

# Domains of cognition and their assessment

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Cognitive performance is typically conceptualized in terms of domains of functioning. These domains are hierarchical in nature, with the bottom referring to more basic sensory and perceptual processes and the top referring to elements of executive functioning and cognitive control. Domains are not independent of each other and executive functioning exerts control over the utilization of more basic processes. Assessments are typically targeted at subdomains of each ability area and careful combination of tasks can reveal patterns of performance consistent with a variety of different neurological and neuropsychiatric conditions. This review covers the general structures of domains, the patterns of impairments across domains seen in common neuropsychiatric conditions, and use of assessment strategies to differentiate, to the extent possible, between different types of conditions manifesting cognitive impairment.

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## Introduction

Typical approaches to the characterization and classification of cognitive performance in clinical neuropsychology refer to domains of cognitive performance. Within each domain there are typically subdomains, which refer to component ability processes within the larger constructs. Individual neuropsychological tests are characterized under these subdomains, with these tests measuring one or more discrete abilities.<sup>1</sup> Although the nature of most of these domains is generally agreed upon, there are clear inconsistencies in the clinical and research literature. Most inconsistencies are in broad domains that may include multiple component processes. Whether these processes belong in more general domains (executive functioning) or a simpler domain (processing speed) is often unclear. The origin of these domains was originally linked (ie, localized) to the areas of the brain in which these processes were seen to be occurring,<sup>2</sup> a perspective that is still important today.<sup>3</sup> Contemporary circuit-based conceptions focus on activation and interaction of these circuits.<sup>4</sup> An additional issue is the intrinsic validity of cognitive domains in populations

other than those with specific regional brain damage, such as caused by stroke, penetrating injuries, or localized (cortical vs frontostriatal) degenerative conditions. For instance, people with schizophrenia and bipolar disorder perform poorly across a wide array of tests that were historically developed for exploring regional brain functions.<sup>5</sup>

## Global structure of cognitive ability domains

There are several ways to conceptualize cognitive ability domains. These include classification by the general process involved, such as memory or attention, language, or executive functioning. Other strategies are based on regional brain functions, derived on the basis of lesion studies, which characterize functions as originating from the frontal lobe, temporal lobe, parietal lobe, hippocampus, or other structures. An additional organizational structure is hierarchical and based on the complexity of the operations. Often referred to as top-down versus bottom-up, the idea is that basic sensory and perceptual operations are least complex and reasoning and problem solving, referred to as executive functioning, are most complex.<sup>6</sup> Thus, executive functioning

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tasks often involve the co-ordination of multiple sensory, perceptual, attentional, and other less complex functions, while simple sensory tasks require minimal higher-level processing. In this paper, we will organize our review of assessment of cognitive domains by the general ability area and will comment in each domain where that domain fits into the structure of top down vs bottom-up and views based regional brain functioning.

*Table I* presents the general organizational structure of cognitive abilities based the types of processes and content of the domains. Each of the domains will be discussed in turn on the basis of performance-based assessments and then observational and self-reported functioning will be reviewed at the end. The focus will be entirely on cognition in humans, although there is an enormous amount of literature on animal cognition as well.

### Sensation and perception

Sensation refers to the ability of a person to detect a stimulus that occurs in one of the five sensory modalities. Thus, tests of intactness of visual, auditory, tactile, gustatory, and olfactory senses fall into this area. As such, tests of visual and auditory acuity fall into this domain. The ability to identify a meaningful stimulus falls under the domain of perception, regardless of sensory modality.

In the domain of perception, sensory information is processed and integrated. One of the concepts of perception is identification of previously experienced objects from sensory information. Perception can be assessed in terms of ability to recognize objects, sounds, and also for the intactness of the perceptual fields. For example, inattention to a full side of a visual field is referred to as “neglect.”<sup>7</sup>

#### Deficits in sensation and perception

Basic sensory impairments have been identified for millennia. Blindness, deafness, and impairments in the other senses can arise from illnesses, experiences, trauma, or congenital abnormalities. For instance, certain physical or brain trauma can result in loss of basic sensory abilities. Impairments in perception can arise from similar origins.

### Cognitive assessment can give clues as to the breadth of any functional deficits and their potential for treatment

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There are a variety of challenges in identification of objects, sounds, tastes, smells, and tactile sensations that can be seen clinically. These include agnosia, defined as the inability to recognize previously identifiable objects, sounds, smells, tastes, and tactile sensations (see Coslett<sup>8</sup> for a detailed description). Within each sensory domain, there are multiple subtypes of agnosia, such as inability to perform sensory-specific recognition of previously experienced or otherwise common stimuli that is not due to impairments in memory or the verbal ability to describe the object. Testing of these deficits is commonly performed with structured recognition tests which are focused in the different sensory modalities after confirmation of basic sensory examinations.

