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REVIEW

Dementia Screening Using Computerized Tests

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The preclinical phase of dementia usually precedes the clinical diagnosis by many years. Early detection of dementing conditions during this preclinical phase may provide opportunities for treatments that may slow or mitigate progression. Conventional assessment tools usually can only detect dementia when the symptoms are overt and the disease is well-established. Computerized neurocognitive screening tools hold promise for diagnosing dementia in its early phase. The use, performance and development of several computerized screening tools to diagnose and monitor patients with pre-dementias and dementia are reviewed. The ability to accurately assess the presence of dementia clearly has direct relevance to insurance risk assessment and risk management. As new treatments appear, their role in clinical management of dementia patients will increase as well. In a future issue, the differential diagnosis of dementias related to the findings on these screening tools will be reviewed.

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The preclinical phase of dementia usually precedes clinical diagnosis by many years. Early detection of dementing conditions during this presyndromal phase holds the promise of early treatment, if not to prevent dementia, at least to slow its course or mitigate disability. It also allows patients and families to make appropriate long-term plans. Conventional tools for dementia screening, like brief office-based tests or dementia rating scales, are gross measures. They will only detect dementia when the symptoms are overt and the disease is well established. The availability of computerized neurocognitive screening batteries that are reliable and highly sensitive to very mild cognitive impairment will put the possibility of early diagnosis into the hands of primary care providers.

Some physicians believe that it is pointless to screen for dementia because there's nothing we can do about it. Some people don't want to be screened because they simply don't want to know. But not everyone feels that way. In fact, when older people are given the opportunity to be tested, they are usually quite agreeable.[1] Physicians are interested in early diagnosis because of advances in dementia treatment. Families have a stake in knowing, too, because they have to make the necessary plans.

For many years, physicians have appreciated that some dementias are reversible, for example dementia caused by nutritional deficiencies, endocrine disorders or depression. What is altogether new, however, is the proposition that dementing conditions like Alzheimer's disease (AD) and vascular demen-

tia can be prevented or effectively treated. It may not be possible to reverse the course of the disorder once it is well established. But it may be within our power if the disease is detected early to delay its onset, slow its course, or limit the disability it brings.[2–5] This being the case, the issue of early diagnosis is particularly important.

The problem is, though, that by the time the symptoms of dementia are apparent, the pathology is well established and neurodegeneration is proceeding apace. The solution is to detect the disease during its *presymptomatic* phase. In fact, the preclinical phase of dementia usually precedes clinical diagnosis by many years.[6] During the presyndromal phase, people who will ultimately become demented have detectable cognitive deficits in memory, attention, reaction time, psychomotor speed and/or executive function. This is true of all forms of dementia irrespective of the cause or pathology. If one were able to detect this mild impairment in individuals who were at risk for dementia, appropriate steps could be taken perhaps in the direction of early treatment or at the very least, in the service of long-term planning.

Studies that have demonstrated presyndromal cognitive deficits rely on sophisticated neuropsychological tests, evoked potentials and psychophysical measures of reaction time and information processing speed. These measures are precise and reliable but too expensive and far too cumbersome to use routinely in a primary care setting. As a result, physicians still rely on brief cognitive screening tests, like the Mini-Mental State Exam (MMSE), or the Alzheimer's Disease Assessment Scale-Cognitive Function Module (ADAS-Cog). While such tools are adequate for establishing that a patient has disabling cognitive impairment, they are not sufficiently sensitive to screen for early dementia or to capture the disease during its presyndromal phase.

In the past couple of years, highly precise and reliable instruments have become available to screen for mild cognitive dysfunction in general and early presymptomatic dementia in particular. They are computerized neurocognitive test batteries. They are derived from the PC-based neuropsychological batteries that have been used for 25 years in military and aerospace medicine, the pharmaceutical industry, and industrial and sports medicine. In those settings, they are used to detect mild cognitive dysfunction related to many different causes. Several computer-based test batteries have been introduced as clinical screening tools (Table 1).

Table 1. Computerized Batteries for Dementia Screening

Battery	Source
Cantab-PAL	www.bioportfolio.com/cantab.html
CNS Vital Signs	www.cnsvs.com
CogScreen	www.cogscreen.com
CogState	www.cogstate.com
MicroCog	Psychological Corporation

Computerized neurocognitive test batteries are accurate, reliable and highly efficient. It is only a matter of time before they are used to screen individuals for mild dysfunction in various applications, for example in individuals who are engaged in hazardous occupations or individuals who apply for disability or long-term care insurance. This review will address one potential application for computerized testing—detecting presymptomatic dementia. In fact, all of the dementing conditions are characterized by presyndromal cognitive impairment—different patterns for different kinds of dementia, but amenable in every case to early detection.

