of neuropsychology, the nomenclature can be confusing. "Frontal lobe tasks" and "executive function tasks" are often used interchangeably, although the frontal lobes encompass many functions in addition to those considered executive. Deficits in executive function-related behaviors, typically occur following damage to the frontal lobes, although damage to other areas of the brain may result in similar deficits (Baddeley, Della Sala, Gray, Papagno, & Spinnler, 1997). A wide range of deficits are seen in patients with frontal lesions, including difficulties in planning and carrying out the activity sequences that make up goal-directed behaviors. Other constructs of ability domains thought to be representative of executive functioning are working memory, self-monitoring and self-regulating, inhibiting irrelevant stimuli, shifting between concepts or actions, generating and applying strategies, temporal planning, and recruiting or integrating multimodal inputs from throughout the brain. 

Examining executive function in individuals with brain injury: A review

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Background: Patients with aphasia resulting from a stroke may exhibit cognitive executive function impairments, in particular, may be critical to the clinician's understanding of the clinical and language abilities of these patients. This review will address the definitions and measurement of executive function as well as studies of cognitive processes that are typically assessed in aphasia. The purpose of this review is to provide a framework for understanding executive function in aphasia and to guide future research on this topic.

Aims: This review explores the definition of executive function, describes tests of executive function, and makes recommendations regarding their use in populations with aphasia. The review will also discuss the diversity of executive function constructs discussed in the literature, and there is little agreement as to what processes each executive function test measures. In the present paper, a new framework is proposed to help identify domains of executive function that seem to require similar cognitive processes. The framework is based on a literature review of the test results and correlates of executive function measures. The domains of their descriptions are compared, and the tests are described in each domain.

TABLE 1

<table>
<thead>
<tr>
<th>Domain</th>
<th>Description of cognitive demands</th>
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<tr>
<td>Planning, scheduling, strategy use and rule adherence</td>
<td></td>
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<tr>
<td>Generation, fluency, initiation</td>
<td></td>
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<tr>
<td>Shifting and suppression</td>
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<tr>
<td>Concept formation and abstract reasoning</td>
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</tr>
<tr>
<td>Interests</td>
<td>Sensitivity is the ability to detect dysfunction or damage, whereas specificity refers to the differentiation of one location of damage from another</td>
</tr>
</tbody>
</table>

Conclusions: Proposed classification system for executive function assessment

Although few executive function tests are currently appropriate for use in a language-disordered population without modifications, many have potential. In order to advance the understanding of the cognitive processes involved in executive function, it is important to develop a clear definition of the construct. The tests reviewed here may be helpful in assessing whether cognitive impairment exists in addition to the language dysfunction in those with aphasia.
Executive function has primarily been thought to rely on neural activity in the frontal cortex, particularly the prefrontal cortex (Fuster, 1997). This has led to the development of executive function tests, which are designed to assess the ability to manage and adapt cognitive processes in complex and dynamic situations. These tests often require individuals to plan, organize, and monitor their behaviors, skills that are critical for everyday functioning.

Theories of executive function are diverse, and the construct is often defined in terms of its relationship to other cognitive functions. Some theories emphasize the role of the prefrontal cortex in executive function, suggesting that tasks involving executive function are more likely to activate this region of the brain. Other theories argue that executive function is a more general construct that encompasses a range of cognitive processes, including attention, working memory, and decision-making.

Despite these differences, most theories agree that executive function is a critical component of everyday functioning. Impaired executive function can lead to difficulties in planning, organizing, and completing tasks, and can have a significant impact on an individual's ability to function in daily life. Therefore, understanding the nature and extent of executive function deficits is crucial for developing effective interventions and treatment strategies.

The assessment of executive function is an active area of research, and new tools and techniques are being developed to better understand the nature of these deficits. As our understanding of executive function continues to grow, so too will our ability to develop effective interventions to help individuals with executive function impairments.
EXAMINING EXECUTIVE FUNCTION

The term "executive function" typically refers to the ability to plan, organise, and carry out tasks, and includes abilities such as problem solving, inhibiting impulsive responses, and shifting between tasks. Many tasks that are used to assess executive function are sensitive to damage in the frontal lobes, but the specificity of these tasks has been a subject of debate. Some tasks may be sensitive to damage in the frontal lobes, but nonspecific to other brain regions, making it difficult to determine the exact nature of the impairment. This can be problematic in the design of neuropsychological assessment tools.

One set of observations supporting a regulative role of language in frontal regions is that of a verbal—action dissociation in some patients with frontal damage. Milner (1964) noted that patients with dorsolateral and superior mesial lesions verbalised test instructions before the onset of their actions, indicating that some patients with frontal damage may have difficulty with verbal—action integration. This dissociation can be observed in patients with lesions in the frontal lobes, where the patient may verbalise the test instructions before the onset of their action, indicating a difficulty with verbal—action integration.

There do seem to be differences between frontal lesion patients and those with other brain damage, e.g., increased intracranial pressure (Zangwill, 1966). Other authors have cited the dearth of specific word fluency, Block Design (BD, from the WAIS-III), and the Porteus Maze test (PM), although patients will not typically show deficits on all of them (Stuss & Benson, 1984).

