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# OCCUPATIONAL SCREENING FOR NEUROTOXICITY: COMPUTERIZED TECHNIQUES

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SUMMARY

Computer-administered testing systems for assessing the functional consequences of neurotoxicant exposure in the workplace have recently been developed. Mainly, they have been applied in laboratory studies of acute exposures, quasi-experimental field studies of acute and sub-acute exposures, and cross-sectional epidemiologic investigations of chronic exposures. Some automated tests appear quite sensitive and reliable in these situations where group comparisons are made. However, testing methods suitable for the purpose of clinical evaluation are not yet well developed. Programs of neurobehavioral surveillance in industry are necessry to provide reference data for clinical, screening and epidemiologic purposes and to provide essential baseline data for individuals at risk.

*Key words:* Neurobehavioral testing; Computers; Occupational health

## INTRODUCTION

Neurobehavioral testing allows non-invasive assessment of the functional integrity of the nervous system. In occupational health settings it has served several functions [1]. These include:

(1) Investigating the acute neurotoxic effects of controlled exposures in the laboratory (Experimental) and of variable exposures in field investigations (Quasi-experimental).
(2) Quantifying central nervous system (CNS) functions in epidemiologic studies (Epidemiological).

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(3) Evaluating individual symptomatic workers (Clinical).
(4) Identifying individuals having neurotoxic effects among exposed workers (Screening).
(5) Detecting early, reversible CNS impairment in exposed workers (Surveillance).
(6) Evaluating the effectiveness of health intervention programs (Hygienic evaluation).

Hanninen gives an historical narrative of how a clinical psychologist has approached application of psychological tests in toxicology [2]. Gamberale not only provides a superb review of the use of performance tests for investigating the effects of solvents, but also addresses many methodological issues that are of general interest in using such tests in occupational health [3].

It is generally agreed that standardized neurobehavioral testing protocols are needed, but agreement on the details has rarely been achieved (c.f. Ref. 4). One reason that agreement is difficult is that there are a huge number of neurobehavioral tests from which to choose. Many dozens have been borrowed from experimental and clinical psychology and used in research in occupational health. In addition, even tests with the same name are not performed in the same way in different laboratories. Such a state of affairs promotes confusion and hinders cross-study comparison. Another reason that agreement on neurobehavioral test protocols is difficult is that the various uses of neurobehavioral tests are so different that no single standard protocol can meet the demands of all situations. It is not surprising that investigators with different academic backgrounds and different intended uses for neurobehavioral tests can not agree. However, it should be possible to work toward standardizing the protocols of a few individual tests that can be used as part of the testing in a wide variety of applications. Computer-administered tests are an obvious way of achieving such standardization.

## COMPUTER-BASED NEUROBEHAVIORAL TESTING

Recently, several laboratories have developed computer-based systems specifically for use in occupational health [5—8]. Other computer-administered neurobehavioral test systems have been developed in related fields [9—11]. Some of the important aspects of developing computer-administered neurobehavioral testing systems in occupational health are presented by Letz and Baker [12].

There are many reasons for using automated methods in neurobehavioral evaluation. Automated methods provide for standardized, objective collection of quantitative information. Manually-administered neurobehavioral tests are subject to observer bias as well as substantial variation between testers and within testers over time. Other reasons favoring the use of computer-administered tests in many situations in occupational health concern

efficiency. Highly-trained personnel are not needed for data collection, and data recording is performed accurately and tirelessly. Stimuli can be presented very precisely, and multiple aspects of responding can be monitored simultaneously. Data can be reduced immediately and subsequent testing within a session can be modified according to the data just collected on an individual.

On the other hand computer-administered tests currently have several limitations. Current computer-based tests involve, almost exclusively, visual presentation of stimuli and manual responding. Presentation of stimuli to other sensory systems requires special conditions, usually involving expensive equipment not suitable for field use. Also, speed of responding is the primary datum recorded by computer-based tests. Expressive and organizational aspects of responding are not usually measured, aspects which are particularly important for discovering the nature and extent of an individual's deficits.

