Mindstreams® Computerized Cognitive Tests: Test Descriptions

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INTRODUCTION

Mindstreams computerized tests assess performance across an array of cognitive domains including: memory, executive function, visual spatial perception, verbal function, attention, information processing speed, and motor skills. The psychometric properties of the tests exploit the advantages of computerized testing, providing precise accuracy and reaction time measurements. Mindstreams offers an unbiased, standardized, accurate and inexpensive tool with a wide range of applicability in clinical medicine.

MILD IMPAIRMENT TESTS[1]

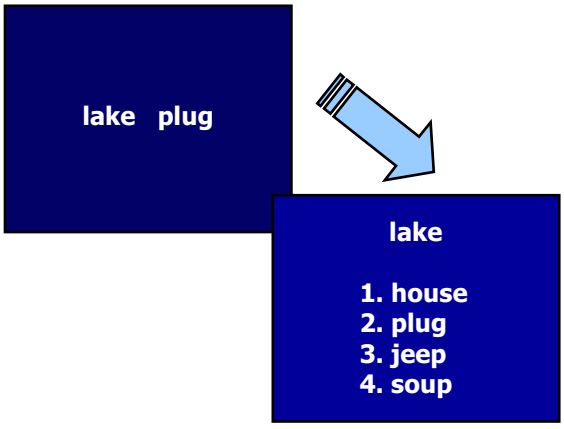
Verbal Memory

Cognitive Domain(s): Memory

- Theoretical Framework

The formation of new associations between items is critical for establishing episodic memories. Yet elderly individuals who suffer from cognitive decline have trouble forming these new associations (e.g., Fowler, Saling et al., 2002). The Mindstreams verbal memory test, inspired by the Logical Memory test of the Wechsler Memory Scale, 3rd Edition (WMS-III), is designed to detect such impairment. Strength of association is varied among word pairs presented at study and foils presented at test to yield the appropriate range of performance to distinguish among healthy elderly and those with cognitive impairment (see Nelson, Zhang et al. 2001).

- Test Description



The Verbal Memory test measures immediate and delayed recognition memory for verbal paired associates. Participants are presented with 10 pairs of words to study followed by a recognition test in which they are presented with one member of a previously presented pair together with four possible alternatives for the other member of the pair. Responses are made using the keyboard number pad to indicate which pair was previously presented. Up to four consecutive study/test repetitions follow immediately, and an additional recognition test is administered following two other Mindstreams tests for a delay period of approximately 10 minutes. *Outcome*

[1] Screenshots are adaptations of screens presented during actual testing and are provided for illustration purposes only.

parameters include accuracy for each of the four immediate recognition tests, total accuracy across these repetitions, and accuracy for the delayed recognition test. Slope of learning across repetitions may also be computed.

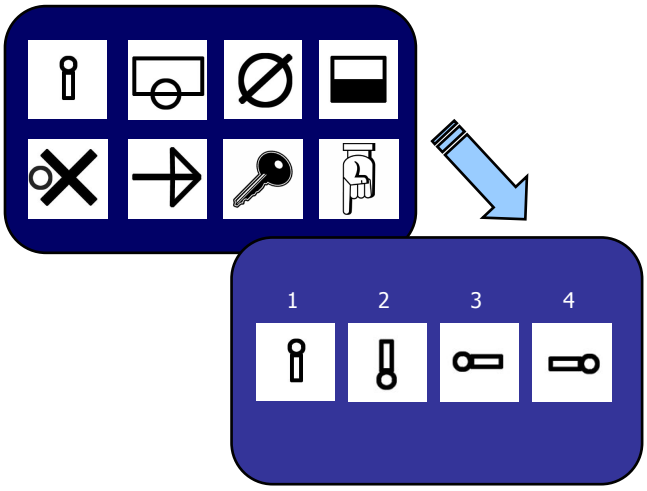
Non-Verbal Memory

Cognitive Domain(s): Memory

- Theoretical Framework

Non-verbal memory performance has been shown to be a better predictor of early Alzheimer's disease than even performance on verbal tests (Kawas, Corrada et al., 2003). Like the paper-and pencil Benton Visual Retention Test (BVRT) and Brief Visuospatial Memory Test (BVMT), the Mindstreams Non-Verbal Memory test assesses memory for the spatial orientation of geometric visual designs. The repeated study-recognition test format is used to facilitate better comparison across Verbal and Non-Verbal memory tests.

