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Computerized Cognitive Testing for Older Adults: A Review

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Abstract

Objective: This article is a review of computerized tests and batteries used in the cognitive assessment of older adults. **Method:** A literature search on Medline followed by cross-referencing yielded a total of 76 citations. **Results:** Seventeen test batteries were identified and categorized according to their scope. Computerized adaptive testing (CAT) and the Cambridge Cognitive Examination CAT battery as well as 3 experimental batteries and an experimental test are discussed in separate sections. All batteries exhibit strengths associated with computerized testing such as standardization of administration, accurate measurement of many variables, automated record keeping, and savings of time and costs. Discriminant validity and test–retest reliability were well documented for most batteries while documentation of other psychometric properties varied. **Conclusion:** The large number of available batteries can be beneficial to the clinician or researcher; however, care should be taken in order to choose the correct battery for each application.

Keywords

Alzheimer's disease, cognitive impairment, dementia, computerized testing, older adults

A critical aspect of dementia care is early diagnosis. Although a new case of dementia is detected every 4 seconds, dementia remains largely underdiagnosed even in high-income countries with less than half of dementia cases being routinely recognized.[1] Diagnosis is often delayed, thus hindering treatment. Furthermore, diagnosis in primary care is often difficult as general practitioners lack the necessary specialized knowledge[1] while at the same time referrals for neuropsychological testing can be costly and time consuming.

The implementation of computer technology in cognitive testing followed the development of personal computers (PCs), and by the 1980s, reports on the merits and limitations of computerized testing started appearing in the scientific literature. The development of such instruments followed the path of either adapting pencil-and-paper neuropsychological tests for computer administration or developing new computerized tests. Test designers have been quick to adopt technological innovations such as the mouse and touchscreens and utilize them in their test interface.

Computerized tests have many advantages over traditional neuropsychological testing such as savings of costs and time, accurate recording of responses, and the ability to automatically store and compare a person's performance between testing sessions. Their administration is standardized and unaffected by examiner bias and they can often be administered by personnel with limited training such as nurses and health care associates. Furthermore many of them offer alternate batteries for brief screening or for assessing specific cognitive functions. Often, tests can adapt to the examinee's level of performance in order to cover a wide range of cognitive ability and minimize floor and ceiling effects.[2]

At the same time, these tests pose some limitations such as lack of normative data and psychometric standards. Furthermore, the test interface can appear intimidating and counterintuitive to older adults. Lack of familiarity with computers and the presence of computer anxiety in a number of older adults can influence both their performance and their willingness to undergo such testing.[3]

The aim of this review is a presentation of the test batteries most commonly used in the cognitive assessment of older adults, with reference to their relative merits and weaknesses.

Methods

A search was conducted on Medline at December 2012 using the following terms: computerized test, elderly, geriatric, dementia, Alzheimer*, neuropsychological, neuropsychiatric, cognitive deficit, and touch screen. This search yielded 346 abstracts of which 14 citations were identified, one of which was a previous review on the subject. A second search using the

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names of the computerized tests identified in the first search and in the previous review (ANAM, CAMCOG-CAT, CANS-MCI, CANTAB, CNS Vital Signs, CNTB, COGDRAS, CogState, CSI, MCI Screen, MicroCog, Mindstreams, TDAS) as key words along with cross-referencing and a review of the literature available at the test designers' Websites yielded a total of 76 citations.

Studies related to batteries and tests used in the measurement of the cognitive ability of older adults and the detection of dementia and mild cognitive impairment (MCI) using computerized methods were included in this review. Studies on batteries designed for other demographics and applications were excluded. A previous review of computerized tests for older adults[2] and a previous review of computerized tests for older adults in primary care settings[4] were also identified and information from these reviews has been included in this review. Batteries for which no information is available and batteries that lack relevant studies have been excluded as well. Computerized adaptive testing (CAT) and the Cambridge Cognitive Examination CAT (CAMCOG-CAT) battery as well as recent developments including experimental tests and batteries are presented in separate sections. It is worth noting that, as in the majority of scientific research, a large volume of the literature on computerized tests derives from institutions and researchers who have been involved in the construction of these tests; therefore, any conclusions on their performance should be treated with some skepticism.

Results

Seventeen test batteries were subject to review (see Table 1). The availability of normative data and basic information such as scoring and reporting of results, length of administration, alternate testing forms, and languages was inconsistent, therefore these are presented only when available. Tests and batteries have been grouped according to their main purpose into instruments designed for evaluation or screening with another category reserved for very brief short-screening instruments. This grouping is just one way of organizing the plethora of available batteries and is by no means definitive. Older screening tests were lengthier and focused on a large number of cognitive domains, while newer screening tests have benefited from later advances in scientific knowledge and target only those domains that have been found to exhibit signs of impairment before any functional decline. Therefore, some screening tests can provide data for the evaluation of a patient's cognitive functioning, while instruments designed for evaluation can also be used for screening if short administration time is not of the essence. Still the instruments of each category are more efficient at their prescribed role. It is worth noting that no computerized instrument can provide a diagnosis on its own as final diagnosis is always based on both clinical and neuropsychological criteria and therefore, there is not a category for diagnostic tests in this review. Both screening and evaluation tests can be used to aid diagnosis of cognitive disorders but a clinician should take into account other factors as well before reaching a definitive diagnosis.

Tests and Batteries Used for Evaluation

The purpose of these batteries is the evaluation of an individual's cognitive status. They provide a detailed description of the patient's overall cognitive functioning as well as the status of specific cognitive domains. Overall and domain cognitive ability are assessed and often rated against the average cognitive ability of the examinee's age group. The wealth of data provided by these instruments makes them ideal for obtaining a complete picture of a patient's mental functioning and for tracking subtle changes in specific domains.

Automatic Neuropsychological Assessment Metrics. The battery was originally developed by the US Department of Defense and its original purpose was to measure performance changes in healthy individuals undergoing environmental challenges.[5] It is the product of 30 years of research and has been used in various clinical and research settings. The battery runs on a desktop or laptop PC, while there are also Web-enabled and handheld Palm operating system (OS) modules. The battery is administered by a trained professional and administration lasts 20 minutes for the core Automatic Neuropsychological Assessment Metrics (ANAM) battery and 45 to 60 minutes for the general ANAM battery. Responses are recorded using the computer's mouse. Speech recognition and the computer's keyboard can also be used as input devices. The battery calculates various scores such as mean response times and number of correct responses and also includes a unique measure known as throughput that represents correct responses/min and measures the efficiency of performance.[6] The ANAM has been designed for repeat testing and it can create virtually limitless alternate forms to reduce practice effects. The ANAM currently includes 22 test modules that can be grouped in standard or custom batteries including the ANAM Dementia Battery (DEMBAT). It is worth noting that the DEMBAT does not include any tests of language or delayed memory.[2]

In a study by Levinson et al,[6] DEMBAT has been shown to be sensitive in detecting performance impairments in patients with Alzheimer's disease (AD) who exhibited otherwise high levels of functioning, with throughput being more sensitive than accuracy in the detection of cognitive impairments. It is argued that the DEMBAT can be a useful instrument for detecting AD in its earliest stages. Patients taking part in this study had some difficulties using the mouse to respond and this has led to modifications of the DEMBAT such as more detailed instructions concerning the use of the mouse, safeguards that detect misunderstanding of instructions, and the inclusion of a code substitution task.[6]

Automatic Neuropsychological Assessment Metrics tests exhibit convergent validity with standard neuropsychological tests assessing the same domains.[7-9] A components analysis of ANAM measures has yielded 3 factors: processing speed/efficiency, retention/ memory, and working memory.[7] An

Table 1. Characteristics of Tests Featured in the Review.

