9 | Orientation and Attention

ORIENTATION

Orientation, the awareness of self in relation to one's surroundings, requires consistent and reliable integration of attention, perception, and memory. Impairment of particular perceptual or memory functions can lead to specific defects of orientation; more than mild or transient problems of attention or retention are likely to result in global impairment of orientation. Its dependence on the integrity and integration of so many different mental activities makes orientation exceedingly vulnerable to the effects of brain dysfunction.

Orientation defects are among the most frequent symptoms of brain disease. Of these, impaired awareness for time and place is the most common, accompanying brain disorders in which attention or retention is significantly affected. It is not difficult to understand the fragility of orientation for time and place, since each depends on both continuity of awareness and the translation of immediate experience into memories of sufficient duration to maintain awareness of one's ongoing history. Moreover, disorientation can result from a confusion of memory traces from different events or different temporal contexts that sometimes results in confabulations (Schnider et al., 1996). Thus, impaired orientation for time and place typically occurs with widespread cortical involvement (e.g., in Alzheimer-type dementia, acute brain syndromes, or bilateral cerebral lesions), lesions in the limbic system (e.g., Korsakoff's psychosis), or damage to the reticular activating system of the brain stem (e.g., disturbances of consciousness). Lesions involving the orbitofrontal cortex, basal forebrain, or limbic system are common in confabulators (Schnider, 2000). However, when cognitive impairments or deficits in attention are relatively mild, orientation can still be intact. Thus, while impaired orientation, in itself, is strongly suggestive of cerebral dysfunction, good orientation is not evidence of cognitive or attentional competence (Varney and Shepherd, 1991).

Inquiry into the subject's orientation for time, place, and basic personal data such as name, age, and marital status is part of all formalized mental status examinations (pp. 698–699) and most memory test batteries (e.g., General Information section of the Randt Memory Scales; Orientation section of The Rivermead Behavioural Memory Test; Orientation test of the Wechsler Memory Scales). Time orientation is usually covered by three or four items (e.g., day of week, date, month, year) and orientation for place by at least two (name of place where examination is being given, city it is in). In these formats, orientation items fit into scoring schemes such that, typically, if two or more of the five or seven time/place orientation items are failed, the score for that section of the test or battery falls into the *defective* range.

Tests of specific facets of orientation are not ordinarily included in the formal neuropsychological examination. However, their use is indicated when lapses on an informal mental status examination call for a more thorough evaluation of the patient's orientation or when scores are needed for documenting the course of a condition or for research. For these purposes, a number of little tests and examination techniques are available.

Time, place, and person orientation can be quite naturally examined by asking the subject to provide the examination identification data requested on most standardized test forms. For example, relevant identification data for the Wechsler Intelligence Scales include subject name, address, age, marital status, and date of birth, place of testing, and date tested. Inpatients can be asked the reason for their hospitalization to assess their understanding of their situation. By the time subjects have answered questions on these items or—even better, when possible—filled these items out themselves, the examiner should have a good idea of how well they know who and where they are and when. Although patients with compromised consciousness or dementia usually respond unquestioningly, alert patients who are guarded or sensitive about their mental competence may feel insulted by the simplicity of these "who, where, when" questions. Asking time, place, and person questions in the context of filling out a test form comes across to the subject as an integral part of the proceedings and is thus less likely to arouse negative reactions.

In a patient population, orientation status was related to memory impairment and age but was independent of education and simple attention as measured by digit span (Sweet, Suchy, et al., 1999). However, even normal, healthy older persons may have mild orientation difficulty, especially when experiencing the routine sameness of hospital days.

Awareness Interview (S.W. Anderson and Tranel, 1989)

This structured interview format consists of questions relevant to patient orientation for person, place, and time, plus items dealing with patients' appreciation of deficits in motor functioning, thinking, memory, speech and language, and visuoperceptual functions. An additional question asks how patients evaluate their test performances. This interview not only provides a graded scoring schedule for evaluation of overall severity of awareness problems but also gives examiners useful wording for the questions they must ask in evaluating patient orientation and awareness. Although the 3-point ratings for each item are subjective, the authors reported a high ($r = .92$) interrater reliability coefficient. High awareness scores correlate with patient abilities to successfully function in daily activities such as telephone use, money management, and cooking (LaBuda and Lichtenberg, 1999).

Time

To test for time orientation, the examiner asks for the date (day, month, year, and day of the week) and the time of day. Sense of temporal continuity should also be assessed, since the patient may be able to remember the number and name of the present day and yet not have a functional sense of time, particularly if in a rehabilitation unit or similarly well-structured setting (J.W. Brown, 1990). Likewise, some patients will have a generally accurate awareness of the passage of time but be unable to remember the specifics of the date. Poor performances on time orientation items have been demonstrated with control subjects with less than eight years of schooling (J.C. Anthony et al., 1982). Questions concerning *duration* will assess the patient's appreciation of temporal continuity. The examiner may ask such questions as "How long have you been in this place?"[1] "How long is it since you last worked?" "How long since you last saw me?" "What was your last meal (i.e., breakfast, lunch, or dinner)?"[2] How long ago did you have it?" Time disorientation occurs more commonly in patients with impaired memory who are older, have limited education, and perform digits reversed poorly (Sweet, Suchy, et al., 1999).

Temporal Orientation Test (Benton, Sivan, Hamsher, et al., 1994)

This is a scoring technique in which negative numerical values are assigned to errors in any one of the five basic time orientation elements: day, month, year, day of week, and present clock time. It has a system of differentially weighted scores for each of the five elements. Errors in naming or numbering days and errors in clock time are given one point for each day difference between the correct and the erroneously stated day and for each 30 minutes between clock time and stated time. Errors in naming months are given 5 points for each month of difference between the present and the named month. Errors in numbering years receive 10 points for each year of difference between the present and the named year. The total error score is subtracted from 100 to obtain the test score. Scores from the original study in which 60 patients with brain disease were compared with 110 control patients are given in Table 9.1. For more comprehensive and recent test data, see the 1994 manual or the manual for the *Iowa Screening Battery for Mental Decline* (Eslinger, Damasio, and Benton, 1984). However, elaborate normative tables are not necessary here: suffice it to say that any loss of score points greater than 5 indicates significant temporal disorientation as only 4% of one study's elderly (ages 60–88) control subjects received an error score greater than 2 (Eslinger, Damasio, Benton, and Van Allen, 1985).

Neuropsychological findings. Both control subjects (hospitalized patients without cerebral disease) and brain damaged patients most commonly erred by missing the number of the day of the month by one or two. For both groups, the second most common error was misestimating clock time by more than 30 minutes. The brain damaged group miscalled the day of the week with much greater frequency than the control patients. Patients with undifferentiated bilateral cerebral disease performed most poorly of all. Applying this test to frontal lobe patients, Benton (1968) found that it discriminated between bilaterally and unilaterally brain injured patients, for none of the frontal lobe patients with unilateral lesions gave defective performances but 57% of those with bilateral lesions did. For many patients with a history of alcoholism, failure on this test predicted poor performances on several tests of short-term

[1] It is important not to give away answers before the questions are asked. The examiner who is testing for *time* orientation before *place* must be careful not to ask, "How long have you been in the *hospital?*" or "When did you arrive in *Portland?*"

[2] Some mental status examinations for recent memory include questions about the foods served at a recent meal. Without checking with the family or dietitian, one cannot know whether the patient had chicken for dinner or is reporting an old memory of what people usually eat in the evening. The menu problem is most apparent with breakfast as the variety is usually limited making it impossible to tell whether the patient's memory is old or new when "toast, cereal, eggs, and coffee" are given as breakfast items.

TABLE 9.1 Temporal Orientation Test Scores for Control and Brain Damaged Patients

	SCORE			
Subjects	*100*	*99*	*98–95*	*94 & below*
Control (n = 110)	67 (61%)	33 (30%)	10 (9%)	0
Brain damaged (n = 60)	27 (45%)	6 (10%)	19 (32%)	8 (13%)

memory; yet many other patients had short-term memory deficits but made few if any temporal orientation errors (Varney and Shepherd, 1991).

This test is sensitive to the cognitive ravages of dementia (Andrikopoulos, 2001), with all of a small group of Alzheimer patients in day care receiving error scores of 4 or higher (mostly much higher) (Winogrond and Fisk, 1983). It is also very sensitive to the course of dementia: one group of dementia patients had an average error score of 4.9 ± 7.2 when first examined for suspected dementia; on a second evaluation (19 ± 15 months later) their average error score increased to 15.3 ± 23.9 (R.D. Jones et al., 1992). It was also one of the three most effective tests in distinguishing dementing patients from subjects classified as "pseudodemented."

Time estimation

Benton, Van Allen, and Fogel (1964) also asked their subjects to estimate the passage of a minute. They reported that error scores of 21–22 sec are in the "average range," an error score of 33 sec is "moderately inaccurate," and scores over 38 sec are "extremely inaccurate." For neither the controls nor the brain injured patients was there a relationship between low scores on the Temporal Orientation Test and size of time estimation error, leading the authors to conclude that "temporal orientation and the ability to estimate brief temporal durations reflect essentially independent behavior processes" (p. 119). C.A. Meyers (1985) too found no relationship between time orientation (on the Galveston Orientation and Attention Test) and estimated duration of short time intervals (ranging from 5 to 15 sec) for TBI patients still suffering posttraumatic amnesia. Patients who could repeat five or more digits correctly tended to underestimate the time intervals, while those with lower digit spans experienced time as passing more slowly than it actually was. Another simple time estimation task required the patient to guess the length of time taken by a just-completed test session (McFie, 1960). Estimations under one-half the actual time are considered failures. Only one of 15 patients whose lesions were localized on the left temporal lobe failed this task, although one-third or more of each of the other groups of patients with localized lesions and one-half of those suffering presenile dementia failed.

Women are less accurate than men at estimating short intervals (1 to 5 min), and an age-related decline in time estimation begins at about the sixth decade (Espinosa-Fernandez et al., 2003). Inaccuracy of time estimation has been shown in patients with amnesia (Nichelli, Venneri, et al., 1993) and Alzheimer's disease (Carrasco et al., 2000; Nichelli et al., 1993). Untreated Parkinson patients are likely to have impaired time estimation which normalizes when their dopamine is restored (Lange et al., 1995; Malapani et al., 2002). Patients with strokes involving the basal ganglia may have impaired time estimation (Rubia et al., 1997). These observations suggest that the basal ganglia are critical for accurate time estimation.

Recognition of the source of information presented in successive sets is another way of assessing temporal discriminations. These tests were developed to test the hypothesis that memories normally carry "time tags" that facilitate their retrieval (Yntema and Trask, 1963). After hearing or seeing two sets of similar stimuli, subjects are asked to indicate whether an item was present in the first or second set or is novel (M.K. Johnson, Hashtroudi, and Lindsay, 1993). The prefrontal cortex appears to have a special role in correct performance of this task (Simons et al., 2002).

Discrimination of Recency (B. Milner, 1971; M.L. Smith and Milner, 1988)

The verbal format consists of 184 cards on which are printed two spondaic words such as "pitchfork" and "smokestack." Each card has a different word pair, but the same word may occur on a number of cards. At intervals in the deck are cards with a question mark between two words. The task requires the subject to read the word pairs aloud and, when the subject comes to the card with the question mark, to indicate which of the two words was seen more recently. Usually both words have come up previously; occasionally only one had already been seen. The nonverbal format presents paired pictures of abstract art.

On the verbal format, normal control subjects recognized an average of 94% of previously seen words when they were paired with new words and correctly guessed relative recency an average of 71% of the time (M.L. Smith and Milner, 1988). Both left frontotemporal and left temporal groups were significantly impaired on one or both of these tasks relative to the control subjects and right brain injured patients. The patients with right-sided lesions were only defective relative to controls and left brain injured patient groups on the nonverbal version of this task. Patients with frontal lobe involvement had difficulty with the recency aspect of the task, especially those with right-sided lesions. However, other studies found that temporal lobe lesions did not impair recency judgments (B. Milner, Corsi, and Leonard, 1991; Sagar, Gabrieli, et al., 1990). Poor performances on the picture format were strongly related to aging ($p < .001$), but the verbal format was also sensitive to advancing age ($p < .01$) (Mittenberg, Seidenberg, et al., 1989). Intercorrelations within a test battery showed that Discrimination of Recency (words) correlated most highly with Design Fluency, another test known to be sensitive to frontal lobe dysfunction.

Place

Assessment of orientation for place generally begins with questions about the name or location of the place in which the examination is being held. The examiner needs to find out if patients know the *kind* of place they are in (hospital, clinic, office, nursing home), the name, if it has one (Veteran's Hospital, Marion County Mental Health Clinic), and where it is located (city, state, province). Orientation for place also includes an appreciation of direction and distance. To test for this, the examiner might ask where the patient's home is in relation to the hospital, clinic, etc., in what direction the patient must travel to get home, and how long it takes to get there. The examiner can also check the patient's practical knowledge of the geography of the locale or state and awareness of the distance and direction of the state capital, another big city, or an adjacent state relative to the present location. Moderate to severe TBI or moderate dementia produces disorientation for person or place in 15% to 51% of patients (Andrikopoulos, 2001).

Body Orientation

Disorientation of personal space (*autotopagnosia*) tends not to be associated with problems of localization in space. It has been described with left frontal penetrating wounds (Teuber, 1964) and is a common concomitant of aphasia (Diller, Ben Yishay, and Gerstman, 1974; Hécaen and Albert, 1978), rarely occurring with right hemisphere damage (Semenza and Goodglass, 1985). Although associated with left-sided damage, the autotopagnosic phenomenon involves both sides of the body (Frederiks, 1985a). Disturbances of body schema occurring with frontal lesions appear to be associated with defects in scanning, perceptual shifting, and postural mechanisms (Teuber, 1964). Semenza and Goodglass (1985) reported that whether the test stimuli or responses were verbal or nonverbal was irrelevant with respect to the correctness of their left brain damaged patients' responses; only frequency in which the word is used in the language made a difference (e.g., more errors occurred for "thigh" and "hip" than for "chest" and "hair"). They concluded that the disorder reflects the conceptual strength of the specific body part.

Informal tests for body orientation are part of the neurological examination (Frederiks, 1985a; Lishman, 1997). Finger orientation, which is most frequently disturbed of body parts, is examined in tests for finger agnosia (Cummings and Mega, 2003; Strub and Black, 2000). Orientation to body parts can be reviewed through different operations: pointing on command, naming body parts indicated by the examiner, and imitating body part placements or movements of the examiner. The examination of body orientation and finger recognition has complications. Tests for disorientation of personal space typically require the patient to make right–left discriminations that may be disrupted by left posterior lesions. Moreover, communication disabilities resulting from the aphasic disorders likely to accompany left hemisphere lesions can override subtle disorders of body or directional orientation. A thorough examination asks patients to identify parts of their own and of the examiner's body and will include crosswise imitation (e.g., right-side response to right-side stimulus) (Frederiks, 1985a). Human figure drawing may also reflect distortions in body part orientation (see pp. 550–551).

Personal Orientation Test (Semmes et al., 1963; S. Weinstein, 1964)

This test calls for patients (1) to touch the parts of their own body named by the examiner, (2) to name parts of their body touched by the examiner, (3) to touch those parts of the examiner's body the examiner names, (4) to touch their body in imitation of the examiner, and (5) to touch their body according to numbered schematic diagrams (see Fig. 9.1, p. 341). A sixth task tests for astereognosis by asking for the names of seen and felt objects.

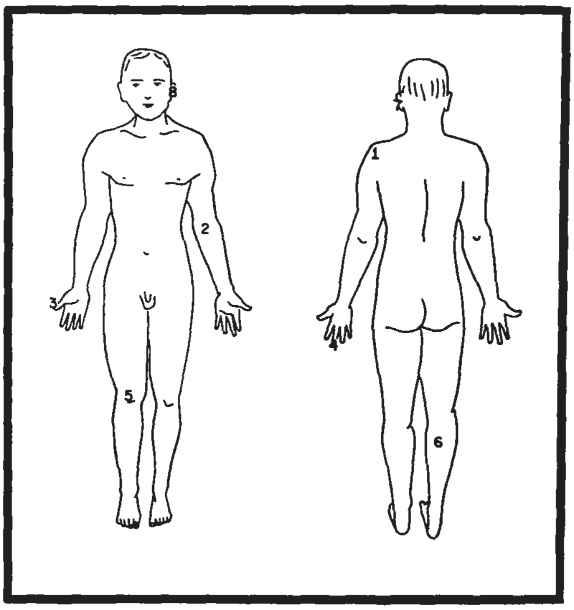

FIGURE 9.1 One of the five diagrams of the Personal Orientation Test (Semmes et al., 1963).

A comparison of left and right hemisphere damaged patients' performances on this task indicated that the left hemisphere patients have greatest difficulty following verbal directions, whereas patients with right hemisphere lesions are more likely to ignore the left side of their body or objects presented to their left (i.e., left hemi-inattention) (Raghaven 1961). Parkinson patients tend to have difficulty with this test (Raskin, Borod, and Tweedy, 1992). Using part 5 of this test, which is mostly nonverbal, F.P. Bowen (1976) showed that Parkinson patients suffered some defects in body orientation. Those whose symptoms were predominantly left-sided or bilateral made many more errors than patients with predominantly right-sided symptoms.

Finger Agnosia

Impaired finger recognition is associated with different kinds of deficits. When the impairment involves only one hand it may be due to a sensory deficit resulting from brain damage contralateral to the affected hand (Denburg and Tranel, 2003). The bilateral disorder will typically be a *finger agnosia,* a specific manifestation of autotopagnosia, and be most evident on examination of the middle three fingers (Frederiks, 1985a). A variety of techniques designed to elicit finger agnosia have demonstrated that it can occur with lesions on either side of the brain (Denburg and Tranel, 2003), but most lesions associated with finger agnosia involve the left angular gyrus (Mesulam, 2000b). The problem shows up in impaired finger recognition, identification, differentiation, naming, and orientation, whether they be the patient's fingers or someone else's, and regardless of which hand. Finger agnosia is one of the four disorders that make up Gerstmann's syndrome (see p. 71).

As the stimulus in both the following tests is tactile, it becomes important to distinguish between a sensory deficit due to impaired somatosensory processing and the perceptual/conceptual problem of somatic disorientation. The Boston Diagnostic Aphasia Examination supplementary section includes items for examining finger identification. When the problem is associated with compromised speech functions and involves the hand ipsilateral to the lesion—for which sensation should be relatively intact—as well as the contralateral one, then it probably reflects a finger agnosia. Other tests of the hands' sensory competence can help distinguish between a sensory deficit and the agnosic condition.

Finger Localization (Benton, Sivan, Hamsher, et al., 1994)

This technique for examining finger agnosia has three parts: Part A requires subjects to identify their fingers when touched one at a time at the tip by the examiner. Part B differs from Part A only in shielding the hand from the subject's sight using a curtained box in which the hand is placed (see Fig. 9.2, p. 342). In Part C two fingers are touched at a time. Ten trials are given each hand for each of the three conditions. Benton and his colleagues (1994) provide outline drawings for each hand with the fingers numbered so that speech-impaired patients can respond by pointing or saying a number (see Fig. 9.3, p. 342).

Of 104 control subjects, 60% made two or fewer errors with fewer than three errors on average. There were no differences between sexes or between hands. Both patients with right and with left unilateral hemisphere disease made errors, but a higher proportion of aphasic patients were impaired than any other group, and most of the patients with right-sided lesions who performed poorly were also "mentally deteriorated." Both control subjects and brain damaged patients made a larger proportion of errors on Part C than the other two parts. Seven to nine errors is considered a *borderline performance,* 10 to 12 errors is *moderately defective,* and performances with 13 or more errors are *defective.* The test manual also provides normative data for children.