New experimental measures are continually being developed to attempt to refine the sensitivity and specificity of frontal lobe function measures, stating that even performance on the gold standards used in many experimental studies, i.e., the Wisconsin Card Sorting Test (WCST) and the Stroop test, may not be sufficient to accurately assess frontal lobe function. This highlights the need for separation of executive and contributing functions. This can be achieved in part by administering control tasks in addition to executive-level tasks. If a clinician (or experimenter) can discern that a deficit exists in basic or focal processes (outside of prefrontal areas), he or she should be cautious in interpreting the results of executive tests, e.g., if the patient performs poorly on Trails A, performance on Trails B will be more indicative of a prefrontal deficit rather than the general level of impairment actually being measured.

A second issue is sensitivity. Sensitivity is an important element of assessment for the determination of executive function. It is crucial to note that even if an executive task is sensitive, it may not be specific to frontal lobe function. For example, the Stroop test is sensitive to frontal lobe damage, but it is also sensitive to other types of cognitive impairment, such as attentional deficits and poor inhibitory control. Therefore, it is important to consider the specificity of an executive task when assessing frontal lobe function.

In conclusion, while executive function is a complex and important aspect of cognitive function, it is important to consider both the sensitivity and specificity of tasks used to assess this function. This can help to identify the specific nature of executive impairments and guide the selection of appropriate assessment tools.
The challenges of testing the executive function of individuals with aphasia.

There are clearly numerous non-cognitive tests for the measurement of executive function, yet it remains difficult to test aphasic individuals' executive ability. The reason for this difficulty is the complex interaction of all language abilities, particularly in the domain of executive function. Other authors have made comparable suggestions. A study, in which patients with aphasia (across the board) have been shown to perform significantly worse than normal controls, has been conducted. This study found that patients with aphasia, particularly those with aphasia with primarily auditory comprehension deficits, have also shown impairment on complex tasks involving spatiotemporal abilities (Hambley, 1998).

One of the important criteria for a valid test of executive functioning is that it must be sensitive to the examination of nonverbal as well as verbal behaviour. Nonverbal requirements, for instance, may be lower. Comprehensive deficits in aphasia may lead to difficulty in understanding tasks that require complex executive function, such as the Wisconsin Card Sorting Test (WCST). The WCST involves reading events written on cards, while Trails A and B use letters and numbers. Reitan's (1995) comparison of subjects with and without aphasia found lower verbal answers for reading events on the WCST, while Trail A and B showed better performance by aphasic subjects.

Patients with aphasia (across the board) have been shown to perform significantly worse on verbal intelligence and memory tests than normals or right hemisphere lesioned individuals. While some authors seem to suggest that deficits in planning contribute to the aphasic impairment (Costello & Warrington, 1989, as cited in Burgess & Shallice, 1996), the reverse may also be true: impairments in internal language reduce ability to plan or create effective plans. While some studies (Benson, Bales, Rubens, & Kertzman, 1973; Glosser & Goodglass, 1990) have found the Token Test or WAB Auditory Comprehension Commands section (Lezak, 1995) to be more difficult for subjects with aphasia than for normals, some studies have found the WCST to be more difficult for subjects with aphasia than for normals.

The ability to generate, select, and apply strategies is important in execution of executive function. Individuals with frontal lobe deficits have been shown to have impaired strategy generation processes (Burgess & Shallice, 1996; Owen, Downes, Sahakian, Polkey, & Robbins, 1990). Once the patient has been taught cognitive and behavioural strategies to compensate for his/her communication impairment, it is key that the patient generalises the learned methods for circumventing his or her impairments. The reason for lack of ability to generalise, however, if strategy generation is impaired, the patient may be less likely to utilise trained methods for circumventing his or her impairments.

Possible mechanisms for achieving more equitable testing conditions include removing time constraints, simplifying the formal instructions, and modifying tasks administered to subjects with aphasia to mitigate non-task-related effects such as poor instruction comprehension and psychomotor slowing.
Some patients show clear cognitive impairment in addition to their linguistic deficits. It is important to recognize that nonverbal intelligence or executive function deficits in individuals with aphasia may be purely spurious: a consequence of the underlying neurological damage of adjacent areas contributing to language and higher cognitive function, or to disturbances in pathways of blood flow between areas (Maly et al., 1977). In the aphasia literature, the phrase nonverbal intelligence is often used to refer to praxis and conceptual deficits rather than executive functioning. For example, Kertesz and McCabe (1977) found that measuring attention and praxis in individuals with aphasia improved classification and prediction of recovery. Several authors have found evidence that aphasic patients may be impaired on tests of conceptual knowledge deficits, independent of perceptual or linguistic impairments (Bay, 1982; de Renzi, Faglioni, Scotti, & Spinnler, 1972; Sage, Meter, & Hanson, 1980), although Bay (1982) discusses the obstacles to testing conceptual knowledge nonverbally.