Test Category	Test Name	Hardware Used	Mode of Input	Administration Time	Administered by	Domains/Functions Assessed
Evaluation tests	ANAM	PC/ laptop (Web-based and handheld/Palm OS modules available)	Mouse (keyboard/ speech recognition optional)	20 minutes (core battery); 45-60 minutes (general battery)	Testing technician	Memory, attention, concentration, reaction time, processing speed, decision making, executive function
	CANTAB	PC with touch screen	Touch Screen	Depends on subtests/ battery used	Testing technician	Memory (verbal and visual), attention, decision making, social cognition, executive function
	CALLS	Telephone (technician records answers)	Verbal	30 minutes	Testing technician	Verbal learning and memory, processing speed, attention and working memory, verbal fluency and naming, concept formation
	COGDRAS-D	PC with 2-button answering device	Two-button answering device	20-25 minutes	Examiner	Memory, attention, reaction time
	CNTB	PC	One keyboard key, verbal, pointing the answer on the screen	50 minutes	Examiner	Memory, motor speed, information processing rate, verbal and spatial learning, attention, language, spatial abilities
	Mindstreams	PC	Mouse and keyboard's number pad	45-60 minutes	Testing technician	Memory (verbal and nonverbal), verbal fluency, visual spatial attention, information processing speed, executive function, attention, motor skills
	TDAS	14-in touch screen and computer device built into one case	Touch screen	30 minutes	Self-administered	Memory, visuospatial perception, language, praxis, orientation, executive function
Screening Tests	CNSVS	PC (Web-based version also available)	Restricted set of keyboard keys	30 minutes	Self-administered (initiated by testing assistant)	Memory (verbal, visual, and composite), executive function, processing speed, psychomotor speed, reaction time, complex attention, cognitive flexibility
	CSI	Web-based	Spacebar, backspace or number keys	25-35 minutes	Testing technician	Memory, attention, processing speed, response speed
	CogState	Laptop computer	2 keyboard keys	15-25 minutes	Testing Technician	Memory (working and episodic), processing speed, attention, decision making, visual learning, visual attention
	CANS-MCI	PC with touch screen	Touch screen	30 minutes	Self-administered (testing technician enters patient information and initiates the test)	Memory, language, executive function
	CAMCI	Tablet PC	Touch screen	25 minutes	Self-administered	Memory (verbal, non-verbal, functional, and incidental), attention, executive function, processing speed
	MicroCog	PC	Restricted set of keyboard keys	30-45 minutes (short form); 60-90 minutes (standard form)	Self-administered	Memory, reasoning, attention, spatial ability, reaction time

(continued)

Table 1. (continued)

Test Category	Test Name	Hardware Used	Mode of Input	Administration Time	Administered by	Domains/Functions Assessed
Short Screening Tests	CANTAB Mobile	iPad	Touch screen	10 minutes	Self-administered	Episodic memory
	CFT	Web-based	Mouse	15 minutes	Self-administered	Episodic memory, executive function, processing speed
	COGselftest	Web-based	Keyboard and mouse	15 minutes	Self-administered	Working memory, orientation, visuospatial organization, verbal fluency, executive function
	MCI Screen	Web-based (can also be administered through telephone)	Verbal	10 minutes	Examiner	Memory, language, executive function

Abbreviations: ANAM, Automatic Neuropsychological Assessment Metrics; CALLS, Cognitive Assessment of Later Life Status; CAMCI, Computer Assessment of Mild Cognitive Impairment; CANS-MCI, Computer-Administered Neuropsychological Screen for Mild Cognitive Impairment; CANTAB, Cambridge Neuropsychological Test Automated Battery; CFT, Cognitive Function Test; CNSVS, CNS Vital signs; CNTB, Computerized Neuropsychological Test Battery; COGDRAS, Cognitive Drug Research Assessment System; CSI, Cognitive Stability Index; MCI, mild cognitive impairment; OS, operating system; PC, personal computer; TDAS, Touch Panel-type Dementia Assessment Scale.

assessment of the ANAM mood scale suggests that ANAM can be a reliable and valid testing system for mood as well as cognitive function.[10] Although ANAM is not shown to provide the same information as a comprehensive neuropsychological assessment, it appears sensitive and specific in identifying patients with neurocognitive deficits.[5]

It is suggested that ANAM's sensitivity to change combined with the availability of alternate forms and its ease and speed of administration make it suitable for studies or clinical applications requiring repeat testing.[9,6,11] Furthermore, ANAM test results appear to be less sensitive to effects related to the examinee's English language proficiency and level of education.[9]

Cambridge Neuropsychological Test Automated Battery. Cambridge Neuropsychological Test Automated Battery (CANTAB) includes various tests assessing visual memory, executive function, attention, semantic/verbal memory, decision making and response control, and social cognition. Tests can be configured in various batteries including batteries designed specifically for the detection of AD and MCI. Tests are nonverbal and culturally independent. Stimuli are presented on a touchscreen and the patient responds by touching the screen. The test is administered by a trained technician, and a clinician is needed for the interpretation of the test results. The CANTAB includes an internal normative database of 3000 healthy volunteers.

Cambridge Neuropsychological Test Automated Battery is currently the most widely publicized battery with reports on normative data, test–retest reliability, and clinical use. The battery has been shown to be sensitive in differentiating between healthy controls, patients with early-stage AD, and patients with Parkinson's disease (PD).[12] Practice effects were observed in some CANTAB subtests and the size of these practice effects varied with the level of ability of the patients assessed.[13] Studies have shown that patients with AD and MCI have significantly impaired performance in the Paired Associate Learning (PAL) task, and it has been suggested that impairment on this task can be used both as a marker for the onset of preclinical AD and as an indicator for the initiation of treatment.[14] The CANTAB mobile screening test is based on the PAL task.

