuals who do not share their feelings. Only 9.1% of the sample were very high. Boldness scores were 36.4% high and 27.3% low. High scorers are bold, energetic, adventurous, and successful. Low scores indicate individuals with little insulation. External stresses reach them more easily, and great amounts of energy must be spent

to maintain homeostasis with possible psychological exhaustion. Self-sufficiency scores included 48.5% high, indicating that dentists are successful, prefer to work and solve problems alone, and are usually at the upper end of the educational level. Low scores were 18.2%, indicating factors which may contribute to anxiety patterns and to the individual's inability to keep his or her emotions in order. Very high scores may be indicative of underlying pathology. The group score was 9.1% very low. Self-discipline high scores are expected by individuals who are able to bind anxiety and have strong control over emotional life and behavior. Low scores indicate anxiety and inability to control emotions. The sample scores were 24.2% low and 27.3% high. Tension scale contributes to anxiety and medical-risk factors. High tension may be associated with frustrated motivation, anger, hostility, and irritability. Very high scores may indicate a cry for help. The dental sample scores were 33.3% high, 24.2% very high, 33.3% low, and 21.2% very low (Table 9).

The clinical factors which were remarkable with respect to the dental sample and the scores and interpretations follow. Approximately 27.3% of the subjects showed mild to moderate depression and preoccupation with bodily dysfunctions. With thoughts and feelings of hopelessness and helplessness, 27.3% showed signs of suicidal depression

Table 9

Clinical Analysis Questionnaire - Personality Traits

	Personality Traits	% Deviations from Norm	% > 1 SD Out of Norm	% Score > 4	% Score > 7	% Score < 5	% Score > 6
A	Warmth	72.7	39.4	27.3	30.3	54.5	18.2
B	Intelligence	42.4	33.3	3.0	30.3	15.2	30.3
C	Emotional Stability	72.7	48.5	18.2	24.2	24.2	48.5
E	Dominance	54.5	42.4	18.2	12.1	30.3	27.3
F	Impulsivity	51.5	24.2	12.1	27.3	21.2	30.3
G	Conformity	54.5	30.3	3.0	9.1	18.2	36.4
H	Boldness	63.6	24.2	15.2	12.1	27.3	36.4
I	Sensitivity	69.7	33.3	27.3	12.1	51.5	24.2
L	Suspiciousness	63.6	39.4	27.3	12.1	36.4	27.3
M	Imagination	63.6	18.2	6.1	24.2	30.3	33.3
N	Shrewdness	51.5	42.4	18.2	12.1	21.2	30.3
O	Insecurity	57.6	27.3	15.2	6.1	36.4	21.2
Q_1	Radicalism	75.8	33.3	27.3	15.2	48.5	27.3
Q_2	Self-sufficiency	66.7	24.2	9.1	15.2	18.2	48.5
Q_3	Self-discipline	51.5	30.3	15.2	15.2	24.2	27.3
Q_4	Tension	66.7	45.5	21.2	24.2	33.3	33.3

Sample n = 33
Normal Range = 5-6
1 Std. Dev. Range = 3.5 - 7.5
2 Std. Dev. Range = 1.5 - 9.5
Mean = 5.5

including disgust with life, emptiness, meaninglessness, despondency, and despair. Approximately 30.3% showed increased agitation, which when combined with high scores on suicidal depression increases the risk of suicide. Agitation may be exhibited by a search for excitement which may be associated with a death wish or a feeling of restless and sometimes reckless adventure with a lessened awareness of physical and psychological danger, and 27.3% of the subjects showed increased anxiety with possible feelings of clumsiness or shakiness when handling instruments, causing a loss of self-confidence and need for increased attention and help. These people may become confused and unable to cope with new or unusual demands. Boredom with their work was reported by 36.4% of the subjects, who indicated that they felt that their work and life were rather pointless.