COGNITIVE IMPAIRMENT RELATED TO AGING

Three broad categories of cognitive impairment are related to aging: ''benign senescence,'' ''mild cognitive impairment,'' and dementia. Benign senescence is a feature of normal aging and is characterized by mild cognitive deficits, especially psychomotor slowing and dysnomia (word finding difficulty). Mild cognitive impairment (MCI) re-

fers to patients who have more in the way of cognitive impairment than normally occurs with aging but without significant disability. For some patients, it is an adumbration of dementia; for others, it is simply a less benign correlate of normal aging. Dementia is a general term that refers to disabling loss of mental power. Dementia may be static (brain injury or stroke) or progressive; if the latter, the result of neurodegenerative disease (eg, Alzheimer's or Parkinson's) or systemic disease (eg, metabolic syndrome, HIV).

Benign Senescence

On a clinical level, the cognitive and behavioral correlates of normal aging are well known. For example memory decline is the most prominent feature of cognitive aging. Older adults score lower not only in laboratory tests of free recall, cued recall and recognition memory but also in memory tasks with greater pertinence to day-to-day life, like memory for prose passages, medication instructions, the names of geographic landmarks, the appearance of common objects (like coins or telephones), the activities they have performed, and the names and faces of people.[7] Mild memory impairment begins at age 40 and is usually apparent to individuals by the time they reach 50.

''Slowness of behavior'' or psychomotor slowing is also a characteristic of becoming old. There is a limited contribution to slowing by peripheral sensory-motor factors—even peripheral nerve conduction is slowed—but the central nervous system, especially its subcortical structures, is the primary locus for slowing of reaction time, evoked potentials and information processing speed.[8,9] Psychomotor slowing begins at age 30 and may be apparent to an individual by age 40.

One of the firmest correlates of normal aging is a diminution of visual-motor performance; a subtle change during middle age, but quite dramatic thereafter. This age-related change is so robust it has been incorporated as a ''correction factor'' in most standardized tests of visual-motor function. For example, on the WAIS-R Symbol-Digit Coding subtest, a timed measure of visual-spatial scanning, visual memory and visual-motor copying, a 35-year-old male with a raw score of 56 achieves the same percentile rank (50%) as a 70-year-old male with a raw score of 33.[10] (Translation: an average 35-year-old can code 56 figures in the same time it takes an average 70-year-old to code 33. They are both perfectly normal.)

Measures of ''crystallized intelligence'' (eg, vocabulary) do not change with aging but a group of abilities known as ''fluid intelligence'' are especially vulnerable to the effects of aging: nonverbal reasoning, rule discovery and concept formation.[11] Neuropsychological deficits in frontal lobe functions, like cognitive flexibility, tend to be more pronounced.[8,12]

Aging is always associated with at least some degree of cognitive decline, but aging does not affect all cognitive functions uniformly, and the cognitive decline that accompanies normal aging—even if it reaches criterion for MCI—is not necessarily debilitating. Many older patients can compensate well in the face of significant cognitive deficits. Education level is a reliable predictor of that. People who are well educated and intellectually active tend to be relatively stable on tests of language and memory. Nevertheless, they deteriorate as rapidly as less educated people do on measures of visual-perceptual ability like coding.[13]

On the behavioral level, healthy old people frequently have a stooped posture and a slowed gait, with some Parkinsonian features. Hand steadiness is reduced, postural tremor is frequent, and coordination and balance are impaired. There are mild delays in movement initiation, decrements in complex somesthetic tasks like writing and aiming, and complaints of excessive fatigue during testing. There may be a patchy loss of light touch perception and a generalized reduction of deep tendon reflexes.[14] Simple tests of motor speed, like the Finger Tapping Test, gradually decline with aging (Figure 1).