Cognitive Assessment of Later Life Status. Cognitive Assessment of Later Life Status (CALLS) is a computer-assisted battery designed for administration through telephone. Its administration is standardized with precise cues and scripts for interviewers. Some subtests are audio-recorded for post-test scoring and the test does not proceed to the next item until a valid response is given. A number of items are adaptations from standard neuropsychological tests such as the Mini-Mental State Examination (MMSE) while some are unique to the test's telephone-administered format and include volume configuration, pitch discrimination, simple reaction time, and choice reaction time. The participant can select the hearing level he or she prefers, ensuring that the test is administered at the appropriate volume. The battery also includes a depression scale and a brief hearing survey. Administration requires 30 minutes.

The test exhibits high internal consistency with an overall Cronbach's coefficient α of .81 and a moderate correlation with the MMSE ($r = .60$). A components analysis identified 5 components: verbal learning and memory, processing speed, attention and working memory, verbal fluency and naming, and concept formation. In a comparison with a 2.5-hour neuropsychological test battery, the CALLS total score had statistically significant, moderate correlations with all the tests included in the battery (Verbal Learning and Memory [$r = .41$; $P < .001$]; Processing Speed [$r = .24$; $P < .001$]; Attention and Working Memory [$r = .23$; $P < .001$]; Verbal Fluency and Naming [$r = .38$; $P < .001$]; and Concept Formation [$r = .33$; $P < .001$]) while it was not associated with nonverbal and visuospatial factors of the test battery. Significant correlations were also observed between CALLS score and age and education.[15]

Cognitive Assessment of Later Life Status can be used in place of an in-person evaluation where such an evaluation would be impossible or impractical. Compared with other telephonic measures, it provides unique measures of reaction time and processing speed and accesses more cognitive domains, similar to a standard paper-and-pencil battery. The limitations of the battery are a lack of nonverbal or visuospatial tasks, the composition of the sample used in the validation study (a limited number of individuals with lower education and no individuals with cognitive impairment), and the fact that the test is not adapted for persons whose primary language is not English. The lack of visuospatial tasks can be a serious limitation as visuospatial deficits can be among the first manifestations of AD; however, it also makes the test suitable for administration to visually impaired individuals.[15]

Cognitive Drug Research Computerized Assessment System. Cognitive Drug Research Computerized Assessment System (COGDRAS) was originally designed to measure the effects of drugs in cognitive performance in various patient populations. An adaptation of the battery (COGDRAS-D) has been designed for use with patients having dementia. The battery is administered by an examiner and the patients respond via 2 buttons. Stimuli are presented in a computer screen. The COGDRAS includes 8 subtests: immediate verbal recognition, picture presentation, number vigilance task, simple reaction time, choice reaction time, memory scanning task, delayed word recognition, and picture recognition. The battery includes alternate forms for repeat testing.

The attitude of older patients toward COGDRAS was positive and most of them, including patients with dementia, were able to complete the battery.[16-18] A validation study has shown that COGDRAS is comparable to standard instruments used in the assessment of dementia when differentiating between patients with dementia and controls. Furthermore, it also correlates to everyday functional deficits of patients with dementia measured by the Stockton Rating Scale and exhibits good test–retest reliability.[16] The battery was able to differentiate between patients with dementia, patients with minimal

cognitive impairment, and worried well older adults, with measures of response speed being more sensitive to differentiating between the minimally impaired group and the worried well group.[17] A study by Mohr et al[19] comparing the ability of different neuropsychological instruments to distinguish between patients with mild AD, patients with mild Huntington's disease, and healthy controls demonstrated that while all instruments could differentiate healthy controls from patients, COGDRAS was the most sensitive in differentiating between patients with AD and patients with Huntington's disease. In a study by Ballard et al,[18] the COGDRAS subtests of attention have demonstrated good discriminant ability when differentiating between patients with AD, patients with Lewy bodies dementia (DLB), and healthy controls. It was suggested that the battery's ease and speed of administration make it ideal for clinical use.[18] On the contrary, a study by De Lepeleire et al[20] suggested that the use of COGDRAS subtests did not add any significant diagnostic value to basic pencil-and-paper neuropsychological tests and raised the question whether the limited added value of computerized tests justifies the expense of time and money.

Computerized Neuropsychological Test Battery. Computerized Neuropsychological Test Battery (CNTB) includes 11 subtests that assess motor speed, information-processing rate, verbal and spatial learning, memory, attention, language, and spatial abilities. It is one of the first computerized batteries and despite being computerized it is not an automated battery and an examiner is needed throughout the testing process in order to provide instructions to the participant and record responses. Administration requires approximately 50 minutes. The battery offers 2 alternate forms and displays excellent test–retest reliability.[21,22] Unlike most computerized batteries, it also features tests of recall.

The CNTB has been designed as an alternative to the Alzheimer's Disease Assessment Scale (ADAS)[21] and therefore correlates highly with the Alzheimer's Disease Assessment Scale-Cognitive Subscale (ADAS-Cog).[22,23] Significant correlations have been observed between some subtests of the CNTB and ADAS that measure similar domains[22,23] such as the word list learning, spatial, and naming subtests.[22] The CNTB also correlates significantly with the Blessed Information–Memory–Concentration Test (Blessed IMC)[21] and the MMSE.[23] The CNTB appears to be a sensitive measure of cognitive impairment in both patients with mild and moderate impairement.[23] It is more sensitive than the ADAS-Cog; however, this sensitivity also extends to random noise such as day-to-day variations in response.[23]

Mindstreams. Mindstreams battery includes 11 subtests that assess verbal and nonverbal memory, verbal fluency, visual spatial attention, information-processing speed, executive function, attention, and motor skills. Many subtests are digital adaptations of pencil-and-paper tests and all subtests are available in different languages. Mindstreams software resides on a local computer and raw test data are sent to a Mindstreams server for scoring and evaluation. Responses are given through the computer's mouse and the number pad of the keyboard. Administration lasts 45 to 60 minutes.

Tests are adaptive[24,25] and alternate forms are provided to minimize learning effects.[26] It is suggested that Mindstreams is user friendly,[24] easy to administer,[27] and practical for in-office use with older patients as it can be administered by test supervisors with minimal training.[25] In a study by Fillit et al,[25] the majority of older adult participants, even those with considerable cognitive impairment, rated the battery easy to use while the majority of test supervisors reported no patient frustration.