- Test Description



The Non-Verbal Memory test measures immediate and delayed recognition memory for the orientation of simple geometric patterns and symbols. Participants are presented with an array of eight simple geometric patterns and are required to remember their orientation. Immediately following is a recognition test in which four possible alternatives are presented, each depicting one of the previously presented patterns facing a different direction. Participants use the keyboard number pad to indicate which of the four alternatives exactly matches a previously presented pattern. As with the Verbal Memory test, up to four consecutive study/test repetitions follow immediately, and an additional recognition test is administered following a delay of approximately 10 minutes with two other Mindstreams tests intervening. *Outcome parameters* include accuracy for each of the four immediate recognition tests and for the delayed recognition test. Slope of learning across repetitions may also be computed.

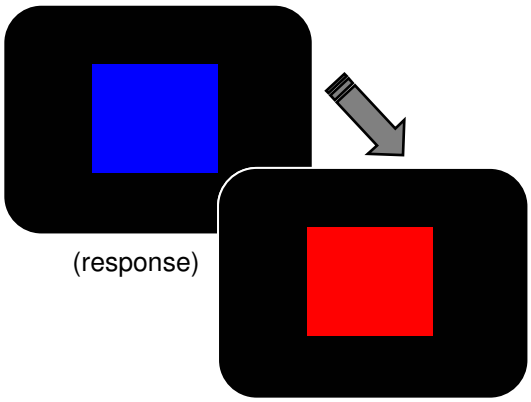
Go-NoGo Response Inhibition

Cognitive Domain(s): Attention, Executive Function

➢ Theoretical Framework

The Mindstreams Go-NoGo test is a variant of the Continuous Performance Task (CPT), which has been shown in hundreds of studies to index attention and executive function (Riccio and Reynolds, 2001). In the most common variant of the CPT, a string of English letters is presented sequentially and responses are made immediately following the presentation of any letter but X. For added robustness, the Mindstreams Go-NoGo test utilizes large colored squares similar to the TOVA (Greenberg and Waldman, 1993). Omission errors are thought to reflect deficient sustained attention or vigilance; commission errors are thought to reflect a combination of underlying processes, including impulsivity and inattention/memory deficit (Halperin, Wolf et al., 1991). CPTs have been shown to discriminate multiple clinical groups from healthy individuals, including adults with head injuries (e.g., Burg, Burright et al., 1995) and children and adults with attention-deficit-hyperactivity disorder (e.g., Holmes, Hever et al., 2002; Ossmann and Mulligan, 2003).

➢ Test Description



The Go-NoGo test is a test of response time and response inhibition. Participants are presented with a series of large colored squares at variable delays. Each square may be one of four colors. Participants are instructed to respond as quickly as possible by pressing a mouse button if the square is any color but red. *Outcome parameters* include accuracy, response time and its associated variance, a composite score computed as accuracy divided by response time, number of errors of omission, number of errors of commission, and response time associated with errors of commission.

An "expanded" version of the Go-NoGo test includes additional test levels during which the task is made more difficult by shortening the inter-stimulus interval, increasing the proportion of red squares, or by adding distracting shapes in the periphery. By taxing attention and executive function in different ways, the Expanded Go-NoGo test yields a more detailed profile of performance.

Stroop Interference

Cognitive Domains: Attention, Executive Function

➢ Theoretical Framework

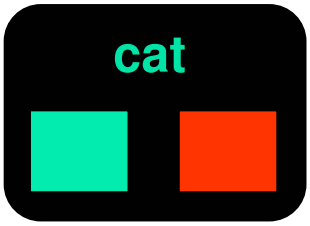
The Stroop is a well-established cognitive test (MacLeod, 1991) that measures the facility with which an individual can shift his perceptual set to conform to changing demands and suppress a habitual response in favor of an unusual one (Spreen and

Strauss, 1998). As with the CPT, there are numerous versions of the Stroop Test, dating back to the original developed by Stroop himself in 1935. The key comparison is between a condition in which responses are habitual (e.g., indicate the color of the letters) and a condition in which responses are unusual (i.e., indicate the color of the letters despite the fact that they spell a different color-word). The Stroop test has been shown to discriminate among brain-damaged individuals, those with schizophrenia, Parkinson's disease, and Huntington's disease (e.g., Batchelor, Harvery et al., 1995; Hanes, Andrewes et al., 1996). Perrett (1974) and Stuss et al. (2001) have reported that the Stoop interference effect is greater for patients with frontal lobe damage than for other groups, supporting the notion that the Stroop interference effect indexes executive function. Importantly, the Stroop test has also been shown to index severity of dementia (Koss, Weiner et al., 1984).

