

Neuropsychological assessment in behavioral toxicology — Developing techniques and interpretative issues

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This paper discusses some neuropsychological techniques that have proved sensitive to the kinds of mental change associated with industrial toxins. It also considers several problems of assessment and test interpretation that can compromise neuropsychological research in this area. Its focus is on cognitive functions known to be susceptible to the toxic effects of organic solvents. It also addresses the issue of examining for neuropsychological disorders that appear to be associated with solvent exposure, but for which there are few recognized and standardized assessment techniques.

Testing for impairments associated with exposure to organic solvents

Speed of response

Response speed in itself has been reported as slowed in some studies of workers exposed to organic solvents (1, 8, 12, 16). Slowing is the most consistently reported for complex tasks such as choice reaction time. Studies that include both simple and complex tasks typically show a differential between the speeds at which simple and complex tasks are performed (9, 12, 17). It is the difference in the speed with which these two kinds of tasks are performed that is of the most interest neuropsychologically, rather than performance speeds simply taken by themselves.

On the Wechsler Adult Intelligence Scale (WAIS) (35), the Digit Symbol test is the one most likely to be sensitive to psychomotor slowing (15, 16, 25). Unfortunately, a simpler version of this test is not available to provide a comparison of performances on a simple and complex form. However, Aaron Smith's Symbol Digit Modalities Test (27) offers a similar format in which the slightly more complex task of writing responses can be compared with the slightly less complex task of reading them. The Trail

Making test (2, 15) is another that tests response speed, in this case, visuomotor tracking with a pencil on a simple and a complex form of the same task. It has proved to be very sensitive to decreased efficiency in processing complex material. Speed and tracking tasks require age-graded norms for accurate clinical interpretation.

Attention and concentration

A second kind of deficit that frequently occurs with toxic exposure is vulnerability to interference (1, 16, 17). On an everyday basis this deficit shows up in complaints of concentration difficulties and distractibility (1, 6). It reflects an impaired mental capacity to keep track of more than one thing at a time.

Concentration and tracking deficits show up in a number of ways on testing. On the WAIS they can appear as markedly impaired performance with digits backward relative to digits forward (15). The custom of summing these two quite different activities, established by Wechsler decades ago (33, 34), runs counter to research findings and rational interpretations of neuropsychological test scores (10, 13, 31). Digits forward measures breadth of immediate auditory memory span — how much can be gotten in at one time. It is relatively unrelated to cognitive prowess, shrinks slightly with age, and is vulnerable to conditions that affect alertness, such as acute organic brain syndromes and left hemisphere damage. It is a relatively sturdy function that is little affected by chronic toxic conditions (eg, even the digit span of patients with Korsakoff's psychosis and chronic alcoholic deterioration tends to be within normal limits). In contrast, reversed digits measures breadth of span plus mental tracking ability plus verbal learning ability, particularly in spans of five or more in which the digits first heard have to be retained through a considerable amount of interference. It is not surprising then that digits backward tends to be very vulnerable to conditions that affect mental tracking and to those that impair learning ability. Except for those subjects who score very low or very high on both of these tasks,

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when forward and backward scores are summed, all information is lost that would allow the examiner to discriminate between problems involving span of auditory attention and the additional functions assessed by digits backward. In many cases summing obscures the presence of a problem. For example, the typical intact adult will recall 6 digits forward and 5 reversed, for a summed raw score of 11 — well within normal limits. The patient with a good verbal memory who has concentration or tracking deficits may achieve a forward span of 7 but recall only 4 digits reversed and also receive a summed score of 11. It is also not rare to find patients whose tracking or learning problems are so severe that they can only reverse 3 digits and yet they grasp as many as 8 digits forward. They too would receive a score of 11. If the summed score is the only one reported and if the clinician interpreting the data does not look up the original performance, then serious deficits can be overlooked. Unfortunately, the changes in handling Digit Span data recommended in the revised WAIS (36) only add to the confusion. The new administration and scoring system attempts to measure efficiency of retention as well as length. This system not only obscures discrete span lengths, but provides no means for interpreting efficiency or for discriminating the contributions of efficiency from those of span.

A number of familiar mental tracking tasks which require the subject to perform one operation while keeping data or the results of another operation in mind are useful measures of distractibility (15). These tasks include the many “backwards” operations, such as serial subtraction, reversed spelling, and reversing familiar series such as the alphabet.

A powerful technique for examining susceptibility to distraction was devised by Stroop (15, 28). One study of toxicity using the Stroop test involved juvenile paint sniffers (30). On each of the three parts (using the original test format), the paint sniffers scored significantly lower (at the 0.01 level and beyond) than a matched reference group. Norms developed on an epileptic population by Dodrill (5) are applicable to the dysfunctions associated with exposure to industrial toxins as well.