The battery has demonstrated good discriminant validity between varying degrees of cognitive impairment in older adults.[24] Mindstreams Global Score has been shown to be particularly useful in differentiating between various forms of MCI as well as between moderate and mild dementia, with measures of memory and executive function being more sensitive in the differentiation between mild and very mild impairment and measures of orientation best differentiating between mild and moderate cognitive impairment.[24] A short form of the battery has demonstrated equal discriminant ability, compared to the full battery, when distinguishing healthy older adults from persons with mild dementia and MCI.[2] Subtests assessing memory, executive function, visual spatial skills, and verbal function demonstrated discriminant ability that is at least comparable to standard neuropsychological tests of the same domains when distinguishing individuals with MCI from healthy controls.[27] The battery has been shown to be able to detect MCI and mild dementia even in the presence of depressive symptoms. Mindstreams performance in all cognitive domains except psychomotor speed was unaffected by depressive symptom severity.[28]

Touch Panel-Type Dementia Assessment Scale. This battery was designed as a substitute for the ADAS-Cog subscale of the ADAS. Touch Panel-Type Dementia Assessment Scale (TDAS) hardware comprises a 14-in touchscreen and computer devices built into one case. The TDAS runs on Windows OS bundled with a custom program. It includes 7 ADAS-Cog items modified for computerized administration and 2 other tasks for a total of 9 tasks: word recognition, following a command, orientation, visual–spatial perception, naming fingers, object recognition, accuracy of the order of a process, money calculation, and clock time recognition. The battery is self-administered and scoring is calculated automatically without the need for a specialist rater. Test questions are asked verbally or presented visually and responses are made using the touch screen. Administration lasts approximately 30 minutes.[29]

The battery was easy to operate for most patients except for patients with severe dementia. The TDAS and ADAS-Cog total scores were significantly correlated ($r = .69$, $P < 0.01$). Comparing TDAS tasks with corresponding ADAS-Cog items, Kendal's coefficients of concordance were high for 3 tasks: word recognition ($W = 0.57$), orientation ($W = 0.41$), and naming fingers ($W = 0.32$). These tasks can rate cognitive decline symptoms equally as well as the corresponding

ADAS-Cog items.[29] The battery has been shown to be more sensitive than the Revised Hasegawa's Dementia Rating Scale (HDS-R).[30] It is argued that the battery's main advantages are its short administration time and lack of need for a specialist rater. Its disadvantages include not being able to respond flexibly according to the condition of the patient undertaking the assessment and its inability to assess the speaking fluency and behavioral characteristics of the patients which is an inherent disadvantage of computerized testing.[29]

Screening Tests

Screening tests are designed to detect possible cognitive impairment in the preclinical phase and serve as a marker for referral for further, more specialized, testing. They provide a brief picture of the patient's mental functioning while some of them can detect impairments in specific domains. Newer screening tests focus on functions that deteriorate first in the preclinical stage of cognitive disorders.

CNS Vital Signs. The battery includes 7 subtests that assess verbal, visual, and composite memory, executive function, processing speed, psychomotor speed, reaction time, complex attention, and cognitive flexibility. It runs on an ordinary Windows-based PC and responses are made using a restricted number of keyboard keys. A special keyboard is also available. An assistant may initiate the test; however, CNS Vital Signs (CNSVS) is self-administered to any person with the reading abilities of a fourth grade child. Administration lasts 30 minutes and the presentation of stimuli is randomized in order to minimize practice effects. A Web-based version, CNSVS Online, is also available. The battery is available in more than 50 languages while test reports are available only in English. The CNSVS features a normative database of 1662 healthy volunteers aged between 8 and 90 years which are divided in 10 age groups.[31] The CNSVS is not suitable for patients with severe dementia.

As soon as the test is completed, the program generates a report that includes 5 domain scores derived by factor analysis: memory, psychomotor speed, reaction time, cognitive flexibility, and complex attention and the Neurocognition index which is an average of the domain scores and reflects the overall performance of the patient. The battery also includes validity indicators for each subtest in order to ensure that the results accurately reflect the patient's cognitive ability.[32]

Most of CNSVS subtests are based on standard pencil-and-paper tests and 5 of these subtests correlate significantly with their pencil-and-paper equivalents. The battery exhibits good test–retest reliability and that reliability remains unaffected by age or clinical status.[31] A study by Gualtieri and Johnson[32] has demonstrated that CNSVS has good sensitivity and specificity in differentiating between MCI, mild dementia, and healthy controls with subtests of memory, processing speed, and cognitive flexibility being the most sensitive and specific. It is argued that the test is specific enough to be used as a screening test for mild cognitive dysfunction as long as the interpretation of test results is undertaken by a trained clinician; however, it is not specific enough to provide a diagnosis on its own.[31]

Cognitive Stability Index. This battery is Web based and features 10 subtests preceded by demographic questions and questions about computer and keyboard familiarity. Instructions appear on the screen and the patient responds using the spacebar, backspace, or number keys. All stimuli are nonverbal. Normative sample includes healthy adults aged 18 to 89 years from various age and ethnic groups. Cognitive Stability Index (CSI) measures 4 factors identified in an analysis of the normative sample population performance: attention, memory, processing speed, and response speed.[33] Administration lasts 25 to 35 minutes. Scoring is Web based and test reports are available instantly after the completion of the test. Test reports are not available directly to the patient as only a licensed health specialist can view the test report. Multiple alternate forms are available and there is evidence of alternate form equivalence.[34]

The battery exhibits good test–retest reliability and minimal practice effects, appearing to be a valid measure of cognitive performance in various populations including non-English–speaking persons.[34] It is argued that the battery is suitable for serial assessment.[33] The CSI subtests and the 4 factors the battery measures display good concurrent validity with standard neuropsychological tests of the same domains. Some patients with AD were unable to complete all subtests of the battery in a valid manner indicating that the usefulness of CSI in monitoring cognitive change in patients with AD is possibly limited.[33] A shorter version of CSI, the Cognitive Screening Test, is aimed at community screening. It features 3 subtests and has been shown to have good concordance with patient diagnoses.

CogState. The battery includes 8 subtests that assess processing speed, attention, decision making, working memory, visual learning and visual attention, and episodic memory. It is presented on a laptop computer with stimuli displayed in a playing card format and 2 keyboard keys are used for responses. Written instructions appear on the screen. Administration requires 15 to 25 minutes depending on whether the standard or short form of the battery is used. There are an unlimited number of equivalent forms to minimize learning effects making the battery suitable for serial assessment.[35]

CogState has been developed for repeat testing.[2] Minimal practice effects[36-38] and good test–retest reliability[36] have been observed, making the battery suitable for measuring intraindividual cognitive decline in healthy and cognitively impaired older adults.[39,40] Practice effects have been observed in healthy controls during repeat assessments in a single day,[38,41] and it has been suggested that these practice effects can be used to differentiate between healthy older adults and patients with MCI who don't demonstrate similar practice effects, by administering the battery 4 times in the span of 3 hours.[41] CogState is the only example of a computerized instrument where practice effects are used to aid assessment.