- Test Description

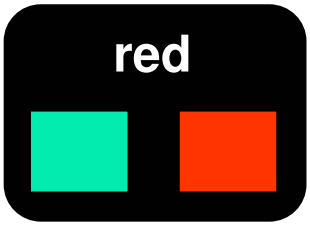
The Stroop test measures response time and executive function. The Mindstreams Stroop test consists of three levels. *Outcome parameters* for each phase include accuracy, response time and its associated variance, and a composite score computed as accuracy divided by response time.

Level 1 (No Interference: Letter Color)



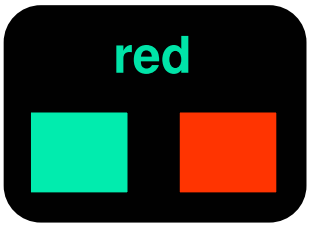
In Level 1, participants are presented with a word in colored letters, with the stipulation that the word does not name a color. Following a brief delay, participants are presented with a pair of colored squares, one on the left and the other on the right. They are instructed to choose as quickly as possible which of the two squares is the same color as the letters of the word presented immediately prior (e.g., blue) by pressing either the left or right mouse button, depending upon which of the two squares is the correct color.

Level 2 (No Interference: Word Meaning)



For Level 2, participants are presented with a word that names a color in white letters. As in Phase I, participants are then presented with a pair of colored squares and must choose as quickly as possible which square is the color named by the color word presented immediately prior.

Level 3 (Interference: Color vs. Meaning)



In Level 3, participants are presented with a word that names a color in letters of a color other than that named by the word. As in Level 1, participants must choose as quickly as possible which of two squares is the same color as the letters of the word presented immediately prior. The conflicting information

provided by the meaning of the word and the color of its letters leads to a decrement in performance relative to the other levels where there is no conflict. This reduced performance is termed the "Stroop" interference effect and is a classical finding in cognitive psychology.

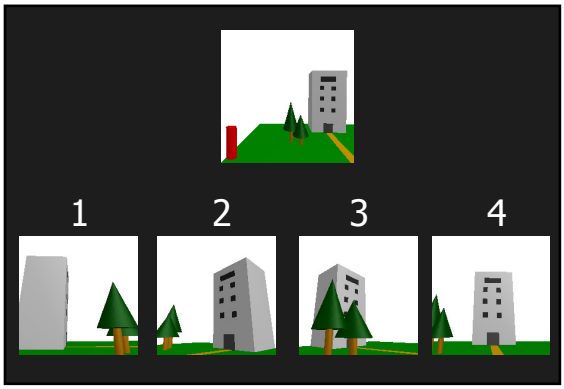
Visual Spatial Processing

Cognitive Domain(s): Visual Spatial

- Theoretical Framework

Individuals with Alzheimer's disease get lost in familiar surroundings, in part, because of visuospatial disorientation. Indeed there is ample evidence that individuals with Alzheimer's disease are impaired in visual-spatial perception (Butter, Trobe et al., 1996; Rizzo, Anderson et al., 2000). Hence included in the Mindstreams mild impairment battery is a novel test of visual-spatial perception designed to assess ability to perceive such features as depth, shape, and size, each of which may operate independently to permit accurate visual-spatial perception in the real world (see Brenner and van Damme, 1999).

- Test Description



The Visual Spatial Processing test assesses abstract spatial ability. Participants are presented with a computer-generated everyday scene containing a red *pillar* (rectangle). They are instructed to imagine standing at the location of the red pillar. Four views of the scene are presented at the bottom of the screen, and participants are required to indicate using the keyboard number pad which of the four views corresponds to the view of the scene from the location of the *pillar*. The *outcome parameter* for this test is a total accuracy score.

Verbal Function

Cognitive Domains: Verbal Function

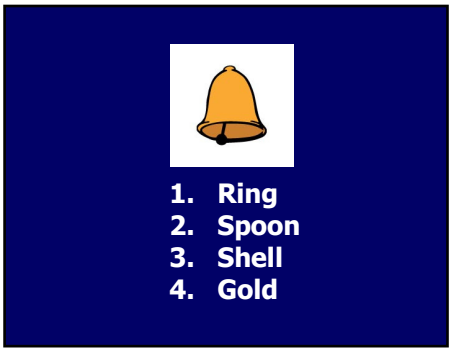
- Theoretical Framework

Impairment in verbal fluency is a common sign of dementia, especially in its more advanced stages (e.g., Monsch, Bondi et al. 1992). Paper-based verbal fluency tests typically require the naming of common objects within a semantic category or those that begin with a particular letter (e.g., Kitabayashi, Ueda et al., 2001). The Mindstreams Verbal Function test is designed to assess this cognitive domain but is adapted for computer-based administration. The Rhyming portion of the Verbal Function test