Examples include visual object recognition tests,<sup>9</sup> tactile object recognition tests, auditory recognition assessments, and even assessments of olfactory recognition.<sup>10</sup> Also commonly examined in this domain is the ability to make judgments about the orientation of spatial stimuli.<sup>11</sup>

### Motor skills and construction

#### Motor skills

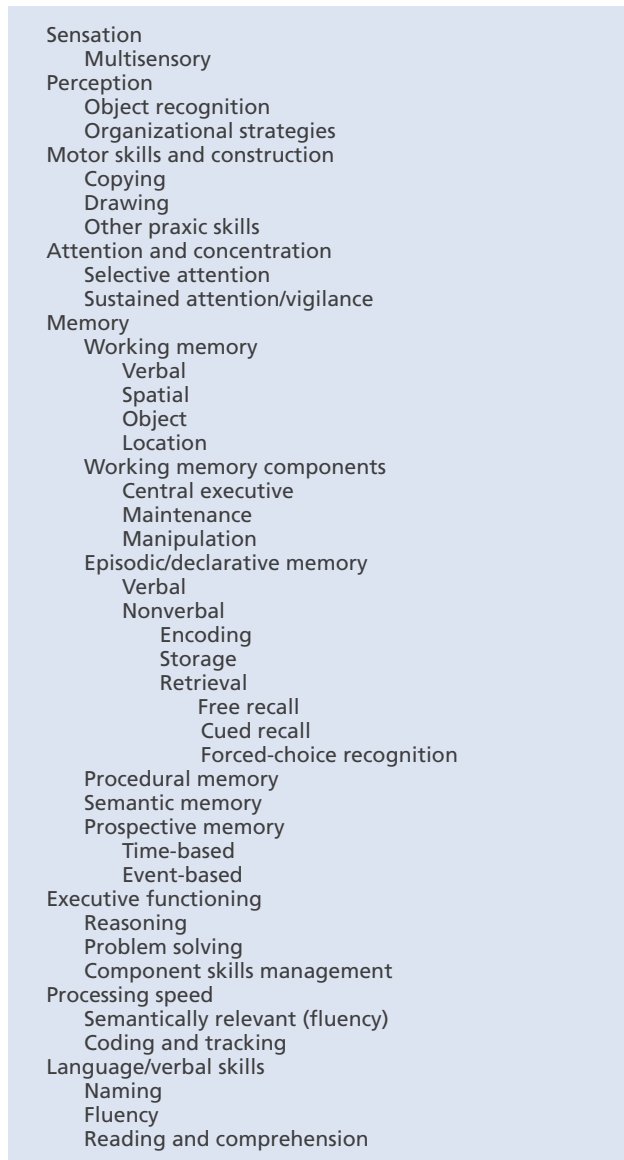
These include several different basic elements of motor activity. They include fine motor abilities, including manual dexterity and motor speed, as well as reaction time, and more global skills such as balance. There are several structured assessments of motor abilities including finger tapping,<sup>12</sup> pegboard tasks, both simple<sup>13</sup> and grooved,<sup>14</sup> and assessments of grip strength.<sup>12</sup> Many of these tasks are used to make global assessments of lateralized brain dysfunction, as they can be performed in identical ways with dominant and nondominant hands. As these tasks have minimal cognitive demands; they are helpful for identification of basic motor skills problems and inability to understand instructions which are a prerequisite for valid assessments of the more complex cognitive abilities described below.

#### Construction

Construction is the ability to either copy or produce drawings of common objects. Some conceptions of visual construction processes group them as perceptual tests<sup>15</sup> and others, such as Lezak et al,<sup>1</sup> group them under tests of motor skills. Further, there is a clear organization component

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Sensation
Multisensory
Perception
Object recognition
Organizational strategies
Motor skills and construction
Copying
Drawing
Other praxic skills
Attention and concentration
Selective attention
Sustained attention/vigilance
Memory
Working memory
Verbal
Spatial
Object
Location
Working memory components
Central executive
Maintenance
Manipulation
Episodic/declarative memory
Verbal
Nonverbal
Encoding
Storage
Retrieval
Free recall
Cued recall
Forced-choice recognition
Procedural memory
Semantic memory
Prospective memory
Time-based
Event-based
Executive functioning
Reasoning
Problem solving
Component skills management
Processing speed
Semantically relevant (fluency)
Coding and tracking
Language/verbal skills
Naming
Fluency
Reading and comprehension

**Table 1. Domains of cognitive functioning: presented as a bottom-up conceptualization.**

which means that the tasks can be seen to have some executive functioning demands as well. Classic construction tests include the copy component of the Rey Complex Figure,<sup>16</sup> as well as other drawing tests that are embedded in other tasks such as the Mini-Mental State Examination (MMSE)<sup>17</sup> or the Montreal Cognitive Assessment (MOCA).<sup>18</sup> Various clock drawing paradigms<sup>19</sup> are also considered to be tests of construction.