Memory and learning

Many memory tests have shown some impairment in workers exposed to organic solvents (1, 9, 16). Most, however, have focused on short-term memory as measured by the Benton Visual Retention Test (3) or some of the tests on the Wechsler Memory Scale (34). One test that probably gives the most information about different aspects of memory with the least amount of effort is an expanded version of Rey's word-learning test, the Auditory Verbal Learning Test (AVLT) (15). This version includes a 30-min recall trial and a recognition test in addition to the five

learning trials. By using this form of Rey's AVLT, the examiner can measure (i) immediate span under overload conditions, (ii) learning, (iii) immediate span under overload with interference, ie, proactive inhibition, (iv) retention following interference, ie, retroactive inhibition, (v) fixation of learning, and (vi) differentiation of learning and retrieval. This method also measures susceptibility to confusion and the nature of that confusion and provides a learning curve which can be numerically expressed.

Some of the items of the Wechsler Memory Scale are useful, particularly if a delayed recall trial is added. Russell (24) has developed norms for measuring delayed recall of the Logical Memory and Visual Learning tests. He also treats the data from each of these tests separately.

Executive functions and neurotoxicity

A category of deficits that tends to accompany impairments in cognitive functioning has only been hinted at in the literature. Grandjean and his colleagues (6) allude to these deficits when describing impoverished and poorly focused Rorschach responses given by workers exposed to trichloroethylene. Knave and his associates (12) found that *variability* in reaction times distinguished workers exposed to jet fuel from carefully matched referents. Härkönen and his co-workers (8) documented decreased drawing accuracy along with unreliability of performance on a visuomotor tracking test in workers exposed to styrene. The higher incidence of presenile dementia among workers exposed to paint solvents and other organic solvents (1, 7, 20) also points to this special set of deficits.

All of these cases have in common the impairment of *executive capacities* — the abilities (i) to formulate goals, (ii) to plan, (iii) to carry out plans, and (iv) to carry plans out effectively (14). Defective executive functions — not simply defective memory — are what make patients with presenile dementia dependent and ultimately helpless. In its early stages, the presentation of presenile dementia does not differ greatly from that of toxic reactions in which listlessness, muted affect, loss of initiative, social withdrawal, and social dependency are among the prominent features (1, 7, 12). Clinical experience suggests that mild deficits in executive functions occur in many of these patients. Such deficits do not show up in the usual structured examination, however, unless the examiner takes pains to look for them.

Our habits of observing and conceptualizing behavior are geared toward identifying cognitive or emotional deficits. The behavioral changes associated with defective executive functions do not, however, fall into familiar classifications; rather, they cut across them. Defects in executive functions are rarely ap-

parent in themselves. Moreover, executive defects that are only mildly to moderately disabling are usually interpreted in terms of the patient's wilfulness ("he's just lazy"), unfortunate developmental or family dynamics (eg, "emergence of latent dependency"), or as a psychiatric disorder (most usually depression, even when the patient shows little dysphoric affect). In the absence of a systematic approach to observing and classifying executive functions and the absence of a widely accepted vocabulary for discussing them, defects of executive functioning may seem subtle and difficult to conceptualize.

Even more important is the fact that structured examinations typically give the patient no opportunity to demonstrate the intactness of some of the most important executive functions, such as planning, complex goal-directed activity, initiating the behavior, and carrying it out effectively. Efforts to observe these aspects of executive behavior in a formal examination places the examiner in a logically absurd position, because the examiner must give the directions and provide the setting (structure) in which the subject can "spontaneously" demonstrate his executive capacities. Since relatively few clinicians observe the patient in situations in which the patient must act on his own behalf, most are simply not aware when executive capacities are missing from a patient's behavioral repertoire.

Each of the four major classes or functional categories that comprise the executive capacities involve distinctive behavior. All are necessary for socially appropriate, responsible, and constructively self-serving adult conduct. They can break down at any stage in the sequence of behavioral events that make up intentional action. Impaired executive capacities may show up in interviews and under observation or be demonstrated by tests and improvised assessment techniques.

Goal formulation

Mild impairment of the capacity for goal formulation becomes evident in the patient's inability to resume premorbid responsibilities that require appreciation of long-term or abstract goals, or to take on new activities independently. Without direction, mildly impaired patients tend to wander aimlessly or just sit in front of the television or at a neighborhood tavern or coffee house. Severely impaired patients may undertake no activities unless prompted, and then require continuous direction.

Persons who see the patient in the course of day-to-day living are the best informants about his motivational capacity. The examiner can also ask the patient about likes and dislikes, amusements, and complaints. Severely impaired subjects will have little to say about themselves and are emotionally flat. Persons whose capacity for motivation is mildly impaired are

often prone to irritability and chronic depression; however, many experience a general emotional dampening.

Impaired awareness of self or of one's surroundings makes appropriate goal formulation impossible. Awareness of self and surroundings is best evaluated through reports of other observers (family, nursing staff) and observation. The mental status examination is useful for evaluating a patient's awareness of what goes on around him (15, 29). Questions about the time of day or the season of the year test not only orientation but also the ability to use environmental cues spontaneously.

Having the patient make up a story about a picture of familiar characters engaged in familiar activities tests the patient's ability to infer a story from a picture, and also shows how well he can make sense out of his perceptions and spontaneously order and integrate them.