Of the subjects tested 42.4% had increased scores on the psychopathic deviation scale, indicating that they are generally less inhibited than the average person. They are less intimidated by physical danger or pain and by criticism of society. When agitation is high in addition to the psychopathic deviation scale, the profile has greater pathological implications. These individuals may want to be the center of attention and probably do not mind being the butt of jokes. They may go long periods without sleep, and

they may enjoy emergencies and quarrels. This may represent a kind of "emotional anesthesia" in professional people.

Approximately 27.3% of the subjects tested showed signs of thinking of themselves as having been harshly treated by their environment and of being relatively unimportant with many needs unmet. Reality may seem so unkind that withdrawal can occur to an unrealistic extent and schizophrenic-like behavior may occur in a rather mild form. This elevation may be caused by physiological or organic factors such as chemical exposures (Table 10).

A composite of the CAQ scores indicates the group scores regress toward the mean of 5.5. This would statistically negate the outliers which represent a significant deviation from the norms (Table 11).

The group most affected neurophysiologically, cognitively, and psychologically included individuals over 55 years of age and/or those in practice for longer than 15 years. This group was 1 1/2 standard deviations above the normal population. The remainder of the groups were more than 1 standard deviation above the normal population (Table 12).

Discussion

Tests results indicate that there is reason for concern about dental office environment and exposure of dentists and other office personnel to toxic chemicals. Personnel showed

Table 10

Clinical Analysis Questionnaire - Clinical Factors

	Clinical Factors	% Deviations from Norm	% > 1 SD Out of Norm	% Score > 4	% Score > 7	% Score < 5	% Score > 6
D_1	Hypochondriasis	54.5	36.4	15.2	21.2	18.2	48.5
D_2	Suicidal Depression	72.7	45.5	39.4	6.1	45.5	27.3
D_3	Agitation	72.7	39.4	24.2	15.2	42.4	30.3
D_4	Anxious Depression	72.7	15.2	3.0	12.1	15.2	27.3
D_5	Low Energy Depression	39.4	6.1	0	6.1	18.2	21.2
D_6	Guilt and Resentment	54.5	15.2	9.1	6.1	30.3	24.2
D_7	Boredom and Withdrawal	66.7	33.3	27.3	18.2	30.3	36.4
P_a	Paranoia	45.5	18.2	15.2	3.0	30.3	15.2
Pp	Psychopathic Deviation	63.6	36.4	12.1	24.2	21.2	42.4
S_c	Schizophrenia	51.5	21.2	15.2	6.1	24.2	27.3
A_s	Psychoasthenia	69.7	33.3	21.2	12.1	51.5	19.2
P_s	Psychological Inadequacy	27.3	6.1	0	6.1	3.0	21.2

Sample n = 33
Normal Range = 5-6
1 Std. Dev. Range = 3.5 - 7.5
2 Std. Dev. Range = 1.5 - 9.5
Mean = 5.5