Construction deficits are commonly found in individuals with dementia, with right hemisphere damage, or with identified lesions to the parietal cortex.<sup>20</sup> These tests are very appealing because they are very rapidly performed and do not depend on comprehension of the task demands.

### Attention and concentration

Attention and concentration is a multifaceted construct and is generally divided into two global subdomains: selective attention and sustained attention (or vigilance). Concentration would generally fall under the rubric of sustained attention. Divided attention could be viewed as falling under the concept of selective attention. All of these attentional skills have executive functioning components that are described below.

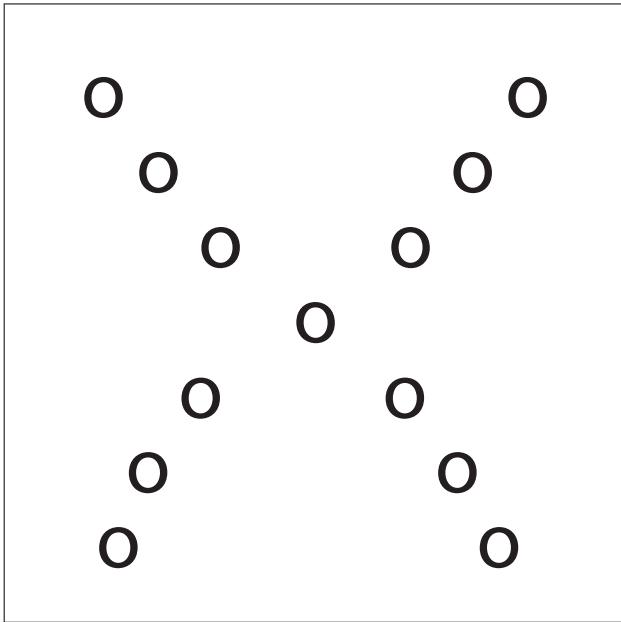
#### Selective attention

This is the process of attending to information that is relevant and important and ignoring other nonrelevant information. Selective attention tasks often provide distracting information and request the examinee to attend specifically to the relevant information. Distractors can be presented in an opposite sexed voice for auditory tasks and otherwise identified as irrelevant (font color, size) for visual tasks.<sup>21,22</sup> An additional selective attention task is the global-local task, where there are two concurrent information streams, a large figure which is typically a letter (global) which is comprised of individual alternative letters. For example, in *Figure 1*, you see a stimulus which is an X, comprised of Os. Typically global stimuli are perceived more rapidly than local stimuli, much like a reader recognizes words more efficiently than their component letters.<sup>23</sup> The ability to respond to instructions to shift focus across global and local properties is a critical feature of this task and is impaired in many populations with problems in attentional control.

An additional selective attention paradigm is dual-task processing.<sup>24</sup> In dual task processing, there are two concurrent information streams, such as an auditory stream and a visual stream, and the participant can be instructed to prioritize processing of one stream, the other, or to attempt to optimize processing of both streams. There are formal indices of the ability to divide attention, which can identify impairments in the ability to divide attention which are common in several neuropsychiatric conditions.<sup>25</sup>

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**Figure 1.** Global-local stimulus.

An additional use of the dual task paradigm is to test component tasks for automaticity. Automatic information processing refers to process that can be performed without apparent resource costs.<sup>26</sup> Thus, when a central task can be performed concurrently to a secondary task without degradation in performance of the central task, then it would be inferred to be automated. Controlled processes, those that require resource costs, can become automated after practice. The development of automatic processing is a critical feature of much complex skill learning, with driving being a primary example.<sup>27</sup> Beginning drivers can tolerate many fewer concurrent tasks while maintaining adequate performance and have the highest rates of accidents.<sup>28</sup> After practice, many functions required for driving become automated and accident rates decline. However, with aging, resource availability typically declines and older drivers are involved in many more accidents than younger experienced drivers. Interestingly, distracted driving is a major cause of accidents in the US and distracted driving is specifically the attempt to perform other tasks while driving. The more complex the secondary task (eg, text messaging compared with using a push-button radio control), the more likely it is to be associated with traffic accidents. A specific assessment of divided or dual task attention is the Useful Field of View (UFOV) task.<sup>29</sup> This task requires detection of central and peripheral

stimuli concurrently. Performance on the UFOV has been shown to predict driving problems and interventions aimed at speed dual-task processing have been shown to reduce accidents in older drivers.<sup>30</sup>