incorporates a novel design that taxes not only naming ability, but also the higher-order ability to form an association among similar-sounding words. Notably, there is some evidence for a deficit in phonological processing in Alzheimer's disease (Biassou, Grossman et al., 1995). The Picture Identification portion of the Verbal Function test assesses ability to name low-familiarity pictures, a skill shown to be selectively impaired in Alzheimer's disease and due to some combination of perceptual and semantic dysfunction (Goldstein, Green et al., 1992, Auchterlonie, Phillips et al., 2002). In addition to assessing naming deficit in dementia, Picture Identification performance serves as a control for the Rhyming portion. The same items are presented in both portions, and performance on the Rhyming portion is excluded for any items that are not namable on the Picture Identification portion. This design is based on the premise that ability to name is a prerequisite for ability to rhyme. Hence the Mindstreams Verbal Function test offers sensitivity to multiple stages of verbal fluency impairment.

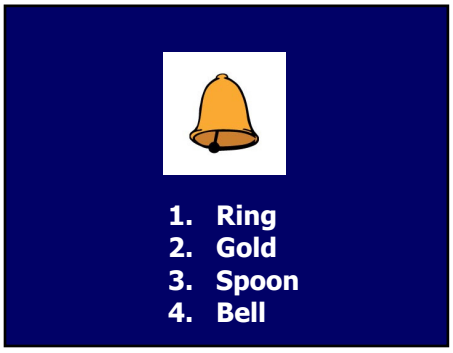
- Test Description

Rhyming



The Rhyming portion of the Verbal Function test assesses higher-order verbal skill. Participants are presented with a picture of a common object of either low or high familiarity. Following a brief delay, a list of four words appears on the screen. Participants are instructed to respond as quickly as possible by using the keyboard number pad to indicate which one of the four words rhymes with the name of the preceding picture. The outcome parameter for the Rhyming portion is accuracy.

Picture Identification



The Picture Identification portion of the Verbal Function test assesses basic verbal skill. Participants are presented with the same low familiarity pictures of common objects as in the Rhyming portion. As in the Rhyming portion, a list of four words appears following a brief delay. Now participants must respond by indicating which of the four words presented names the preceding picture. The outcome parameter for the Picture Identification portion is accuracy.

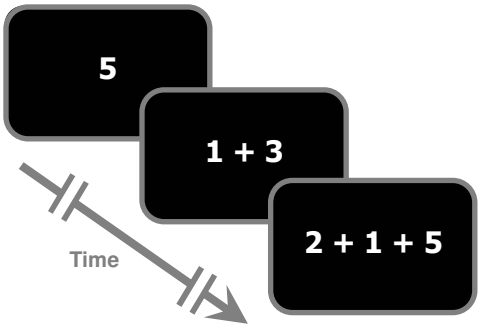
Staged Information Processing Speed

Cognitive Domain(s): Attention, Information Processing Speed

➢ Theoretical Framework

The Mindstreams test of Staged Information Processing Speed utilizes simple arithmetic to reveal differences in performance as a function of stimulus presentation rate and information processing load. The test is designed to exploit the advantages of computer-based testing to accurately assess information processing speed. Its multi-level, timed format is fashioned to incrementally tax cognitive resources, resulting in a precise indicator of extent of impairment.

➢ Test Description



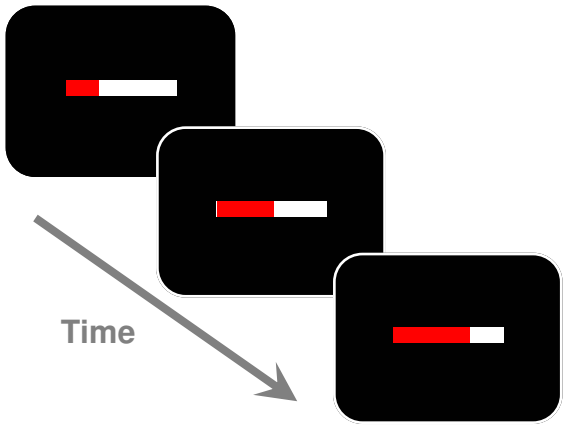
The Staged Information Processing Speed test measures information processing at increasing levels of complexity. The test is comprised of three levels of information processing load: single digits, two-digit arithmetic problems (e.g., 5-1), and three-digit arithmetic problems (e.g., 3+2-1). For each of these three levels, stimuli are presented at three different rates, incrementally increasing as testing continues. Participants are presented with a series of digits or arithmetic problems (as per the level) and are instructed to respond as quickly as possible by pressing the left mouse button if the digit or result is less than or equal to 4 and the right mouse button if it is greater than 4. Outcome parameters for each rate increment for each level include accuracy, response time and its associated variance, and a composite score computed as accuracy divided by response time.