Table 11

Clinical Analysis Questionnaire Composite Mean Scores

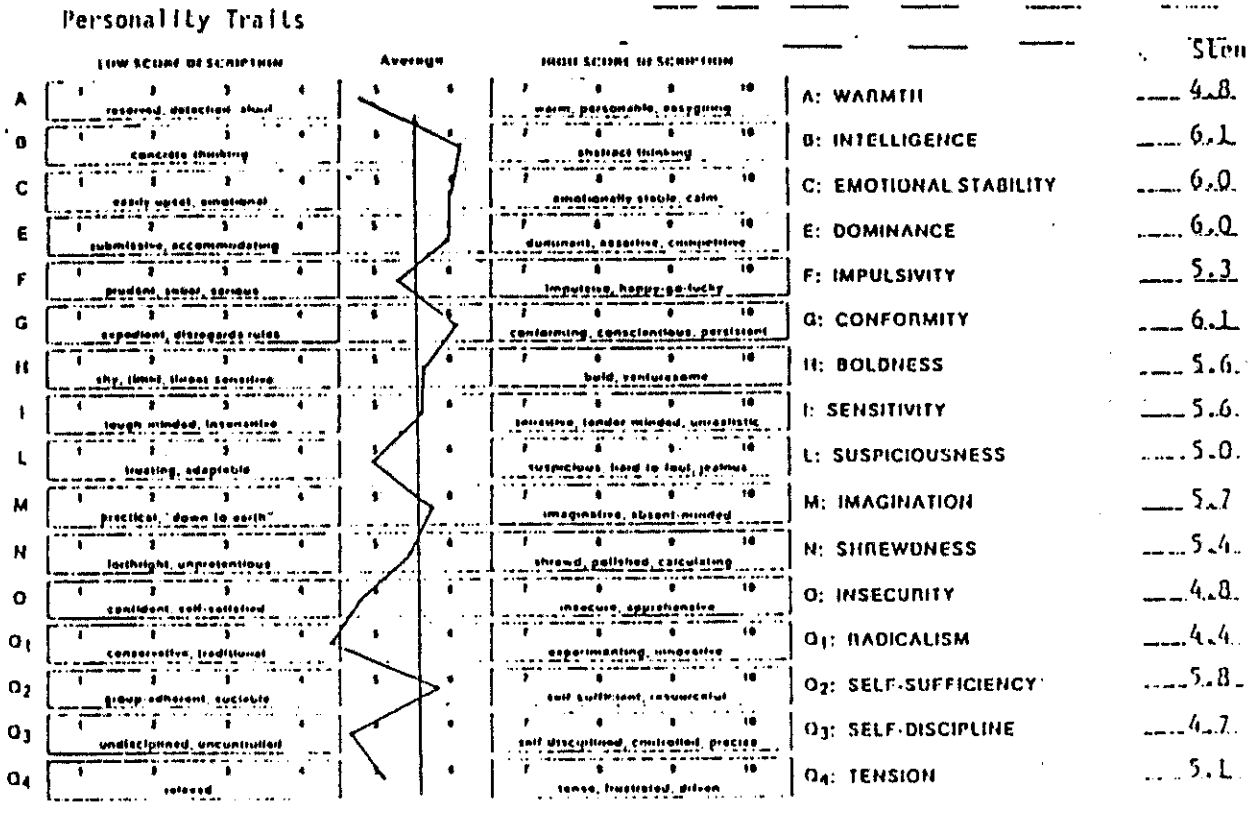
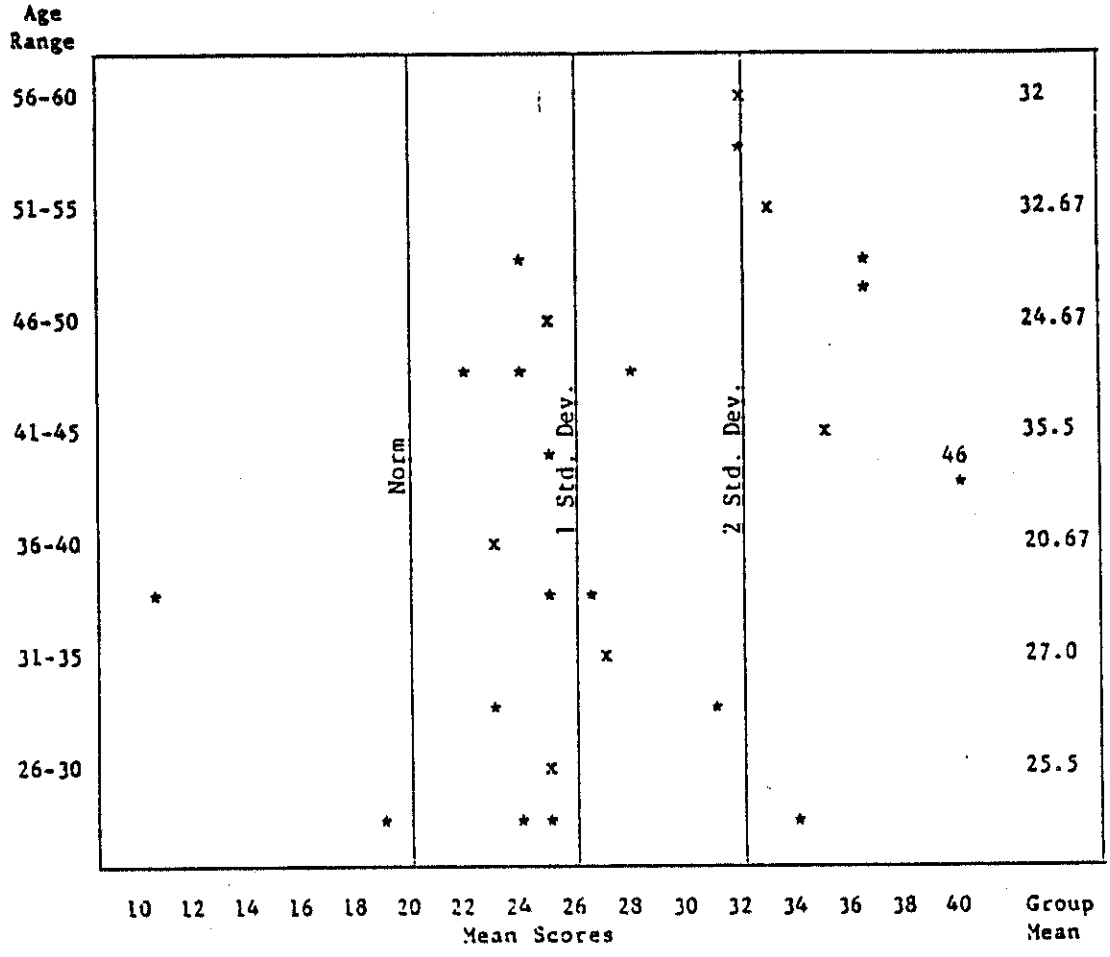