## Sustained attention/vigilance

The ability to sustain attention over time has been referred to as vigilance. Tasks measuring vigilance often require the detection of simple stimuli, presented infrequently in the midst of a stream of other stimuli, with the prototypical task being variants of the continuous performance task (CPT).<sup>31</sup> For instance, detection of an “x” that occurs 10% of the time in a stream of other letters is a prototypical simple CPT. The task can be made more complex by requiring detection of a sequence, such as “A-X” or an identical pair of stimuli, such as “X-X” or “3-3.” Variation in the frequency of the targets can be used to manipulate difficulty. The more common the target, up to about 50% frequency, the easier the task. However, when the target frequency does over 50%, difficulty increases because inhibition of the dominant response to respond on all stimuli is required and even completely healthy people have an increase in errors.

Performance on the CPT is indexed by correct detections, missed target stimuli (errors of omission), and responses to nontarget stimuli (errors of commission). Signal detection indices of  $d'$  (accuracy) and B (Bias) can also be calculated. Different populations make different patterns of errors on the CPT.

## Neuropsychiatric conditions commonly show attentional problems

For instance psychotic populations are commonly associated with increases in errors of omission and reduced  $d'$  without increased errors of commission.<sup>32</sup> Attention deficit hyperactivity disorder (ADHD) is associated with increases in errors of commission and greater B, based on impulsive responses to nontarget stimuli.<sup>33</sup>

High target frequency on the CPT leads to a normal bias to respond to nontargets. Interestingly, people in the schizophrenia spectrum fail to develop this normal bias and do not have an increase in errors of commission with increased frequency of targets.<sup>34</sup> Dual-task processing is particularly impaired in neuropsychiatric conditions, with people with schizophrenia manifesting considerable challenges in dual-task demands. Further, selective attention is also impaired,

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particularly when the selective attention test requires adhering to instructions to ignore some stimuli and respond to others.

### Memory

Memory functioning is the most complex and multifaceted of cognitive domains. There are multiple subdomains and formal assessments have been developed for most of them. We will examine them from the bottom-up perspective that we have adopted to date.

#### Working memory

This is the ability to hold information in consciousness for adaptive use. This can include information from all sensory modalities and includes verbal and nonverbal information. Further, working memory is conceptualized to include two separable components: maintenance of information and manipulation of information.<sup>35</sup>

Maintenance working memory includes memory for verbal information, spatial information, and other information (including emotional) across multiple sensory channels. The prototypical cognitive measure for maintenance working memory is a digit span task,<sup>36</sup> wherein the task is recalling a an ascendingly longer series of digits in order. Similarly, recall of the spatial location of an object<sup>37</sup> is a similar task as is differentiating between an object seen immediately before and a different one that was not seen previously.

There are several critical features of maintenance working memory. Both iconic (visual) and auditory (echoic) storage are duration and capacity limited and processing of new information can lead to the loss of memory currently in storage. Information can be transferred from working memory to longer-term storage, but that process requires either active processing or salience of the stimulus in working memory for encoding. Maintenance working memory can handle information from multiple sensory modalities at the same time and storage capacity of maintenance working memory is capacity limited across all aspects of information. The maintenance of information in working memory requires intact sensation, perception, and attention: information that is never detected consciously may be stored (unconscious processing) but typically cannot be retrieved volitionally although it may be available with the right implicit prompt.

Manipulation working memory refers to the process of operating on information stored in working memory storage. The prototypical manipulation working memory task is digit span backwards, where the participant is asked to recall information in reversed order compared with presentation (“258”→”852”).<sup>36</sup> Variants of this task can include letter number sequencing (rearranging numbers and letters into separate streams (“5B2A”→”AB25”)<sup>38</sup> and letter or number sequencing. Similarly, instructions to recall only portions of information presented can also fall under this category. Paradigms such as this differ from selective attention paradigms with prior instructions, in that partial-recall paradigms involve learning an entire set of information and then recalling only parts of it (eg, a list of colors and animals, then cued to respond with only animals after the list has been presented). Generally, there is a “resource cost” for such operations and typically performance in digits backward is about one item less than performance on digit span forward (6 digits forward = 5 digits backwards). More complex operations, such as storage of multiple items then retrieval of a selected set, have even greater capacity cost.