The number of studies evaluating the executive attentional resource of subjects with aphasia has increased in recent years. Let’s summarize a few. Studies have shown that patients with aphasia may have less normal attention allocation than normal controls, after the effects of processing speed and word fluency are taken into account (Murray, Holland, & Beeson, 1997). Patients with aphasia are more likely to show a lack of sustained attention and divided attention (Murray, Holland, & Beeson, 1997). Patients with aphasia have worse performance on tasks such as the Tower of Hanoi (TOH) puzzle, which assesses executive function (Dettmers, Grothe, & Spatt, 1994; Gutbrod, Cohen, Mager, & Meier, 1989; Kertesz & McCabe, 1979), verbal fluency (Cohen, Kelter, & Woll, 1989), and working memory (Basso, Capitani, Luzzatti, Spinnler, & Zanobio, 1985; Cohen et al., 1980; Glosser & Goodglass, 1990; Gutbrod, Cohen, Mager, & Meier, 1989, for executive functions).

Evidence is available that individuals with aphasia, assessed nonverbally, have reduced performance on nonverbal tasks (Bay, 1982; de Renzi, Faglioni, Scotti, & Spinnler, 1972; Sage, Meter, & Hanson, 1980). After finding that aphasic subjects with schizophrenia did worse on picture matching tasks when compared to brain-damaged control groups, Cohen et al. (1980) suggested that a general cognitive factor was responsible for the deficit, rather than language impairment per se.

Most studies of intelligence and frontal lobe damage exclude patients with aphasia, while those studies of intelligence in patients with aphasia are limited to primarily nonverbal assessment tests. Nonetheless, some existing research compares aphasic to other brain-damaged groups and controls on intelligence tests. One study compared patients with aphasia (10 with expressive aphasia, 18 with both expressive and receptive aphasia, and 4 with receptive aphasia), patients with brain damage but without aphasia, and controls (with psychiatric diagnoses) on two commonly used intelligence batteries. Both groups with brain damage did significantly worse than the control groups across measures. Between the aphasic and nonaphasic groups, however, the patients with aphasia did worse on the verbal subtests, the Trail Making test (B), and divided attention (Murray, Holland, & Beeson, 1997). Patients with aphasia showed significant difficulties on memory and attention tasks, such as the Continuous Performance Test (CPT), a task requiring sustained attention and selective response to nonverbal stimuli (Glosser & Goodglass, 1990). They modified the CPT to avoid independent language impairment and administered it to nonverbal performances. Comparisons between aphasic and control groups revealed that a general cognitive factor was responsible for the deficit, rather than language impairment per se.

A number of researchers have studied cognition in aphasic populations, examining executive functions, memory, and intelligence. The outcomes of such studies are discussed in this section. Executive function studies, particularly those that examine intelligence, memory, and praxis, are important for understanding the underlying mechanisms of aphasia. While it is clear that individuals with aphasia have deficits in executive function, the exact nature of these deficits remains unclear. Further research is needed to clarify the role of executive function in the production of aphasia.

In conclusion, the role of executive function in the production of aphasia is complex and multifaceted. Executive function deficits are common in aphasic patients, and these deficits may contribute to the overall cognitive impairment seen in this population. Further research is needed to better understand the nature and extent of executive function deficits in aphasic patients and how these deficits may be targeted in intervention programs. 

STUDIES WITH PATIENTS WITH APHASIA

A number of researchers have studied cognition in aphasic populations, examining executive functions, memory, and intelligence. The outcomes of such studies are discussed in this section. Executive function studies, particularly those that examine intelligence, memory, and praxis, are important for understanding the underlying mechanisms of aphasia. While it is clear that individuals with aphasia have deficits in executive function, the exact nature of these deficits remains unclear. Further research is needed to clarify the role of executive function in the production of aphasia.

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planning, problem solving, and rule adherence. Patients with aphasia with nonfluential lesions or Broca's aphasia, with whom the researchers expected to see deficits in the left frontal region, were impaired relative to patients with aphasia with Wernicke's aphasia (left temporal damage). The authors stated that the differences do not reflect language or visuospatial impairments, as the left frontal subjects with aphasia were not significantly more impaired on standard psychometric tests thought to measure auditory comprehension and visual perceptual and constructional abilities. The experimental groups were compared with the results of the WAIS-Revised version. For each test she created accuracy, efficiency, and speed scores. 5

In summary, individuals with aphasia in general may be impaired on visuospatial tasks, which has led to the hypothesis that individuals with aphasia lack the ability to perform certain tasks. However, the results of the study showed that individuals with aphasia were able to perform these tasks well. These findings suggest that individuals with aphasia are able to perform certain tasks, but their performance is impaired compared to individuals without aphasia.

In conclusion, the results of the study suggest that individuals with aphasia may be impaired on visuospatial tasks, but their performance is not significantly different from individuals without aphasia. However, further research is needed to determine the extent of the impairment and to explore the potential causes and implications of these findings.

5 The accuracy variable reflected whether subjects had all the cognitive abilities necessary to complete the structured communication task. The executive function variables were: TOL speed, TOL efficiency, PM speed, PM efficiency, WCST speed, WCST efficiency, WCST perseverative errors, BD speed, and BD efficiency.

6 The accuracy variable reflected whether subjects had all the cognitive abilities necessary to complete the structured communication task.