FIGURE 9.2 Curtained box used by Benton to shield stimuli from the subject's sight when testing finger locationation and other tactile capacities (e.g., see p. 341). (Photograph courtesy of Arthur L. Benton)

Tactile Finger Recognition (Reitan and Wolfson, 1993; called *Tactile Finger Localization* by Boll, 1974)

In this test the examiner assigns a number to each finger. When subjects' eyes are closed and hands extended, the examiner touches the fingers of each hand in a predetermined order, and subjects report the number of the finger they think was touched. Patients with right-sided lesions made more both contralateral and ipsilateral errors than patients with left hemisphere damage (Boll, 1974). This test is part of the Halstead-Reitan Battery.

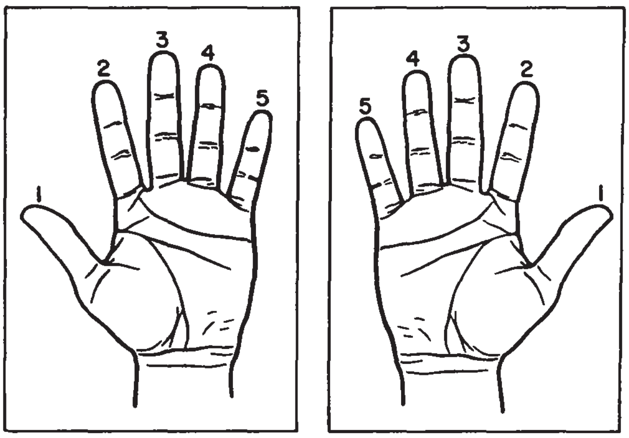

FIGURE 9.3 Outline drawings of the right and left hands with fingers numbered for identification. (© Oxford University Press. Reproduced by permission)

Directional (Right–Left) Orientation

As the examination of body orientation almost necessarily involves right–left directions, so the examination of right–left orientation usually refers to body parts (e.g., Strub and Black, 2000). Healthy normal adults make virtually no mistakes on right–left discriminations involving their own body parts or those of others (Benton, Sivan, Hamsher, et al., 1994; T.J. Snyder, 1991; see Right–Left Orientation Test, below), although women tend to respond more slowly than men and report more susceptibility to right–left confusion. When verbal communication is sufficiently intact, gross testing of direction sense can be accomplished with a few commands, such as "Place your right hand on your left knee," "Touch your left cheek with your left thumb," or "Touch my left hand with your right hand." Standardized formats such as in the Boston Diagnostic Aphasia Examination supplementary section (which includes items exploring right–left orientation to body parts) or the following tests are useful for determining the extent and severity of a suspected problem when a detailed documentation of deficits is required, or in research.

Right–left Orientation Test (RLOT) (Benton, Sivan, Hamsher et al., 1994)

This 20-item test challenges the subject to deal with combinations of right and left side with body parts (hand, knee, eye, ear) and with the subject's own body or the examiner's (or a front view model of a person). Excepting items 13 to 16, the side of the responding hand and the indicated body part are specified to randomize and balance right and left commands and combinations. Items 1 to 4 each ask the subject to show a hand, eye, or ear; items 5 to 12 give instructions to touch a body part with a hand; then items 13 to 16 request the subject to point to a body part of the examiner; the last four items have the subject put a hand on the body part of the examiner or of a model that is at least 15" (38 cm) in height. The A and B forms of this test are identical except that "right" and "left" commands are reversed. Two other forms of this test (R, L) are available for examining hemiplegic patients. The maximum number of errors in the normal range is 3, with no more than one error on the first 12 items involving the subject's own body. No sex differences have shown up on this test (T.J. Snyder, 1991). On a small patient sample, aphasics gave the largest number of impaired performances (75%), while 35% of patients with right-sided lesions made all their errors on the "other person" items, in which right and left must be reversed conceptually (Benton, Sivan, Hamsher, et al., 1994).

Standardized Road-Map Test of Direction Sense (Money, 1976)

This easily administered test provides developmental norms for a quick paper-and-pencil assessment of right–left orientation (D. Alexander, 1976; Fig. 9.4). The examiner traces a dotted pathway with a pencil, asking the subject to tell the direction taken at each turn, right or left. The test is preceded by a demonstration trial on an abbreviated pathway in a corner of the map. Although norms for ages above 18 are not available, a cutoff point of ten errors (out of 32 choice points) is recommended for evaluating performances, regardless of age. Since it is unlikely that persons who make fewer than 10 errors are guessing, their sense of direction is probably reasonably well-developed and intact.

Test characteristics. Women tend to make more errors than men, but their average is well under 10

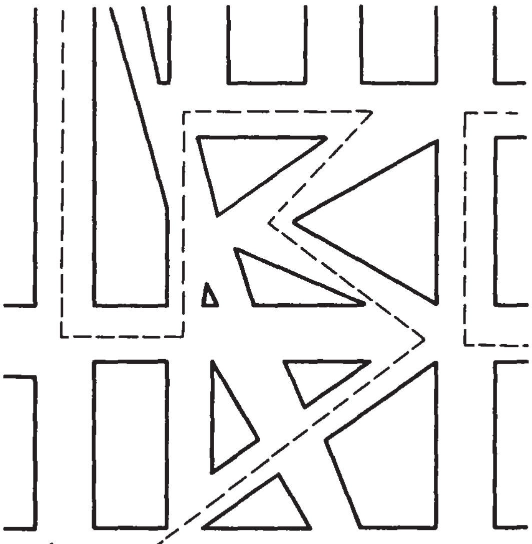

FIGURE 9.4 A section of *The Standardized Road-Map Test of Direction Sense* (© J. Money. Courtesy of the author)

(Brouwers et al., 1984; W.W. Beatty and Troster, 1987); both age and dementia may exaggerate this difference. Young and elderly control groups performed equally well, making on the average fewer than two errors on the unrotated turns; but subjects age 62 and older had significantly more errors than younger ones when judging the direction of rotated turns, and more errors than for unrotated turns (Flicker, Ferris, Crook, et al., 1988). Still, the older subjects' average score for both kinds of turns combined did not exceed 10. Almost all brain injured patients who are capable of following simple instructions pass this test, so that failure is a clear sign of impaired right–left orientation. It may also result from inability to shift right–left orientation, which will show up particularly at those choice points involving a conceptual reorientation of 90° to 180° (e.g., see Vingerhoets, Lannoo, and Bauwens, 1996).

Neuropsychological findings. N. Butters, Soeldner, and Fedio (1972) examined the performances of four groups of patients with localized lesions (right parietal and temporal, left frontal and temporal). The left frontal group averaged 11.9 errors, more than twice as many as the right parietal patients who were next highest with a mean error score of 5.5. The authors suggested that the failures of the left frontal patients reflect the test's conceptual demands for making mental spatial rotations. Without left parietal and right frontal groups, this study did not address the question of whether the right–left confusion that some patients with left hemisphere damage experience may have contributed as much or more than conceptual disabilities to the left frontal patients' poor performances. A more recent study showed that parietal injuries affect Road-Map orientation much more than do frontal injuries (Vingerhoets, Lannoo, and Bauwens, 1996). Although not statistically significant, a tendency for patients with left parietal injuries to have greater error scores (6.0 ± 7.7) than those with right parietal lesions (4.5 ± 3.4) suggests that impaired coordinate orientation was a relevant factor in left-lesioned patients' performances.

Patients with early probable Alzheimer's disease made an average number of errors that is still less than ten although somewhat higher than the average for elderly controls (Brouwers et al., 1984; Flicker, Ferris, Crook, et al., 1988). They tended to show a differential between unrotated and rotated turns similar to that of elderly control subjects. Moderately impaired Alzheimer patients have difficulty on this task even when the paper is rotated so that all intersections are aligned with the participant (Rainville et al., 2002). Their impairment may be based on visuoperceptual difficulties specific for this disease (H.L. O'Brien et al., 2001). The average performance for patients with advanced dementia is at chance levels for both kinds of turns. This test was instructive in bringing out differences between Alzheimer and Huntington patients, as the Huntington patients' near-normal unrotated performances indicate that simple right–left orientation was intact while their much lower scores on rotated turns implicate a conceptual problem (Brouwers et al., 1984).

Space

Spatial disorientation refers to a variety of defects that in some way interfere with the ability to relate to the position, direction, or movement of objects or points in space. Different kinds of spatial disorientation do not arise from a single defect but are associated with damage to different areas of the brain and involve different functions (Farah, 2003; McCarthy and Warrington, 1990; Schachter and Nadel, 1991). As in every other kind of defective performance, an understanding of the disorientated behavior requires careful analysis of its components to determine the extent to which the problem is one of verbal labeling, inattention, visual scanning, visual agnosia, or a true spatial disorientation. Thus, comprehensive testing for spatial disorientation requires a number of different tests.

Spatial orientation is one of the components of visual perception. For this reason, some tests of visuospatial orientation are presented in Chapter 10, such as Judgment of Line Orientation, which measures the accuracy of angular orientation, and line bisection tests, which involve distance estimation and are susceptible to left visuospatial inattention.

Distance estimations

Both spatial disorientation (Benton, 1969b) and visual scanning defects (Diller, Ben Yishay, Gerstman, et al., 1974) can contribute to impaired distance judgment. Benton divided problems of distance estimation into those involving local space, i.e., "within grasping distance," and those involving points in the space "beyond arm's reach." He noted a tendency for patients with disordered spatial orientation to confuse retinal size with actual size, ignoring the effects of distance.

In examining distance estimation, Hécaen and Angelergues (1963) gave their patients a number of informal tasks. They asked for both relative (nearer, farther) and absolute (in numerical scale) estimations of distances between people in a room, between the patient and objects located in different parts of the room, and for rough comparisons between the relative estimates. Patients also had to indicate when two moving objects were equidistant from them. These distance estimation tasks were among other tests for visuospatial deficits. Although some visuospatial deficits accompanied lesions in the left posterior cortex, more than five times as many such deficits occurred in association with right posterior—particularly occipital—lesions.

Mental transformations in space

Abilities to conceptualize such spatial transformations as rotations, inversions, and three-dimensional forms of two-dimensional stimuli are sensitive to various kinds of brain disorders (e.g., Boller, Passafiume, and Keefe, 1984; N. Butters and Barton, 1970; Royer and Holland, 1975). Examination methods are mostly paper-and-pencil tests that require the subject to indicate which of several rotated figures matches the stimulus figure, to discriminate right from left hands, or to mark a test figure so that it will be identical with the stimulus figure. Luria (1966, p. 371) showed samples of the last two kinds of items in the "parallelogram test" and the "hands test." These items and others have been taken from paper-and-pencil intelligence and aptitude tests (e.g., the *California Tests of Mental Maturity* [E.T. Sullivan et al., 1963]; the *Primary Mental Abilities Tests* [L.L. Thurstone and Thurstone, 1962], among others). For example, the multiple-choice *Cognition of Figural Systems* subtest of the *Structure of Intellect Learning Abilities Test* (*SOI-LA*) has one section requiring the subject to identify figures rotated 90° and another section calling for 180° rotation (Meeker and Meeker, 1985; see also Sohlberg and Mateer, 1989).

Performance deficits on tests requiring mental rotations have been associated with parietal lobe lesions;

neuroimaging studies support clinical findings that mental rotation requires bilateral parietal involvement with greatest contributions from the right (Farah, 2003). Studies involving conceptual transformations from two to three dimensions have consistently demonstrated the importance of the right hemisphere to these operations (Nebes, 1978). These tests were not designed for diagnostic discriminations; but rather, they are of value in gaining information about visuospatial orientation for planning, treatment, and research purposes.

Mental Re-orientation (Ratcliff, 1979)

This spatial orientation test, devised for neuropsychological studies, has also been called the *Left–Right Reorientation Test* (see Fig. 9.5). The "Little Men" figures can be presented by slide projection or on cards. Each of the four positions is shown eight times; in half the cases the black disc is on the figure's right, in half on the left. The subject's task is to state whether the black disc is on the figure's right or left side. Before and after the test, the subjects were given 12 trials of a simple right–left discrimination task (indicating whether a black circle was right or left of a white one) that did not involve reorientation in order to evaluate accuracy of simple right–left discrimination. When given to healthy college students, the sexes did not differ with respect to accuracy, but women had longer response latencies than men, with male left-handers having the shortest latencies, female left-handers the longest (T.J. Snyder, 1991). Not surprisingly, these subjects made fewer errors to the upright figures, regardless of whether forward or backward, than to the inverted figures. This test proved to be more sensitive to left–right confusion than the Right-Left Orientation Test (T.J. Snyder, personal communication, 1990). Comparing small patient samples (e.g., only 11 in the "nonposterior" group), Ratcliff (1979) found that those with right posterior lesions made more errors ($p < .05$) than any other group.

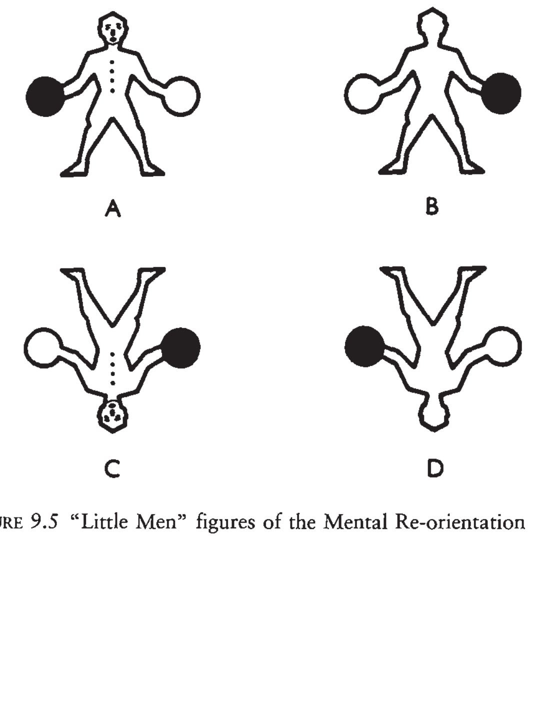

FIGURE 9.5 "Little Men" figures of the Mental Re-orientation Test.

The *Puppet Test,* a variation of the Mental Reorientation task, examines spatial reorientations on visuoperceptual and visuomotor tasks (Boller, Passafiume, and Keefe, 1984). The visuoperceptual format displays 12 multiple-choice items; for each the subject must match a Little Man, each oriented differently, to one of four differently oriented alternatives. The visuomotor format presents pairs of variously oriented Little Men, only one with a black disc; the task here is to blacken the disc on the same side of the other figure as the sample figure's black disc. Despite the motor response required by this test's visuomotor format, factor analysis indicated that both parts of the test have a significant visuoperceptual component, while the motor response part has a relatively low loading on a factor strongly associated with drawing and other motor response tests.

Space Thinking (Flags) (L.L. Thurstone and Jeffrey, 1984)

This 21-item multiple-choice test of spatial orientation was developed for use in industry but is readily applicable to neuropsychological questions. Each item displays a rectangular geometric design, the "flag," with six other designs which may differ in their spatial rotation, mirror the target design, or both (see Fig. 9.6). The subject's task is to indicate whether the flag shows the same or the opposite side of the flag as the target. Norms are available for a 5-minute time limit. For different items, from 0 to 4 responses may be correct.

Spatial dyscalculias

Difficulty in calculating arithmetic problems in which the relative position of the numbers is a critical element of the problem, as in carrying numbers or long division, tends to occur with posterior lesions, particularly involving the right hemisphere (A. Basso, Burgio, and Caporali, 2000; Denburg and Tranel, 2003). This shows up in distinctive errors of misplacement of numbers relative to one another, confusion of columns or rows of numbers, and neglect of one or more numbers, although the patient understands the operations and appreciates the meaning and value of the mathematical symbols.

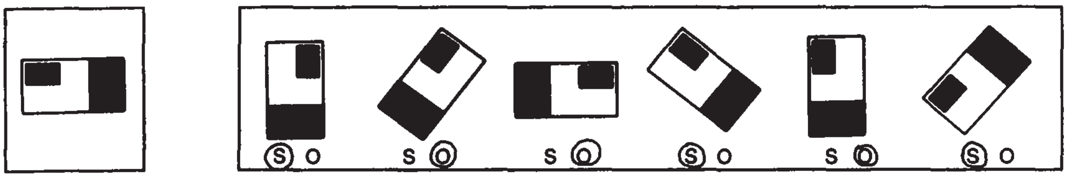

FIGURE 9.6 *Space Thinking* (*Flags*) example, marked correctly for *same* (S) or *opposite* (O) positions relative to the model on the left of the figure. (Courtesy of Pearson Reid London House, Inc.)

Tests for spatial dyscalculia are easily improvised (e.g., see Macaruso et al., 1992; Strub and Black, 2000). When making up arithmetic problems to bring out a spatial dyscalculia, the examiner should include several relatively simple addition, subtraction, multiplication, and long division problems using two- to four-digit numbers that require carrying for their solution, written out in fairly large numbers. The examiner can also dictate a variety of computation problems to see how the patient sets them up. Items involving multiplication and division are particularly challenging for patients with this disorder. With unlined letter-size sheets of paper, the patient does not have ready-made lines for visual guidance. A large sheet of paper gives the patient a greater opportunity to demonstrate spatial organization and planning than do smaller ones on which abnormally small writing or unusual use of space (e.g., crowding along one edge) may be less apparent.

Some items of the Arithmetic subtest of the Wide Range Achievement Test–Revised (WRAT-3) (Wilkinson, 1993) will elicit spatial dyscalculia. However, writing space is limited so that subjects may work out their calculations on various parts of the problem sheets, making it difficult for the examiner to see how an erroneous answer was computed. A useful set of problems that are graduated in difficulty, but none too hard for the average 11- or 12-year-old, are shown in Figure 15.12, p. 609. On this untimed test patients are instructed to work out the problems on the sheet as sufficient space is provided for each problem. Most of the problems require spatial organization and are thus sensitive to spatial dyscalculia.

Topographical orientation

Defective memory for familiar routes or for the location of objects and places in space involves an impaired ability for *revisualization,* the retrieval of established visuospatial knowledge (Benton, 1969b; Farah, 2003). Testing for this defect can be difficult, for it typically involves disorientation around home or neighborhood, sometimes in spite of the patient's ability to verbalize the street directions or descriptions of the floor plan of the home.

When alert patients or their families complain that they get lost easily or seem bewildered in familiar surroundings, topographical memory can be tested by asking first for descriptions of familiar floor plans (e.g., house or ward) and routes (nearest grocery store or gas station from home), and then having them draw the floor plan or a map, showing how to get from home to store or station, or a map of the downtown or other section of a familiar city. The catch here is that the locale must be familiar to both patient and examiner to be properly evaluated. One way of getting around this problem is to find the patient's spouse or a friend who can draw a correct plan for comparison (e.g., see Fig. 9.7a,b, p. 347).

A reasonably accurate performance of these kinds of tasks is well within the capacity of most of the adult population. Thus, a single blatant error, such as an east–west reversal, a gross distortion, or a logically impossible element on a diagram or map, should raise the suspicion of impairment. More than one error may be due to defective visuospatial orientation but does not necessarily indicate impaired topographical memory. Visuographic disabilities, unilateral spatial inattention, a global memory disorder, or a confusional state may also interfere with performance on tests of visuospatial orientation. Evaluation of the source of failure should take into account the nature of the patient's errors on this task and the presence of visuographic, perceptual, or memory problems on other tasks.