Aside from mild memory and word-find-

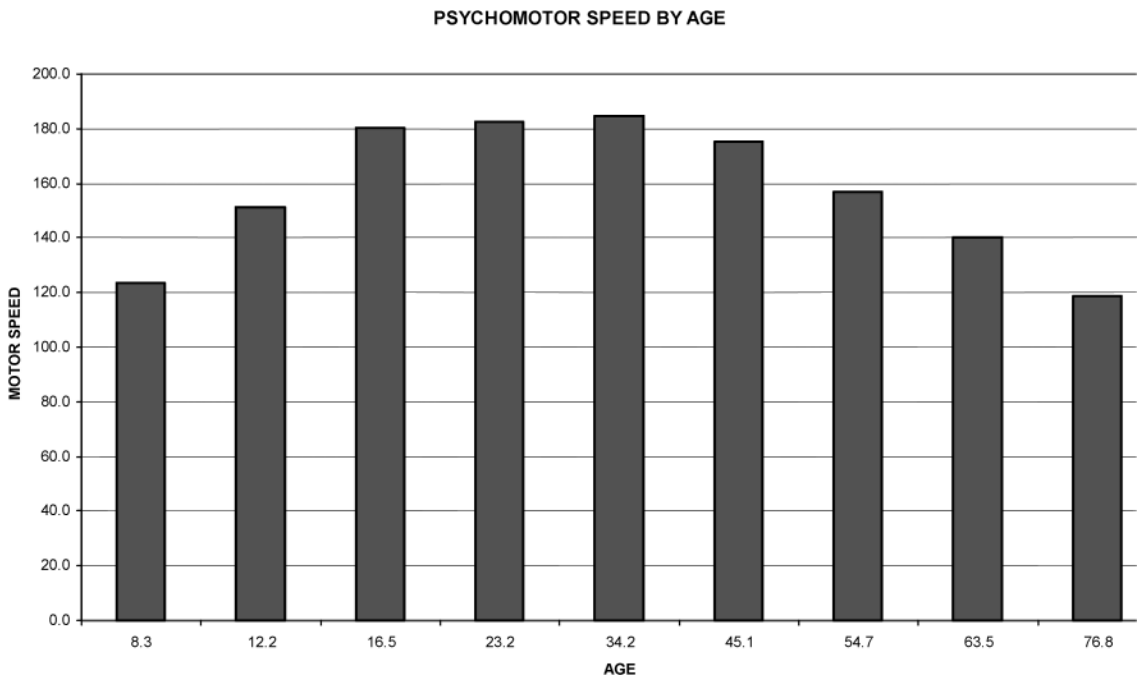

Figure 1. *Changes in psychomotor speed by age (CNS vital signs) (vertical axis = psychomotor speed; horizontal axis=age).*

ing problems, these changes are rarely problematic to healthy individuals during the 5th and 6th decades of life. In studies of athletes, however, it is clear that speed, strength and endurance begin to decline during the 4th decade. In marathoners, for example, there is a linear decrement in maximum performance from age 30 to 70 by about 1% per year.[15] This pattern of change in neuro-muscular performance is only indirectly reflective of events in the brain.

A more direct example is the experience of patients who have experienced mild brain injuries. The severity and persistence of post concussive symptoms is much more problematic in older patients, and the statistical dividing line is around age 40.[16] The gradual decline in cerebral reserve during middle age accounts for a wide range of clinical and subclinical phenomena, like intolerance to the effects of intoxicating drugs, the development of fatigue-related hypacusis, the increased severity of neuroleptic-induced neurotoxicity and the late clinical manifestations of encephalitis lethargica.

The trajectory of benign senescence is most apparent after the age of 70. By this point, the changes enumerated above often are starkly apparent, and it is common wisdom to ascribe to elderly people the attributes of poor memory, slowness, diminished flexibility, reluctance to engage in novel pursuits, emotional dependence or liability, depression, etc. But it is also clear, from cross-sectional studies, and from the complaints of some patients, that behavioral and cognitive changes occur as early as the 5th or 6th decade of life. Benign senescence is a universal event. For that reason, every standardized psychological test takes aging into consideration in establishing its normative database. Patients can only be compared to ''normals'' of the same age. This level of standardization is not taken into account in brief clinical screening batteries, like the MMSE, but is built into most of the computerized test batteries.

Mild Cognitive Impairment

''Mild cognitive impairment'' (MCI) is a general term that could apply to many different kinds of patients: children with learning disabilities, twenty year olds who have had a severe concussion, forty year olds who have been exposed to solvents at the workplace. All of these patients have mild cogni-

Table 2. Prevalence of Dementia Percent by Age

Age	Evans[25]	Hofman[26]	Wernicke[27]	Kokmen[28]	Prencipe[29]	White[30]
30–59		0.1	—	—	—	—
60–65		1.0	—	0.5	—	—
65–69	3.0	1.4	—	1	1.1	—
70–74		4.1	—	2	3.3	3.0
75–79	18.7	5.7	8	5	6.7	9.2
80–84		13.0	14	9	22.5	17.2
85–93		21.6	22	16–21	23.8	46.2
>90	47.2	32.2	42	—	34.8	—
>95		34.7	42	—	—	—

tive impairments of one sort or another. However, MCI has acquired specific meaning in dementia studies. There it is used to describe individuals who have memory impairment greater than one would expect simply from normal aging, but whose general cognitive function and activities of daily living are undisturbed. Such patients do not meet diagnostic criteria for the diagnosis of dementia or Alzheimer's disease (AD). But when they are followed longitudinally, they convert to clinical AD at a rate of 10%-15% per year.[16]

The diagnosis of MCI is made by administering neuropsychological tests. There is no consensus, however, about how precisely the ''condition'' should be defined. Minor differences in the defining criteria have resulted in big differences in prevalence and outcome.[17] The problem is compounded by the heterogeneity of MCI. It is defined as a significant impairment in one cognitive domain, or a mild impairment in more than one cognitive domain, with perhaps ''a slight impairment in activities of daily living, but not of sufficient magnitude for the clinician to call the patient demented.''[18]

Many studies indicate that MCI is just an early stage of AD,[19] but not all patients with MCI necessarily progress to overt AD. For example patients who possess the apolipoprotein E4 allele are much more likely to convert than patients who do not have the E4 allele.[20]

When healthy control subjects are compared to patients with early AD in testing, a proportion of the former group is usually discovered to have MCI. MCI patients score as poorly as the AD patients on tests of memory, but AD patients tend to be more impaired in other cognitive domains. MCI patients decline at a faster rate than healthy controls who do not have MCI but less rapidly than the AD patients. It is possible that MCI in elderly patients comprises a distinct clinical group and not just an early manifestation of AD.[21]

It has been recommended that patients with MCI be monitored for conversion to dementia every 6 months or so.[22] August bodies have opined: ''clinicians should be able to recognize persons in their practices with intermediate stages of cognitive impairment.''[23] They do not suggest how precisely that should be done.

