



## Review

## Computerized neuropsychological testing in epilepsy: Overview of available tools

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## ABSTRACT

**Purpose:** Neuropsychology has become an essential diagnostic tool for epilepsy-related cognitive comorbidities and treatment evaluation. However, a lack of resources may prevent routine neuropsychological assessments outside specialized epilepsy centers. Computerized testing appears to offer a time- and cost-effective approach to assess cognitive functions in patients with epilepsy. Moreover, the technical advances of computerized tests provide interesting tools to address specific diagnostic questions around epilepsy. This review is intended: (1) to outline the advantages and disadvantages of computerized testing, (2) to delineate its indications and fields of application, and (3) to give an overview of available tools that have been applied in epilepsy or antiepileptic drug research. **Method:** Iterative review of computer-based neuropsychological assessment batteries previously applied in clinical epileptological settings or antiepileptic drug trials.

**Results:** Among nine reviewed computer tests merely three were explicitly devised for epilepsy and showed sensitivity to clinical parameters like focus lateralization or localization or the presence/absence of epileptiform activity. Concurrent validity with established measures was demonstrated for two of these three tests. Some sensitivity to antiepileptic pharmacotherapy was reported for seven of all nine reviewed test batteries.

**Conclusion:** Additional studies are needed to demonstrate the sensitivity and specificity of computerized neuropsychological tests to epilepsy and treatment related variables. In most clinical scenarios exclusive computerized testing cannot substitute a thorough neuropsychological examination in patients with epilepsy at present.

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## 1. Introduction

Neuropsychology provides evidence-based methods to answer clinical questions regarding epilepsy and its treatment.<sup>1</sup> Apart from its role in the assessment of cognitive dysfunction in relation to the type of epilepsy and the underlying pathology, neuropsychology plays an increasing role in the individual quality and outcome control of all kinds of medical interventions, be they invasive (e.g. epilepsy surgery, radio- or stereotactic surgery, deep brain stimulation), semi-invasive (e.g. vagal nerve stimulation) or non-invasive (pharmacological treatment).<sup>2,3</sup>

As a consequence of the increasing dissemination and acceptance of neuropsychological diagnostics for monitoring CNS (central nervous system) diseases and treatment outcomes, there

is the understandable interest in brief, cost effective, and easy-to-apply assessment and screening tools. Technical advances during the last decade now offer a unique possibility to transfer neuropsychological assessment into the world of computers, laptops, tablets, handheld devices and mobile phones. The transfer to and the utilization of such novel testing platforms is only just beginning. Nevertheless there has been an increasing interest in computerized diagnostics in patients with epilepsy.

The quality of neuropsychological results – and this holds true in equal measure for computerized as well as classical paper-pencil tests – depends on the validity of the neuropsychological instruments applied. The chosen measures and testing methods need to be sensitive and specific in regard to the intended field of application and the underlying clinical question. Beyond the three classical test criteria of “objectivity”, “reliability” and “validity”, the following additional criteria have to be considered: the quality and range of the normative data provided, the availability of parallel test versions and information about practice effects due to repeated test administration, i.e. test-retest norms. Furthermore, the effort in terms of time (duration of administration and scoring) and costs (test materials and staff) are relevant. Finally, the best

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test is useless if it is not available in the patient's language or if it is not valid in a particular patient group because of cultural variations.<sup>4</sup>

## 2. The pros and cons of computerized assessments

Computerized neuropsychological tests usually have a high objectivity in terms of administration and scoring. A high level of test objectivity is a required but not sufficient precondition for high test-reliability. The same is true for the relation between test reliability and test validity. In contrast to paper-pencil testing, computer tests allow for the exact assessment of reaction times in milliseconds. This is particularly advantageous when evaluating processes of attention (e.g. alertness/speed of information processing). Furthermore, computerized tests can make use of enhanced interactive and multimedia-based question styles or virtual realities. They do not require stationary hardware since they can potentially be used on mobile phones or handheld computers. The possibility of a continuous and instant registration of cognitive performance can be utilized for adaptive testing, i.e. the tailoring of the task difficulty/demands to the individual performance level. The possibility of randomly selecting items from a pool of stimuli instead of using fixed parallel versions is an advantage when multiple reassessments are required. Moreover, computer tests are usually easy to administer or even self-administrable. Although the application thus does not necessarily require neuropsychological expertise, computerized testing without neuropsychological supervision bears the risk of false interpretations. Fully computerized tests must be differentiated from computer-guided or -aided tests. Whereas "fully computerized" implies computerized task presentation and automated response registration, computer-guided or -aided testing uses the computer either for stimuli presentation or as an electronic log sheet where the examiner records the patient's reactions/answers. Therefore computer-guided or -aided testing is by definition not self-administrable and always requires an examiner.