Finger Tapping

Cognitive Domain(s): Motor Skills

➢ Theoretical Framework

Though not as prominent as cognitive decline, motor dysfunction occurs in Alzheimer's disease, particularly in the later stages of the disease. Kluger et al. (1997) have shown that tests of motor skill can distinguish between even mildly impaired and normal individuals. These authors found that motor/psychomotor assessments are equally sensitive to traditional tests of cognitive function in identifying early AD. Tests of finger tapping have been utilized in clinical contexts from stroke to Parkinson's disease to Attention-deficit-hyperactivity-disorder (ADHD) to index fine motor skills (Pal, Lee et al., 2001; Zemke, Heagerty et al., 2003; Pitcher, Piek et al., 2002). The novel Mindstreams Finger Tapping test is designed to quantify fine motor function in individuals with mild cognitive impairment.



➢ Test Description

Participants are presented with a white rectangle, which fills with red from left to right over 12 sec. The task requires the participant to tap the left mouse button as many times as possible while the rectangle fills with red. The outcome parameters for this test include inter-tap interval and associated variance (in milliseconds) for the participant's dominant hand.

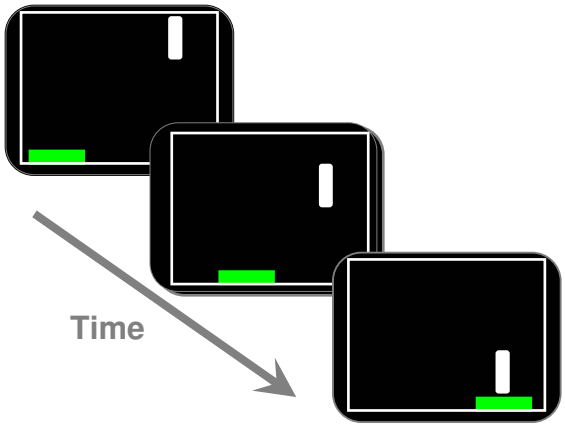
'Catch' Game

Cognitive Domain(s): Executive Function, Motor Skills

➢ Theoretical Framework

The 'Catch' Game is a novel motor screen that assesses cognitive domains distinct from those in other *Mindstreams* tests, including motor-related response time, motor learning, motor planning, and performance speed. Importantly, individuals with Alzheimer's disease have shown impairment on a response programming task measuring preparation and execution of movements (Bellgrove, Phillips et al., 1997). The 'Catch' Game assesses similar skills with an engaging video-game format that utilizes adaptive testing and capitalizes upon the fine timing possible with a computerized system.

➢ Test Description



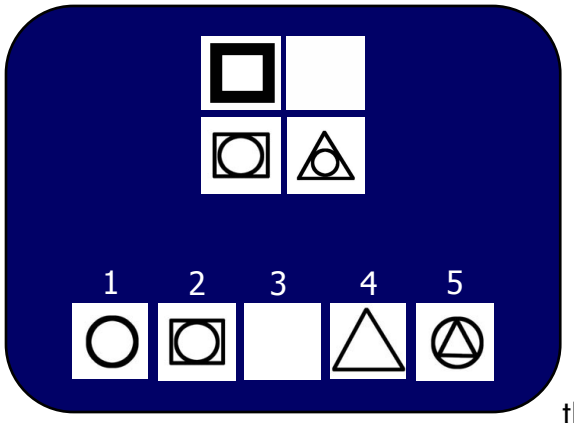
During the 'Catch' Game participants see a rectangular white *object* falling vertically from the top of the screen. Their task is to "catch" the *object* before it reaches the bottom of the screen by positioning the rectangular green *paddle* directly in the path of the falling object. The *paddle* is a green rectangle that can be moved horizontally across the bottom of the screen. Participants position the *paddle* by pressing the left mouse button to move the *paddle* leftward and the right button to move it rightward. Responses are made with the participant's best hand. The rate of the falling *object* increases incrementally as the test continues making it increasingly difficult to "catch" the object in time. *Outcome parameters* include response time and associated variance for the first move, number of direction changes per trial, error for missed catches, and a total performance score.