7 The executive function variables were: TOL speed, TOL efficiency, PM speed, PM efficiency, WCST speed, WCST efficiency, WCST perseverative errors, BD speed, and BD efficiency.
The need for adequate control tasks

In summary, there are conflicting reports of multiple cognitive impairments in individuals with aphasia, which can be attributed to the high number of tasks used in these studies. Some tasks are designed to assess specific cognitive abilities, while others are used to assess overall cognitive function. The choice of tasks is crucial in determining the presence of a specific impairment in aphasia. The selection of appropriate control tasks is essential in assessing executive function in aphasia patients. Without adequate control tasks, it is difficult to determine whether the observed impairments are specific to executive function or are due to other cognitive deficits.

In conclusion, the selection of control tasks is crucial in determining the presence of specific impairments in executive function in aphasia patients. The choice of control tasks should be guided by the specific hypotheses being tested, and the results should be interpreted with caution. Further research is needed to develop a standardized set of control tasks for use in assessing executive function in aphasia patients.

The general construct of “frontal” or “executive” function is frequently applied to tests presumed to measure frontal functions. Some authors attempt a more specific classification,Unique different classification systems are used for the following domains: executive function, generation/initiation, suppression/shifting, and abstract reasoning/concept formulation. Given the lack of agreement regarding the specific domains, the following table includes a brief review of the executive function tests used in this study. The table will also summarise the usefulness of each test in the context of aphasia, rating it on a scale of 1 to 5, with 5 being the most useful. The following table includes a brief review of the executive function tests used in this study. The table will also summarise the usefulness of each test in the context of aphasia, rating it on a scale of 1 to 5, with 5 being the most useful.
summarise each test, and recent research regarding its specificity and sensitivity, where available, will be included, with a richer review of the limitations to testing language-impaired population. In the tables, tests will be organised alphabetically (for quicker review), while in the text they will appear clustered by related methodology.

**TESTS OF PLANNING, SCHEDULING, STRATEGY USE, AND RULE ADHERENCE**

The cognitive processes involved in planning and scheduling seem to overlap highly. For effective planning to occur, a person must be able to comprehend and maintain the goal in mind, while creating subgoals towards that goal. Similarly, scheduling involves creating a temporal order of the individual goals or subgoals to meet certain requirements imposed by the environment (or examiner). Depending on the requirements of the task, rules must be adhered to for effective task performance, while creation/selection and application of strategies can make task performance more effective and efficient. The tests described in this section require one or more of the mentioned components (planning, scheduling, strategy use, rule adherence) for successful completion of the task. Table 2 provides a simple description of each task and summarises its usefulness for testing individuals with aphasia. Tests considered too low in usefulness for aphasic populations to be discussed in detail include the Planning Test (von Cramon, Mathers-von Cramon, & Mai, 1991) due to its low validity, and the Six Elements Test (Levine et al., 1998; Shallice & Burgess, 1991) due to the naming and writing components.

**Multiple Errands Test (MET)**

This recently developed test is challenging to administer, given its environmental requirements. The test is proposed to be more ecologically valid and potentially less structured than most clinical executive function tests (Shallie & Burgess, 1991). The

<table>
<thead>
<tr>
<th>Test name</th>
<th>Description</th>
<th>Usefulness with individuals with aphasia</th>
</tr>
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<tbody>
<tr>
<td>Rey-Osterrieth Complex Figure (ROCF)</td>
<td>In the ROCF, the subject must draw, and then reproduce from memory, a complex geometrical figure. Scoring may be based on number of correct elements or a more qualitative analysis of strategy use in the drawing process.</td>
<td>High: If the scoring is controlled for visual and visuo-spatial deficits, a measure of strategy use could be determined that reflects executive function in individuals with aphasia.</td>
</tr>
<tr>
<td>Tinkertoy Test (TTT)</td>
<td>The TTT is a test of initiation and planning in which subjects create an object from tinker toy pieces. Scoring is based on organisation, creativity, planning, and impulsivity criteria.</td>
<td>Moderate: The TTT would be useful for patients without significant hemiparesis and may need a change in scoring to reduce verbal output requirements.</td>
</tr>
<tr>
<td>Tower of London (TOL)</td>
<td>The TOL is a test of planning in which subjects move three rings from a starting position to a goal position in a limited number of transfers. Scoring is based on moves and time to completion.</td>
<td>High: There do not seem to be verbal requirements to this task; however, achieving a goal based on ring colour (as well as position) could be problematic to those with aphasia.</td>
</tr>
<tr>
<td>Tower of Hanoi (TOH)</td>
<td>Like the TOL, the TOH requires transfer of rings from a starting peg to specified goal positions. The disks vary in size, rather than colour, and require use of a stacking rule based on size. Scoring is based on moves and time to completion.</td>
<td>High: Individuals with aphasia should be able to complete the task without involving linguistic processes. The timing element of scoring may need to be dropped or adjusted for thought process slowing due to general brain damage.</td>
</tr>
<tr>
<td>Virtual Planning Test (VIP)</td>
<td>The VIP requires subjects to organise a number of events into a specified period of time. Events can be constrained or unconstrained by the time framework.</td>
<td>High: Requires extensive reading and keeping track of multiple bits of written information.</td>
</tr>
<tr>
<td>Visual Search Test (VST)</td>
<td>Subjects performing the VST must locate a token hidden beneath one of n blue boxes (on a computer screen). Measures include a strategy score and between- and within-search errors.</td>
<td>High: Individuals with aphasia should be uncompromised on the visual abstract objects condition.</td>
</tr>
<tr>
<td>Wheelbarrow Assembly</td>
<td>The Wheelbarrow Assembly task requires subjects to assemble a wheelbarrow based on written or verbal instructions within 45 minutes. Ratings of skills and emotional factors are completed by the examiner.</td>
<td>Moderate: The instructions may be difficult to read or comprehended by individuals with aphasia. Those with greater hemiparesis would not be able to perform the bimanual, fine motor movements required.</td>
</tr>
</tbody>
</table>
The scoring system is somewhat subjective, and has low but significant reliability on retesting. The TT requires minimal motor coordination, making it possible to use with patients who are otherwise unable to perform a task. With the addition of a quantitative physical output measure, the TT should be appropriate for use with those individuals with aphasia without hemiparesis.