Topographical Localization (Lezak, no date)

Topographical memory can be further tested by requesting the patient to locate prominent cities on a map of the country. An outline map of the United States of convenient size can be easily made by tracing the Area Code map in the telephone directory onto letter-size paper. When using this technique, I [mdl] first ask the patient to write in the compass directions on this piece of paper. I then ask the patient to show on the map where a number of places are located by writing in a number assigned to each of them. For example, "Write 1 to show where the Atlantic Ocean is; 2 for Florida;

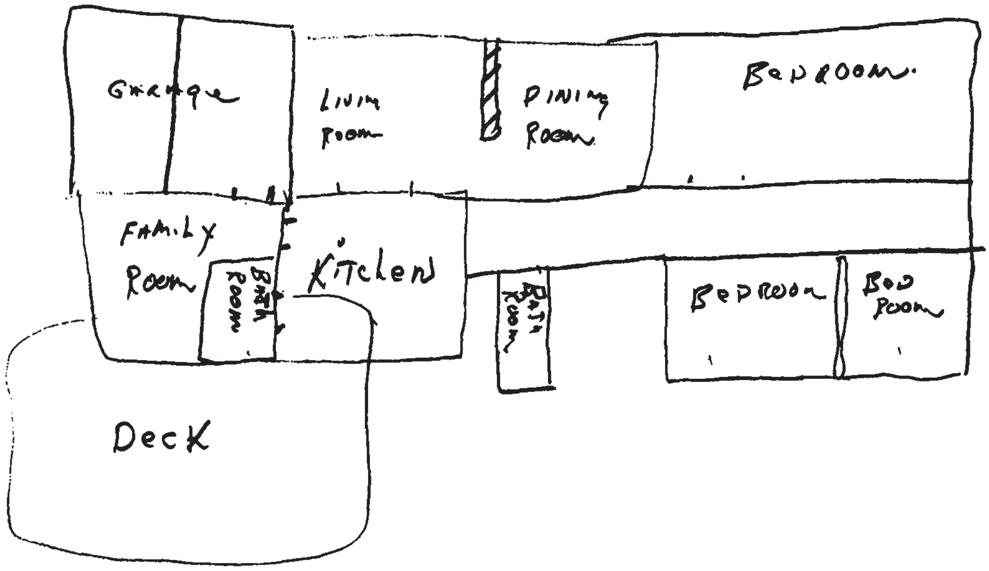

FIGURE 9.7a Floor plan of his home drawn by a 55-year-old mechanic injured in a traffic accident who complained of difficulty finding his way around his hometown.

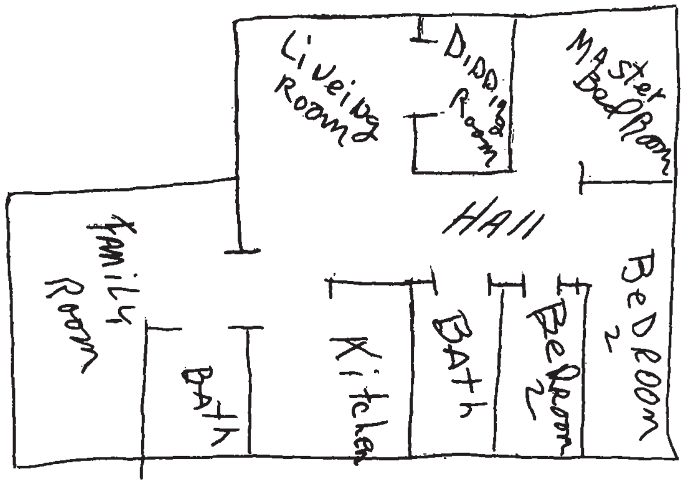

FIGURE 9.7b Floor plan of their home drawn by the mechanic's spouse.

3 for Portland; 4 for Los Angeles; 5 for Texas; 6 for Chicago; 7 for Mexico; 8 for New York; 9 for the Pacific Ocean; 10 for the Rocky Mountains, and 11 for your birthplace" (see Fig. 9.8, p. 348). The places named will be different in different locales as appropriate for different patients. To insure this test's sensitivity to visuospatial inattention, at least as many of the places named should be in the west as in the east.

For clinical purposes, scoring is not necessary as disorientation is usually readily apparent. It is important, however, to distinguish between disorientation and ignorance when a patient misses more than one or two items. Committing a few errors, particularly if they are not all eastward displacements of western locales, probably reflects ignorance. Many errors usually reflect disorientation. Most patients mark the points of the compass correctly. However, a scoring system that gives one point for each correct compass direction and one point for each of the 11 named locales (including the patient's place of birth) discriminated better than chance ($p < .05$) between performances made by 45 head injury patients in the second year posttrauma or

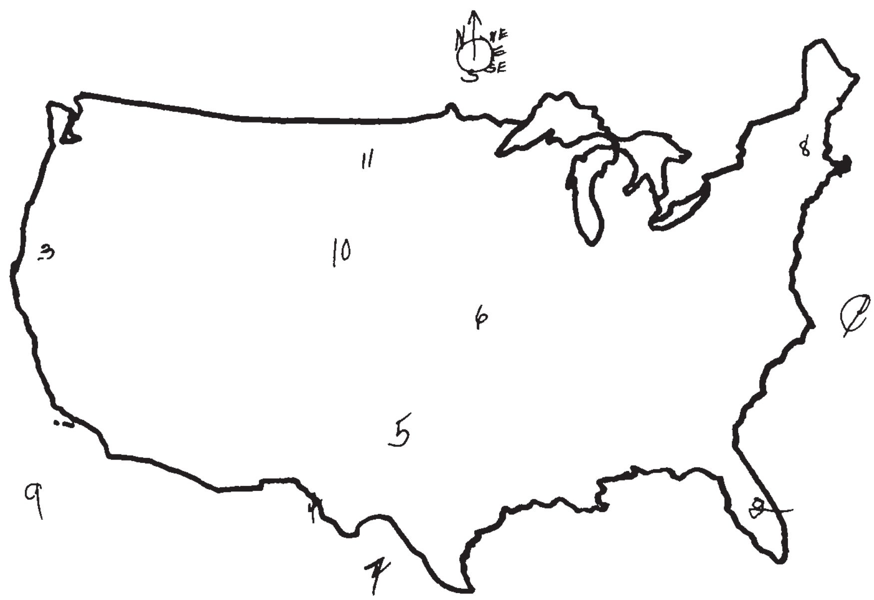

FIGURE 9.8 Topographical Localization responses by a 50-year-old engineer who had been hemiparetic for 14 years since suffering a ruptured aneurysm of the right anterior communicating artery. Although only two of his respones are notably displaced (4 and 6), he betrayed left visuospatial inattention in an overelaborated set of compass points from which the West was omitted.

later (M = 12.40 ± 3.07) and 27 normal control subjects (M = 14.26 ± 1.26).[1] In contrast, none of an older (age range 42–76) group of six patients with right CVAs achieved scores above 11 (M = 7.83 ± 2.79).

Fargo Map Test (FMT-S)[2] (W.W. Beatty, 1988, 1989a)

This test of geographic knowledge takes into account not only familiarity with the major features of the United States but also the regions with which the subject, by history, should have familiarity. It tests a variety of functions, particularly recent and remote spatial memory and visuospatial orientation. The materials consist of two kinds of maps, an outline map of the United States and 17 regional outline maps, including two of states (New York, Florida), one for New England, with the rest covering from two- to four-state regions (e.g., California, Nevada; Nebraska, Iowa, Kansas, Missouri); and lists of numbered target geographic features (e.g., Atlantic Ocean, Canada) and cities. After recording all of the places in which subjects have lived for a year or more and their age when residing in each place, subjects locate from 12 to 16 designated target items on each map. A near-correct location receives a score of 1; a less precise approximation earns .5, and of course 0 is scored for a complete failure. Only targets within correctly identified maps count in the scoring. Percent correct can be calculated for each regional map to make regional comparisons with respect to the subject's dates of residence.

Test characteristics. Normative studies indicated that test scores increased directly with education and age—even past age 70 for men, although women's accuracy declined a little after 70 (W.W. Beatty, 1988, 1989a). Men tend to outperform women but not in every comparison (W.W. Beatty and Troster, 1987). The standard form takes about an hour to complete. A shortened revised version (*FMT-R*) provides outline maps on which numbered dots correspond to gross geographic features and cities, with answer sheets for writing in the number associated with printed place names (W.W. Beatty, 1988). This procedure is less difficult for those who lack fine motor control than the standard requirement of positioning the code number on the outline map.

Neuropsychological findings. Parkinson patients whose mental status is intact performed normally ex-

[1] The control subjects and 41 of the patients had been given neuropsychological examinations as part of a Veterans Administration funded research project on the long-term cognitive consequences of nonprogressive brain damage. All of the control subjects were in the 19–49 year age range; the patients were in that age range when injured. Two were in their 50s when tested.

[2] To obtain copies of the Fargo Map Test, contact W.W. Beatty, Ph.D., Dept. of Psychiatry and Behavioral Sciences, University of Oklahoma Health Sciences Center, POB 26901, Oklahoma City, OK 73190.

cept for excessive errors in locating cities, but deteriorated patients were impaired on all test sections requiring geographic localization (W.W. Beatty and Monson, 1989). Huntington patients did poorly for both where they lived earlier and their present region (W.W. Beatty, 1989b). Mildly and moderately demented Alzheimer patients achieved higher scores for their early region of residence than for their current one (W.W. Beatty, personal communication, 1992); these patients were only moderately impaired for knowledge of gross geographical features but severely impaired in locating cities with any precision.

Route finding

The inability to find one's way around familiar places or to learn new routes is not uncommon in brain impaired patients. The problem can be so severe that it may take days before an alert and ambulatory patient can learn the way to the nurses' station. It often dissipates as the acute stage of the illness passes, but some confusion about locations and slowness in learning new routes may remain.

The *Rivermead Behavioural Memory Test* (B.A. Wilson, Clare, et al., 1999) includes a test of learning and recalling a route. A more challenging technique shows a videotape of an unfamiliar neighborhood; later the examiner asks the subject about routes through the neighborhood and the location and relationship of landmarks. Compared to control subjects, patients with either right or left temporal lobe lesions were less accurate in their topographical orientation (Maguire et al., 1996). The only difference between these patient groups was the inaccuracy of the right-side lesion group in judging the proximity of landmarks.

ATTENTION, CONCENTRATION, AND TRACKING

> There are no tests of attention . . . one can only assess a certain aspect of human behavior with special interest for its attentional component.
>
> *van Zomeren and Brouwer, 1992*

Although attention, concentration, and tracking can be differentiated theoretically, in practice they are difficult to separate. Purely attentional defects appear as distractibility or impaired ability for focused behavior, regardless of the patient's intention. Intact attention is a necessary precondition of both concentration and mental tracking activities. Concentration problems may be due to a simple attentional disturbance, or to inability to maintain a purposeful attentional focus or, as is often the case, to both problems. At the next level of complexity, conceptual tracking can be prevented or interrupted by attention or concentration problems and also by diminished ability to maintain focused attention on one's mental contents while solving problems or following a sequence of ideas.

Clarifying the nature of an attention problem depends on observations of the patient's general behavior as well as performance on tests involving concentration and tracking, for only by comparing these various observations can the examiner begin to distinguish the simpler global defects of attention from the more discrete, task-specific problems of concentration and tracking. Further, impaired attention is not always a global disability but may involve one receptive or expressive modality more than others.

Reaction Time

As slowed processing speed often underlies attentional deficits (see pp. 35, 176), reaction time tests can serve as relatively direct means of measuring processing speed and understanding the nature of the associated attentional deficits (Godefroy et al., 2002; Posner, 1978; Shum, McFarland, and Bain, 1994). Simple reaction time is frequently slowed with brain disease or injury, and slowing increases disproportionately with increases in the complexity of the task, whether it be the addition of choices requiring discrimination of stimuli (J.K. Foster et al., 1999; Gronwall, 1987; Ponsford and Kinsella, 1992; van Zomeren, Brouwer, and Deelman, 1984) or introduction of a distractor (van Zomeren and Brouwer, 1987; van Zomeren, Brouwer, and Deelman, 1984). This slowing is particularly apparent in patients with severe TBI (Spikman, van Zomeren, and Deelman, 1996; Spikman, Deelman, and van Zomeren, 2000) and in many multiple sclerosis patients (Kail, 1998). What additionally may distinguish TBI patients from control subjects is inconsistency in levels or individual performances (Stuss, Stethem, Hugenholtz, et al., 1989). Simple reaction time slowing in itself distinguishes dementing patients from matched elderly control subjects, but differences between the healthy and dementing groups become much larger when stimulus choices (e.g., red or green light) and/or response choices (e.g., right or left hand) are introduced (Ferris, Crook, Sathananthan, and Gershon, 1976). Depressed patients too tend to have slowed reaction times on simple as well as complex formats (Cornell et al., 1984), although depression did not add to slowing in one group of cognitively impaired elderly patients (Bieliauskas and Lamberty, 1995). Should reaction time apparatus be unavailable, slowed processing can also be inferred from sluggish performances on other speeded attention tasks (van Zomeren and Brouwer, 1992).

Vigilance

Successful performance of any test of attention, concentration, or tracking requires sustained, focused attention. Vigilance tests examine the ability to sustain and focus attention in itself. These tests typically involve the sequential presentation of stimuli (such as strings of letters or numbers) over a period of time with instructions for the patient to indicate in some way (tap, raise hand) when a given number or letter (the target stimulus) is perceived. Thus, lists of 60 or more items can be read, played on a tape, or presented in a visual display at a rate of one per sec (Strub and Black, 2000). The simplest form of the task presents only one target item but two or more can be used. More complex variations of the vigilance task require the subject to respond only when the target item is preceded by a specified item (e.g., to tap B only when it follows D). Strub and Black's *"A" Random Letter Test* (p. 42) contains one run of three As and two runs of two embedded among other alphabet letters randomly sequenced; the triplet and pairs additionally sample the patient's ability to stop an ongoing activity. These vigilance tasks are performed easily by persons whose capacity for sustained attention is intact, and they are unaffected by age, at least well into the 80s (M.S. Albert, Duffy, and Naeser, 1987). Thus, even one or two lapses on these tests may reflect an attention problem. Tests for assessing unilateral spatial inattention, such as letter or line cancellation, are discussed in Chapter 10, pp. 378–383. In addition to the tests reviewed in this section, the Speech Sounds Perception Test and/or the Seashore Rhythm Test may be useful for examining a known or suspected concentration or tracking problem.

Continuous Performance Test (CPT) (1) (Rosvold et al., 1956)

Computerized vigilance tests usually present stimuli briefly and provide reaction times as well as accuracy data. Letters of the alphabet in random order appear briefly in the center of the screen. In the simple condition, subjects are asked to respond to every X and, in the more difficult version, X only if it follows A. Although the CPT is intended to measure sustained attention, failure can occur for a variety of reasons, including impulsivity or dyscontrol, anxiety, and environmental noise (Ballard, 1996; Halperin et al., 1991). Total error scores mask the differences between errors of omission and commission and should be avoided as these two types of errors have different interpretations (Halperin et al., 1991).

Continuous Performance Test (CPT) (2) (Conners, 1992)

In this format the subject indicates every time a letter other than X appears on the screen, which allows for measures of commission as well as omission. Because the test takes 14 min., it also measures ability to sustain attention—or waning attention—over a relatively long period for such a monotonous task. A newer version, the *CPT-II* (Conners, 2000), has a larger normative sample and includes data from adults with brain disorders as well as people with attention deficit disorders (ADD, ADHD). Adults with ADHD have a higher rate of commission errors than control subjects, which suggests that they have trouble inhibiting responses (Barkley, 1997; Epstein et al., 2001). They also make omission errors and have high reaction time variability (A.J. Walker et al., 2000). Patients with temporal lobe epilepsy are less able to sustain attention throughout the test (Fleck et al., 2002).

Continuous Performance Test of Attention (CPTA) (Cicerone, 1997)

An auditory CPT presents a series of letters read at the rate of one per sec on an audiotape. Subjects are asked to tap their finger each time they hear a target letter. Task difficulty is heightened by increasing the complexity of the target. In the first three conditions the targeted letters increase from one to two to five specified letters. In the fourth condition subjects are asked to respond only when they hear **A** immediately following **L**. In the last condition, letters and numbers are intermingled randomly; targets are one letter and one number. Responses are scored for omission and commission errors. An average 13 months post mild TBI, patients made significantly more errors than control subjects on this task.

Short-term Storage Capacity

The dissociation between processing speed, as measured by speed-dependent and mental tracking tests, and short-term capacity reflects the basic dimensions of attention: how fast the attentional system operates and how much it can process at once. Of course speed and quantity are related: the faster a system can process information the more will be processed within a given time. Yet, since this relationship is far from perfect (Shum, McFarland, and Bain, 1990), these two dimensions can—and should—be examined separately insofar as possible. Attentional capacity is measured by span tests which expose the subject to increasingly larger (or smaller, in some formats) amounts of information with instructions to indicate how much of the stimulus was immediately taken in by repeating what was seen or heard or indicating what was grasped in some other kind of immediate response. Depending upon the theoretical bias of the examiner, or the battery in which the test is embedded, these tests have been considered measures of attentional capacity or of short-term memory. While they require short-term memory, performances on these tests are more strongly associated with attention than memory and are covered in this chapter (Howieson and Lezak, 2002). Tests requiring immediate recall of more information than can be grasped at once (e.g., supraspan, story recall) or which interpose an activity or other stimulus between administration and response (e.g., Consonant Trigrams) are presented in Chapter 11, Memory I: Tests.

Digit Span

The *Digit Span* test in the Wechsler batteries (the intelligence and memory scales) is the format in most common use for measuring span of immediate verbal recall. In these batteries it comprises two different tests, *Digits Forward* and *Digits Backward,* each of which involves different mental activities and are affected differently by brain damage (see Banken, 1985; E. Kaplan, Fein, et al., 1991). Both tests consist of seven pairs of random number sequences that the examiner reads aloud at the rate of one per sec, and both thus involve auditory attention. Additionally, both depend on a short-term retention capacity (Shum, McFarland, and Bain, 1990). Here much of the similarity between the two tests ends.

A note on confounded data

In combining the two digit span tasks to obtain one score, which is the score that enters into most statistical analyses of the Wechsler tests, these two tests are treated as if they measured the same behavior or very highly correlated behaviors. The latter assumption holds for most normal control subjects into their 70s (E. Kaplan, Fein, et al., 1991) and 80s (Storandt, Botwinick, and Danziger, 1986). Differences between these two tests become most evident in studies of brain damaged patients in which forward and reverse digit spans are dissociated in some patient groups (F.W. Black, 1986; Lezak, 1979; E.V. Sullivan, Sagar, et al., 1989) but not in others (F.W. Black and Strub, 1978).

For example, of 52 patients (age range 18-63) with TBI of mild to moderate severity, 24 could reverse no more than four digits, yet 41 had digit forward spans ranging from 6 to 9, in the *average* or better range (clinical record review, mdl). This difference, significant at the .05 level ($\chi^2 = 3.938$), clearly demonstrates that these two tests each measure something different. Yet with so many of these patients unable to recall more than four digits in reverse, only seven of the 52 received WIS-R Digit Span scaled scores below 8, the lowest score in the *average* ability range. The difference between the number of patients receiving *below average* scores on Digits Reversed and the number with *average* or better scores when Digits Forward and Digits Reversed were combined for the scaled score was significant ($\chi^2 = 5.797$, $p < .02$), further demonstrating how combining scores from these two tests obscure the data that each test generates.

The risk of losing information by dealing with these two tests as if they were one and combining their scores becomes obvious when one considers what the Wechsler Adult Intelligence Scale scaled score, based on the combined raw scores, might mean.

To obtain a scaled score of 10, the *average* scaled score, young adults need to achieve a raw score of 11 which, in the majority of cases, will be based on a Digits Forward score of 6 and a Digits Backward score of 5. However, they can get this *average* rating based on a Digits Forward score of 7 and a Digits Backward score of 4 with a three-point difference between the scores, a difference that occurs more often in brain damaged groups than in intact populations. The same scaled score of 10 may also be based on a Digits Forward score of 8 and a Digits Backward score of 3. A disparity between scores of this magnitude is almost never seen in normal, intact subjects. Moreover, a Digits Backward score of 3 in a young adult, in itself is indicative of brain dysfunction in a compliant, attentive, subject.

The problem of obscuring meaningful data is further compounded in all recent revisions of Wechsler's tests, WAIS-III and WMS-III. In order "to increase the variability of scores," two trials are given of each item (i.e., at each span length) and the subject receives one raw score point for each correct trial. Thus, information about the length of span is confounded with information about the reliability of span performance.