MCI is an AD precursor, at least in some cases. It is important to note that vascular dementia risk factors, like elevated cholesterol and hypertension are also associated with MCI.[24]

Dementia

The diagnosis of dementia has 4 components:

1. Loss of cognitive power
2. Disability as a result of cognitive loss
3. Evidence of disease progression
4. Etiopathogenic diagnosis

There are more than 4 *problems* with the diagnosis of dementia. When dementia is di-

agnosed, the etiology can be inferred, but not ''accurately predicted'' during life.[31] During life there is no ''gold standard'' against which clinical diagnostic validity can be measured.[31] And many cases of dementia, if not most, are ''mixed'' in terms of their etiopathogenesis.

To base one's diagnosis on disease progression, or the presence of overt disability, is to surrender the possibility of early diagnosis/treatment. Most dementias are insidious in onset, and the disease begins long before there is evidence of disability. If treatment is to be effective, it should be instituted at the first opportunity (Table 2).

It is impossible to make the diagnosis of dementia, or to suspect it, in the absence of cognitive decline. But convergent information from many sources indicates that before cognitive decline is apparent to patients, to family members or to physicians, subtle cognitive deficits can be detected, if the neurocognitive tests are sufficiently sensitive. In every form of dementia that has been studied in this regard, there is a preclinical phase, with detectable cognitive deficits, that precedes the clinical diagnosis by many years.[6]

What is needed then is a way to detect presymptomatic dementia—a neurocognitive measure that is sensitive to early and subtle neurocognitive changes and that can differentiate between benign senescence and a dementing disease. Were such a system in place, it would afford the opportunity for early treatment and also for long-term planning.

Can such a system be constructed considering the confounding factors of benign senescence and MCI? Yes and no. Yes, for benign senescence as long as the test has proper norms for healthy old people. No, for MCI because it *is* a precursor of dementia for many, if not most, patients. Neither benign senescence nor MCI are problems for dementia screening. As stated above, if a patient has MCI, then he or she will ''convert'' to dementia at a rate of 15% per year.

What is a problem for dementia screening is the clinical diversity of the various dementias and their different neurocognitive profiles. For example, Alzheimer's disease is a cortical dementia with deficits that originate in the cognitive functions of the cerebral cortex: deficits in memory, language, visual and auditory perception, motor performance, etc.[32] On the other hand, leuko-araiosis or ''white matter disease,'' is a subcortical dementia, with symptoms that originate in the subcortical white matter and subcortical nuclei: psychomotor slowing, inattention, lack of initiative and depression.

The diversity of the dementias and the diversity of the neuropsychological symptoms of dementia means that no single test is sufficient for the purpose of diagnosis or screening. Rather, a battery of neurocognitive tests is necessary. The commonality shared by all forms of dementia, however, indicates that an appropriate battery can comprise only a few well-chosen tests. This is important, because the major issue in dementia diagnosis is not necessarily to subtype the various forms of the condition, but rather to make the diagnosis as early as possible.

In a future issue, I shall discuss the differential diagnosis of the dementing conditions. In the next sections, I examine the present state of dementia screening and the potential of several new computerized methods for early diagnosis.

SCREENING FOR DEMENTIA

Quick, Office-Based Tests

Physicians use the Mini-Mental State Examination (MMSE) more than any other instrument to evaluate patients with cognitive disorders. It is quick and easy to administer and is particularly useful for tracking demented patients over time. Although it covers several cognitive domains, it generates a single score: a number from 30 (best) to 0 (worst). It does that, however, in the most superficial way. It has a ''ceiling effect''; that is, it is not at all sensitive to patients with mild degrees of cognitive impairment. It is not hard to score 29 or 30 on the MMSE, especially if you are a well-educated person. The insensitivity of the MMSE to relatively mild states of cognitive impairment is well estab-

lished. Patients who do perfectly well on the MMSE may still be impaired when they are administered a more sophisticated cognitive battery.[33]

On the MMSE, a score of 21–24 has been suggested as ''the cutoff point for suggesting the presence of dementia.''[34] By the time the patient has declined to this level, though, the condition is already well-established. The MMSE is certainly useful for diagnosing the condition when it is symptomatic, and it is good for tracking the course of dementia as the disease progresses. But it is not appropriate for picking up early or presyndromal signs.[35]

Even though the MMSE is a crude instrument compared to neuropsychological testing, it is far more likely to detect cognitive impairment in elderly patients than routine clinical assessment by a medical practitioner. In one study of 446 elderly patients, for example, general practitioners diagnosed cognitive impairment in only 5% and the MMSE is 21%.[36]

Researchers have tried to refine the process of medical screening for early dementia. Since memory impairment is an early sign of dementia, they have focused on short but reliable tests of episodic memory, such as the Memory Impairment Screen[37] and the Hopkins Verbal Learning Test.[38] Such tests are quick and easy to administer and have high sensitivity and specificity. They are sensitive though to dementia not to pre-symptomatic dementia.