Porteus Maze Test (PM)

This test is thought to require planning and forethought, as well as motor speed and dexterity. The patient is required to construct a series of moves to connect start and goal positions on a maze-like figure. There is limited instruction, and no context or feedback is provided. The test is untimed, and the patient is given a set number of moves to complete the task. The scoring system is based on the number of errors made, and the time taken to complete the task. The PM is less sensitive to executive function deficits than other office-administered tests, as it is not affected by the patient's physical or cognitive abilities.

Tinkertoy Test (TTT)

This test was developed by Lezak (1995) to be a less structured test of planning and strategy use. It is a block-building task in which the patient is given 50 pieces of standard tinker toys and asked to arrange them to make a cube. The test requires more flexibility in the construction of the cube, and may have more sensitivity to executive function deficits than other office-administered tests. One study found that it correlated well with the WCST and the Trail Making Test (Maunder & Lezak, 1995). The scoring system is somewhat subjective, and has low but significant reliability on retesting. The TTT requires minimal motor coordination, making it possible to use with patients who are otherwise unable to perform a task. With the addition of a quantitative physical output measure, the TT should be appropriate for use with those individuals with aphasia without hemiparesis.

Tower of London (TOL)

The TOL is generally well accepted as a measure of planning. In order to move the rings from the starting position to the goal position in a limited number of moves, the patient must plan ahead in a series of subgoals, following a plan and monitor and change the plan as necessary. The test can be administered in its original disk-pegboard format or via computer where the display appears as coloured balls and virtual pegs. One study showed that the reliability and validity of the TOL for frontal lobe functions was sufficient for a clinical assessment measure (Humes, Welsh, Retzlaff, & Cookson, 1997). Despite the reportedly weak reliability of the test, it has been used in numerous experimental studies. Patients with frontal damage, particularly in the left prefrontal cortex, tend to be impaired on the TOL (Molnar, 1964; Shallice, 1982; Shallice & Burgess, 1991). Additionally, neuropsychological studies using fMRI and PET techniques have found activations of left, right and bilateral DLPFC while subjects performed the TOL (Baker et al., 1996; Morris, Ahmed, Syed, & Tonne, 1996; Rezza et al., 1998). The TOL tends to load on a separate factor from other executive function tests, suggesting it has unique demands from other executive function tests. The TOL is generally well accepted as a measure of planning, but its reliability and validity as a clinical assessment measure are insufficient for a clinical assessment measure (Humes, Welsh, Retzlaff, & Cookson, 1997).
moderate to severe alexia. Perhaps if the test was modified to have nonverbal (pictorial) stimuli of the activities to be performed, it could be tested with individuals with aphasia.

The test itself does not appear to make large linguistic demands—no verbal output is required and the instructions are relatively simple to comprehend. Verbal mediation could benefit performance to the extent that the construct of executive function relies on language mediation. The requirement of using the colour of the rings to create the solution may be problematic due to colour conceptualisation difficulties that some individuals with aphasia evidence (Ren et al., 1997).

The VST may seem at first glance to be primarily a visuospatial measure, like the Rey Figure. The authors (Owen, Downes, Sahakian, Polkey, & Robbins, 1990), however, have pointed out that formal components or patients, who might be sensitive to the lack of strategy use in frontolimbic excisions, were more impaired on the typical search tasks. In the difficult VST condition, error measures correlated with the extent to which patients used a strategy in their search. The frontal group was more impaired on the difficult subsets, and the increase in errors was related to an inability to utilise strategic processes from spatial working memory processes in the frontal patients. The test does not have norms for use with executive function appears to be bound. Were validity and sensitivity of the TOH to frontal system dysfunction has been noted (see Goel & Grafman, 1995). Goel and Grafman (1995) found that patients with prefrontal cortex resections (from tumour, epilepsy, ACoA clips) and 25 normal controls matched for age, education, sex, handedness, NART, and verbal IQ from the WAIS-R. They found that patients, who made more errors in several categories, involving time-specific and time-nonspecific activities, broken down into whether the items were absent or in the wrong order. There are also measures of conflict resolution difficulties. The total score correlated significantly with the Trail Making Test B–A difference score, suggesting a switching component in common between the two tests. Also, the testing of executive function (i.e., the WCST, Verbal Fluency and the Trail Making Test), the length of move sequences to be planned is thought to place a greater load on working memory (Humes et al., 1997).