A person in the 18- to 34-year-old range who passes only one of the two trials on each pair of Digits Forward items containing four to six digits and Digits Backward items of three to five digits in length would receive a total raw score of 10, which would be classified at the level of a scaled score of 6, just above the *borderline* level. Yet, for neuropsychological purposes, this subject has demonstrated an *average* span for both digit span forward and the reversed digit span. That this subject is more prone to error than most people whose span for digits of the same length is interesting information. However, neither the subject's *average* capacity nor proneness to error is evident in the final score. Rather, the final score can easily be misinterpreted by anyone who does not know that both the subject's forward and reversed span of recall were *within normal limits* (i.e., 6 and 5).

For neuropsychological purposes, none of the Wechsler scoring systems is useful. Digit span forward and digit span reversed are meaningful pieces of information that require no further elaboration for interpretation. The examiner seeking to place the subject's performance into a statistically meaningful context will find the cumulative percentiles for the longest digit spans (forward and reversed data are presented separately) in the manual for the *WAIS-R as a Neuropsychological Instrument* (*WAIS-RNI*) (E. Kaplan, Fein, et al., 1991). The examiner who is interested in assessing the *reliability* of a patient's attention span should give at least three trials at each span length (J.R. Shelton and her coworkers [1992] recommend "at least 10"), but should not confound data about the consistency of response with data concerning its length.

Forward Span: Digits, Verbal

All WIS-A and Wechsler Memory Scale (WMS) batteries use the same digit sequences, except that the original two WMS batteries began with the four-digit sequence. Table 9.2 provides four other lists, drawn from a table of random numbers, for repeat examinations. These are most likely to be useful when examinations are frequently repeated, as may be required in drug studies; or for patients whose problems are due to attentional and not learning deficits and who fail after only two or three trials but learn one or more of these short sequences, particularly if retested several times. These sequences can be used with any kind of number-based span test.

For digit span recall, the subject's task is to repeat each sequence exactly as it is given. When a sequence is repeated correctly, the examiner reads the next longer number sequence, continuing until the subject fails a pair of sequences or repeats the highest (9 digits in WIS-A batteries, 8 in WMS) sequence correctly. Occasionally a patient's failure will appear to be due to distraction, poor cooperation, inattentiveness, etc., such that a third trial at the twice-failed sequence seems appropriate to the examiner whose interest is in finding out span length. The other occasion for giving a third trial arises when the patient recalls more digits reversed than forward and the examiner can assume that the patient is capable of doing at least as well on the much less difficult Digits Forward as on Digits Backward. This infrequently occurring disparity probably reflects the patient's lack of effort on a simple task. Almost invariably, such a patient will pass a third trial and occasionally will pass one or two of the longer sequences. When giving the third digit series, the easiest method is to take the requisite number of digits out of one of the nine forward or eight backward sequences that are unlikely to be used. Another administration variant has been introduced by Edith Kaplan and her colleagues (see Milberg, Hebben, and Kaplan, 1996) who give the next longer series of digits when failure on both trials results from mixing up the sequence of the correct digits. They then score for both the longest correct span and the longest span of correct but out-of-sequence digits.

Although examiners are instructed to begin with the three-digit sequence in the WAIS-R and WMS-R, and two digits in the WAIS-III and WMS-R, this is a waste of time and can try the patience of most alert and responsive patients. Beginning with four digits loses no data in most cases. Subjects who have tracked well in conversation and already have performed adequately on the Sequential Operations Series (see p. 362) may

TABLE 9.2 Randomized Digit Lists for Span Tests

Forward Span		*Reversed Span*	
3-6-5	4-8-5	2-9	5-1
2-4-9	2-6-8	9-4	3-7
3-1-7-4	5-7-2-4	8-7-2	9-1-8
4-6-2-9	7-6-2-9	5-8-1	6-2-9
1-8-5-2-4	4-7-1-5-9	7-8-6-4	9-7-1-3
8-7-1-9-5	2-8-3-6-9	8-4-1-7	3-9-8-6
2-4-7-3-9-1	8-3-7-1-4-2	8-2-5-9-4	5-9-6-8-1
1-9-5-7-4-3	7-8-4-9-3-6	5-8-6-3-9	2-1-8-9-3
5-6-3-9-2-1-8	8-2-1-9-3-7-4	9-2-4-8-7-1	9-5-7-4-3-8
6-4-3-2-8-5	2-9-5-4-9-6-8	3-7-4-9-1-6	1-9-3-7-4-2
2-7-5-8-6-4-9-3	3-1-7-9-4-2-5-8	8-7-5-2-6-3-9	6-9-4-2-7-3-1
9-4-3-7-6-2-5-8	7-2-8-1-9-6-5-3	4-8-1-2-5-9-7	5-8-4-2-1-9-6

begin with five digits. If they fail at the four- or five-digit level it is easy to drop down to a lower one. For most clinical purposes, subjects who recall seven digits correctly have demonstrated performance well *within normal limits;* whether they can recall 8 or 9 digits is usually irrelevant for the examination issues, and the test can be discontinued at this point without losing important clinical information. Of course, when following a research protocol, such clinical liberties cannot be taken.

Test characteristics. The WIS-A manuals provide a method to convert raw scores into standard scores that can be juggled into separate standard score estimates for each of the two Digit Span tests. However, because Digit Span has a relatively restricted range (89% of a large normative sample had spans within the 5 to 8 digit range [E. Kaplan, Fein, et al., 1991]) and does not correlate very highly with other measures of cognitive prowess, it makes more sense to deal with the data in raw score form than to convert them. Taking into account that the normal range for Digits Forward is 6 ± 1 (G.A. Miller, 1956; Spitz, 1972), and that education appears to have a decided effect on this task (Ardila and Rosselli, 1989; A.S. Kaufman, McLean, and Reynolds, 1988), it is easy to remember that spans of 6 or better are well *within normal limits,* a span of 5 may be *marginal to normal limits,* a span of 4 is definitely *borderline,* and 3 is *defective.* Age tends to affect forward span only minimally beyond ages 65 or 70 as reported in most studies (Craik, 1990; Jarvik, 1988); even healthy subjects in the 84–100 age range achieved a forward span mean of 5.7 ± 1.0, range 4–8 (Howieson, Holm, et al., 1993; see also Hickman et al., 2000).

What Digits Forward measures is more closely related to the efficiency of attention (i.e., freedom from distractibility) than to what is commonly thought of as memory (A.S. Kaufman, McLean, and Reynolds, 1991; P.C. Fowler, Richards, et al., 1987; Spitz, 1972). Anxiety tends to reduce the number of digits recalled (J.H. Mueller, 1979; Pyke and Agnew, 1963), but it may be difficult to identify this effect in the individual case. For example, one study of 144 students (half tested as high anxiety; half, as low anxiety) reported a Digits Forward mean score of 7.15 for the high-anxiety students and 7.54 for the low-anxiety students, a difference indicating a large overlap between the two groups (J.H. Mueller and Overcast, 1976). Stress-induced lowering of the Digits Forward score has been shown to dissipate with practice (Pyke and Agnew, 1963). When it appears likely that a stress reaction is interfering with a subject's Digit Span performance, the examiner can repeat the test later. If the scores remain low even when the task is familiar and the patient is presumably more at ease, then the poor performance is probably due to something other than stress. Practice effects are negligible (McCaffrey, Duff, and Westervelt, 2000a), with test–retest reliability coefficients ranging from .66 to .89 depending on interval length and subjects' ages (Matarazzo and Herman, 1984; W.G. Snow, Tierney, et al., 1989).

Neuropsychological findings. Digit repetition is resistant to the effects of many brain disorders. It tends to be more vulnerable to left hemisphere involvement than to either right hemisphere or diffuse damage (Hom and Reitan, 1984; Risse et al., 1984; Weinberg et al., 1972). Since it appears to be primarily a measure of attention, it is not surprising to find that, in the first months following head trauma or psychosurgery, the Digits Forward span of some patients is likely to fall *below normal limits,* but it is also likely to show returns to normal levels during the subsequent years (Lezak, 1979; Uzzell, Langfit, and Dolinskas, 1987). However, repeated blows to the head appear to impair span, as the number of concussions in soccer players was inversely correlated with Digits Forward performance (Matser, Kessels, Lezak, et al., 1999). It tends to be reduced in individuals with long-term exposure to industrial solvents (Morrow, Robin, et al., 1992). Although among the tests least sensitive to dementia, once past the early, mild stage, forward span becomes noticeably reduced in length (Kaszniak, Garron, and Fox, 1979; Storandt, Botwinick, and Danziger, 1986). In previously healthy persons, shrinkage of both forward and reversed span was likely to herald death within several years (B. Johansson and Berg, 1989).

If systematic studies of digit span error types associated with different kinds of neuropsychological conditions have been conducted, they must be rare and unreported. However, clinical experience does provide some suggestive error patterns. For example, patients with conditions associated with diffuse damage who have mental tracking difficulties (e.g., mild TBI, many multiple sclerosis patients) are apt to repeat the correct digits but mix up the order, usually among the middle digits. More severely impaired TBI patients with significant frontal lobe involvement may substitute bits of overlearned sequence strings (e.g., 3-5-6-7 instead of 3-5-9) or perseverate from the previous series. With severe brain injury, span tends to be reduced (Ruff, Evans, and Marshall, 1986). When moderately demented patients fail they are likely to repeat no more than their limit (e.g., 4-8-2-9 or 4-8-9-5 instead of 4-8-2-9-5). The WAIS-RNI record form contains a section for recording Digit Span errors in detail, and possible interpretations are discussed in the manual (E. Kaplan, Fein, et al., 1991).

Point Digit Span (A. Smith, 1975)

Along with the standard administration of forward and reversed digit span, Aaron Smith (1975) also had his subjects point out the digit series on a numbered card. The "point" administration parallels the digit span tests in all respects except that the response modality does not require speech, so that the verbal span of patients who are speech impaired can be tested. It has been used with aphasic patients for both auditory and visual digit presentations (Risse et al., 1984). When given with Digit Span to the speaking patient, marked performance differences favoring the "point" administration suggest a problem in speech production. A "point" performance much below the performance on the standard presentation suggests problems in integrating visual and verbal processes (A. Smith, personal communication, 1975 [mdl]). J.R. Shelton and her colleagues (1992) advised that this technique always be used with patients whose ability for expressive speech is compromised.

Point Digit Span requires a large (approximately 30 cm × 30 cm) white cardboard card on which the numbers 1 through 9 appear sequentially in a 3 × 3 arrangement in big (approximately 6 cm high) black print. The subject is instructed to point out the number sequence read by the examiner, or the reverse sequence for Digits Backward. The procedure is identical with that of Digit Span; i.e., presentation begins with three digits (two for Digits Backward), and increases one digit following each success. As with the Digit Span tests, the examiner may begin with longer sequences than those prescribed in the WIS-A. The test is usually discontinued after two failures at the same level. To keep language-handicapped patients from developing a spatial strategy that would then obscure their verbal attention span, J.R. Shelton and her colleagues (1992) gave them a response sheet with a different layout of numbers for each succeeding set of numbers of a given length.

Letter span

Normal letter span (6.7 in the 20s, 6.5 in the 50s) is virtually identical with digit span except beyond age 60 when some relative loss has been documented (5.5 in the 60s, 5.4 in the 70s) (Botwinick and Storandt, 1974). McCarthy and Warrington (1990) suggested that letter span is likely to be a little smaller than digit span as random letters are less susceptible to "chunking" into "higher order units" than digits (e.g., 3-2-6-8 converts readily into "thirty-two sixty-eight").

Every localization group in Newcombe's (1969) study of missile wound patients had lower average scores on a simple letter span task, analogous to Digits Forward, than on the digit version of the task, as did the control subjects and two groups of head trauma patients studied by Ruff, Evans, and Marshall (1986). With a mean age of 28, these control subjects' average letter span was 6.3 ± 1.3. On Letter Span, with the single exception of the left frontal group, the left hemisphere damaged groups also obtained lower average scores than the right hemisphere groups. The mean score range for the left hemisphere groups was from 5.00 (temporal or temporoparietal, and mixed) to 5.75 (frontal); for the right hemisphere patients, group mean scores ranged from 5.50 (frontal and mixed) to 6.00 (temporal or temporoparietal). The overlap of scores of the different patient groups was too great to permit inferences about localization of the lesion in any individual case.

Forward Span: Visual

Since the first appearance of a test for immediate recall of visually presented sequences, several variations on this concept have been developed. Not only is it useful for immediate visual span but the format can be adapted for examining visuospatial learning as well (see pp. 466–467).

Knox Cube Test (KCT)

This is one of the tests in the *Arthur Point Scale of Performance* battery (Arthur, 1947). The four blocks of the Knox Cube Test are affixed in a row on a strip of wood. The examiner taps the cubes in prearranged sequences of increasing length and complexity, and the subject must try to imitate the tapping pattern exactly. Administration time runs from two to five minutes.

Test characteristics. Correlational studies supported the clinical impression that this test measures immediate visuospatial attention span with the addition of a "strong" sequencing component (Bornstein, 1983a; see also Shum, McFarland, and Bain, 1990). The ease of administration and simplicity of the required response recommend this task for memory testing of patients with speech and motor disabilities and low stamina, and elderly or psychiatric patients (Inglis, 1957). Edith Kaplan has pointed out that the straight alignment of four blocks allows the patient to use a numerical system to aid recall so that there may be both verbal and nonverbal contributions to responses. Mean scores of a large general hospital population of middle-aged and elderly men tested twice on four different administrations of this test correlated significantly ($p < .01$) with the WAIS Digit Span, Arithmetic, Block Design, and Picture Arrangement tests, but less highly with Vocabulary (Sterne, 1966). Bornstein and Suga (1988) reported a significant ($p < .01$) education effect. Having demonstrated improved performance on the Knox Cube Test immediately following electroconvulsive shock therapy to the right hemisphere, Horan and his colleagues (1980) concluded that this test examines the sequential, time-dependent functions of the left hemisphere.

Corsi Block-tapping Test

B. Milner (1971) described the Block-tapping task devised by P. Corsi for testing memory impairment of patients who had undergone temporal lobe resection. It consists of nine black $1^1/_2$-inch cubes fastened in a random order to a black board (see Fig. 9.9). Each time the examiner taps the blocks in a prearranged sequence, the patient must attempt to copy this tapping pattern.

Test characteristics. Using the Corsi format, block span tends to run about one block lower than digit span (E.V. Sullivan, Sagar, Gabrieli, et al., 1989; Ruff, Evans, and Marshall, 1986), although Canavan and his colleagues (1989) found more than a two-point disparity for healthy young control subjects. Smirni and coworkers (1983) observed that, due to the layout of the blocks on the Corsi board, different sequences vary in length and spatial configuration. This will be true of the WAIS-RNI version too (see below). Beyond the 3-block items which almost all healthy young adults repeated correctly, the sequences with the shortest distances between blocks were most likely to be failed. When the length of the paths was equal, success was associated with the sequence pattern.

Education contributed significantly to performance levels in an Italian study in which more than one-third of the subjects had less than a sixth grade education (Orsini, Chiacchio, et al., 1986). Men tended to achieve slightly (in the general range of one-third of a point) but significantly ($p < .001$) higher scores than women, although this discrepancy became smaller with more years of schooling and was virtually nonexistent for persons with more than 12 years of education. Age effects did not appear in this study until after 60 when they became increasingly pronounced. In another study, despite the subjects' wide age range (20–75), no age effects appeared, but these subjects averaged 13+ years of schooling and it is unlikely that any had less than an eighth grade education (Mittenberg, Seidenberg, et al., 1989).

Neuropsychological findings. DeRenzi, Faglioni, and Previdi (1977) found that stroke patients with visual field defects had a shorter immediate recall span on Corsi's test than patients without such a defect, regardless of hemisphere side of lesion. In another study, patients with right hemisphere lesions performed more poorly than those with lesions on the left (Kessels et al., 2001). Although their score range was wide (2 to 8), right temporal lobectomy patients' average score equaled that of the control group (5.0), while those with left temporal lobectomies had a much smaller range (4 to 6) and a slightly but not significantly higher average score (5.6) (Canavan et al., 1989). Patients with frontal lobe lesions performed least well ($M = 4.4$). With only one to three moves to copy, Alzheimer patients achieved relatively normal scores (E.V. Sullivan, Corkin, and Growdon, 1986); but following the standard procedure of increasing the number of blocks in a sequence after each successful trial, mildly and moderately impaired Alzheimer patients' scores were lower ($M = 4.4$) compared to control subjects ($M = 5.5$), and severely impaired patients had an average span of only 2.5 (Corkin, 1982). Severe anterograde amnesia did not appear to affect this visuospatial attention task. Patients

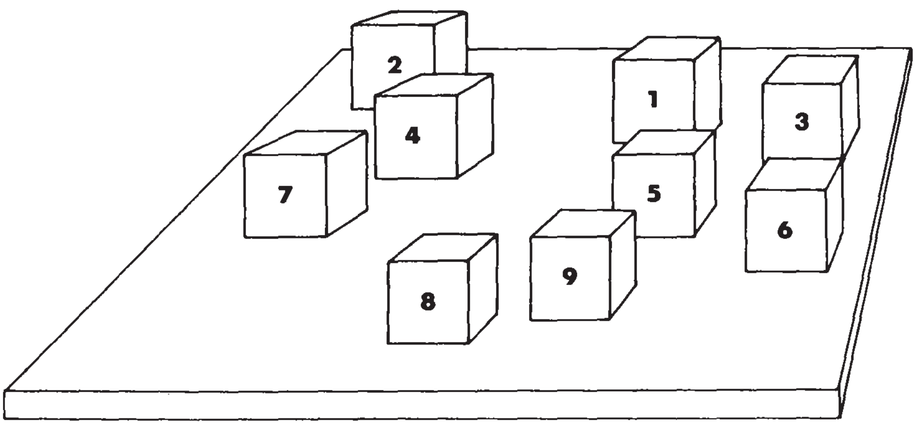

FIGURE 9.9 Corsi's Block-tapping board. (From Milner, 1971)

with moderately severe TBI lagged behind normal subjects about 0.5 point (6.4 to 5.8), and those with severe head injuries performed on the average another half-point lower ($M = 5.3$) (Ruff, Evans, and Marshall, 1986).

Corsi variants. Three variations on the Corsi theme are found in the WMS-R, WMS-III, and WAIS-RNI. For a comprehensive discussion of many other variations, see Berch et al. (1998). The difficulty level of a particular variant depends on many factors, including the length of the spatial path and the number of crisscrosses (Orsini, Pasquadibisceglie, et al., 2001). The Wechsler variants most like the original Corsi format are the WAIS-RNI and WMS-III *Spatial Span,* which use ten cubes on a board attached in an irregular arrangement. Separate WMS-III norms are available for total span (i.e., counting both trials at each level) forward and total span backward. The WAIS-RNI version too requires two administrations at each level but registers only the longest span. E. Kaplan, Fein, and their coworkers (1991) observed that block span will normally be one to two points below digit span. If it is much lower than the longest digit span, right hemisphere dysfunction is implicated; and when the block span exceeds the digit span, left hemisphere dysfunction may be suspected. These workers also noted the usefulness of the block array in eliciting evidence of lateralized dysfunction.

The WMS-R *Visual Memory Span* provides two cards on each of which are printed eight squares in a nonlinear pattern—red squares for forward span and green for reversed span. The administration procedure is the same as for Digit Span, requiring two trials at each level regardless of whether the first was passed. It thus also confounds span length with response consistency, producing a score that is uninterpretable except at the extremes of the continuum.

Finding herself without a Corsi board when this test seemed to have clinical utility, but in an office with a blackboard, a Veterans' Administration Hospital Psychology Service intern (Jeanne Taylor) marked up nine X's in random fashion with chalk and was able to examine her patient's visuospatial span this way. Lacking any of these materials, an examiner can gain some sense of a patient's visuospatial span by drawing X's or circles on a piece of paper. The chief advantage of having either a block board or the WMS-R cards is that number cues (on the block side facing the examiner or diagramed in the WMS-R manual) enable the examiner to keep track of the patient's performance more easily.