CogState measures of visual learning and working memory have been shown to be particularly sensitive to cognitive impairment in the clinical and preclinical stages of dementia.[40] CogState appears to have discriminant ability that is comparable to standard neuropsychological tests when used to differentiate patients with MCI or AD from healthy controls, with its discriminant ability being higher when distinguishing patients with AD from healthy controls; however, it was unable to differentiate between various dementia types.[42] When detecting patients with MCI from healthy controls, its discriminant ability is higher than that of the MMSE and marginally lower than that of the Hopkins Verbal Learning Test (HVLT).[35] There is a significant correlation between CogState and standard neuropsychological tests such as the HVLT[35]; however, CogState subtests did not correlate significantly with validated pencil-and-paper tests that assess similar cognitive domains.[42] Significant correlations with subjective memory complaints (SMCs) and activities of daily living have also been demonstrated.[35]

It is argued that with little practice or supervision CogState can be completed successfully by older adults with limited computer experience.[37] Testing with CogState was well tolerated by older adults; however, some found the speed of the program too fast to respond to in time.[35] It has been suggested that the efficiency, acceptability, and good test–retest reliability of this battery make it ideal for epidemiological studies in older adult populations even with patients who have limited familiarity with computers.[37] It is argued that the battery's brevity, user friendliness, and limited need for specialist personnel combined with its sensitivity to cognitive decline and its stability over time make it suitable for dementia screening.[42]

Computer-Administered Neuropsychological Screen for Mild Cognitive Impairment. Computer-Administered Neuropsychological Screen for Mild Cognitive Impairment (CANS-MCI) has been specifically designed to be administered to older adults as a screening test for MCI. It includes 8 subtests that assess 3 cognitive domains that have been found to be predictive of AD in previous research: memory, language, and executive function.[43] The battery is mostly self-administered; however, a testing technician is required in order to enter the patient's information before the testing process begins. Instructions are given in audio format through the computer's speakers and responses are made via touchscreen. Scoring and reporting is Web based. Test results are sent to the test developer's headquarters where they are analyzed by a live neuropsychological testing technician. A report is generated based on the test results and the patient's information and it is forwarded to the physician within 1 hour after the completion of the testing process. The report includes an assessment of the patient's performance in the 3 cognitive domains examined, an estimate of the likelihood that the patient would be diagnosed with MCI after a full neuropsychological examination and other useful background information such as levels of depression, past head injuries or exposure to solvents, and so on. Administration requires 30 minutes. The battery does not offer alternate forms. The developers are currently designing alternate forms for future release.[4] The CANS-MCI is available in English, French, Spanish, Portuguese, and Dutch.

A factor analysis supported the test designers' 3-factor model.[43] In the same study, CANS-MCI was shown to have good internal consistency and high test–retest reliability. Test–retest reliability was found to improve after familiarization with the testing procedure. At the same time, the test displayed good discriminant validity. It was also sensitive to measuring change over time, a feature that could be useful in assessing highly educated people who usually have greater cognitive reserves.[43]

A comparison of CANS-MCI with the Addenbrooke's Cognitive Examination-Revised (ACE-R) and the Montreal Cognitive Assessment (MoCA) demonstrated equivalent sensitivity in distinguishing between healthy older adults and patients with MCI. All test subscales demonstrated good sensitivity and specificity with executive function exhibiting the highest discriminant ability. It was suggested that the longer duration of the CANS-MCI battery makes it less suitable for screening compared to the MMSE and MoCA; however, its self-administered format makes it suitable for large-scale studies.[44]

Computer Assessment of Mild Cognitive Impairment. The battery is designed for preclinical screening of abnormal cognitive decline. It comprises 8 subtests that assess 4 cognitive domains: attention, executive function, processing speed, and memory (verbal, nonverbal, functional, and incidental). It has been designed to replicate the results of an expert's review of a comprehensive neuropsychological examination.[45] Computer Assessment of Mild Cognitive Impairment (CAMCI) is preinstalled in a tablet PC and responses are recorded by touching the tablet PC's touchscreen. The test is designed to be fully self-administered without supervision and its administration lasts approximately 25 minutes. The CAMCI does not offer alternate forms for repeat testing; however, alternate forms are under development.[4] The battery is scored automatically and a health care professional is required for the interpretation of the test report. It is worth noting that CAMCI is the only computerized test to feature a virtual reality (VR) task, a driving simulation task.

Computer Assessment of Mild Cognitive Impairment has been shown to have good test–retest reliability being highly stable over a relatively short period of time. It exhibits high sensitivity (86%) and specificity (94%) when differentiating between patients with MCI and healthy older adults. It may incorrectly classify a small number of cognitively impaired individuals as normal; however, its specificity and sensitivity remain higher than that of the MMSE.[45] At the same time, it appears to be easy to use, with older patients reacting positively to using the computerized battery.[45] The CAMCI is currently in the research and development stage and only available to researchers. It is being used on a number of research studies, 2 of which focus on the cognitive assessment of older adults and the detection of dementia.

MicroCog. The battery was originally designed to screen older physicians for cognitive impairment and malpractice risk and it was the first computerized battery developed for clinical applications.[46] It includes 18 subtests and features a standard form as well as a short form using only 12 subtests. Both forms assess 5 cognitive domains: memory, reasoning, attention, spatial ability, and reaction time. Administration lasts 30 to 45 minutes for the short form and 60 to 90 minutes for the standard form. The testing software runs on a standard PC. Instructions and all stimuli, apart from an aural tone used to measure auditory reaction time, are presented on the computer's screen and the patient responds using a restricted set of keys. The battery is self-administered and answers follow the multiple-choice format. The administrator can customize the report generated and the software can provide brief or detailed reports.

MicroCog has been shown to differentiate between healthy controls and patients with MCI, exhibiting a sensitivity of 98% and a specificity of 83%.[47] The battery is relatively unaffected by depression.[48] It is argued that MicroCog was normed better than most neuropsychological tests when it was introduced.[48] Validation against traditional neuropsychological tests yielded modest results[2]; however, it is suggested that the battery's construct validity shouldn't be judged against traditional tests, some of which exhibit poor construct validity themselves.[48] It is possible that the battery's computerized format enhances its discriminant ability while it limits its construct validity.[48] Significant correlations between the Wechsler Adult Intelligence Scale-III Full Scale IQ and the MicroCog short form General Cognitive Functioning score have been reported.[2] Correlations, ranging from weak to significant, between MicroCog subtests and subtests of the Wechsler Memory Scale-III have also been reported.[48] It is worth noting that MicroCog is the only battery designed to screen older adults with a high level of education and therefore, it can be useful in avoiding ceiling effects associated with testing individuals with higher education or enhanced mental capacity.

There is no consensus on the comparability of the battery's short and standard forms. Elwood[48] argues that the short form is a good alternative for the standard form while Lopez et al[49] argue that there is a lack of comparability between test forms, specific to the assessment of the Spatial Processing index. It has been suggested that the testing experience can be frustrating for impaired individuals[47] although it is argued that this can be said for any procedure that tests the upper limits of an individual's functionality.[48]

Short Screening Tests

This category represents a new generation of screening tests focused on reducing administration time while providing an outlook of the patient's overall cognitive functioning. The administration time for these tests ranges from 10 to 15 minutes, marking them as possible alternatives to standard pencil-and-paper screening tests such as the MMSE.