The sensitivity of the TOH to frontal system dysfunction has been noted (see God & Marjoribanks, 1999). The TOH was used as a measure of executive function in the prefrontal cortex resection patients and 25 normal controls matched for age, education, sex, handedness, NART, and verbal IQ from the WAIS-R. They found that patients, who made more errors in several categories, involving time-specific and time-nonspecific activities, broken down into whether the items were absent or in the wrong order. There are also measures of conflict resolution difficulties. The total score correlated significantly with the Trail Making Test B–A difference score, suggesting a switching component in common between the two tests. Also, the testing of executive function (i.e., the WCST, Verbal Fluency and the Trail Making Test), the length of move sequences to be planned is thought to place a greater load on working memory (Humes et al., 1997).

The Wheelbarrow Assembly may seem to have greater face validity than typical clinical tests. Ratings both of cognitive (e.g., organisation) and emotional (e.g., coping with frustration) processes may provide valuable qualitative information to treatment providers.

Another concept that has been included as an executive function in the literature is that of generation (initiation) or fluency. Tests of this concept typically require the participant to generate as many words or designs as they can within a time limit while monitoring heavy reading demands of the VIP.

*12 However, an unpublished study by Shallice & McCarthy found that the executive suppression did not impair the performance of normals on the task.*
to prevent the repetition (perseveration) of previously generated items. The test demands are similar to those of the Ruff Figural Fluency Test, although the former has more structured conditions, and the Free condition is scored using a different formula. The test is sensitive to frontal lobe dysfunction, and scores are often lower in patients with brain damage than in healthy controls. The test is also sensitive to the effects of Alzheimer's disease and other dementias. The test has been shown to be a valid measure of executive function and can be used to assess the severity of cognitive impairment in patients with brain damage.

In conclusion, the Design Fluency Test is a useful measure of executive function, particularly in patients with brain damage. The test is sensitive to the effects of frontal lobe dysfunction and can be used to assess the severity of cognitive impairment. The test is also sensitive to the effects of Alzheimer's disease and other dementias. The test is a valid measure of executive function and can be used to assess the severity of cognitive impairment in patients with brain damage.
use of other design fluency tests with individuals with aphasia (see earlier), although the time constraints of the other measures may need to be removed or compared to norms of groups with similar motoric slowing.

Sequence Generation Test (SGT)
In this task, the participants generate three-number sequences using a computer keypad, somewhat like a random number generator. The test measures perseverations and perseveration distance, and also may assess response to feedback, as a tone sounds each time a perseveration occurs. In the Glosser and Goodglass (1990) study, groups with lesions to the right frontal, left frontal, and right posterior regions produced significantly more perseverations than the normal controls and left posterior group during the later trials of the task. The perseverative error measure correlated with the WCST, PC, and BD scores and with naming and auditory comprehension scores. As with the GPG, the correlations suggest that there are multiple processes involved in performance on this test, including visuospatial and linguistic (i.e., using numbers). The test seems useable with individuals with aphasia; however the scores will not be independent of language impairment and may not add any nonredundant information. Therefore the other nonverbal fluency tests may be better choices for measuring initiation/fluency and perseverations.

TESTS OF SHIFTING AND SUPPRESSION
The ability to shift attention from one goal to another (e.g., as measured by Trails B) has long been a hallmark of executive function. An additional necessary component to successful behavioural responding is suppression of habitual responses. Clinicians observing patients with executive dysfunction have at times noted distractibility (inability to maintain focused attention and responding to irrelevant environmental stimuli) and at other times perseveration (inability to shift away from inappropriate behaviours). The ability to adequately self-regulate behaviour (i.e., shifting to appropriate responses and suppressing inappropriate ones) is characteristic of intact executive control. Table 4 lists tests thought to tap these important regulatory processes. The Stroop test seems to have limited usefulness for individuals with aphasia, but is included here for review of previous studies in which it was used to such a purpose.

**Trail Making Test B (Trails B)**
Trail B measures sustained attention, shifting, and motor speed. It is generally sensitive to the slowed processing speed often seen with brain damage (Channon & Crawford, 1999). Studies have failed to find differences between frontals and nonfrontals (Channon & Crawford, 1999; Reitan & Wolfson, 1994), suggesting that Trail B may be sensitive, but not specific, to frontal lobe damage. In another study, six out of seven subjects performed normally on Trails B, raising the question of whether it is even sensitive (Tranel et al., 1994). Reitan and Tashesh (1959, p. 258) hypothesised that left hemisphere damage would cause greater impairment on Trails B than right hemisphere damage, due to “impaired ability to perceive and use the symbolic material represented in the content of the test”. However, many researchers and clinicians regard this as a nonverbal test (Burgess et al., 1998).

It seems likely that Trails B could be used with some individuals with aphasia. The measure interpreted should be the Trails B – Trails A time, as the comparison controls for general motor slowing (which in patients with aphasia may be higher-order or a result of using the nondominant hand). Within the test administration instructions is the limitation that the test should not be given to a patient who cannot count to 25. The administrator should make sure the patient can meet this criterion and can adequately complete the practice item before continuing with the Trails B. Even with a smooth test administration, however, the interpretation of the results may be difficult. In Reitan’s (1960) study, patients with aphasia performed much worse on the Trails B than nonaphasic patients (with organic lesions or psychiatric diagnoses), which he interpreted as a deficit in language symbol use, rather than a “frontal sign”.