Still another variant is the *Dot Location* task (D.L. Roth and Crosson, 1985), which consists of a pattern of dots on a sheet of paper. Following the Corsi administration format, the examiner points to two or more dots (up to nine), but instead of repeating the examiner's movements, the subject must draw the dots on a blank sheet of paper in the correct order and general location (within a 4 cm radius of the original dot position). This test proved to be the most sensitive to the presence of brain damage when compared with other span formats (digit and word span, Corsi blocks).

Sentence repetition

Unlike many span tests, this technique for assessing auditory span has a naturalistic quality that can be directly related to the patient's everyday functioning. Patients with intact language skills but an abnormally short sentence span are like persons with a reading knowledge of a second language but little conversational experience trying to understand native speakers who always seem to be talking too fast. Foreign language beginners tend to grasp only fragments of what they hear, often losing critical elements of speech that go by them too quickly to be fully accessed. The difference between patients with a reduced sentence span and the foreign language novice is that, because it is their native tongue, patients frequently do not realize how much they are missing. Their experience, typically, is that the people around them have become argumentative and disagreeable to them. Family members perceive these patients as not paying attention because of disinterest or self-absorption, or as having a memory disorder when this is not the case. These problems of mishearing verbal instructions or getting only part of telephone messages can seriously affect work as well as disrupt family interactions.

The number of data bits grasped in a meaningful sentence is normally considerably greater than digit or word span (McCarthy and Warrington, 1990), with only small decrements occurring after age 65 and appearing more prominently in men's than women's performances. Repeatability of sentences by normal subjects depends on their length, complexity, and meaningfulness, and the speed at which they are spoken (Butterworth et al., 1990; J.R. Shelton et al., 1992). The importance of meaningfulness to length of span becomes evident in studies of patients whose span for unrelated items may be very short but whose recall of sentences is relatively well preserved (R.C. Martin, 1990; McCarthy and Warrington, 1990). Comparing sentence span with word or digit span, the examiner can determine the extent to which meaning contributes to the patient's span of auditory-verbal attention. Goodglass and Kaplan (1983a) and Goodglass, Kaplan, and Barresi (2000) also acknowledged the role that familiarity can play in the rapidity and efficiency with which a sentence is grasped by providing two lists of phrases and sentences in a sentence repetition test, *Repeating Phrases.* The "high probability" set contains commonplace words and expressions (such as, "I drove home from work"), which contrast with "low probability" sentences composed of less frequently used words and phrases (e.g., "The spy fled to Greece").

Some mental status examinations include one or two sentences for repetition (e.g., Mini-Mental State Examination [MMSE], Neurobehavioral Cognitive Status Examination). Godwin-Austen and Bendall (1990) recommended inclusion of a sentence for repetition when examining older persons, suggesting the "Babcock" sentence: "One thing a nation must have to be rich and great is a large secure supply of wood." The *Memory for Sentences* test in the 1986 revision of the Stanford-Binet scales contains sentences appropriate for the range of difficulty levels from two years to late adolescence (Thorndike et al., 1986).

Administration of sentence repetition tests typically proceeds from easy items to the most difficult, or until the subject has made four or five failures (e.g., Benton and Hamsher, 1989; Spreen and Strauss, 1998; Thorndike et al., 1986). When the test is given this way, the patient who is having difficulty on this task will experience repeated failures until the criterion for stopping has been reached. John A. Walker (personal communication, 1985 [mdl]) suggested that skipping around between shorter and longer items in a quasi-random manner will avoid unnecessary unpleasantness for the patient, as successes will be intermixed with failures. Moreover, when giving this test to persons whose language abilities are intact, it is not necessary to begin with the easiest items. For example, on the original version of Sentence Repetition (Table 9.3), a good place to start with nonaphasic patients is item 7, both because it is getting close to the length where many attentionally impaired patients begin to fail, and because missing the pronoun shift may indicate confusion about the instructions. This pronoun error suggests that the subject may not have understood the requirement of repeating the sentence *exactly,* and instructions must be given again carefully before proceeding further. Some Americans whose normal speech has a grammar base that differs from the usual English forms (e.g., "black English," some rural dialects) will not be able to respond appropriately because they "hear" what is said in their vernacular. Persons with strong dialects should not be given this test.

Neuropsychological findings. As on other highly verbal tasks, failure on sentence span tests has long been associated with lesions of the left hemisphere.

TABLE 9.3 Sentence Repetition: Form I

1. Take this home
2. Where is the child?
3. The car will not run.
4. Why are they not living here?
5. The band played and the crowd cheered.
6. Where are you going to work next summer?
7. He sold his house and they moved to the farm.
8. Work in the garden until you have picked all the beans.
9. The artist painted many of the beautiful scenes in this valley.
10. This doctor does not travel to all the towns in the country.
11. He should be able to tell us exactly when she will be performing here.
12. Why do the members of that group never write to their representatives for aid?
13. Many men and women were not able to get to work because of the severe snow storm.
14. The members of the committee have agreed to hold their meeting on the first Tuesday of each month.

Failures may occur at the level of auditory comprehension or articulation of words, or because of a dissociation between auditory input and speech output (Goodglass and Kaplan, 1983a). The attentional aspects of this span test show up in the difficulty patients with attentional deficits have in accurately recalling sentences containing as many as 18 or 20 syllables. Patients with conditions in which damage tends to be diffusely distributed, such as TBI and multiple sclerosis—which are also conditions in which attentional deficits are prominent—are most likely to perform *below normal limits* on this task. Alzheimer patients have reduced sentence repetition span, particularly when the sentences are complex (J.A. Small et al., 2000).

Sentence Repetition (1) (Benton and Hamsher, 1989)

This subtest of the Multilingual Aphasia Examination (MAE) can do double duty. The 14 sentences in Form I graduate in length from three syllables to 24 syllables (Table 9.3). They thus provide a measure of span for meaningful verbal material ranging from abnormally short to the expected normal adult length of 24 syllables. In addition, seven different linguistic constructions are represented among each of the two sets of sentences, Forms I and II (e.g., positive declaration, negative interrogation, etc.). This allows examiners to test for the patients' sensitivity to syntactical variations in what they hear. This feature appears useful for registering mild or subtle linguistic deficits of patients whose communication abilities may seem intact when they take the usual tests in a neuropsychological examination. A scoring

TABLE 9.4 Sentence Repetition (MAE): Demographic Adjustments for Raw Scores

Add	*Education*	*Age*
0	≥ 12	≤ 59
1	≥ 12	≥ 60
2	= 9-11	≤ 59
3	= 9-11	≥ 60
3	= 6-8	≤ 59
4	= 6-8	≥ 60

From Benton, Hamsher and Siran (1994)

system gives one point for each sentence repeated correctly and provides an adjustment formula for additional points to be added to the raw score of persons in the age groups 25 to 29 and 60 to 64 who have had 15 years or less of schooling (see Table 9.4). Scores of 11 to 13 are in the *average* range (%iles 25–75, approximately); scores between 9 and 10 are considered *borderline* to *low average;* below 9 performances are *defective.* Scores of 14 or higher were obtained by 35% of the control group. Developmental norms offer age-equivalent values that can be meaningful in interpreting impaired performances to lay persons (Carmichael and MacDonald, 1984); e.g., recall no better than sentence 8 is at the level of an eight-year-old child.

Sentence Repetition (2) (Spreen and Strauss, 1998)

The overall format of this test is similar to Benton and Hamsher's Sentence Repetition test, but the 22 sentences in each of the two forms (A and B) are unique to this version (printed in Spreen and Strauss, 1998, p. 368). The first item is a one-word statement (e.g., "Look") with graduated lengths up to the last 26-syllable item. Although the sentences can be read, the recommended administration is by audiotape. Both adult and developmental norms are provided by Spreen and Strauss.

Silly Sentences (1) (Botwinick and Storandt, 1974)

The contribution of meaning to retention was examined by means of a set of long silly sentences developed as a parallel task to paragraph recall:

1. The Declaration of Independence/sang/overnight/while/the cereal/jumped/by the river./
2. Two dates/ate/the bed/under the car/seeing/pink flowers/forever./
3. They slept/in the fire/to avoid the draft./It was cold there/and their sweaters kept them/cool./
4. I eat pink mice./They are delicious/but their green fur/gives me heartburn./

Each of these silly sentences is read to the subject and is immediately followed by a recall trial. Correct recall of each unit—marked by slashes—merits one point so that the total possible score is 24. The average recall of subjects by decades was 21.9 for the 20s, 20.7 for the 30s, 20.6 for the 40s, 20.0 for the 50s, 19.0 for the 60s, and 15.6 for the 70s. A comparison of these data with scores obtained for paragraph recall indicated that meaningfulness of material played an increasingly greater role in recall in the later decades.

Silly Sentences (2) (Baddeley, Emslie, and Nimmo-Smith, 1993)

Speed of comprehension is the central feature of this test. The subject reads 100 short sentences, half of which are sensible, and indicates whether each is sensible or silly. The score is the total number of correct responses completed within two min. An alternate form is available for retesting. Test–retest reliability using the alternate form is high (r = .78). However, a practice effect was observed with scores 11 points higher on a second administration one to two weeks later (Hinton-Bayre et al., 1997). These authors found this test to be more sensitive to the effects of concussion 24 to 48 hours after injury in rugby players than either the WAIS-R Digit Symbol or Symbol Digit Modalities Test.

Mental Tracking: Tests of Working Memory

Working memory tests require people to hold information in mind while performing a mental operation. Thus tests which require the subject to keep track of ongoing mental activity typically involve at least very short-term memory of what was just done or heard while performing another operation. For instance, the WIS Arithmetic test questions must be held in mind while the subject performs the mental operations. A good example of this process is the paper clip item on the WAIS-III, which requires that the long, convoluted problem be held in mind in order to recall the number of green paper clips while mentally adding all (red, yellow, and green) paper clips. Many examinees require that this item be re-read and some require a visual assist. Working memory is a favorite paradigm for functional imaging studies; the left dorsolateral prefrontal cortex is activated for verbal working memory tests and the right dorsolateral prefrontal cortex for spatial versions (Cabeza and Nyberg, 2000; Dolan et al., 1997; Henson, 2001).

The simplest test of mental tracking is digit span reversed, also known as *Digits Backward* (WIS-A, WMS), which tests how many bits of information a person can attend to at once and repeat in reverse order. Tests of mental tracking may involve some perceptual tracking or more complex mental operations, and many of them also involve some form of scanning. The role of visual scanning in conceptual tracking has become apparent in studies demonstrating the scanning eye movements that accompany the performance of such conceptual tracking tasks as digit span reversed or spelling a long word or name in reverse (Weinberg, Diller, et al., 1972).

A general attentional deficit has also been implicated in these problems (I.H. Robertson, 1990). Tracking tasks can be complicated by requiring the subject to track two or more stimuli or associated ideas simultaneously, alternatively, or sequentially on double or multiple tracking tests involving divided and/or shifting attention. The capacity for double or multiple tracking is one most likely to break down first with many brain disorders. Occasionally, loss of this capacity may be the only documentable mental change following TBI or a brain disease. The disturbance appears as difficulty in keeping two or more lines of thought going, as in a cocktail party conversation, in solving two- or three-number addition or multiplication problems mentally, or in remembering one thing while doing another, and thus can be very burdensome for the patient.

Reversing serial order: digits

The *Digits Backward* number sequences of the Wechsler Intelligence and Memory Scales are two to eight digits long and two to seven digits long, respectively. On hearing them, the subject's task is to repeat them in an exactly reversed order. Although Wechsler's instructions suffice for most subjects, when dealing with patients who are known or suspected to have brain impairment, some variants may help to elicit maximum performance on this test without violating the standardization.

Patients whose thinking is concrete or who become easily confused may comprehend the standard instructions for Digits Backward with difficulty if at all. Typically, these patients do not appreciate the transposition pattern of "backward" but only understand that the last number need be repeated first. To reduce the likelihood of this misconception, the digits backward task can be introduced using the wording in the Wechsler manuals, giving as the first example the two-digit number sequence, which even very impaired patients can do with relative ease. Everyone who seems likely to have difficulty on this task but recalls two digits reversed on either the first or second trial then receives the following instructions: "Good! [or some other expression of approval], Now I am going to say some more numbers, and once again, when I stop I want you to say them backwards. For example, if I say 1-2-3, what would you say?" Most patients can reverse this three-number sequence because of its inherently familiar pattern. If the subject fails this example, it is given again verbally with the admonition, "Remember, when I stop, I want you to say the numbers backwards—the last number first and the first one last, just as if you were reading them backwards." The examiner may point in the air from the patient's left to right when saying each number, and then point in the reverse direction as the patient repeats the reversed numbers so as to add a visual and directional reinforcement to the concept "backwards." If the patient still is unable to grasp the idea, the examiner can write each number down while saying "1-2-3" the third time. The examiner needs to write the numbers in a large hand on a separate sheet of paper or at the top of the Record Form so that they face the subject and run from the subject's left to right, i.e., Ɛ-Ƨ-Ɩ. Then the examiner points to each number as the patient says or reads it. No further effort is made to explain the test. As soon as the subject reverses the 1-2-3 set correctly or has received all of the above explanations, the examiner continues with as much more of Digits Backward as the patient can do. The WAIS-III manual gives the cumulative percentages of differences between the longest Digits Forward and Digits Backward spans for each age group.

Test characteristics. The normal raw score difference between digits forward and digits reversed tends to range a little above 1.0 (E. Kaplan, Fein, et al., 1991), with a spread of reported differences running as low as .59 (J.H. Mueller and Overcast, 1976) and as high as 2.00 (Black and Strub, 1978). The examiner who chooses to evaluate the Digits Backward performance on the basis of the raw score should consider raw scores of 4 to 5 as *within normal limits;* 3 as *borderline defective* or *defective,* depending on the patient's educational background (Botwinick and Storandt, 1974; Weinberg, Diller, et al., 1972); and 2 to be *defective* for everyone. The Digits Backward span typically decreases about one point during the seventh decade. However, as age groups 60 and over are increasingly likely to be better educated than the groups examined in the reported studies, these classifications may be appropriate at least to age 70. Howieson and her colleagues (1993) reported that for 34 subjects in the 84–100 age range, digit span reversed did not differ greatly from normal expectations ($M = 4.5 \pm 1.0$, range 3-6). Thus some but not all older subjects get lower scores than younger ones (Canavan et al., 1989; Kaszniak, Garron, and Fox, 1979).

The reversed digit span requirement of storing a few data bits briefly while juggling them around mentally is an effortful activity that calls upon the working memory, as distinct from the more passive span of apprehension measured by Digits Forward (Banken, 1985; F.W. Black, 1986). The task involves mental double-tracking in that both the memory and the reversing operations must proceed simultaneously. Many people report that they perform this task by making a mental image of the numbers and "reading" them backward. Impairment is found in patients with unilateral spatial inattention or with attentional bias to the right-side of space, supporting the role of mental imagery in performing this task (Rapport, Webster, and Dutra, 1994). Factor analysis indicated that both visual and verbal processes contribute to the reversed digit span performance (Larrabee and Kane, 1986).

Neuropsychological findings. Like other tests involving mental tracking, digit span reversed is sensitive to many different brain disorders. By and large, patients with left hemisphere damage (F.W. Black, 1986; Newcombe, 1969; Weinberg, Diller, et al., 1972) and patients with visual field defects have shorter reversed spans than those without such defects. Yet following temporal lobectomy neither right- nor left-lesioned patients performed much differently than control subjects (Canavan et al., 1989). In general, the more severe the lesion the fewer reversed digits can be recalled (Leininger, Gramling, et al., 1990; Uzzell, Langfitt, and Dolinskas, 1987). This test is very vulnerable to the kind of diffuse damage that occurs with solvent exposure (Morrow, Robin, et al., 1992) and in many dementing processes. Patients with frontal lesions may also have difficulty (Leskela et al., 1999). Frontal lobe lesions, such as those produced by psychosurgical procedures, may lower reversed span (Canavan et al., 1989; Scherer et al., 1955), but not necessarily (Stuss, Kaplan, et al., 1981).

Reversing serial order: spelling and common sequences

The sensitivity of digit span reversed to brain dysfunction also is seen in other tasks requiring reversals in the serial order of letters or numbers (M.B. Bender, 1979). Bender used a variety of reversal tasks to assess normal children, adults, and several groups of older persons (over age 60); adult patients with a dementing disease or diffuse encephalopathy, or with aphasia; and dyslexic children. In addition to counting forward and backward (mostly to establish a set for reversing serial order on subsequent tasks), subjects were given the following reversing tasks. Spelling two- (I-T), three- (C-A-T), four- (H-A-N-D), and five- (W-O-R-L-D) letter words backward was the first. Any word of the designated length in which each letter appears only once can be substituted as needed (e.g., H-O-U-S-E, Q-U-I-C-K). Bender also compared letter reversing with serial word reversing; for example, days of the week, months of the year. Reading words forward and backward and vertically printed words from top to bottom and bottom to top were examined next.

Approximately one in ten normal adults and older subjects over age 60 made reversed spelling errors. The older the subject group, the greater the incidence of errors, up to an error rate of 38% for a group of normal adults aged 75 to 88. The percentage of patients with diffuse encephalopathy making reverse spelling errors was less (78%) than the percentage of aphasic patients failing this task (90%). Aphasic patients also had more difficulty than others reading in reverse or from bottom to top, although many who failed these tasks could read satisfactorily in the left–right or top to bottom directions. Bender (1979) suggested that the ability to reverse letter, number, and word strings is characteristic of normal thinking and language processes. It is vulnerable to many different kinds of cerebral disorders because defects in reversal ability can result from (a) reading disability; (b) memory disorder; (c) aphasia; (d) the mental rigidity that may accompany aging; (e) perseverative tendencies; (f) a specific disability for learning to reverse symbolic material; or (g) "latent" alexia that shows up on the unfamiliar reversing task.

Jenkyn and his coworkers (1985) asked their subjects to spell *world* forward as well as backwards. When misspelled, the reversal of the misspelling becomes the correct backwards response. In their normative group the incidence of failure increased from 6% at ages 50–54 to 21% in the 80+ age range.

Mental Control (Wechsler Memory Scales) (Wechsler, 1945, 1987, 1997b)

This section of the original Wechsler Memory Scale and its revisions (WMS-R) has little to do with memory. Its attentional character has been consistently attested by factor analytic studies (e.g., Bornstein and Chelune, 1989; D.L. Roth, Conboy, et al., 1990). This three-item test of mental tracking requires the subject to (1) count backwards from 20 in 30 sec; (2) repeat the alphabet in 30 sec[1]; and (3) count from 1 to 40 by 3's in 45 sec. Only items completed within the time limits are scored on a 3-point scale on which no errors earns 2 points, reduced to 1 point if there is one error, with no credit for two or more errors. Item scores are summed, making this a 7-point scale (WMS-R) on which 0 indicates failure on all three items and 6 is a perfect score; each

[1]Examiners should be aware that the Spanish alphabet has two additional letter units.

WMS item is credited one more point for responses completed within 10 sec, resulting in a 10-point scale for the original version of this test.

The WMS-III has expanded items to include counting from 1 to 20, saying the days of the week and the months of the year forward and backward, and counting by 6's while alternating with the days of the week beginning, "0—Sunday–6—Monday, etc." For patients unable to recite the alphabet and who appear to be too dilapidated to succeed on even the simplest sequencing task, it is unnecessary to give the more difficult items. Recitation of the alphabet indicates whether the subject recalls it sufficiently to do alphabet-based tasks such as Trail Making and provides some evidence of whether old over-learned sequences are intact.