## TEST SELECTION, SENSITIVITY AND VALIDITY

The potential range of applications of computer-administered tests in occupational health is great. Some of the variables that distinguish the various uses of neurobehavioral testing are presented in Table I, which is modified from a table prepared by Gamberale [3]. The form of the neurobehavioral testing that is actually performed in a particular situation is primarily a function of the purpose of the testing. The most important factors are whether the focus of the analysis is a group or the individual and whether the effects to be measured are subtle or severe. However, many other considerations help to determine the type and extent of testing; e.g. the amount of time available for testing, where the testing will take place, what equipment and personnel are available or required, and whether repeated testing of individuals will be performed.

Ideally, the tests should be highly sensitive and reliable, and they should be targeted at detecting deficits in specific cognitive functions. Knowledge of effects of exposure is rarely adequate, except sometimes in experimental testing situations, to accomplish such focused testing. Therefore, a collection of tests tapping a broad range of behavioral functions is usually administered. However, time constraints may allow use of only 2 or 3 highly-reliable tests in a quasi-experimental field investigation with repeated testing over the course of a day. Or, it may be necessary to settle for a number of moderately-reliable, but easily and quickly-administered, tests for group comparisons in a field epidemiologic investigation. Alternatively, testing for clinical purposes may allow time for, and even require, use of many highly-reliable tests with functional over-lap and redundancy.

Perhaps the most attractive aspect of neurobehavioral testing in exposure situations is that it may be used to detect subtle nervous system dysfunction before chronic, irreversible deficits are produced. A major obstacle to establishing the validity of particular neurobehavioral tests for

TABLE I

NEUROBEHAVIORAL TESTING SITUATIONS IN OCCUPATIONAL HEALTH

| Type of study or activity | Focus | | Effect | | Exposure | | Repeated testing? |
|---|---|---|---|---|---|---|---|
| | Group | Individual | Mild | Severe | Acute | Chronic | |
| Experimental | * | | * | | * | | * |
| Quasi-Experimental | * | | * | | * | | * |
| Epidemiologic: | | | | | | | |
| Cross-sectional | * | | + | * | | * | |
| Longitudinal | * | | + | * | | * | * |
| Clinical | | * | | * | + | * | + |
| Screening | | * | | * | + | * | |
| Surveillance | | * | | * | | * | * |

*, Exclusively or usually.
+, Sometimes or possible.

this purpose is that there is no criterion, or "gold standard", with which computer-administered tests can be compared. Several groups have compared computer-administered and similar manually-administered "standardized" psychological tests, (e.g. see Ref. 13). In general, only moderate correlations have been found, indicating that the tests are not the same. However, "validation" is not a global attribute of a test; it is population- and situation-specific. "Standardized" clinical psychological tests may not be any more "valid" tests than computer-administered ones for detecting subtle neurotoxic effects in laborers under field-testing conditions.

There is a widely-held hypothesis that higher-order cognitive processes are more sensitive to the disruptive effects of exposure than lower-order ones, and therefore, that more complex tests are better than simple tests for detecting such effects. This may be true in experimental, repeated-measures testing situations. For example, Hooisma et al. found that a Color Word Vigilance task was sensitive to the effects of 0.035% blood ethanol, while other, simpler tests showed only non-significant trends in the correct direction [14]. In addition, Mahoney et al. found that the complex condition of a Switching Attention test showed significant decrements in performance from exposure to 20% nitrous oxide, while the simple conditions of the same test did not [15]. However, this particular Switching Attention test was found to be unacceptable for use in a cross-sectional epidemiologic study of painters (Baker and Letz, unpublished observations). A substantial percentage of painters (5 of 33) tested under these conditions could not complete the test with a minimally acceptable performance. To most non-laboratory populations the "face-validity" of such complex tests is not as apparent as it is for simple tests such as reaction time and hand-eye coordination. Also, relative to simple tests, complex tests take more practice time to reach stable, reliable performance, and they are potentially very sensitive to a host of non-exposure factors such as native intellectual ability, level of education, language skills and socio-economic status. Thus, for many reasons, potentially less-sensitive simple tests may be more desirable than complex tasks for use in many situations.