**Stroop Test**
The Stroop Test assesses the ease with which a person can shift his or her perceptual set to conform to changing demands, and suppress a habitual response in favour of an unusual one (Spreen & Strauss, 1998). The test seems to be sensitive to brain disease, including schizophrenia, Parkinson’s disease, Huntington’s disease, head injury, and severity of dementia, although patients with frontal lesions have been shown to perform normally on it (Stuss et al., 1981, as cited in Tranel et al., 1994). Left frontal damage leads to greater interference effects than other areas of brain damage (Perret, 1974, Regard, 1981, as cited in Spreen & Strauss, 1998). Perret (1974, p. 329) reported that successful performance on the Stroop required the ability to “handle verbal information correctly ... independently of aphasia” which he ascribed to the left hemisphere generally, while the suppression and separation of concepts required frontal lobe contribution. The Stroop Test does not appear to be extremely specific to frontal lobe damage. Functionally, there is support for its utility in tapping into suppression processes. The rapid reading aloud of (written) words required by the test could pose a difficulty for many individuals with aphasia. Even the within-subject nature of the measure may not mitigate the measurement error, as individuals with aphasia with verbal production deficits may be variable in their fluency. Also, perseverative tendencies in aphasia could affect the accuracy of word reading (e.g., the patient would say “red’ regardless of the actual word presented).
TESTS OF CONCEPT FORMATION AND ABSTRACT REASONING

Although this proposed domain of executive function is sometimes relegated to a different construct altogether (Lezak, 1995), the tests listed in Table 5 have a long history of being used to measure executive function.

Wisconsin Card Sorting Test (WCST)

The WCST is one of the most often clinically used neuropsychological tests for assessing executive function. It may be challenging, and often frustrating, to the patient, who receives minimal instruction regarding the goal of the test. The purpose is to assess the ability to form abstract concepts, to shift and maintain set, and utilise feedback (Spreen & Strauss, 1998). This test has been clearly linked to lesions and activations in the DLPFC (Nagahuma et al., 1996), a localisation supported by deficits on it in schizophrenic individuals, who have shown hypoperfusion in the DLPFC. Spreen and Strauss (1998) reported that the WCST requires attention, problem solving, concept formation, working memory, and effective processing of feedback information. The WCST is sensitive to brain damage, although left-right differences remain controversial; it seems that right frontal damage is associated with greater perseveration (Spreen & Strauss, 1998). While the test thus appears sensitive to brain damage and dysfunction, it is reportedly not specific to frontal lobe disruption (Pennington & Ozonoff, 1996) and cannot differentiate between dementia aetiologies affecting frontal cortex (i.e., Huntington’s disease and Dementia of the Alzheimer’s Type; Paulsen et al., 1996). Burgess et al. (1998) considered this a nonverbal task. Although the WCST has validity as a measure of several components of executive function, its functional specificity may not be robust, as other processes must be intact for successful performance. Of particular concern is the conceptual interpretation required to arrive at the categories available for the sort. Research has indicated conceptual disorders in some individuals with aphasia, independent of executive dysfunction (de Renzi et al., 1972). Between this confound and the difficulty of communicating the complex instructions for the task to individuals with aphasia with comprehension deficits, interpretation of the results is problematic. One might expect to see impairments in patients with aphasia with anterior and posterior lesions, but for potentially different reasons.

The Category Test

According to Spreen and Strauss (1998), the Category Test loads on three factors other than intelligence and other neuropsychological measures: (1) symbol recognition/counting, (2) spatial position reasoning, and (3) proportional reasoning. It is sensitive to a variety of disturbances—almost as sensitive as the full Halstead-Reitan battery in detecting neurological damage (Spreen & Strauss, 1998). The test is not specific to a particular brain region (Reitan, 1988; Reitan & Wolfson, 1994; Tranel et al., 1994), although glucose metabolism PET studies found activations in the cingulate, orbitomedial, and dorsolateral frontal during Category Test performance (Spreen & Strauss, 1998). Both aphasic and nonaphasic patients with brain damage or psychiatric disorders performed poorly on the test as well, indicating that the deficit may be seen in brain-damaged patients but is not linked to the language impairment. It may be administered to individuals with aphasia; however, it would be expected that they would perform below the levels of controls. There is no clear interpretation available for such a result. It is already known that patients with aphasia have brain damage; a deficit on the Category Test would neither specify an anatomical localisation nor lead to a definite conclusion regarding loss of a particular function. In addition, the test requires up to 2 hours for completion, making it a lengthy, nonspecific assessment tool.