CANTAB Mobile. The CANTAB Mobile is a short, 10-minute test of episodic memory that runs on the iPad tablet device. The test is designed for assessing older adults who are worried about their memory and it is based on the PAL task of the CANTAB battery. Furthermore, it includes a number of questions from the Geriatric Depression Scale and questions about instrumental activities of daily living (IADLs). The test features an internal normative database of 4000 older adults. Instructions are given verbally and are available in 18 languages and responses are given via touchscreen. Scoring is automatic, and according to the patient's performance, an indication of "No present concern," "Monitor," or "Investigate" is given.

The CANTAB Mobile will be incorporated in a new digital health care system that will be trialed in the United Kingdom from early 2013. It will be used to screen patients for referral to memory clinics where a more detailed secondary care version of CANTAB Mobile will be used in combination with brain scans to provide a more detailed assessment.[50]

Cognitive Function Test. Cognitive Function Test (CFT) is a short screening test battery designed for Web administration. It is aimed at detecting subtle cognitive changes that predate dementia in adults aged 50 to 65 years. Responses are recorded using the computer's mouse and administration lasts approximately 15 minutes. The test assesses those cognitive domains found to be associated with MCI, namely, episodic memory, executive function, and processing speed, with each of its subtests focusing on one of these domains. Many of its subtests have been adapted from pencil-and-paper tests that assess similar domains.

The battery has been normed on a sample of healthy adults and cutoff points based on standard deviation have been established for MCI. Statistical analysis has shown good internal consistency with a Cronbach's α of .73 while factor analysis has found 2 factors, 1 memory factor and 1 executive/processing speed factor. The loading of both executive function and processing speed in 1 factor could indicate possible redundancy and it is argued that the test may be equally sensitive with only 1 of the 2 subtests. The CFT scores correlated positively with a number of pencil-and-paper tests and its subtests correlated with pencil-and-paper tests of similar domains indicating good concurrent validity. The battery has not yet been tested with patients having MCI or dementia so further studies are needed in order to determine its clinical value.

It is worth noting that CFT is the only test aimed at adults as young as 50 years old without cognitive impairments or SMCs. It is designed to be used before the onset of clinical symptoms or SMCs and therefore is more challenging as it is aimed at individuals with good cognitive functioning. The test's designers suggest that such an early screening could alert people about possible signs of early impairment and enable them to target modifiable risk factors for MCI and dementia such as diet, smoking, mental and physical inactivity, and so on.[51]

COGselftest. The COGselftest is a short test battery designed to be Web based and self-administered. It is based on a pencil-and-paper, self-administered test designed by Dougherty Jr et al. It includes measures of orientation, visuospatial organization, verbal fluency, working memory, attention, and executive functions. Stimuli appear on the computer screen and the participant is given both oral and written instructions. Responses are recorded via the computer's keyboard and mouse. A caregiver or technician can help the patient by controlling the input devices. Administration requires approximately 15 minutes. When the test is completed the patient receives feedback; however, the results, as seen by patient, have been designed so no diagnosis can be inferred.[52]

A recent study has demonstrated that the battery has good discriminant ability when distinguishing healthy controls from cognitively impaired older adults as well as when distinguishing between various degrees of cognitive impairment. In both occasions, it demonstrated higher discriminant ability than the MMSE and the Mini-Cog tests.[52]

MCI Screen. The MCI Screen has been developed specifically for screening older adults for cognitive impairment. It is based on a modified version of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) word-listing task and runs as an online application. Unlike the CERAD word-listing task, scoring is calculated using a correspondence analysis algorithm and presented using the Memory Performance Index (MPI), which can take a value between 0 and 100, and a designation of "normal" or "impaired" is given based on the MPI score. The 10-minute test is administered by an examiner or via telephone. It assesses memory, language, and executive function.

The algorithm used in producing the MPI score has been shown to be more sensitive than the traditional method of scoring the same task. When compared to total scores, the MPI explains 2 to 3 times more variance. Furthermore, the MPI score declines progressively with increased dementia severity[53] allowing the clinician to monitor changes in a patient's cognitive ability. The MCI Screen has been shown to be more sensitive in the detection of cognitive impairment in a primary care setting compared to the MMSE and the Clock drawing test.[54] In a comparison with a standard neuropsychological test battery (*Alzheimer's Disease Research Center* battery) assessing verbal and visual memory, attention and psychomotor speed, language and spatial abilities, and executive functioning, MCI Screen has been shown to have similar discriminant validity in distinguishing patients with amnestic MCI from healthy controls and patients with AD despite using only memory performance as an indicator.[55] A Japanese version of the test is reported as having good equivalence with the English version, making it suitable for early detection of MCI in a Japanese population.[56]

Computerized Adaptive Testing

Computerized adaptive testing is a method for electronically administering neuropsychological tests which adapts to the patient's level of functioning. The test items are graded for difficulty and the patient's level of performance is constantly monitored based on responses given and mistakes made while completing the test. The CAT tailors the testing progress by administering only those items appropriate for the patient's ability level.[57] Testing with CAT can reduce administration time[57] and the psychological burden of the patient while it limits errors due to fatigue and minimizes floor and ceiling effects.[58]

Computerized adaptive testing has been used to administer the Cambridge Cognitive Examination (CAMCOG) in an effort to combine the thoroughness of the CAMCOG with the brevity of short screening tests such as the MMSE.[57] The CAT has led to a decrease in the CAMCOG administration time that ranges between 37% and 55% while CAMCOG-CAT estimated ability levels and diagnostic accuracy displayed excellent agreement with the pencil-and-paper CAMCOG test.[57-60] Despite CAMCOG's reduced sensitivity to cognitive impairment,[57] CAMCOG-CAT's accuracy in detecting MCI and mild dementia remains slightly better than that of the MMSE.[58]

The CAMCOG-CAT deviates from the standard approach in the design of short screening tests which consists in fixed format test reductions based on average group results. It is argued that while it retains the brevity of fixed format reductions it preserves the information of the whole test, tailoring the test to the individual patient.[57] Furthermore, it reduces the burden of the patient by omitting items that are too difficult or too easy for him or her, thus it is likely to incur less measurement error due to patient's reduced concentration or fatigue.[57]

It is worth noting that CAT is not the only form of adaptive testing available. Other tests such as Mindstreams[24,25] and the short supplementary screening test designed by Maki et al[61] also feature adaptive tasks. Furthermore, the only available computerized questionnaire for IADLs is also adaptive, asking only those questions that are relevant to the activities the patient used to perform in the past.[62] One should expect adaptive testing to become more common in future computerized instruments.