Planning

Several capacities are necessary for planning. These include the capacity for sustained attention; the ability to deal objectively with oneself in relation to the environment and to view the environment objectively, ie, to take the abstract attitude (32); and abilities to think of alternatives, to weigh them, to make choices, and to evolve a conceptual framework which can serve to direct activity.

Questioning can bring out defective planning. For example, patients can be asked about their plans — for working, taking a vacation, the coming weekend. When they present a plan, they can be asked to explain in detail how they will carry it out. Sometimes a patient telling about familiar activities can sound good when in reality he performs poorly. Here, too, reports from other observers are invaluable.

The Porteus Mazes (15) were developed for the examination of abilities involved in "choosing, trying, and rejecting or adopting alternative courses of conduct or thought" (22). Their proved sensitivity to frontal lobe damage (26) supports the impression that defective planning may contribute to lower scores. The Complex Figure Test (15, 19, 23) also provides the patient with an opportunity to demonstrate planning behavior. Analyses of approaches to copying a complex figure have given standards for evaluating how systematic the patients' response to this task is (4, 21). A haphazard or fragment mode of response implicates poor planning. The task of copying all nine Bender-Gestalt designs on one page is also excellent for eliciting planning behavior (11, 15). The examiner needs to look at the order of placement, whether adequate space was allowed for the designs and whether a design was drawn so close to the paper's edge or another design that it had to be distorted or it violated the integrity of the adjacent design.

Carrying out activities

The translation of an intention or plan into self-serving, productive behavior requires orderly and integrated initiation, maintenance, switching, and stopping of sequences of behavior. Luria's (18) characterization of normal activity as the product of organized *behavioral programs* provides a conceptual framework for studying purposive behavior and its disruptions. The task of making a construction without a model can be used to assess the abilities to plan and carry out an activity even within the confines of a formal examination. This task has been carried out using a type of children's play material, Tinkertoys® (14, 15). Scoring constructions for the number of pieces used and for constructional features — such as its dimensions (two or three), whether it has moving parts, and whether it resembles the name given it — dramatized the differences between socially dependent and independent brain-damaged patients and between these patients and normal referents in their respective abilities to conceptualize and carry out a project. Other constructional material that lends itself to a scoring system could also be used for this purpose. Referents use relatively many pieces and make distinctive constructions that almost always resemble their names, and frequently the constructions have moving parts. At the other extreme are the constructions made by totally dependent patients (eg, patients with Korsakoff's psychosis, Alzheimer's disease, severe traumatic head injury) who use few pieces, typically piling them up or moving them about purposelessly. Mildly and moderately impaired patients tend to achieve scores between the extremes set by bright referents and the most dependent patients.

Effective performance

Unreliable performance is one of the hallmarks of impaired executive functions. Assessment of reliability — the self-regulatory functions — usually depends upon sensitive observations. Scores do not indicate the presence of errors of carelessness or oversight (as distinguished from errors due to lack of skill or knowledge) or whether the patient was aware of errors at all. Nor do scores reveal performance idiosyncracies or irregularities that reduce the patient's effectiveness without lowering the score significantly (for instance, cramped writing or even an occasional perseverated letter might not reduce a score on a written test). Constructional tasks such as the WAIS Block Design test or the Tinkertoy Test, or drawing and writing samples, or written arithmetic can be very informative as they allow the examiner to observe how the patient errs, self-corrects or not, and monitors the performance.

Some principles for neuropsychological research on behavioral toxicity

From an assessment standpoint, the behavioral effects of toxic substances are interesting because these conditions illustrate three practical principles for getting the most information possible from a neuropsychological evaluation.

Principle 1

Different kinds of conditions have different behavioral manifestations and therefore call for different assessment programs. A research program, or battery, should be selected on the basis of its appropriateness for the patient population and the question under study. In clinical practice, the same standards of appropriateness for the patient and the problem being investigated should dictate test selection.

Principle 2

In order to learn about a condition, tools appropriate for studying that condition must be used. Unless planning ability is specifically examined, for example, defective planning may not be noticed. Careful observation will sometimes bring to light phenomena such as inability to plan even when they have not been tested for. However such an occurrence is possible only when the examiner pays attention to both the qualitative and the quantitative aspects of the patient's performance.

Principle 3

Scores should be handled discretely and not submergled or obscured in summed scores or averages or intelligence quotients or indices of any kind. It makes as much scientific sense to lump together neuropsychological test scores obtained by a brain-damaged person as it would to describe the motor strength of someone with a broken leg in terms of an average of strength of each of the four limbs.

From a neuropathological standpoint neuropsychological assessment probably offers the most sensitive means of examining the effects of toxic exposure, of monitoring for industrial safety, and of understanding the complaints and psychosocial problems of persons exposed to these toxins. It is important that neuropsychologists remain open and flexible in their approaches to studying behavioral responses to potentially dangerous elements in the workplace. Neuropsychologists must continue to develop new techniques and to use old ones as effectively as possible so that neuropsychological assessment can keep pace with the broadening understanding of industrial hazards.

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