There are also abbreviated batteries of tests for dementia screening. The Seven Minute Screen (which actually takes 7 minutes and 42 seconds) includes tests of memory, orientation, clock drawing and verbal fluency.[39] Another battery employs the Boston Naming Test, the Selective Reminding Test and the similarities subtest from the Wechsler Adult Intelligence Scale (WAIS-R), but it probably takes a lot longer than 7 minutes and 42 seconds.[40] There are many other screening tests used by neurologists and psychiatrists: the Clock Drawing Test, the Time and Change Test, the Blessed Information-Memory-Concentration Test, the Kokmen Short Test of Mental Status, and others.[41] These are all worthwhile tests, but they share the disadvantages of the MMSE. They are quick and easy to administer, but they are not sufficiently sensitive to pick up early cases of cognitive decline.[42] An instrument widely used by the insurance industry is the Minnesota Cognitive Acuity Screen (MCAS), a telephone-based interview administered by a trained nurse.[43] It has been tested in normal elderly people and nursing home residents who were ''beyond the mild stage of impairment.'' The authors cautioned, however, that ''we cannot comment about the sensitivity of the MCAS for mild dementia.''[43]

None of these batteries address the subcortical deficits that arise early in the course of vascular dementia and the various neurodegenerative diseases.

Dementia Rating Scales

Rather than test a patient for cognitive impairment, some physicians prefer just to inquire about the problem. They ask the patient or ask someone who lives with him. In fact this is what is done in clinical trials of potential dementia drugs; the inquiries though are systematic and in the form of rating scales.

Several dementia rating scales have been developed. They are reliable, and they tend to correlate well with the results of neuropsychological tests.[44] In fact tests like the MMSE are neither more sensitive nor specific than informant questionnaires.[45]

Dementia rating scales in common use include the ADAS (Alzheimer Disease Assessment Scale), the SADAS (Standardized Alzheimer Disease Assessment Scale), the IADLS (Instrumental Activities of Daily Living Scale), the PSMS (Physical Self-Maintenance Scale), the CPS (Cognitive Performance Scale), the DRS (Dementia Rating Scale), and the SIDAM (Structured Interview for the Diagnosis of Dementia). There are many others. In fact, an informal assessment of a patient's cognitive status can be derived from information on the Minimum Data Set, a compre-

Table 3. An Ideal Dementia Screening Battery

Psychomotor speed (eg, Digit-Symbol Substitution)
Verbal memory (ie, word list learning)
Visual memory (faces, geometric figures)
Prose memory (sentences, stories)
Executive function (eg, Stroop Test, Halstead Categories, Wisconsin Card Sort)
Selective attention (Set shifting, multitasking)
Motor speed (Finger Tapping Test, Grooved Pegboard)
Simple and Complex Reaction Time
Information processing speed (Trails A and B, Digit Symbol Substitution)
Sustained attention (Continuous Performance Test)
Working memory (Digit Span, Digit Ordering)

hensive assessment of the patient's functional status that all US nursing homes are required to complete (by Medicare) when patients are admitted.[46] The course of a dementing illness can be tracked by administering a questionnaire to the patient's caregiver. For example, the Short Memory Questionnaire inquires after problems observed by the caregiver in various situations.

Rating scales are probably as good as the MMSE for tracking the course of a dementing condition, but they are not suitable for screening or early diagnosis. A questionnaire will only record data that the patient or caretaker observes. It cannot identify the pre-symptomatic patient.

Formal Neuropsychological Testing

Formal neuropsychological testing has always been considered the ''gold standard'' for dementia diagnosis. In Table 3, we list the cognitive tests that are most likely to express the earliest cognitive signs of cortical and subcortical dementia. They are tests that are ordinarily administered as part of a neuropsychological battery. If these tests were given together, they would be sufficiently sensitive to pick up the earliest signs of dementia, whatever the cause.

(The list in Table 3 does not include all of the cognitive deficits that occur during the course of a dementing illness. It is just a list of the deficits that are known to occur during the pre-symptomatic stage.)

The tests in Table 3 are components of standard neuropsychological assessment. In fact, they comprise most of the components of a full neuropsychological battery. (Formal testing also includes an IQ test and psycho-educational tests that address the patient's premorbid cognitive status, and personality tests like the MMPI to screen for psychopathology.) Neuropsychological testing may be the ''gold standard'' for dementia diagnosis, but a full battery takes 4–8 hours and costs $1200-$2400. For this reason alone, it is not appropriate for routine annual screening, even for patients at special risk.