Table 12

H-BINE Neuroscreen Scores



* Individual scores

x Group mean

n = 19

G = 26.53

norm = 20.6

SD = 6

3/19 = 15.79% scores within normal range

16/19 = 84.21% were above the norm thus showing some neuro-physiological dysfunction

5/19 = 26.32% > 1 Std. Dev. above the norm showing moderate to severe neurophysiological dysfunction

psychological and neurophysiological dysfunction consistent with patients with known heavy body burdens of toxic chemicals. Test results also showed that the longer the exposure to the contaminants, the greater the probability of neurophysiological and psychological dysfunction.

This extent of dysfunction would seem even more germane because of the assumption of high quality of functioning this population must have had prior to exposure to the contaminated environment. The history of achievement of these people--successful completion of undergraduate and post-graduate work in a professional school with subsequent professional practice--strongly suggests that they possessed higher than average intelligence, energy, motivation, drive, persistence, and efficiency. The intelligence scale showed that only 30.3% of the dentists were high in ability. This may be consistent with chemical toxicity. It would be expected, given the requirements to attain the professional status, that the intelligence scale would be much higher.

Results of this study demonstrate some of the serious behavioral consequences of chemical-heavy metal exposure in the dental office--poor memory, problems in perceptual motor and psychomotor function, withdrawal, etc. It should be observed that behavior is the end of a response pattern that began with stimuli that evoked a set of interactive body/mind reactions including the various systems, such as

nervous, limbic, and endocrine, integrating with the end responses--cognitive, emotional, and perceptual motor.

There is no technique or procedure for internal study of the functional aspects of these various systems. The resultant behavior should be the focus of study if individual capacity to function is to be understood in an integrative fashion. Behavioral techniques are becoming more precise and sophisticated and can be adapted to accurate evaluation of the behavioral outcome of individual reaction to the environmental toxins (as this study has suggested). The question of threshold becomes important in behavioral toxicology and is dependent on the criterion for response and the measurement instrument's sensitivity to that response or reponse pattern. Further maximal acceptable concentrations (MAC) must be at sufficiently low levels to account for individual susceptibility and individual responses.