Test characteristics. There appear to be virtually no age effects for either the WMS-R version of Mental Control (Ivnik, Malec, et al., 1992c; Wechsler, 1987) or the WMS version (Storandt, Botwinick, and Danziger, 1986). Hulicka (1966) reported that the lowest Mental Control mean scores she obtained were made by the 60 to 69 and 70 to 79 age groups, while 80- to 89-year-olds achieved higher scores ($n = 25$, $M = 6.92$) than 30- to 39-year-olds ($n = 53$, $M = 6.75$), a finding that may reflect selective processes allowing some persons to reach their 80s sufficiently intact to participate in a study such as this one. A moderate age effect is seen with the WMS-III version. Average scores for 21- to 29-year-olds range from 21 to 29 while for 80- to 84-year-olds scores were in the 15 to 22 range with practically no overlap. Education effects have been documented for the WMS version of Mental Control, with a 1.4-point differential between persons with less than 12 years of schooling (5.6) and those with more than 15 years (7.0) (Ivnik, Smith, et al., 1991).

Neuropsychological findings. Performance on this test reflects the progressive deterioration of Alzheimer's disease (Storandt, Botwinick, and Danziger, 1986). However, it did not discriminate either between depressed patients and normal controls or between depressed patients and mildly to moderately demented Alzheimer patients, although the latter group's Mental Control scores were significantly lower than those of control subjects (R.P. Hart, Kwentus, Taylor, and Hamer, 1988). It also did not discriminate between multiple sclerosis patients and normal subjects (Fischer, 1988) despite the prominence of attentional problems in MS.

TABLE 9.5 Consistency of Serial Addition (Wechsler Memory Scale–Revised Scoring) and Sequential Operations Series Performances for 67 Patients

Serial Addition	NUMBER OF SEQUENTIAL OPERATION SERIES ITEMS FAILED 0	1	2	3
Pass	28	15	6	6
Fail	3	3	3	3

In reviewing examinations by others who routinely gave the WMS or WMS-R in its entirety and relied on Mental Control data for evaluating mental tracking, I [mdl] came across a number of patients who had failed one or more items in the more difficult *Sequential Operations Series* (*SOS*) that I generally give but succeeded on Mental Control items (see above and Tables 9.5 and 9.6). As all but very dilapidated persons can count from 20 to one in reverse, and—excepting the few, usually with limited educational backgrounds, who placed U after Q in the alphabet—almost every adult raised in a Western culture can recite the alphabet, these two items are not sensitive techniques for measuring mental tracking or any other attentional activity.

To investigate the sensitivity of the sequential addition task, my colleagues (Katherine Wild, Julia Wong-Ngan) and I [mdl] administered it, along with the more difficult tasks comprising SOS (alphabet reversed, subtracting 3's from 50, 7's from 100) to 67 subjects. This group of adult patients mostly came from the MS clinic or for evaluation of postconcussion complaints, but it also includes a few referred for a dementia workup or with other conditions. Of this group, only three who failed serial addition succeeded on the SOS tasks, while 27 who failed one or more of the SOS tasks passed the serial addition task (see Table 9.5, see Table 9.6 for pass/fail criteria). A χ^2 comparison of failures on the serial addition task and the three SOS tasks was significant ($p < .05$), as was a comparison of the number of perfect performances on each of these tests ($p < .001$).[1]

[1]These data were analyzed by Gary Ford.

TABLE 9.6 Performances on Serial Addition and the Sequential Operation Series for 67 Patients

	Serial Addition *(1 → 40)*	*Subtracting Serial 3's* *(50 → 14)*	*Subtracting Serial 7's* *(100 → 16)*	*Alphabet Reversed* *(R → A)*
Criteria for failure (in errors)	≥2	≥2	≥4	≥4
n perfect performances	41	39	15	27
n satisfactory performances	14	14	31	16
n failures	12	14	21	24

Sequential Operations Series (SOS)

Typically I begin an examination with these little tasks, often introducing them as "brain teasers" [mdl]. They can be scored for errors, time, or—as in the WMS serial attention test—for both. Time to completion is one way of measuring the subject's ease of responding (e.g., Shum, McFarland, and Bain, 1990). I count the number of 5 sec intervals between responses. Most persons who can do these tasks pause for 5 sec or more only once or twice in a sequence, if at all. More than three such pauses suggest difficulty with the task. While these tasks examine the ability to maintain an activity and retain an item while performing another kind of mental operation (complex mental tracking), they also require continuous self-monitoring. Most failures will result from subjects' inability to keep track of where they are in a sequence or, less often, what they are supposed to do (e.g., "Subtract threes or fours?"). Occasionally failure occurs for subjects who demonstrate adequate concentration and tracking abilities but who neglect to monitor errors of carelessness. Close attention to the subject's responses, including self-corrections, expressions of confusion, etc., will help the examiner understand the nature of the failure.

Alphabet Reversed. Following a correct alphabet recitation at the beginning of the examination, I [mdl] ask for the alphabet reversed beginning with the letter *R*. R was chosen both to shorten the task to 16 items and because it is within the "**Q-R-S-T**" sequence that often appears in rhythmic recitations of the alphabet, thus forcing subjects to break up an habituated sequence. This is a not infrequent problem for patients with impaired mental flexibility or perseverative tendencies who understand the instructions but, having difficulty wresting themselves free from an ingrained "**Q-R-S**" habit, will begin with "**R-S**" several times before being able to say "**R-Q.**" Approximately two-thirds of the sample patient group performed similarly on the serial subtraction and the alphabet reversed tasks (32 passed and 12 failed both). Alphabet Reversed was the only successful performance for 14 patients, while nine who failed it passed both subtraction tasks. M.A. Williams, LaMarche, and their colleagues (1996) had patients repeat the entire alphabet backwards: cardiac transplant candidates were slower than control subjects but did not make more errors. Comparing this task to other tests of attention in a larger group with brain disorders, these authors found that alphabet backwards was most related to performance on the PASAT and Serial 7s and least to tests of attention involving visuomotor responses.

Serial Subtractions. There is little statistical data on Subtracting Serial Sevens (SS7) for it is not generally used by psychologists except for the truncated version in the Mini-Mental State Examination. It is part of the mental status examination given by psychiatrists, neurologists, and other medical examiners (e.g., Strub and Black, 2000). Subjects are first instructed to "Take seven from 100." When they have done this, they are told, "Now take seven from 93 and continue subtracting sevens until you can't go any further." Some workers ask for serial subtraction by 13's, a task which should probably be reserved only for bright subjects as it can be very frustrating (Shum, McFarland, and Bain, 1990). Whether SS13 adds information not elicited on SS7 is questionable. Occasionally a patient will have recited SS7 so many times that much, if not all, of the number sequence will have been committed to memory. When a well-oriented patient has been given many mental status examinations, particularly during the previous weeks or months, the examiner should start the test at 101 or 102 instead of 100.

Many patients who are unable to perform SS7 can handle serial threes (SS3): "Take three from 50 . . . " (see Table 9.6). When the patient's attention abilities seem questionable, SS3 can be given first in order to accustom subjects to serial subtraction and to see whether they can perform the task at all. When SS3 is failed (3 or more errors), SS7 should not be given; even two SS3 errors should give the examiner pause. Patients who cannot perform the simpler serial subtraction task can be asked to count from 20 backward or say the months of the year backward, both very simple mental tracking tasks. A. Smith (1967) gave SS7 to 132 employed adults, most of them with college or professional educations, and found that only 99 performed the task with two errors or less. He thus showed that this test's usefulness in discriminating between normal and brain injured populations does not rest simply on the presence or absence of errors. He also demonstrated that grossly impaired performances are rarely seen in the normal population—only three (2%) of Smith's subjects were unable to complete the task and only six made more than five errors. The women in Smith's study were more error-prone than the men, particularly women over 45 who had not attended or completed college. J.C. Anthony and his colleagues (1982) found that, even on the 5-item MMSE version of this test, control subjects with less than eight years of schooling performed poorly. Patients with serious cardiac disease made few errors but their completion time was 58% longer than that of matched controls (M.A. Williams, LaMarche, et al., 1996). Very defective recitations of SS7 are fairly common among brain injured patients (Luria, 1966).

Other mental tracking tests

In a Chinese version of the WMS, since alphabet tasks are not usable, subjects are asked to count backwards from 100 to 0. This task is more sensitive than the 20 to 1 counting task, as persons with impaired mental tracking tend to slip decades (e.g., . . . 63-62-61-60-69, etc.) or simply get lost among all the numbers. These problems are more likely to show up after the first 20 or 30 numbers. This task can be given to persons with very limited education and those who cannot recite the alphabet correctly.

Alpha Span (Craik, 1990)

Subjects listen to increasingly longer lists of common, unrelated words and recall them in alphabetical order. Two trials are presented at each length (from two to eight). The test ends when both trials are failed. Age accounted for 6.3% of the variance in a large sample of 50- to 90-year-old participants (Lamar et al., 2002). Correlations were strongest with Digits Forward and Backward and category fluency (r = .34, .30, .27, respectively), very weak (r = .16) with letter fluency, and unrelated to Trail Making Test performances.

Alphanumeric Sequencing (Grigsby, Kaye, and Busenbark, 1994)

The patient alternates between counting and reciting the alphabet aloud beginning with "**1-A-2-B** . . . " continuing through **L**. Scores are obtained for time and errors. Chronic progressive MS patients performed worse than control subjects on both measures, while patients with the relapsing-remitting form of MS performed poorly only on time to completion (Grigsby, Ayarbe, et al., 1994).

Using essentially the same format, Ricker and Axelrod (1994) administered an oral version of the Trail Making Test to three groups of adults, two younger and one elderly. The comparability of oral and written performances, as assessed by oral-to-written ratios, was consistent across age groups. This task can be used for patients who are unable to perform visuographic tasks. This test differs from the Trail Making Test in that visual scanning is not required but demand is greater on working memory because visual cues are lacking.

Letter–Number Sequencing (WAIS-III, WMS-III) (Wechsler, 1997a,b)

Many elderly persons and patients with brain disorders have an immediate memory span as long as that of younger, intact adults. Thus digit span, as traditionally administered, frequently does not distinguish brain impaired or aged persons from normal, young ones, nor does it elicit the immediate recall problems characteristic of many persons with brain disorders. Because of these limitations, longer and more complex span formats have been devised in the hope that they will have greater sensitivity to attentional deficits.

In this test subjects hear lists of randomized numbers and letters (in alternating order) of increasing lengths (from two to eight units). Subjects are asked to repeat numbers and letters from the lowest in each series, and numbers always first. For example, on hearing "**6-F-2-B**," the subject should respond, "**2-6-B-F**." This requires subjects to keep the items in mind long enough to rearrange their order. The span is increased until the subject fails all three items of one length. This test is not recommended for persons with impaired hearing who may have difficulty discriminating the rhyming letters, such as **C**, **V**, and **Z**. It may even be difficult for them to differentiate **A** from **8**. Normative data show a moderate age effect. Scores obtained by healthy young adults correlate with performance on WIS-III Digits Forward and Backward, Arithmetic, Symbol Search, and on visual spatial learning (Crowe, 2000).

Neuropsychological findings. Alzheimer patients have difficulty on this test (Earnst et al., 2001). For age and education matched HIV^+ and HIV^- subjects, no differences were observed on the standard condition (E.M. Martin, Sullivan, et al., 2001). When asked simply to repeat the letter–number sequences as heard, many in the HIV^+ group repeated more of the long sequences than did the HIV^- group. However, when ability to reorder the sequences was corrected for repetition length, the HIV^- subjects outperformed the HIV^+ ones. Performance is also related to TBI severity as mild TBI patients did not differ from control subjects but those with moderate injury performed more poorly (Donders, Tulsky, and Zhu, 2001). However, these authors note that more variance was accounted for by level of education (r = .13) than by injury severity. *They urge caution in interpreting scores.*

N-Back Task

Used primarily for research, this task asks the subject to report when a stimulus item presented serially is the same as an item "n" steps back from the item at hand. For the 2-back condition, if the sequence were **8-7-1-8-6-3-6**, the subject would say "yes" following the second **6**. Working memory is required to keep previous items in mind while attending to the current item. Imaging studies have consistently shown prefrontal cortex involvement (e.g., C.S. Carter et al., 1998; D'Esposito, Ballard, et al., 1998), making this technique attractive for research purposes. An age effect showed up in comparisons of 68-year-olds to 20-year-olds (See and Ryan, 1995) and of persons over 70 years to 30-year-olds (Salat et al., 2002). The Salat team found that both groups made increasingly more errors when the demands expanded from 1-back to 3-back; the difference between age groups was present for all conditions. Although mild TBI patients did not differ from control subjects, functional MRI showed that the TBI group had higher activation during the high demand condition than the control group; they may have been working harder to achieve this performance level (McAllister, Saykin, et al., 1999).

Paced Auditory Serial Addition Test (PASAT)[1] (Gronwall, 1977; Gronwall and Sampson, 1974)

This sensitive test simply requires that the patient add 60 pairs of randomized digits so that each is added to the digit immediately preceding it. For example, if the examiner reads the numbers "2-8-6-1-9," the subject's correct responses, beginning as soon as the examiner says "8," are "10-14-7-10." The digits are presented at four rates of speed, each differing by 0.4 sec and ranging from one every 1.2 sec to one every 2.4 sec. Precise control over the rate at which digits are read requires a taped presentation. The tape begins with a brief repetition task that is followed by a ten-digit practice series presented at the 2.4-sec rate. Sixty-one digits are given at each rate (see Brittain et al. [1991] or Spreen and Strauss [1998] for detailed instructions). The performance can be evaluated in terms of the percentage of correct responses or the mean score for all trials.

This task is difficult. Normal middle age adults achieved 72% correct responses at the slowest rate but only 45% at the fastest (J.D. Fisk and Archibald, 2001). Comprehensive adult norms are available (Mitrushina, Boone, and D'Elia, 1999) and include most normative studies (e.g., D.D. Roman et al., 1991; Spreen and Strauss, 1998). P.J. Snyder and Cappelleri (2001) noted that on faster trials many patients will skip every third item to make the task more manageable. They suggest scoring the total number of times that two correct responses are given in a row, which they refer to as "dyads."

A shorter form of this test, the *Paced Auditory Serial Addition Test-Revised* (*PASAT-R*) contains only 26 digits in each trial, making a total of 100 possible responses for all four trials (H.S. Levin, 1983). Presentation rates run 0.4 sec. slower for each trial than in the original version.

Test characteristics. Not surprisingly, performance levels on this speed-dependent test decline with age (Brittain et al., 1991; Spikman, Deelman, and van Zomeren, 2000), a decline that Roman and her colleagues (1991) found to be most prominent after age 50. The Brittain group observed that on average men perform a trifle better than women, but while statistically significant, this trifle is of "minimal practical significance." Other studies have not found sex differences (D.D. Roman et al., 1991; Wiens, Fuller, and Crossen, 1997). Education effects have been reported (Stuss, Stethem, and Poirier, 1987) although Wiens and his colleagues found intelligence test scores but not education to be significantly related to PASAT performance. A factor analytic study showed that the PASAT had more in common with other tests of attention and information processing than with tests of memory, visuoconstruction, or verbal knowledge (Larrabee and Curtiss, 1995). Modest correlations with mental ability measures other than attention (which includes WIS-A Arithmetic) have been reported, leading to the recommendation that the PASAT may only be suitable for high functioning subjects who are not mathematically impaired (E.M.S. Sherman, Strauss, and Spellacy, 1997). Practice effects have been reported, ranging from modest and stopping at the second administration (Gronwall, 1977) to continuing significant gains leveling off only between the fourth and fifth administration (Feinstein, Brown, and Ron, 1994; Stuss, Stethem, Hugenholtz, and Richard, 1989). In her examinations of dysarthric patients, Jeanne Harris (personal communication, 1992 [mdl]) observed that it is impossible to differentiate between attentional deficits and motor speech slowing, a problem which Spreen and Strauss (1998) recommend should deter PASAT use with dysarthric patients.

Neuropsychological findings. Postconcussion patients consistently perform well below control group averages immediately after injury or return to consciousness (Gronwall and Sampson, 1974; Stuss, Stethem, Hugenholtz, and Richard, 1989). For most postconcussion patients, scores return to normal within 30 to 60 days; yet others continue to lag behind the performance level of their control group (Leininger, Gramling, et al., 1990). With severe head injuries, performance levels are significantly reduced from the outset and remain low (Ponsford and Kinsella, 1992; Stuss, Stethem, Hugenholtz, and Richard, 1989). Based on an evaluation of how the PASAT performance was associated with performances on memory and attention tasks, Gronwall and Wrightson (1981) concluded that the PASAT is very sensitive to deficits in information processing ability. Ponsford and Kinsella (1992) interpreted their findings as reflecting abnormally slowed information processing. Roman and her colleagues (1991) pointed out that patients whose head injuries are most likely to have produced diffuse damage are

[1]This tape can be ordered from the Neuropsychology Laboratory, University of Victoria, P.O. Box 1700, Victoria, B.C. V8W 2Y2, Canada.

also those most likely to perform the PASAT poorly. By using the PASAT performance as an indicator of the efficiency of information processing following concussion, the examiner may be able to determine when a patient can return to a normal level of social and vocational activity without experiencing undue stress, or when a modified activity schedule would be best (Gronwall, 1977). Sohlberg and Mateer (1989) reported use of this test to measure treatment outcome in traumatically brain injured patients with attentional disorders. This test is also sensitive to cognitive slowing associated with multiple sclerosis (S.M. Rao and National Multiple Sclerosis Society, 1990). A strong inverse correlation has been reported between amount of white matter disease associated with MS and correct responses (Hohol et al., 1997). This correlation improves when correct dyads are scored instead of total correct responses (Fisk and Archibald, 2001; P.J. Snyder, Cappelleri, et al., 2001).

Unfortunately, people experience this sensitive test as very stressful: most persons—whether cognitively intact or impaired—feel under great pressure and that they are failing even when doing well (see also Spreen and Strauss, 1998; Stuss, Stethem, Hugenholtz, and Richard, 1989). Holdwick and Wingenfeld (1999) documented sad or anxious mood states after taking the PASAT, even in healthy college students who had described themselves as happy before taking this test. Since attentional deficits can be elicited in less painful ways, it is frequently not necessary to give the PASAT. However, it can be useful for those patients whose subtle attentional deficits need to be made obvious to the most hidebound skeptics for some purpose very much in the patient's interest. When circumstances necessitates its use, patients can be prepared beforehand by letting them know that it can be an unpleasant procedure and that they may feel that they are failing when they are not.

Stroop Tests (Stroop, 1935; A.R. Jensen and Rohwer, 1966)

This technique has been applied to the study of a host of psychological functions since it was first developed in the late nineteenth century and then, late in the twentieth, it metamorphosed into a popular neuropsychological assessment method. Stroop tests are based on findings that it takes longer to call out the color names of colored patches than to read words and even longer to name the color of the ink in which a color name is printed when the print ink is a color different than the color name (Dyer, 1973; A.R. Jensen and Rohwer, 1966). This latter phenomenon—a markedly slowed naming response when a color name is printed in ink of a different color—has received a variety of interpretations. Some workers have attributed the slowing to a response conflict, some to failure of response inhibition, and some to a failure of selective attention (see Dyer, 1973; Zajano and Gorman, 1986). Patients who become slowed or hesitant on this part of the Stroop task tend to have difficulty concentrating, including difficulty in warding off distractions. The activity required by this test has been described as requiring the selective processing of "only one visual feature while continuously blocking out the processing of others" (Shum, McFarland, and Bain, 1990). The conflicting shape of the word serves as a prepotent stimulus and thus a distractor when combined with a stimulus (the different color) that has a less habituated response. Thus, it is as a measure of concentration effectiveness that this technique appears to make its greatest contribution to neuropsychological assessment.