Recent Developments

Research in computerized cognitive assessment is fast paced and new test batteries are being designed to cater to specific research and clinical needs. At the same time, experimental tests and batteries are created in order to trial new approaches in computerized testing. This review has identified 4 such instruments (see Table 2).

CogniScreen. CogniScreen is a test of verbal episodic memory comprising 3 tasks: pair recognition (Task 1), cued recall (Task 2), and immediate and delayed serial recall (Task 3). It has been developed to identify mild dementia and MCI in community-dwelling older adults while being able to differentiate between cognitive decline and depressive symptoms.[63] The test is administered using a laptop computer and a headset with a microphone for voice recording. Each task is initiated with a button press and afterward participants are self-directed in completing the task. Administration lasts 20 to 40 minutes depending on the speed of the participant. Scoring is

Table 2. Experimental Tests and Batteries.

Test Name	Hardware Used	Mode of Input	Administration Time	Administered By	Domains/Functions Assessed
CogniScreen	Laptop computer with headset including microphone	Verbal, mouse, and keyboard	20-40 minutes	Testing technician	Verbal episodic memory
Battery developed by Kluger et al[63]	Laptop computer	Keyboard	12-15 minutes	Testing technician	Memory, praxis, orientation, executive function
Battery developed by Inoue et al[64]	14-in touch screen and computer device built into one case	Touch screen	4 minutes	Self-administered	Memory (working and short term), temporal orientation, visual spatial perception
Test developed by Maki et al[61]	PC with touch screen	Touch screen	3 minutes	Testing technician	Visuospatial short-term memory

Abbreviation: PC, personal computer.

automatic and the testing software can provide unlimited alternate forms to minimize practice effects.

A recent study has examined CogniScreen's ability in differentiating between patients with MCI, individuals with depression, and healthy controls. Tasks 2 and 3 performed better in differentiating between MCI, depression, and normal controls. At the same time, the overall sensitivity and specificity of CogniScreen in distinguishing between patients with depression and controls were average. Task 3 was best at identifying MCI being able to correctly identify 83% of patients with MCI, with a sensitivity of 92.6% and a specificity of 80%. At the moment, further refinement and development of the battery are in progress.[63]

Experimental battery developed by Kluger et al. Kluger et al[64] developed a brief, self-administered screening test for dementia. It includes a memory test based on the HVLT, a praxis test assessing knowledge of transitive actions, a temporal orientation test, and a crossed response inhibition test. The test is performed on a laptop computer using custom software and includes a brief assessment of computer competency in order to verify that the patient can perform the test's tasks. Responses are recorded using the laptop's keyboard while administration lasts 12 to 15 minutes on average. The majority of older adults, including patients with dementia, were able to complete the testing procedure unassisted. The test and its subtests correlated significantly with standard neuropsychological measures. It exhibited a sensitivity of 92% and a specificity of 72% in distinguishing between healthy controls, MCI, AD, and other dementias.[64]

Experimental battery developed by Inoue et al. Inoue et al[65] have created a very brief battery designed for screening in community-based settings. The battery runs on a specially designed device that comprises a 14-in touch screen and computer devices built into one case. It assesses working and short-term memory, temporal orientation, and visual spatial perception. The battery consists of 4 tasks that were designed with reference to the Hasegawa Dementia Rating Scale: a 3-word memory test, a temporal orientation test, a 3-dimensional visual–spatial perception test, and a delayed recall test. A practice session is also included in order to familiarize the patient with the testing procedure. The battery, including the practice session, can be completed within 4 minutes. It is self-administered and the maximum score a patient can achieve is 15. The battery was easy to operate for most patients and only persons with sensory disabilities required some assistance. Maximum sensitivity and specificity in distinguishing patients with AD from healthy controls were 96% and 86%, respectively, with a cutoff score of 13. It is argued that this battery is suitable for community screening due to its short administration time and good sensitivity and specificity.[65]

Experimental test developed by Maki et al. Maki et al[61] developed a computerized visuospatial memory test designed to be used as a supplementary screening test for dementia. This test comprises a single task measuring visuospatial short-term memory. Custom testing software runs on a Windows XP-equipped PC with a 15-in touchscreen display. Numbered circles appear on the screen for 8 seconds and the patient is required to memorize their location sequentially. If the patient fails to provide a correct answer, the next question features fewer stimuli whereas if the patient answers correctly, the number of stimuli is increased. Each error resulting in a reduction in stimuli is recorded as a reversal point and the testing session ends after 4 reversal points. Administration requires an average of 3 minutes. This test was able to evaluate memory function in patients with MCI and mild dementia but not in patients with severe dementia. It is argued that the adaptive nature of the test can reduce the psychological burden of patient and its brevity makes it ideal for use in conjunction with other screening tests such as the HDS-R and the MMSE.[61] The testing software is distributed freely at http://homepage3.nifty.com/maruhi/program/vsmt/index.html.

Discussion

Previous reviews[2,4] have contributed greatly to the field of computerized assessment. This review comes at a time when

there is a flourish of activity in this field. It highlights the shift toward early screening and early diagnosis and the accompanying shift in the way computerized testing is implemented in health care. The categorization of the instruments appearing in this review serves to highlight this shift.

The tests featured in this review differ greatly in the normative data presented as well as in their representation in relevant scientific literature. Most include sufficient data concerning discriminant validity; however, other psychometric properties are not as well documented. Data on concurrent validity with standard pencil-and-paper tests are often incomplete or inconclusive. It should be noted that equivalence between pencil-and-paper tests and their computerized adaptations cannot be taken for granted as differences in instructions and stimuli presentation and response methods may affect the test results and even the cognitive domains and processes the test actually measures. At the same time, it is argued that because of the different format and mode of administration of computerized tests, their discriminant validity should be considered more important than their concurrent validity when judging their psychometric abilities.[48]

Virtual Reality and its Absence in Computerized Testing

At this point, it is worth noting the absence of VR technology elements from available computerized tests. Currently, there is a wealth of interest in the use of VR technology in medicine. Virtual reality enables the user to enter a computer-generated environment and interact with it. It allows for a high degree of ecological validity and can be tailored to suit specific therapeutic or research needs. Virtual reality technology has been used successfully in the field of cognitive rehabilitation and cognitive training. The engaging nature of VR tasks could make them ideal for a wide range of applications including cognitive screening and evaluation. This possibility becomes even more lucrative when taking into consideration that older adults often exhibit a willingness to try new technologies[66] and a positive attitude toward video games and VR environments.[67]

It has been shown that performance in a virtual reality environment can be useful in distinguishing patients with MCI from healthy older adults and that SMCs correlate with performance in a VR test.[68] Despite the evidence supporting the possible use of VR in neuropsychological evaluation and the increased interest in the use of VR in cognitive training, most test designers choose to use tasks based on traditional paper-and-pencil neuropsychological tests. It can be argued that this approach allows test designers to test their batteries against classic pencil-and-paper tests and compare their concurrent validity. At the same time, the increased cost and potential risk of developing a VR-based test from the ground up could also contribute to their decision to take a more "conservative" approach and base their tests on proven instruments.