If the registration of results is computerized, computer tests can provide a fully automated calculation and presentation of the findings (in terms of raw data as well as standardized values related to normative data), which can be included in printed reports or electronic patient files automatically. This is time-efficient and also allows clinicians to provide instantaneous feedback to the patient investigated. In the context of scientific studies, the possibility of an electronic data export facilitates the import into statistical software packages. A major advantage of computerized testing, especially for the field of epilepsy, is the possibility of time-locked coregistration of cognitive processes and physiological measures. By this means the impact of interictal epileptiform discharges on cognitive performance can, for example, be analyzed. Apart from concomitant EEG-analyses, computerized tests can also be applied during functional brain imaging studies (e.g. fMRI). Finally, although the up-front equipment cost of computerized testing procedures may be higher, there may be savings in the long run since paper-pencil tests require constant restocking of log sheets.

Computerized neuropsychological tests may also have some disadvantages. Self-administrable computerized tests dramatically reduce the interaction between examiner and patient. Therefore a potentially important source of information is lost. Another disadvantage can be seen in interface problems, e.g. behavioral responses are reduced to reactions via mouse, keyboard or joystick. For example, the exact position of the index finger (e.g. the distance between finger and key) may be important for the measurements of reaction times in milliseconds. The increasing availability of more intuitive touchscreens may attenuate such reservations.

Future and advanced techniques of video-monitoring, language recognition or movement registration may expand the variety of behavioral expressions. Principally, individual differences in regard to the familiarity with computer devices may affect the affinity to and the performance in computerized tests.

Another issue is that some well-validated traditional paper-pencil tests require written or spoken responses (e.g. free verbal memory recall), patient drawings or manual constructions (e.g. using blocks). This cannot be easily converted into a computerized test – at least not without extensive validation of new patient-test interaction methods. Finally, some computer test batteries require extra hardware (e.g. push-button, touchscreen) or have special software requirements (e.g. in terms of the operating system used). Differences in screen sizes and contrast/clarity may affect results and it can be difficult to adjust the audio volume when presenting sounds or speech.

## 3. Indications for computerized tests

For which diagnostic questions in the field of epilepsy are computer tests suitable? The use of a computerized test battery appears indicated in the following situations:

- (1) Computerized testing may provide an objective screening for cognitive problems in case of self-reported cognitive deficits. However, subjective complaints always call for a concomitant screening for depressed mood, because of the robust finding that subjective cognitive complaints often reflect mood rather than objective performance.<sup>5,6</sup> When objective cognitive problems become evident and more detailed information is required a subsequent more comprehensive standard neuropsychological assessment may be indicated.
- (2) Because of the high objectivity and time-efficient method of administration, computerized tests seem to be an ideal approach if frequent repeated testing is required, for instance to monitor the effect of medical interventions or of acute changes in the course of the disease.
- (3) In conjunction with co-registered EEG-data, computer tests can be used to assess the impact of interictal discharges on cognition and vice versa.
- (4) Postictal computerized testing may provide information on negative symptoms and the dynamics of seizure-related cognitive dysfunctions. The differential postictal recovery of material-specific memory functions in temporal lobe epilepsies has been shown to be related to the lateralization of the seizure onset.<sup>7</sup>
- (5) The use of computerized naming (frontal and temporal functions) and line-bisection tests (parietal functions) during invasive EEG-monitoring or awake surgery can facilitate the surgeon's decision to excise or spare particular areas of the brain.
- (6) Computerized tests are ideal for experimental assessments in cognitive neuroscience. Experiments performed on a group level under controlled conditions, however, may not be suitable for routine diagnostics and for individual level analysis since they lack standardization with normative data.
- (7) To date there are no standardized computer tests which have been used in patients with epilepsy outside the clinic or outpatient setting. However, a first attempt of assessing cognitive and behavioral effects of antiepileptic pharmacotherapy<sup>8</sup> demonstrated the potential of computerized tests to assess patients outside institutional settings in specific situations, at specific locations or times.

For all suggested indications it is essential that the chosen measures are valid in regard to the diagnostic target.<sup>9</sup>

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