Stroop formats. Formats can differ in many ways, some enhancing the Stroop technique's usefulness more than others. (1) The number of trials generally runs from 2 to 4. Some formats use only two trials: one in which reading focuses on color words printed in ink of different colors, and the other requiring naming of the printed colors (e.g., Dodrill, 1978b; Trenerry et al., 1989); some use three, adding one with words printed in black ink (e.g., Golden, 1978) or color dots for simple color naming (e.g., Spreen and Strauss, 1998); some use four, including both a black ink and a simple color-naming trial along with the first two (e.g., N.B. Cohn et al., 1984; Stroop, 1935). In order to increase the test's complexity, Bohnen and colleagues (1992) added a fourth trial to color naming, word reading, and the color–word interference trial by printing a rectangle around 20 color names randomly placed within a 10 line 10 column format and requiring the subject to read these words while naming the colors of the 90 other color names. (2) The number of items in a trial may vary from as few as 17 (N.B. Cohn et al., 1984) or 20 (Koss, Ober et al., 1984) to as many as 176 (Dodrill, 1978b). Two commercially available Stroop formats contain 100 (Golden, 1978) and 112 (Trenerry et al., 1989). (3) The number of colors may be three (e.g., Daigneault et al., 1992; Stuss, 1991a), four (e.g., Dodrill, 1978b; Spreen and Strauss, 1998), or five (Obler and Albert, 1985; Stroop, 1935). (4) Presentation of the stimuli also varies greatly: the 17 items in the format used by N.B. Cohn and her colleagues are arranged vertically but most formats present the stimuli in orderly rows and columns. Koss, Ober, and their coworkers (1984) used a slide projector to display their 20-item trials. The *Press Test* (Baehr and Corsini, 1980) is a paper-and-pencil form of the Stroop Test that was modified for group administration but is suitable for clinical use as well. (5) A random switching condition in which subjects read the color word of some items and name the ink color of other words—designated by being enclosed in boxes—is part of the *California Stroop Test* (Delis, Kaplan, and Kramer, 2001). (6) Scoring may be by time, error, both, or the number of items read or named within a specified time limit (Golden, 1978). Some other names for commercially available Stroop formats are *Modified Stroop Test* (Spreen and Strauss, 1998); *Stroop Color and Word Test* (Golden, 1978); *The Stroop Neuropsychological Screening Test (SNST)* (Trenerry et al., 1989). Norms appropriate for response in sign language have been developed for the Stroop Color and Word Test (A.B. Wolff et al., 1989).

I [mdl] prefer the Dodrill format for a number of reasons, not least of which is that two trials are sufficient for eliciting the Stroop phenomenon of slowing on the color–word interference trial. Of perhaps greatest importance is that it is the longest of formats in current use and, as such, may well be the most sensitive. My experience has been that even patients with significant problems in maintaining focused attention and warding off distractions begin the color–word interference trial with a relatively good rate of speed, but they slow down as they proceed, doing much more poorly on the latter half or quarter of the test.

For example, one TBI patient, a high school educated 35-year-old woman whose reading vocabulary is at the 80th percentile, named 50 color words with no errors in the first minute of Trial II (the interference trial), 41 in the second minute with three errors, 27 in the third minute with no errors, 25 in the fourth minute with three errors, and in the last minute (total time was 301 sec) she named 32 color words, again with three errors. Had the number of items been 100 or less, or the time limited to one minute or even two, this impressive slowing effect would not have appeared and her overall performance would not have been judged to be significantly impaired.

An additional virtue of the Dodrill format is that it is quite inexpensive and the scoring sheets may be copied (see p. 367). Moreover, T.L. Sacks and his colleagues (1991) have developed five equivalent forms. Norms are available for this format as well as those that have been published (Mitrushina, Boone, and D'Elia, 1999).

Test characteristics. The Stroop technique has satisfactory reliability (Franzen, Tishelman, Sharp, and Friedman, 1987; Spreen and Strauss, 1998). Reports of practice effects vary from study to study with some studies showing virtually none but others showing considerable gains on a second administration (McCaffrey, Duff, and Westervelt, 2000b), or even a third one, but not on subsequent ones (Connor et al., 1988; T.L. Sacks et al., 1991). However, Franzen and his group (1987) found practice effects only for the second administration of the word reading trial. A slight reduction in response speed (about 10%) can be expected on the second half of the 176-item (Dodrill format) color–word interference trial but not on the word reading trial, a change in rate ascribed to fatigue (T.L. Sacks et al., 1991). An anxiety arousing testing situation resulted in lowered scores on all three trials of the Stroop Color and Word Test, affecting men more than women (N.J. Martin and Franzen, 1989); and anxiety in TBI patients contributed somewhat to their slower performances but did not fully account for their slowing (Batchelor et al., 1995). A.R. Jensen and Rohwer (1966) reported that in laboratory studies of the Stroop technique women consistently performed better on simple color naming than men, yet N.J. Martin and Franzen (1989) found that, without anxiety-arousing stimuli, men tended to respond a little faster than women on all three trials. However, no male–female differences were found in a large normative study (Ivnik, Malec, Smith, et al., 1996). Slowing with advanced age has been consistently documented (Boone, Miller, et al., 1990; Spreen and Strauss, 1998; Wecker et al., 2000). Age effects may appear most prominently on the color–word interference trial (N.B. Cohn et al., 1984; Daigneault et al., 1992), barely showing up on other trials, if at all.

Neuropsychological findings. Nehemkis and Lewinsohn (1972) found that left hemisphere patients took approximately twice as long as control subjects to perform each trial, but the interference effect was similar for both right and left hemisphere lesioned patients. The Stroop technique is quite sensitive to the effects of closed head injury as even patients with ostensible "good recovery" continue to perform abnormally slowly five months or more after the injury (Stuss, Ely, et al., 1985). However, two to five years following moderate to severe brain injury, patients performed as well as control subjects (Spikman, Deelman, and van Zomeren, 2000). Impaired performance (three trials: reading names, naming colors, and the interference trial) by patients with severe TBI was closely associated with failures on the other attentional tasks and interpreted as reflecting a slowed rate of information processing (Ponsford and Kinsella, 1992). The added requirement of having subjects read some of the color–word items as words while naming the colors of most of these items made this test more sensitive to the subtle attentional deficits of mild head injury patients (Bohnen et al., 1992). Perret (1974) reported slowed performance by patients with left frontal lobe lesions on both Stroop and word fluency tests, with the Stroop test—particularly the color–word interference trials—eliciting the slowing effects most prominently. In contrast, one study reported that right but not left frontal lesions impaired performance (Vendrell et al., 1995). Consistent with the importance of frontal lobe functions, another study found that only bilateral superior medial frontal damage was associated with both increased errors and slowed response times for the interference trial, and that posterior lesions were not associated with any impairment (Stuss, Floden, et al., 2001). Frontal leukotomy patients did not differ from controls on any (of three) Stroop trials (Stuss, 1991a).

Pronounced slowing on the interference trial characterized the performances of mildly and moderately demented patients (Bondi, Serody, et al., 2002; L.M. Fisher et al., 1990; Koss, Ober, et al., 1984), but response slowing in later stage patients tends to be so generalized that the Stroop effect (i.e., interference effect) diminishes. On a happier note, aerobic exercise programs maintained for four months by previously sedentary persons in the 55–70 age range resulted in significantly ($p < .001$) faster performances, even on the very abbreviated 17-item format (Dustman, Ruhling, et al., 1984).

Cautions. This test is unpleasant to take, particularly for patients with concentration problems. I [mdl] therefore always give it last and introduce it by explaining that the patient may find some of it difficult to do but the information it provides is often helpful for understanding the patient's condition. If the patient's attentional problems are sufficiently severe that they have shown up prominently elsewhere in the examination, I may not give the Stroop at all and spare the patient—and myself—the pain.

Visual competence is important. Color blindness may preclude use of this test. Patients whose vision is so hazy that the shape of the words is somewhat degraded will have a decided advantage on the color–word interference task as the interference effect will be diminished (Dyer, 1973).

Stroop Test (Dodrill's Format).[1] This format consists of only one sheet containing 176 (11 across, 16 lines down) color names (red, orange, green, blue) randomly printed in these colors. In Part I of this test, the subject reads the printed word name. Part II requires the subject to report the color in which each word is printed. The times taken to complete the readings are recorded halfway through and at the end, on a sheet the examiner uses for recording the subject's responses. The Part I side of the examiner's record sheet shows the correct word names, the other side has printed in correct order the color names for Part II. This device greatly facilitates the recording of this task since many patients move along quite rapidly, particularly on Part I. Dodrill evaluates the performance on the basis of the total time for Part I, the total time for Part II, and the difference between the total time for Parts I and II (Part II minus Part I) (see Table 9.7). The time at which the subject is halfway through each part, when compared with the total time, indicates whether task familiarity and practice or difficulty in maintaining a set or attention changes the performance rate. A more precise way of documenting response rate changes is to make a slash mark following the color name at the end of each minute. Some patients who have great difficulty doing the interference trial would take longer than five minutes, but Dodrill stops them at ten; I [mdl] stop at five minutes: enough is enough. Dodrill discontinues Part I at five minutes but this would be rare as in well over 200 examinations I have never had a patient take more than three minutes on Part I.

[1]This format may be ordered for $20 a set from Carl Dodrill, Ph.D., 4488 West Mercer Way, Mercer Island, WA 98040. When sending the Stroop material, Dr. Dodrill includes norms based on 100 control subjects, 727 epileptic patients, plus one set from 140 patients in a private neurology practice and one from 160 patients in a "Psychiatric/Neurologic" group. Mean ages for these groups range from 27.66 ± 10.5 to 32.23 ± 13.2; limiting their use with older patients (Dodrill, 1999, unpublished).

TABLE 9.7 Time to Completion (sec)* on Dodrill's Modification of the Stroop Test for Normal Subjects and Three Clinical Groups

	Normal Control (n = *100*)	*Epileptic* (n = *727*)	*Psychiatric/Neurological* (n = *160*)	*Private Neurological* (n = *140*)
Part I (300 ″ max)				
Mean ± SD	88 ± 20	117 ± 46	105 ± 47	120 ± 60
Part II (600 ″ max)				
Mean ± SD	230 ± 71	301 ± 114	266 ± 97	284 ± 121
Part II − I				
Mean ± SD	141 ± 55	176 ± 69	160 ± 64	158 ± 67

*Rounded to nearest whole number
From Dodrill (1999)

Complex Attention Tests

Visuographic tasks

Persons unused to handling pencils and doing fine handwork under time pressure are at a disadvantage on these tests. The great importance that motor speed plays in the scoring, particularly below age 35, renders them of doubtful validity for many low-skilled manual workers and for anyone whose motor responses tend to be slow. They are particularly difficult for elderly subjects whose vision or visuomotor coordination is impaired or who have difficulty comprehending the instructions (Savage et al., 1973). Storandt's (1976) report that half of the total score value of Digit Symbol is contributed by copying speed alone is supported by Le Fever's (1985) finding that copying speed accounts for 72% of its variance. Thus the examiner needs to be sensitive to motor and manual agility problems when deciding to give these tests. However, I [mdl] do give one and sometimes both of the symbol substitution tests to patients suspected of having visual perception or visual orientation problems whose defects might show up as rotations, simplifications, or other distortions under the stress of this task. For example, I typically give a symbol substitution test to patients with known or suspected right hemisphere damage, particularly if it is right frontal, since these patients are most likely to make orientation errors, usually reversals.

Digit Symbol (Wechsler, 1944, 1955, 1981), *Digit Symbol-Coding* (Wechsler, 1997a)

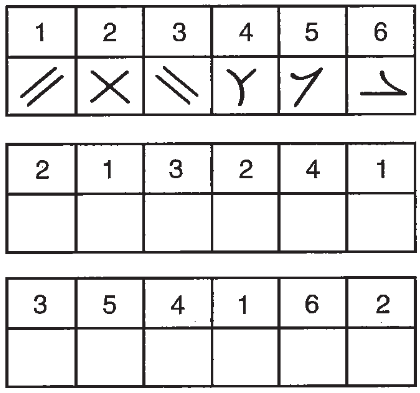

FIGURE 9.10 The symbol-substitution format of the WIS Digit Symbol Test.

This symbol substitution task is printed in the WIS test booklet. It consists of rows containing small blank squares, each paired with a randomly assigned number from one to nine (see Fig. 9.10). Above these rows is a printed key that pairs each number with a different nonsense symbol. Following a practice trial on the first ten (WAIS) or seven (WAIS-R or WAIS-III) squares, the subject must fill in the blank spaces with the symbol that is paired to the number above the blank space for 90 sec or 120 sec for the WAIS-III. The score is the number of squares filled in correctly. Subjects are encouraged to perform the task as quickly and accurately as possible.

To make this test more interpretable when it is given to older persons or others who appear to be motorically slowed, Edith Kaplan, Fein, and their colleagues (1991; Milberg, Hebben, and Kaplan, 1996) have developed the Symbol Copy test in which the subject simply copies the symbol above each empty square into that square, thus bypassing the visual search and shifting and the memory components of this test. In this manner, the Digit Symbol performance can be compared with a somewhat purer visuomotor task to allow evaluation of its more cognitive aspects. Dr. Kaplan and her colleagues also recommended that the examiner note how far the subject has gone at 30 sec and 60 sec as rate changes, particularly at the beginning or toward the end of the trial, may indicate such performance problems as sluggishness in developing a set when beginning a new task or very low fatigue or boredom thresholds.

A variety of format alternatives are described in the literature, such as symbol sets in which the symbols are more or less familiar (e.g., arrow, diamond, or lambda) (Glosser, Butters, and Kaplan, 1977) or sets with fewer symbol pairs (Salthouse, 1978; Teng, Wimer, et al., 1989). Most have been developed with specific research questions in mind. Their clinical usefulness is limited without adequate norms, although they may be applicable to specific cases. Variations on Digit Symbol are provided by the Repeatable Cognitive-Perceptual-Motor Battery in formats in which the symbols are quite similar to the Wechsler format. Comprehensive norms are available in Mitrushina, Boone, and D'Elia (1999) and Heaton, Grant, and Matthews (1991).

Test characteristics. For most adults, Digit Symbol is a test of psychomotor performance that is relatively unaffected by intellectual prowess, memory, or learning (Erber et al., 1981; Glosser, Butters, and Kaplan, 1977). Comparing Digit Symbol with Digit Symbol Copy, the copy component accounted for 52% of the variance for a group of older persons (Joy et al., 2000), and 48% of the variance of performance by a group of veterans with a mean age of 52 years (Kreiner and Ryan, 2001). These findings are consistent with Storandt's earlier report (1976) that half of the total score value of Digit Symbol is contributed by copy speed alone. Motor persistence, sustained attention, response speed, and visuomotor coordination play important roles in a normal person's performance; but visual acuity does not (Schear and Sato, 1989). Learning the paired combinations does not appear to be an important factor (Joy et al., 2000; Kreiner and Ryan, 2001) although incidental memory is another component of this test (see pp. 472–473 for assessment procedures and evaluation). Perceptual organization components show up on this test (A.S. Kaufman, McLean, and Reynolds, 1991; Zillmer, Waechtler, et al., 1992), but a selective attention factor was most prominent for seizure patients (P.C. Fowler, Richards, et al., 1987). The natural response slowing that comes with age seems to be the most important variable contributing to the age differential on this test.

Test–retest reliability tends to run high, with correlation coefficients in the .82 to .88 range (Matarazzo and Herman, 1984; Wechsler, 1981). The level of test-retest reliability varies with different clinical populations, being very unstable for schizophrenics (r =.38) but at the normal adult level for patients with cerebrovascular disorders (G. Goldstein and Watson, 1989). Reliability was near normal levels for people with mild TBI (r = .74) (Hinton-Bayre et al., 1997). Reports of practice effect sizes have varied, probably because they are modest (McCaffrey, Duff, and Westervelt, 2000a), but a small sample of younger (average age in the 30s) control subjects showed a 7% gain on retest following a 15-month interval (R.E. Miller et al., 1984). A change in scaled scores of less than one point was seen in young volunteers retested nearly one year later (Dikmen, Heaton, et al., 1999). Moreover no practice effects appeared when this test was given four times with intervals of one week to three months (McCaffrey, Ortega, and Haase, 1993).

Age effects are prominent (Jarvik, 1988; A.S. Kaufman, Reynolds, and McLean, 1989; Wielgos and Cunningham, 1999), showing up as early as the 30s (Wechsler, 1997a) with raw scores dropping sharply after the age of 60 (Ivnik, Malec, Smith, et al., 1992b). Women outperformed men in the U.S. (A.S. Kaufman, McLean, and Reynolds, 1988) and Canada (W.G. Snow and Weinstock, 1990), but not in France (Mazaux, Dartiques, et al., 1995). Estes (1974) pointed out that skill in encoding the symbol verbally also appears to contribute to success on this test, and may account for the (almost) consistently observed feminine superiority on symbol substitution tasks. Storandt (1976) found no relationship between cognitive ability as measured by WAIS Vocabulary scores and Digit Symbol performances although Digit Symbol and the WAIS-R Vocabulary test were found to be related (r = .50). Education contributed significantly to performances by elderly volunteers (Mazaux et al., 1995) and seizure patients (Kupke and Lewis, 1989). However, Digit Symbol correlations with other WAIS-R tests ranged from .44 to .21 (Wechsler, 1981), suggesting that mental ability does not contribute greatly to success on this test.

Neuropsychological findings. This test is consistently more sensitive to brain damage than other WIS-A tests in that its score is most likely to be depressed even when damage is minimal, and to be among the most depressed when other tests are affected as well. Because Digit Symbol tends to be affected regardless of the locus of the lesion, it is of little use for predicting the laterality of a lesion except for patients with hemi-inattention or a lateralized visual field cut, who may omit items or make more errors on the side of the test form opposite the side of the lesion (Egelko, Gordon, et al., 1988; E. Kaplan, Fein, et al., 1991; Zillmer, Waechtler, et al., 1992). Aphasics typically earn greatly lowered scores due to exceedingly slow but relatively error-free performances (Tissot et al., 1963).

Digit Symbol's nonspecific sensitivity to brain dysfunction should not be surprising since it can be affected by so many different performance components. Failures on this test may be the result of different factors or their interplay, including a sore shoulder, stiff fingers, or a carpal tunnel syndrome. High levels of arousal can result in performance decrements (S.F. Crowe et al., 2001).

This test is extremely sensitive to dementia, being one of the first tests to decline with little overlap with control subjects' scores; and declining rapidly with disease progression (Storandt, Botwinick, and Danziger, 1986; Larrabee, Largen, and Levin, 1985). L. Berg, Danziger, and their colleagues (1984) found Digit Symbol to be a good predictor of the rate at which dementia progresses. It is also one of the few WIS-A tests on which Huntington patients performed poorly before the disease became manifest (M.E. Strauss and Brandt, 1986). Lower scores distinguish patients with rapidly growing tumors from those whose tumors are slow-growing (Hom and Reitan, 1984). Digit Symbol performance is correlated with coma duration in head trauma patients (Correll et al., 1993; B. Wilson, Vizor, and Bryant, 1991) and tends to run below the other WIS-A performances in these patients (Crosson, Greene, et al., 1990). It is likely to be the lowest WIS-A score for chronic alcoholics (W.R. Miller and Saucedo, 1983). Not surprisingly, elderly depressed patients do Digit Symbol slowly, making its use in the differential diagnosis of depression versus dementia questionable, except when a test of incidental learning of the digit–symbol pairs follows the Digit Symbol test (pp. 472–473) (R.P. Hart, Kwentus, Wade, and Hamer, 1987).

Digit Symbol proved to be an effective measure of cognitive improvement in medically treated hypertensives (R.E. Miller et al., 1984). Again, the good news is that for previously sedentary elderly persons Digit Symbol scores improved significantly (an average of 6 raw score points) after aerobic training of three hours a week for four months (Dustman, Ruhling et al., 1984).

Symbol Digit Modalities Test (SDMT) (A. Smith, 1982)

This test preserves the substitution format of Wechsler's Digit Symbol test, but reverses the presentation of the material so that the symbols are printed for the numbers to be written in (see Fig. 9.11). This not only enables the patient to respond with the more familiar act of number writing but also allows a spoken response trial. Both written and oral administrations of the SDMT should be given whenever possible to permit comparisons between the two response modalities. When, in accordance with the instructions, the written administration is given first the examiner can use the same sheet to record the patient's answers on the oral administration by writing them under the answer spaces. Neither order of presentation nor recency of the first administration appears to affect performance (A. Smith, personal communication). As with WAIS and WAIS-R Digit Symbol, 90 sec are allowed for each trial; but there are 110 items, not 100. The written form of this substitution test also lends itself to group administration for rapid screening of many of the verbal and visual functions necessary for reading (A. Smith, 1975).