If a physician decided to administer only the tests listed in Table 3, to use the shortest forms available for each test, and to train an office assistant to administer the tests, it would still occupy a couple of hours and cost the patient several hundred dollars. In fact, the reason why physicians continue to use quick, abbreviated mental state tests is that the alternative is simply impossible to contemplate in a busy and cost-contained primary care office.

It is ironic that even if it were economically feasible to test patients annually with a formal neuropsychological battery, the testing might not be sensitive to presyndromal dementia. That is because tests of reaction time are not always part of a routine neuropsychological battery, and paper-and-pencil tests of information processing speed (like Trails and Coding) are relatively gross. They report patient scores in seconds. To properly address reaction time and information processing speed, one needs to record patient response in *milliseconds.*

COMPUTERIZED SCREENING TESTS

The ''ideal dementia screening battery'' in Table 3 is formidable, even to specialists in psychiatry and neurology, let alone to internists and family practitioners. But if the battery were computerized, it would be feasible to administer it in a physician's office. Patients

could take the test without supervision by medical personnel. A low-cost screening battery could be administered on an annual basis to patients at risk.

Computerized neurocognitive testing has been used in research since the days of the Commodore and the Apple 2e.[47] The technology is well established in military and aerospace medicine, industrial medicine, and Phase I clinical trials. Clinically, computerized tests are used routinely for attention deficit disorder (ADD) diagnosis and in sports medicine for concussion management. Computerized tests are reliable—in some respects more reliable than paper-and-pencil tests.[48] They correlate well with conventional tests, are well-accepted by patients, and are capable of a high degree of accuracy. Some computerized tests generate results with millisecond accuracy, which is necessary for precise assessment of mild impairment in reaction times and information processing speed. As it happens, almost all of the cognitive functions and tests listed in Table 3 as signs of early dementia have been computerized. That they haven't been used for dementia screening is simply accidental. Maybe it's because they were the exclusive domain of researchers not clinicians. Maybe it's because dementia screening hasn't been an important priority until recently. But in the past couple of years, several new computerized batteries have been developed for clinical use and with the specific goal of dementia screening.

Cambridge Neuropsychological Test Automated Battery (CANTAB)

The CANTAB is a battery of tests administered with the aid of a touch-sensitive screen. The CANTAB has been used ''quite extensively'' in the testing of patients with dementia, Parkinson's disease, Korsakoff's syndrome, depression, schizophrenia, HIV, and in children with learning disabilities and autism.[49] It has also been used to evaluate cognitive effects of various drugs.[50] It takes about 90 minutes to administer and is used almost exclusively in academic settings.

A single test from the CANTAB battery (paired associate learning) is said to ''provide firm evidence of risk at least 18 months before formal AD diagnosis. . .[and] distinguishes individual mild AD patients from depressed and control subjects with high accuracy.''[51] Because of ''high demand'' for the test, it has been packaged for clinical use. One buys the ''full working package,'' a touchscreen PC, software and license for £2495 + VAT, which includes 50 tests. Additional tests are available for £600 per 30. The test takes 10 minutes to administer.

CANTAB-PAL, as it is called, is just a memory test. For that reason alone, it is not suitable for dementia screening.

MicroCog: Assessment of Cognitive Functioning

The MicroCog was originally developed at the request of a malpractice insurance carrier to identify impaired physicians. In its present form, it includes measures of a number of abilities in 5 cognitive domains: attention/mental control, memory, reasoning/calculation, spatial processing, and reaction time. There are 18 subtests in the standard administration, which takes approximately an hour to administer. A short form (12 subtests) takes about a half hour.

Despite its modest price and its availability through one of the largest and most widely known test publishers, MicroCog has not been used very much either in clinical practice or in research. There are only a few citations to it in Medline. Elwood[52] contends that it provides an accurate, cost-effective screen for early dementia among elderly subjects living in the community and that it can even distinguish dementia from depression. He points out, however, that its ability to detect cognitive decline in patients who are not elderly or to discriminate dementia from other mental disorders has not been established.

It is currently available from the Psychological Corporation. The initial cost is reasonable ($184) and test credits for the standard administration cost $8.30 to $12.50 depending

Table 4. The CNS Vital Signs Battery

Verbal Memory
Visual Memory
Finger Tapping
Symbol Digit Coding
The Stroop Test
The Shifting Attention Test
Continuous Performance Test

on the number purchased. Computer requirements are described as ''modest.'' In fact, it runs on a DOS platform.

Central Nervous System Vital Signs

Central Nervous System Vital Signs (CNSVS), my contribution to this field, consists of 7 conventional neurocognitive tests that are completely self-administered; a 4th-grader can take the test unsupervised. The cost of each test administration is $25, with no additional licensing or hardware fees. It runs on an ordinary PC equipped with Windows 2000 or XP. No special equipment is required (Table 4).