Raven’s Coloured Progressive Matrices (RCPM)

The RCPM has been shown to correlate strongly with verbal measures of intelligence (Kertesz & McCabe, 1975). Although considered a test of intelligence, logical reasoning, and response selection, the RCPM relies heavily on visuoperceptual skills and is impaired in those with poor constructional praxis (Kertesz & McCabe, 1975). Type and severity of aphasia may play a role in performance on Raven’s tests. In Kertesz and McCabe’s (1975) study, only the patients with aphasia with poor comprehension performed poorly on the RCPM, while van Mourik et al.’s (1992) population of individuals with global aphasia scored low average and below on the Raven’s Progressive Matrices. In contrast, one study found that patients with aphasia did as well as normals on the RCPM (de Renzi & Faglioni, 1965) while another found that patients with aphasia performed more poorly...
than controls but identically to patients with right hemisphere damage (Gainotti et al., 1986, as cited in Lezak, 1995). There is little evidence that this measure is sensitive or specific to frontal lobe damage; no frontal lesioned patients in Bigler’s (1988) study showed deficits. The evidence thus far seems to be conflicting as to whether to expect impairments in patients with aphasia on the RCPM and whether these would fall out by comprehension deficits rather than general severity. The administration of the test seems entirely viable in the language-impaired population, but deficits in constructional praxis and/or visuosperceptual cognition may confound any interpretation of the results with regard to executive-type processes, such as reasoning and response selection. Personal experience with the administration of the RCPM suggests difficulty in some individuals with aphasia with remembering task instructions or in maintaining the task conceptualisation.\(^\text{14}\)

### SUMMARY AND FUTURE DIRECTIONS

This review of executive function and testing of individuals with aphasia is intended to summarise the present state of theory and research. The definition of executive function varies by researcher, although there seems to be a consensus that intact executive functioning is necessary for adequate response to novel and complex environmental demands. The processes required for making the behavioural response include evaluating the situation, creating a goal, generating a plan to reach the goal, translating the plan into action, and self-monitoring and self-regulating the process towards that goal. Additional subcomponents of responding aptly include focusing and sustaining attention, retrieval of information from long-term memory, manipulating information in working memory, temporal sequencing of information, selecting responses and inhibiting responses to distracting stimuli, and suppressing routine behaviours that are not appropriate to the goal. Although localisation of the underlying neural substrates of these multiple processes has not been accomplished, the general area reliably linked to the control of planning and related processes seems to be the dorsolateral region of the prefrontal cortex. Orbital and ventromedial frontal damage can lead to a dysexecutive syndrome, but there appear to be dissociable manifestations of the cognitive deficits attributable to the various frontal subregions. As previous researchers have surmised, in order to advance our understanding of the construct of executive function, it is important to have a clear definition that is independent of frontal localisation. It is likely that with proper neuropsychological control tasks and better spatial resolution in neuroimaging, there will be a convergence of function and localisation.

As a clearer working definition of executive function has emerged in the past decade, an impressive quantity of such tasks have come into existence (in the experimental as well as clinical literatures). Many of these tasks are sensitive to brain damage as well as impaired executive functioning, although few seem specific to frontal lobe damage in particular. Their specificity may improve as the elemental sub-processes needed for performing each task, which are controlled by the executive control system, are dissociated during testing.\(^\text{15}\) It may then be possible to localise the control process to frontal areas specifically (although deep white matter damage may always prove problematic to simple interpretations of location). The necessary complexity of executive function tests continues to pose difficulties to interpretation. As others have suggested (Bigler, 1988; Stuss & Benson, 1986), the best way to test executive function is probably through a collection of measures, particularly as multiple domains of function are currently included under this umbrella term. If the presently proposed framework of executive function constructs proves to represent separable cognitive or neural processes, it may be used to guide test selection for sampling the range of executive functions.

The particular problem of testing for executive dysfunction in those with aphasia has been explored in detail here. Of the many acknowledged executive function tests, few are appropriate for use in a language-impaired population without modifications. As Stuss and Benson (1986) noted, the continual changing of task properties has led to a lack of comprehensive norms in the field. It is noteworthy that there is a greater paucity of tests that can be used with individuals with aphasia in some areas of executive function than others (e.g., shifting/suppression), potentially indicating greater areas of reliance on linguistic processes or language needs during testing. The issue of whether some aspects of executive functioning are integrally related to linguistic functioning (via internal speech or verbal mediation) has not yet been resolved. It is a concept that has declined as the focus of research in normal and aphasic populations. At this point, the necessity of internal speech for intact executive control has not been acceptably distinguished from the possibility of the destruction of tissue necessary to both domains of function.

The ability to test effectively for executive dysfunction in patients with aphasia is critical for several reasons. While those with aphasia have not been noted clinically to have the severe executive dysfunctions described following some cases of frontal lobe damage (Saver & Damasio, 1991; Shallice & Burgess, 1991), there are experimental indications that they do not select or generalise strategies well (Purdy, 1992) and may have deficits on specifically modified executive function tests (Glosser & Goodglass, 1990). Such deficits could have a profound effect on their ability to use treatment strategies effectively. Furthermore, reduced capacity for planning, working with memory, and generating strategies could affect their ability to carry out essential daily functions and could compromise their safety (e.g., the observed inability of some individuals with aphasia to place a phone call to the fire department in emergency situations). In this area, there is a need for tests of executive functioning better suited to the language limitations of individuals with aphasia. Future studies should explore the associations between executive function and auditory comprehension, constructional praxis, and daily function in individuals with aphasia.

\(^\text{14}\) Some aphasics were observed to perform initially according to instruction on the task, but then began pointing to the empty space in the test pattern rather than choosing an answer from the selection below the test item.

\(^\text{15}\) That is to say, the patient can be shown to be intact with regard to primary processes (e.g., visuospatial) but impaired on organisation or some complex cognitive element necessary to successful task performance.

### REFERENCES