Group response patterns or curves are insufficient to predict the safe MAC or the individual's reaction to toxic exposure. For example, group norms in the present study are meaningless in demonstrating the extent of abnormal variance among a significant number of these subjects to the environmental contaminants in the dental office. As a group the dental office personnel measured within the norm which would have indicated few if any problems related to the

chemicals in the environment. Thus it could be assumed that the MAC is at acceptable levels for acrylic, mercury, formaldehyde, phenol, and nitrous oxide. But a behavioral analysis based on neuropsychological cognitive testing provides evidence to the contrary, indicating moderate to severe reactions presumably to these chemicals for many individuals.

Interpersonal variance on the personality test ranged from maximum to minimum for many of the traits (mean deviation from the norm of the composite traits = 61.2%) indicating that chemical exposure and/or total body/mind load may affect personality.

The measuring instruments were sufficiently sensitive to assess abnormal functions in those individuals for whom the threshold (of symptomatology) was lower than the group norm.

Many of those people may have no safe level of tolerance for the chemicals in question, perhaps generalizing to many other chemicals with unsafe tolerances probably because of an increased total (mind/body) stress load and a decreased ability of the immune system to repel the toxin.

The objective behavioral measures in this instance supported the prior clinical observations and also provided clinical utility by interpreting the severity of the problem

and suggesting the need for treatment and the kind of treatment to be implemented.

Very often symptoms of poisoning will be vague and subjective, particularly with low dosage in the early stages of the reactions to the toxins, e.g., forgetful, tired, irritable, feeling down, weak, etc., and the standard medical clinical tests will not be adequate to point to the toxicity and its cause.

There is a pressing need to objectify and systematize the observations of complaints so that early diagnosis and treatment may begin.

It is suggested that new instruments be developed and old ones be interpreted with a pattern of poison and toxification as a possible profile. Revision of present tests could also be done to better account for such problems as latency of response, lowered psychomotor speed, and precise cognitive deficits. Weakness, negativity, anger, problems in perceptual learning, preoccupation with bodily function (but interpreted as hypochondriasis or hysteria), problems in perceptual learning, and perceptual motor difficulty also need a precise mode of measurement.

In summary, the pilot study provided evidence that a significant percentage of dental office personnel including dentists are exposed to chemicals common to the dental office (nitrous oxide, mercury, formaldehyde, phenol, and

acrylic) and this exposure may well contribute to the neuropsychological cognitive dysfunctioning found in a surprisingly high percentage (above 90%) of dental office workers.

It was concluded that these individuals probably suffer adverse reactions to the chemicals in their work environment. These problem areas included perceptual motor difficulty (e.g., 90% showed tremor), deficits in cognitive functioning, concern with bodily function, and despondency, as well as interpersonal problems.

Assuming that this sample population was greater than 1 standard deviation above the normal population prior to exposure, the deficit seems even greater and the urgency of a solution to the problem of existence in the contaminated environment seems more pressing.

Chemicals that alter psychopharmacology, psychoimmunology, and neurochemistry are becoming more suspect concerning their role in altering human behavior. Biological psychiatry joins dynamic and social psychiatry to form the foundation of the biopsychosocial approach to human behavior (Moto, 1986).

Data concerning suicide, divorce, alcoholism, and drug addiction are very difficult to obtain, but there are studies which indicate that these behavioral problems are high in the dental profession (Anderson, 1982). Extreme

scores on the CAQ personality trait scales which prompt inquiry about these behavior problems include warmth, emotional stability, impulsivity, boldness, self-sufficiency, self-discipline, and tension scales. Further research is needed to determine correlation of the above traits with suicide or other serious behavior problems and with toxic dental office chemicals.

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