Problem Solving

- Theoretical Framework

The Mindstreams Problem Solving test is a non-verbal IQ test that assesses the ability to appreciate the spatial relationships among geometric forms that constitute a pattern. The test is conceptually similar to the Test of Nonverbal Intelligence, 3rd Edition (TONI-3; Pro-Ed, Austin, TX, 1997), which measures general intelligence, aptitude, and abstract reasoning. As the TONI and other similar paper-based tests (e.g., Raven's Colored Progressive Matrices, Quick Test of Intelligence), the Mindstreams Problem Solving test is language-free and therefore permits assessment of individuals with disorders of communication (e.g., aphasia, dyslexia, autism, cerebral palsy). Ethnic bias is also reduced in this test as the abstract geometric forms are devoid of cultural significance.

- Test Description



Participants are presented with an incomplete pattern consisting of three squares containing simple geometric forms in a particular configuration. Six additional squares containing geometric forms are presented along the bottom of the screen. Responses with the keyboard number pad indicate which of the six forms best completes the pattern. The spatial relationships among the simple geometric forms become more complex as the test progresses, and the test is adaptive in that it terminates early when performance is poor. The *outcome parameter* for this test consists of a total accuracy score that incorporates performance at differing levels of difficulty.

MODERATE-SEVERE TESTS

Note: Unlike the mild impairment tests described above, only one moderate-severe test (i.e., Go-NoGo Basic) is interactive. For all other tests, responses are entered by the test supervisor rather than directly by the patient.

Orientation to Time and Place

Cognitive Domain(s): Orientation

- Test Description

The subject is asked three basic questions regarding orientation in place and time. Accuracy is weighted such that partial credit is awarded for responses that are nearly correct. For example, the response to the trial asking "What year is this?" is considered nearly correct if it is within one year of the correct answer.

Language Skills

Cognitive Domain(s): Verbal Function

- Test Description

The subject is asked to comply with simple verbal commands and to name pictures of common objects. Partial credit is awarded for responses that are nearly correct. For example, the response to the trial asking "Raise your left hand and touch your right ear" is considered nearly correct if only one part of the command were performed. In the naming portion of the test, responses are considered nearly correct if they do not exactly name the object, but approximate the object name. For example, if the subject answers that the tire is called a wheel, it may be considered "nearly correct" if tires are not commonly referred to as wheels by individuals with a similar demographic profile.

Non-Verbal Memory

Cognitive Domain(s): Memory

- Test Description

The subject is initially presented with a single picture of a common object followed by an immediate recognition test. If performance is adequate, multiple pictures of common objects are presented followed by another immediate recognition test. A delayed recognition test for these same objects is administered following a delay of approximately 5 minutes.

Similarities and Judgement

Cognitive Domain(s): Executive Function

- Test Description

In this multiple-choice test, the subject is asked simple questions relating to similarities and differences of common objects, basic knowledge, and praxis.

Reality Testing

Cognitive Domain(s): Executive Function

- Test Description

The Reality Test is designed to test the subject's ability to detect discrepancies from context-related expected patterns. The subject is presented with a series of pictures in which an aspect of the scene is either incomplete or inconsistent with context. Following presentation of each picture, the subject is asked to determine which aspect is aberrant. If he is unable to identify the aberrant aspect, multiple choices for the correct answer are provided. If the correct answer is given after the hints, partial credit is awarded.

Spatial Orientation

Cognitive Domain(s): Visual Spatial

- Test Description

This test quantifies the subject's ability to appreciate subtle differences in perspective, an important skill for navigating in the real world. A computer-generated common scene is presented at the top of the screen. A cue is given to indicate the perspective from which the subject is to view the scene. This correct perspective of the scene and a number of foils are presented at the bottom of the screen.

Go-NoGo Basic

Cognitive Domain(s): Executive Function

- Test Description

This test is the only timed, interactive moderate-severe test and consists of two parts. The first part tests simple response time. Large green squares are presented at pseudo-random intervals, and the subject must press the mouse button as quickly as possible whenever a square appears. The second part, designed to probe frontal lobe function, tests choice response time. Red circles and white squares are presented in a Go-NoGo response inhibition paradigm. The subject must respond only to a white square and not to a red circle.

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