CNS Vital Signs is unique for two reasons. The tests are very precise—every keystroke is recorded with millisecond accuracy. It is also a very simple battery of familiar tests suitable for use not only by researchers but also by clinicians. In fact, the idea behind CNSVS is to bring computerized neuropsychological testing into the mainstream of clinical practice—not only by psychiatrists, neurologists and psychologists, but also by general medical practitioners; not only for dementia, but as a screening battery for mild cognitive impairment whatever the cause. For example, schools used it for ADD screening. It is sensitive to the cognitive effects of psychotropic drugs.[30,53,54]

CNS Vital Signs has been administered to more than 500 normal subjects and 2000 patients with neuropsychiatric disorders. The tests are reliable (test-retest, 0.67–0.85).[55] The battery generates differential profiles for patients with mild cognitive impairment (MCI) and dementia (Figures 2 and 3).[30,56,57]

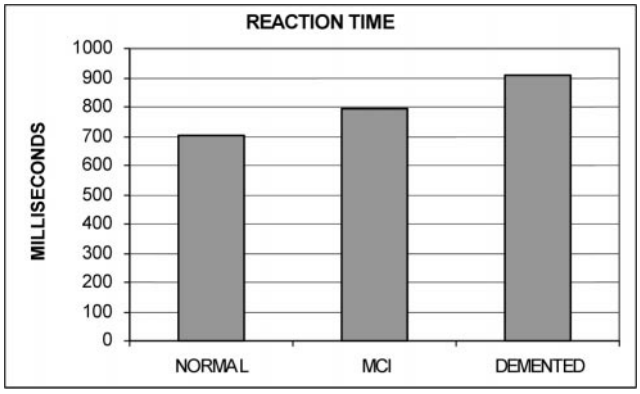

Figure 2. *Reaction times in normals, patients with mild cognitive impairment (MCI) and dementia.*

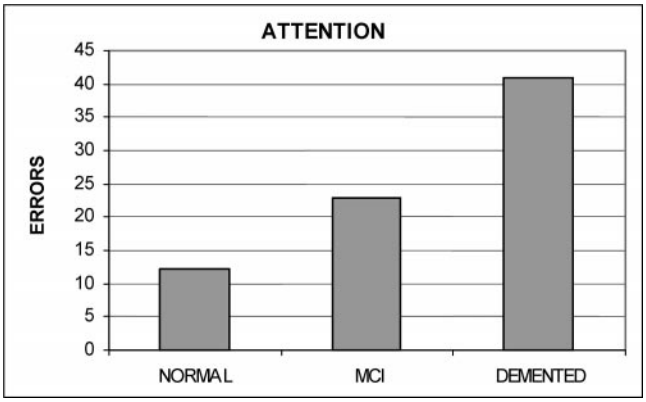

Figure 3. *Attentional errors in normals, patients with mild cognitive impairment (MCI) and dementia.*

Note: CNS Vital Signs was administered to 137 normal controls (mean age 60), 21 patients with mild cognitive impairment (age 57), and 25 patients with dementia (age 68).

The limitations of CNS Vital Signs and the other computerized tests described here are dealt with in a section below.

CogState

CogState is interesting because it is a neurocognitive test battery in the form of a card game. The display is a green baize field with playing cards face down or face up in different arrays. The subject plays a series of games that are graded in difficulty and that measure in progression a number of relevant psychological functions. The construction of the battery is such that there are no ''ceiling'' effects. That is, it is never possible to obtain a perfect score. For that reason, it is sensitive to cog-

nitive decline even in gifted individuals who might attain perfect scores on other tests.

CogState is an engaging test and the graphics are impressive. It is a highly idiosyncratic test, however, and the results are not easy to compare to conventional neuropsychological tests. It requires an active Internet connection to administer and to generate a report. It takes about 18 minutes, and the cost is $22.50 per test.

CogScreen

Gary Kay at Georgetown University developed CogScreen at the behest of the Federal Aviation Authority (FAA). The FAA was looking for a test to evaluate changes in ''cognitive function, which left unnoticed may result in poor pilot judgment or slow reaction time in critical operational situations.'' [58] What the FAA wanted was a screening test to identify pilots who might be impaired, for one reason or another. CogScreen is said to be a ''sensitive and specific neurocognitive test battery for use in the medical recertification evaluation of pilots with known or suspected neurological and/or psychiatric conditions'' (CogScreen Web site).

CogScreen has also been used, clinically, in studies of non-pilot patients with brain dysfunction secondary to head injury, tumors, strokes, substance abuse and mild dementia. It has proven to be a reliable test, sensitive and specific for assessing brain dysfunction, and at least as useful as conventional neuropsychological tests.[59,60]

The US Air Force currently establishes cognitive baselines on all of its pilot trainees using CogScreen,[59] and it may soon be required as a routine part of flight physicals among commercial pilots. It is hard to think of a more critical application for neurocognitive testing than the evaluation of military and commercial pilots. The fact that authorities have come to rely on computerized assessment for this purpose indicates a high level of faith in the technology.