Nevertheless VR technology is still markedly absent from standardized computerized neuropsychological tests and batteries. The only notable exception is CAMCI which includes a VR driving task. This task requires the participant to drive on a VR environment following specific directions and stopping at certain points along the route to perform certain actions like mailing a letter or going to the bank.[4,69] The CAMCI is a relatively new instrument and currently not available commercially. The introduction of a VR element in this computerized battery looks promising, especially since it is a navigation task and navigation is connected with the hippocampal function that is impaired in patients with MCI.[70] It remains to be seen whether this VR element will enhance the battery's diagnostic ability or if other test designers will follow this example and start implementing VR technology in future tests and batteries.

Instrumental Activities of Daily Living Assessment

Additionally, despite the abundance of computerized cognitive measures, a search of the relevant literature revealed a lack of computerized measures of IADLs. Considering the fact that decline in ability to perform IADLs is an important marker for both the onset and the progress of cognitive decline, this is quite surprising. Recent reviews of IADLs measures present a large number of pencil-and-paper IADL measures[71,72]; however, only a few computerized instruments appear in the relevant literature. Only one of these instruments, the Amsterdam IADL Questionnaire, has been designed for older adults with cognitive problems.[62]

The Shift Toward Screening

An interesting development is the increased interest in short screening tests. There is yet no consensus on the necessity and cost-effectiveness of screening older adults for dementia and MCI[45]; however, many test designers focus on providing such short instruments and many authors favor computerized screening as a fast and cheap method of screening large populations for cognitive impairment.[73] There is a shift toward early detection of cognitive decline and there is even one test aimed at detecting very early deficits that may appear in the 50 to 65 years old age group,[51] an age group that is not routinely examined for cognitive deficits related to AD and MCI. It is argued that short tests induce less fatigue and are more suitable for repeat administration compared to lengthier instruments,[39] an important advantage for physicians in need of monitoring the progress of an individual's cognitive decline. These tests are usually self-administered and are often used in primary care or community settings in order to provide a clear "traffic light" signal to family doctors and primary care physicians dealing with older patients. Progress in computerized cognitive testing has led to the point where 5-minute and shorter tests and batteries are already appearing.[61,65] Soon a computerized battery that would combine the brevity and ease of administration of the MMSE with the high sensitivity and specificity needed to screen for MCI and dementia could be a reality. The implementation of screening tests could lead to better management of health care resources as only patients who show clear signs of impairment would be referred for lengthier and costly neuropsychological assessment.

Advances in knowledge about dementia and MCI and the way they affect the brain have led test designers to focus on specific functions that deteriorate in these diseases. Indeed some of the newest short screening tests focus on just one cognitive domain that is known to deteriorate at the onset of dementia or MCI. At the same time, tests become more specialized. Many new tests and batteries focus on the detection of MCI and thus are aimed at individuals with a relatively high level of functioning. Tests aimed at a higher level of functioning may reduce ceiling effects; however, at the same time they may not be suitable for severely impaired individuals.[74] The physician should have sufficient knowledge to administer the instrument applicable to the patient's level of functioning.

Different Attitudes Toward Technology

Despite the test designers' generally positive attitude toward technology, different attitudes exist toward the implementation of the latest technological instruments. Many designers have enthusiastically adopted new technologies such as tablet PCs, touchscreens, and multimedia while others focus on the structure of the test itself and choose to use cheaper, more widespread technology. Some authors argue that cost is an important factor and therefore the low cost and accessibility offered by the use of a standard PC may outweigh the advantages offered by more expensive technological instruments.[48,74] Furthermore, there is lack of consensus on the suitability of some technological instruments. This lack of consensus extends even to well-established instruments such as touchscreens. Some designers prefer them as an intuitive method of response[45] while others argue that they lead to less sensitivity in simple and choice response time tasks and note that they may induce muscle fatigue in older adults.[74]

Still computer technology is ever progressing and some designers are expressing interest in emerging technologies such as speech recognition. If reliable speech recognition technology becomes widely available, computerized batteries could feature tests of verbal recall[4] that could be scored automatically without the need for an examiner and also provide an intuitive method of answering that is not reliant on computer skills. Already, computerized testing is well tolerated by older adults and the experience is pleasant for most patients[16,45]; however, computer illiteracy can cause anxiety in some individuals leading to a drop in performance.[4] At the same time, much like technological progress, one should expect an increase in the familiarity of people with electronic devices in the future. The adults of today have grown up in a world saturated with electronic devices. Older adults currently represent the fastest growing segment of Internet users.[75] One can expect the older adults of the future to be very familiar with technology[37] and this familiarity should be taken into consideration when designing future instruments.

The Present and Future Status of Computerized Testing

The status of computerized testing is still uncertain. Despite the wealth of available tests and batteries, there is still no consensus on their effectiveness and suitability. Short batteries and tests, while adequate for screening, cannot lead to a diagnosis or provide the wealth of information afforded by a lengthier examination. At the same time, lengthier computerized batteries provide a large volume of information which can be misinterpreted by poorly trained clinicians.[31] Cost remains an important factor that can limit access to computerized testing and new technologies in general. Cost should be offset by increased effectiveness and sometimes computerized tests can be no more accurate or even less accurate than standard pencil-and-paper tests, thus raising the question whether the increased cost in equipment and staff training is justified.[20] At the same time, there is little consensus on how computerized testing should be integrated into diagnosis, treatment and follow-up. Only recently, some test designers have proposed models and algorithms for the integration of their tests in neuropsychological practice. These models usually suggest the use of a computerized screening test if signs of possible impairment are identified in the first diagnostic interview. If the results of the screening test suggest possible impairment, a lengthier computerized test is administered in order to provide a more detailed cognitive profile. Computerized testing is then used at regular intervals throughout the treatment phase to assess the patient's progress.[26,50,76] Such models and algorithms and the increased interest in the implementation of computerized testing in health care represent positive steps toward the integration and acceptance of technology in cognitive testing.

At this point, it is impossible to select a test that would be most suitable for dementia and one that would be most suitable for MCI. As noted previously, despite years of research and development, computerized tests remain a new development in neuropsychology and often lack psychometric data and comprehensive research evaluation. Furthermore, the suitability of each test depends on variables such as its cost, length of administration, and the need for a specialist either for administration or for scoring. With reference to these variables, one test could be suitable for one hospital and unsuitable for another hospital with different staff composition and operating mode. It is worth noting that no review has yet proposed one test as definitely better or more suitable.

In conclusion the application of new technologies in cognitive testing offers many opportunities; however, it comes with its own complex set of challenges. Future developments will be guided not only by technological and medical advances but also by the attempts to integrate computerized instruments in the existing health care systems and policies.

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