Test characteristics. The SDMT primarily assesses complex scanning and visual tracking (Shum, McFarland, and Bain, 1990) with the added advantage of providing a comparison between visuomotor and oral responses. Manual speed and agility contribute significantly to SDMT performance, but visual acuity is not an important factor (Schear and Sato, 1989). A significant performance decrement in one response modality relative to the other naturally points to a dysfunction of that modality. In a comparison of symbol-substitution test formats that differed in familiarity of the symbols and whether a digit or symbol response was required, all subjects—normal controls as well as brain impaired patients—performed both the familiar and unfamiliar digit response tests more slowly than those calling for symbol responses (e.g., Digit Symbol) (N. Butters and Cermak, 1976; Glosser, Butters, and Kaplan, 1977). This phenomenon was attributed, at least in part, to absence of an orderly sequence in the symbol stimulus array. Test–retest reliability was .74 in young athletes tested one to two weeks apart (Hinton-Bayre et al., 1997).

The adult normative population was composed of 420 persons ranging in age from 18 to 74 (see Table 9.8). When applied to 100 patients with "confirmed and chronic" brain lesions, these norms correctly identified 86% of the patient group and 92% of the normal population, using a cut-off of ≥1.5 standard deviations below the age norm (A. Smith, 1982). Smith considered scores below this cut-off to be "indicative" and those between 1.0 and 1.5 SDs below the age norm to be "suggestive" of cerebral dysfunction. A cut-off greater than −1 SD gives a somewhat high (9% to 15%) rate of false-positive cases (Rees, 1979). More complete norms are available in the test manual—

TABLE 9.8 Symbol Digit Modalities Test Norms for Ages 18 to 74

Age Group	*Mean Education*	*Mean Written Administration*	*Mean Oral Administration*
18–24 (*n* = 69)	12.7	55.2 (± 7.5)	62.7 (± 9.1)
25–34 (*n* = 72)	13.5	53.6 (± 6.6)	61.2 (± 7.8)
35–44 (*n* = 76)	12.1	51.1 (± 8.1)	59.7 (± 9.7)
45–54 (*n* = 75)	11.7	46.8 (± 8.4)	54.5 (± 9.1)
55–64 (*n* = 67)	11.3	41.5 (± 8.6)	48.4 (± 9.1)
65–74 (*n* = 61)	10.7	37.4 (± 11.4)	46.2 (± 12.8)

Based on studies by Carmen C. Centofanti.

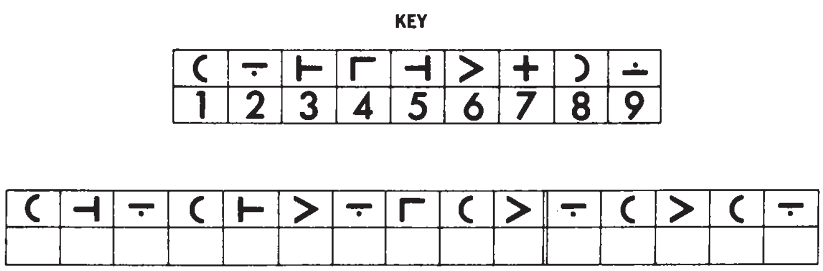

FIGURE 9.11 The Symbol Digit Modalities Test (SDMT). (By Aaron Smith, Ph.D. © 1982 by Western Psychological Services. Reprinted by permission.)

which includes child norms, and in the compilation by Mitrushina, Boone, and D'Elia (1999). Education- and age-corrected norms for people older than 75 have been developed (E.D. Richardson and Marottoli, 1996). Small gains on both the written and oral formats showed up on retesting after an interval of approximately one month with correlation coefficients of .80 and .76, respectively (A. Smith, 1982); with a year-long interval, a reliability coefficient correlation was .78 (W.G. Snow, Tierney, et al., 1988). A small sample (24) of control subjects made a 7% gain on retest after a 15-month interval (R.E. Miller et al., 1984). The trend for small gains shows up on most but not all retest studies (McCaffrey, Duff, and Westervelt, 2000b).

The oral format can be particularly useful with patients whose attentional disorders tend to disrupt ongoing activities, as these patients are apt to skip or repeat items or lines (since no pencil marks guide them) unless they figure out that they can keep track of their place with their finger. These tracking failures provide telling evidence of the kinds of problems these patients encounter when trying to perform their everyday activities. Another virtue of the SDMT format is the three pairs of mirrored figures, which bring out problems of inattentiveness to details or inappreciation of orientation changes.

The norms in Table 9.8 show how early and how rapidly response slowing occurs. Even in an educationally privileged sample ($M = 14.12$ years), men's scores dropped approximately 10% in the fourth decade on both forms of the test, although women's performances remained virtually unchanged during these years (Yeudall, Fromm, et al., 1986). While the female advantage has been documented consistently (A. Smith, 1982; Yeudall, Fromm, et al., 1986), it shrinks when handedness is taken into account, as non-right-handed men do almost as well on the oral format as non-right-handed women who, in turn, do less well than their right-handed counterparts (Polubinski and Melamed, 1986). Educational levels are positively associated with higher scores (E.D. Richardson and Marottoli, 1996; Selnes, Jacobson, et al., 1991; A. Smith, 1982).

Neuropsychological findings. Pfeffer and his colleagues (1981) found the SDMT to be the "best discriminator" of dementia and depression out of a set of eight tests, which included the Trail Making Test plus tests of immediate and short-term memory, reasoning, and motor speed. The average performance of severely injured TBI patients was more than ten points lower than that of controls on the written format, and almost 20 points lower on the oral format, with little overlap between the groups (Ponsford and Kinsella, 1992). MS patients who reported memory problems performed worse on the SDMT than those who did not (Randolph, Arnett, and Higginson, 2001), while the report of memory problems had a weaker association with their performances on memory tests, such as story recall and the California Verbal Learning Test. These comparisons led the authors to suggest that the memory complaints of MS patients represent cognitive domains other than memory (e.g., see Howieson and Lezak, 2002). SDMT scores also correlated significantly with neuroradiologic evidence of caudate atrophy in Huntington patients (Starkstein, Brandt, et al., 1988).

Comparability of Digit Symbol and Symbol Digit Modalities Test

Although these tests tend to be as highly correlated with one another as each is on retesting (.78 for workers exposed to neurotoxins, .73 for their controls [Bowler, Sudia et al., 1992]; .91 for neurology clinic outpatients [Morgan, 1992]), SDMT raw scores run consistently lower than those of Digit Symbol. Both tests can be used to examine incidental learning by having subjects fill in the bottom line (or a blank line on a fresh test form) without seeing the key (see pp. 472–473). Symbol Digit Modalities Test, which allows a comparison of auditory and graphic response speed on a symbol substitution task, and is sensitive to tendencies toward spatial rotation or disorientation, may provide more information than Digit Symbol. When a symbol substitution test is given to patients with pronounced motor disability or motor slowing who will obviously perform poorly on these highly time-dependent tests, their low scores add no new information although qualitative response features may prove informative, and the incidental memory trials always add useful data.

Trail Making Test (TMT)

This test, originally part of the *Army Individual Test Battery* (1944), has enjoyed wide use as an easily administered test of scanning and visuomotor tracking, divided attention, and cognitive flexibility. Developed by U.S. Army psychologists, it is in the public domain and can be reproduced without permission. It is given in two parts, A and B (see Fig. 9.12, p. 372). The subject must first draw lines to connect consecutively numbered circles on one work sheet (Part A) and then connect the same number of consecutively numbered and lettered circles on another worksheet by alternating between the two sequences (Part B). The subject is urged to connect the circles "as fast as you can" without lifting the pencil from the paper.

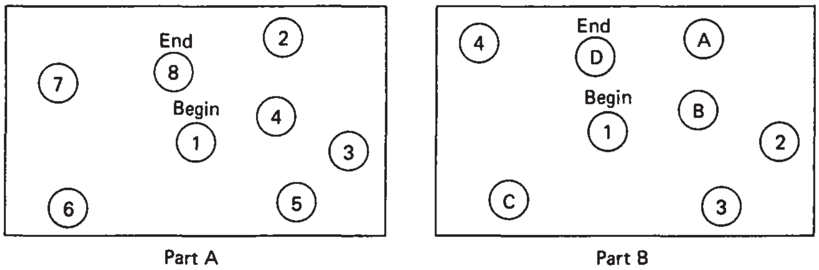

FIGURE 9.12 Practice samples of the Trail Making Test.

Three alternate forms of Part B are offered in the Repeatable Cognitive-Perceptual-Motor Battery (see p. 676). Their comparability to the original format appears to be satisfactory. The *California Trail Making Test* contains five conditions, one of which is similar to the original Part B (see pp. 637–638). One new visual search condition has subjects locate those numbers and letters that have curved parts (e.g., **3**, **D**). Two conditions involve sequencing only numbers or letters where both appear on the page, and one condition involves motor speed in tracing an existing line.

Some administration and scoring procedures for the original version have changed over the years. Originally, the examiner removed the work sheet after three uncorrected errors. Each trial received a score on a 10-point scale, depending on the amount of time taken to complete it. Armitage (1946) changed this procedure, allowing the patient to finish regardless of the number of errors but accounting for the errors by giving a score of zero to performances in which errors were left uncorrected. Reitan (1958) made further changes, requiring the examiner to point out errors as they occur so that the patient could always complete the test without errors and to base scoring on time alone. Spreen and Strauss (1998) provide very detailed administration instructions. It is unnecessary and probably unkind to allow a trial to continue beyond five or even four minutes.

The scoring method introduced by Reitan is the one in most common use today. However, the price for a simplified scoring system may have been paid in diminished reliability, for the measured amount of time includes the examiner's reaction time (in noticing errors) and speed in pointing them out, and the speed with which the patient comprehends and makes the correction. This method penalizes for errors indirectly but does not control for differences in response times and correction styles that can conceivably result in significant biases in the time scores obtained with different examiners (see W.G. Snow, 1987b). A difference score (B − A) essentially removes the speed element from the test evaluation. This score correlates highly with scores on other mental ability tests (e.g., WIS-A) and with severity of cognitive impairment (Corrigan and Hinkeldey, 1987). Mitrushina, Boone, and D'Elia (1999) report test norms for adults, as do Heaton, Grant, and Matthews (1991). Stuss, Stethem, and Poirier (1987) offer a compilation of adult norms; and norms for older adults have also been developed (Ivnik, Malec, Smith, et al., 1996; E.D. Richardson and Marottoli, 1996).

Test characteristics. This test of complex visual scanning has a motor component such that motor speed and agility make a strong contribution to success (Schear and Sato, 1989; Shum, McFarland, and Bain, 1990). Like most other tests involving motor speed and attention, the Trail Making Test is highly vulnerable to the effects of brain injury (Armitage, 1946; Spreen and Benton, 1965). When the number of seconds taken to complete Part A is relatively much less than that taken to complete Part B, the patient probably has difficulties in complex—double or multiple—conceptual tracking. Korrte and colleagues (2002) found that performance on Part B is sensitive to cognitive inflexibility to a modest degree as Part B scores correlated more highly with the Wisconsin Card Sorting Test perseverative errors than with digit span, letter fluency, or memory test scores. However, Part B also correlates very highly with Part A, which argues against cognitive flexibility being the primary determinant. Many patients with mild brain dysfunction will not have difficulty on this test (Nilson et al., 1999).

In general, reported reliability coefficients vary considerably, with most above .60 but several in the .90s and more in the .80s (Spreen and Strauss, 1998). A low reliability coefficient ($r = .36$) comes from schizophrenic patients on Part A; a very high one ($r = .94$), also on Part A, was generated by a group of neuropsychiatric patients with "vascular disorder" (G. Goldstein and Watson, 1989). With few exceptions, some improvement is typically registered for both TMT parts on retesting (Dikmen, Heaton, et al., 1999; McCaffrey, Duff, and Westervelt, 2000b); yet only improvement on

Part A is likely to reach statistical significance because group variances for Part B tend to be very large (e.g., Leininger, Gramling, et al., 1990). As an exception, no practice effect was observed in one study when the second administration occurred one year later (M.R. Basso, Bornstein, and Lang, 1999). With four successive examinations spaced a week to three months apart, Part B showed significant practice effects, although the gains made in the third testing were lost three months later on the fourth examination (McCaffrey, Ortega, and Haase, 1993). The distribution of scores on this test has a positive skew such that use of cut-off scores may be more appropriate than standard scores (Soukup, Ingram, Grady, and Schiess, 1998).

Normative data vary markedly according to characteristics of the normative samples (Mitrushina, Boone, and D'Elia, 1999; Soukup, Ingram, Grady, and Schiess, 1998). Mitrushina and her colleagues recommend care in selecting the most appropriate data set for clinical comparisons. For example, performance times increase significantly with each succeeding decade (Ernst, Warner, et al., 1987; Stuss, Stethem, and Poirier, 1987). In healthy volunteers the age effect is large on component skills (visual search, sequencing, and motor speed) and not dependent on the switching component (Salthouse, Toth, et al., 2000; Wecker et al., 2000). Education, too, plays a significant role in this test (Bornstein, 1985; Ernst, 1987), these effects showing up more strongly on Part B than Part A (Stuss, Stethem, Hugenholtz, and Richard, 1989). Bornstein and Suga (1988) documented the biggest differences between subjects with a tenth grade education or less and those with 11 years or more of formal education. Women may perform somewhat slower than men on Part B (Bornstein, 1985), particularly older women (Ernst, 1987).

Interpretations of TMT performances have typically rested on the assumption that the circled arrangement of symbols on the two test forms calls upon response patterns of equivalent difficulty. To the contrary, Fossum and his coworkers (1992) showed that the spatial arrangements on Part B are more difficult; i.e., response times become slower on Part B even when the symbols are the same as those of Part A as the Part B pathway is 56 cm longer and has more visually interfering stimuli than Part A (Gaudino et al., 1995).

Neuropsychological findings. Both Parts A and B are very sensitive to the progressive cognitive decline in dementia (Greenlief et al., 1985), so much so that Storandt, Botwinick, and their colleagues found that Part A alone contributes significantly to differentiating demented patients from control subjects (1984) and that it documents progressive deterioration, even in the early stages of the disease (Botwinick, Storandt, et al., 1988). The elderly persons who perform poorly on Part B are likely to have problems with complex activities of daily living (Bell-McGinty et al., 2002). Both parts of this test are highly correlated ($r_A = .72$, $r_B = .80$) with caudate atrophy in patients with Huntington's disease (Starkstein, Brandt, et al., 1988).

TMT performances by patients with mild TBI are slower than those of control subjects, and slowing increases with severity of damage (Leininger, Gramling, et al., 1990). However, the large variances on TMT-B keep apparent group differences from reaching statistical significance (e.g., 16+ sec on Part B between mild and more severely concussed patients in the Leininger study; the same difference between mildly injured patients and control subjects in Stuss, Stethem, Hugenholtz, and Richard, 1989). Two to five years following moderate to severe TBI, patients were slower on Trails B than control subjects, although differences between these groups did not show up on the PASAT or the original Stroop format (Spikman, Deelman, and van Zomeren, 2000). Both Parts A and B contributed significantly to prediction of degree of independence achieved in their living situations for a group of moderately to severely injured head trauma patients (M.B. Acker and Davis, 1989).

The kinds of errors made can provide useful information. Among TBI patients, both errors of impulsivity (e.g., most typical is a jump from 12 to 13 on Part B, omitting L in an otherwise correct performance), and perseverative errors may occur such that the patient has difficulty shifting from number to letter (Lezak, 1989). McCaffrey, Krahula, and Heimberg (1989) found some of both kinds of errors made by polydrug users 7 days after detoxification, but few of these patients continued to make these errors after another drug-free week to ten days. Errors are not uncommon among normal control subjects. One study found that 12% and 35% of healthy subjects made at least one error on Parts A and B, respectively (Ruffolo, Guilmette, and Willis, 2000). However, in another study all participants who made more than one error had frontal lesions when compared to patients with posterior lesions and control subjects (Stuss, Bisschop, et al., 2001). Electrophysiological measures that appear to be "associated with frontothalamic functioning"—early stages of the Contingent Negative Variation (CNV)—correlated significantly with both TMT-A and -B, lending support to hypotheses linking the TMT to frontal activation (Segalowitz, Unsal, and Dywan, 1992). However, the importance of frontal lesions to impaired TMT performances has been questioned by findings of no significant differences in failure rates between patients with frontal lesions and those whose lesions were retrorolandic (Reitan and Wolfson, 1995a).

Emotionally disturbed patients, as suggested by elevated scores on the Minnesota Multiphasic Personality Inventory (MMPI), tend to perform more poorly than persons whose emotional status scores are not elevated (Gass and Daniel, 1990). No differences on TMT scores appeared between hospitalized schizophrenic and depressed patients, although the performances of patients with and without brain damage were clearly distinguishable (Crockett, Tallman, et al., 1988). On TMT-B depression has a slowing effect which interacts with the slowing of aging such that elderly depressed patients require a disproportionately greater amount of time to complete the test than emotionally stable elderly subjects or depressed younger ones (D.A. King et al., 1993).

The TMT's clinical value does not rest on what it may contribute to diagnostic decisions. Visual scanning and tracking problems that show up on this test can give the examiner a good idea of how effectively the patient responds to a visual array of any complexity, follows a sequence mentally, deals with more than one stimulus or thought at a time (Eson et al., 1978), or is flexible in shifting the course of an ongoing activity (Pontius and Yudowitz, 1980). When patients have difficulty performing this task, careful observation of how they get off the track and the kinds of mistakes they make can provide insight into the nature of their neuropsychological disabilities.

Color Trails (Maj et al., 1993)

Because the TMT format requires good familiarity with the English alphabet, this sensitive test cannot be given to persons whose written language is not based on this alphabet. In order to capitalize on the value of the TMT format as a neuropsychological test, this version uses color to make a nonalphabetical parallel form of the test for use in cross-cultural World Health Organization studies. In Color Trails-1 subjects are given a page with scattered circles numbered from one to 25, with even-numbered circles colored yellow and odd-numbered ones colored pink. The task is the same as TMT-A, requiring the subject to draw a line following the number sequence. Color Trails-2 also presents the subject with a page containing 25 circles, but on this sheet each color set is numbered: to 13 for the yellow odd numbers, to 12 for the pink even ones. The task is to follow the number series with a pencil but to alternate between the two colors as well (**1Y-1P-2Y**, etc.). Correlations with the two forms of the TMT are .41 and .50 for Color Trails 1 and 2, respectively. TMT-B and Color Trails-2 correlated better ($r = .72$) when the participants were older and had higher levels of education. This format discriminated HIV^+ and HIV^+ subjects well ($p < .001$). Normative data are available for Latinos (Pontón, Gonzalez, et al., 2000) and Chinese (T.M. Lee and Chan, 2000).

Everyday attention

Most everyday activities are dependent on intact attentional mechanisms for directing attention, dividing attention when necessary, and sustaining attention until an activity is complete. Many so-called memory problems are actually problems with attention (Howieson and Lezak, 2002), including the familiar complaint of being unable to recall the name of a recently introduced person—or, worse yet, the name of someone known well.

Test of Everyday Memory (TEA) (I.H. Robertson, Ward, Ridgeway, and Nimmo-Smith, 1994, 1996)

Attention is assessed with activities that are meaningful to patients, such as searching maps, looking through telephone directories, and listening to lottery number broadcasts. The eight tasks measure selective attention, sustained attention, attentional switching, and divided attention. Normative data are presented for 154 adults (J.R. Crawford, Sommerville, and Robertson, 1997). In a study of patients with severe TBI, the Map test of the TEA and a modified Stroop test distinguished the patients from control subjects better than did the Symbol Digits Modalities Test or the PASAT (Bate et al., 2001)