The costs for CogScreen include: $750 for the license and manual, a test key and 17 tests; $20-$25 for each additional test; $345 for a light pen; and $85 for each additional test key. Each workstation needs its own light pen and test key.

Screening for Dementia Using Computerized Tests

When computerized neurocognitive testing is compared head-to-head to conventional neuropsychological batteries, the results are comparable.[48] Similar tests yield similar results. Each method has advantages and disadvantages (Table 5). Examination by a neuropsychologist is more flexible, more comprehensive, and more sensitive to subjective issues like the patient's mood, his level of motivation, and the possibility of exaggerated or invalid responding. Computerized testing is quicker and less expensive. It is also more sensitive to MCI because most computerized tests are timed, and timing is usually done in milliseconds.

Physicians refer elderly patients for formal neuropsychological testing because they suspect dementia. Usually, the patient is exhibiting symptoms and has scored poorly on an office-based test like the MMSE. Therefore, testing is used to *confirm* the diagnosis. As we know, by this time the patient probably has a well-developed dementing condition. Standard testing will usually reveal deficits in several cognitive domains. The pattern of deficits is typical of one form of dementia or another. The diagnosis is thus confirmed.

With computerized testing, however, the process is turned around. Because testing is so efficient and can be administered in a physician's office, it can be done routinely, for example as part of the routine medical examination. But when neurocognitive tests are administered to asymptomatic individuals, they are not likely to reveal deficits in several cognitive domains, or patterns typical of dementia. The test results may be normal, or they may indicate only a mild degree of cognitive impairment.

If an elderly patient scores at a level consistent with his or her education and back-

Table 5. Performance Parameters of 4 Computerized Test Batteries

Performance Parameters	CANTAB PAL	MicroCog	CogState	CNS Vital Signs
Time to take the test (minutes)	10	30–60	18	30
Cost per test	£20	$8.30–12.50	$22.50	$25
Additional fees	£2495	184	N	N
Special Equipment required	Y	N	N	N
Active Internet Connection Required	N	N	Y	N
Number of Tests	1	12	6	4
Visual Memory	Y	Y	Y	Y
Verbal Memory	Y	Y	—	Y
Sustained Attention	—	—	Y	Y
Complex Attention	—	Y	Y	Y
Psychomotor Speed	—	—	—	Y
Executive Control Functions	—	Y	—	Y
Reaction Time	—	Y	Y	Y
Information Processing Speed	—	—	Y	Y
Millisecond Accuracy	—	Y	Y	Y
Familiar (F) or Idiosyncratic (I) Tests	I	I/F	1	F

ground (if all the scores are ''average'' or ''above average''), then one can feel quite confident that the patient does *not* have incipient dementia.

On the other hand, if the patient scores below the cutoff on any of the tests on the battery, it may be an indication of MCI or early dementia. In a standardized test, the ''cutoff'' can be defined in terms of standard deviations (SD) from the mean. One SD below the mean is ''low average'' or the bottom 16% of the population. Two SDs below the mean is ''well below average'' and comprises the bottom 2% of the population. For an individual whose premorbid intelligence is average, one domain score in the ''well below average'' range or more than one score in the ''low average'' range may indicate MCI. More than one domain score in the ''well below average'' range may indicate early dementia.

A patient who scores below the cutoff does not necessarily have an incipient dementia. There are other causes of mild cognitive impairment that include: a congenital learning disability or ADD, a premorbid brain injury, alcoholism, medication effects, depression, etc. But if no other likely cause for the impairment is found, then the abnormal scores probably are an early sign of dementia, and the patient should be worked-up accordingly.

In essence, what one tries to do with a computerized neurocognitive screening battery is to identify patients who are at risk for dementia by virtue of MCI (mild cognitive impairment). We know that not everybody with MCI ultimately develops dementia; but we also know that MCI is one of the strongest predictors of dementia. No other sign or other test, not even genetic testing, is a stronger predictor.

With any new technology, there are risks and limitations. One problem with computerized testing is that it can generate a wealth of precise information that physicians may not be equipped to interpret correctly. Like any laboratory test, it is useless unless you know how to interpret the results.

Computerized tests are similar to other all screening instruments; they are extremely sensitive, but not particularly specific. They are not diagnostic tests. If a patient does well on a computerized test, especially one of the broad-spectrum batteries, one can feel confident that the patient does *not* have early dementia. If a patient does poorly, however, one cannot assume that he does. Dementia is a

clinical diagnosis, and clinical correlation is always necessary.

Computerized neurocognitive testing is actually an old technology (25 years is a long time in information technology), but it is a new technology for clinical medicine. It is reasonable to believe that it will soon occupy a central place in dementia screening. The ability to predict, with at least a degree of accuracy, which middle-aged people will develop a dementing condition is likely to have an impact on the long-term care insurance industry.

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