## APPLICATIONS OF COMPUTER-BASED NEUROBEHAVIORAL SYSTEMS

Computer-based systems have generally been used for epidemiological and experimental purposes in occupational health. Computer systems are not currently well developed for purposes in which the individual is the focus of analysis: clinical, screening and surveillance.

The Neurobehavioral Evaluation System (NES) was developed for use in cross-sectional field investigations of the effects of chronic exposure [5]. For example, NES has been used successfully to study the effects of solvent exposure among construction painters in the United States. Subtle neurobehavioral effects have been found in 2 separate investigations of 101 and 178 construction painters, respectively [16,17]. Data collection using NES

has been completed in other cross-sectional studies involving hundreds of workers conducted by several laboratories in different countries [12].

Computer-administered tests have proven very useful in experimental and quasi-experimental studies of acute effects of neurotoxicants. In Sweden, a computerized test system has been used to study the effects of co-exposure to toluene and xylene [18] and exposure to toluene in combination with ethanol [19]. Some psychomotor tests in NES have been shown to be sensitive to a 20% (subjectively subtle) dose of nitrous oxide [20], and in fact, experimental nitrous oxide exposure may be a useful model system for testing the sensitivity of neurobehavioral tests [15]. In one published study employing a quasi-experimental design to study the effects of exposure to an organophosphate pesticide. NES performed admirably [21]. However, pesticide exposures were particularly low at the time of testing and no neurobehavioral effects of exposure were found.

No studies have yet been published on the use of computer-administered test systems in occupational health for clinical purposes. Clinical evaluation requires testing of a broader range of neuropsychological functions than are currently available in computerized tests. Also, when performance decrements on computer-based tests are detected, the nature of those deficits needs to be explored with other, more specialized tests. Computer-based psychomotor tests are currently being used as adjuncts to clinical neuropsychological evaluations in occupational medicine, but it is unlikely that a full evaluation will ever be done solely by computer [12]. One specialized role that computer-administered tests may provide in individual assessment is to quantify the time course of a disorder: progression of the disease, recovery, or response to therapy.

Currently, in addition to their use as an epidemiologic tool in cross-sectional studies, automated neurobehavioral tests are used as a screening tool. Such use is not entirely appropriate, because the normal range of performance is enormous, and without a pre-exposure baseline only severe deficits, or deficits in already compromised individuals, may be detected. However, in this respect a group of automated tests is probably no worse than a small group of paper-and-pencil tests, since neither has been validated for this purpose.

## A NEED FOR NEUROBEHAVIORAL SURVEILLANCE

Periodic testing with automated neurobehavioral tests has not yet been reported. However, there exists a need for neurobehavioral testing as a part of routine medical surveillance (see Ref. 22, p. 51). This testing would provide several functions simultaneously. First, the initial intake data would provide much-needed cross-sectional normative data for assessing precisely the effect of factors such as age, gender, educational level, socio-economic level, and chronic alcohol intake *directly in the population of interest.* Second, much-needed longitudinal normative data would be developed to determine the true effect of aging and how performance on each test varies

with repeated testing at relatively long time intervals. In addition to providing these normative data gathering functions, such a program would provide baseline performance levels for individuals to be used in later comparisons. Such baseline data would be extremely useful for: (1) assessing the effects of accidents; (2) determining the effects of changes in hygienic conditions; and (3) early detection of the effects of chronic exposures. With baseline data on individuals, not only could such comparisons be performed more precisely among the groups involved, but decisions about individuals could also be made with some confidence.

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