There are multiple other elements of working memory and working memory assessment strategies. For example, simple spatial stimuli can be assessed with delayed response (DR) paradigms. There is evidence of specialized CNS processing for object, location, action, verbal, and spatial working memory.<sup>39</sup> The fact that many elements of working memory appear to be under higher-level control has led some to assert that working memory is an executive function. While executive functioning itself is quite broadly defined, as discussed below, manipulation working memory is clearly associated with executive functioning. Simple maintenance working memory can be measured in drosophila, whose executive functioning ability is clearly limited.

#### Episodic/declarative/explicit memory

This component of the memory system interacts with working memory storage processes to encode, maintain, and retrieve information into and out of longer-term storage. Again, memory information can be from all sensory types and can also be verbal or nonverbal. Thus, recollection of daily experiences, such as what one did the night before or the content of one’s last meal, is episodic memory. There are multiple terms as noted above and the discussion following applies to all of them. In contrast, memory for the skills

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required to perform activities, such as riding a bicycle, is referred to as procedural memory and is examined below.

There are several components of this type of memory processing. They include encoding, storage, and retrieval, all of which are required for successful memory performance. In these domains, there are multiple important features required for understanding the processes involved. In addition, impairments in different elements of the system can lead to the same general outcome of poor memory output. While many of the principles in these processes are similar across types of information, differences will be highlighted.

### Encoding

This is the process of taking information contained in working memory and processing it for longer term storage. Typical episodic memory tasks<sup>40</sup> involve listening to a list of words or a story,<sup>36</sup> or seeing (or copying) an object<sup>16</sup> or series of objects<sup>41</sup> with the instructions to learn the information with the intent to recall it later. Stimuli can be presented once or more than once. Manipulations involving presentation include selective reminding,<sup>42</sup> which involves presenting only those words not learned on presentation  $x$  on presentation  $x + 1$ . Other presentation manipulations can include interference trials after presentation of the explicit learning trials.

Multiple factors are known affect encoding. On word list tests, semantically organized lists (subsets of animals, colors, etc)<sup>43</sup> are easier to learn and telling the participant that the list is organized also facilitates encoding. For visual learning, familiar and namable objects are easier to learn. Drawing objects makes them easier to recall than simply visualizing them. Manipulations aimed at enforcing semantic encoding (eg, make up a story with these words) lead to more encoding than simple instructions to attend.<sup>44</sup> Further, implicit strategies can facilitate encoding. For instance, asking the participant to evaluate stimuli for various semantic characteristics (living/nonliving) facilitates encoding. Presenting stimuli as a stem to be completed (\_\_\_ imal) facilitates encoding and subsequent recall of information.

Encoding manipulations are important in the context of who is being tested. The Hopkins Verbal Learning Test (HVLT)<sup>40</sup> is a 12-item test with three learning trials, while the Cali-

fornia Verbal Learning test (CVLT)<sup>43</sup> has 16 items and 5 learning trials, although both are semantically organized. The Rey Auditory verbal Learning test (RAVLT)<sup>15</sup> has 15 unorganized items and 5 learning trials. These three tests are considerably different in difficulty which needs to be considered when selecting assessment instruments. The HVLT may be too easy for screening younger populations and the RAVLT may be too hard demanding as a dementia screen in order people.

### Storage

Storage refers to the process of retention of information after encoding. Information successfully encoded can be recalled at fairly long post encoding time periods. Some information is clearly permanent (eg, new vocabulary words). Storage is typically affected only by changes in brain functioning and it has been argued that all information ever learned is stored; and that failures to access are entirely due to retrieval failures.

### Retrieval

There are several different ways that information can be retrieved after encoding. Unprompted free recall refers to simply asking the participant to recall the presented information. An additional strategy for retrieval is to give prompts or cues, such as prompting the semantic category of the information (Tell me all the animals) or providing other semantically relevant cues (it is where people go on Sunday). A final strategy is recognition memory. Typically administered as a forced-choice task, the participant is asked whether the word was present on the list or is a recognition foil. Typically, there are approximately equal numbers previously presented items and recognition foils. These strategies are commonly applied across different versions of verbal and visual-spatial memory tests.

### Procedural memory

This is memory for motor actions or skills. For example, learning and remembering how to ride a bicycle is a procedural memory, as is typing, and other similar actions. Procedural memory can be dissociated from episodic memory, in that individuals with amnesia who cannot recall essentially any verbal information can learn and retain procedural skills.<sup>45</sup> Similar findings have been reported in Alzheimer's disease.<sup>46</sup> Interestingly, the two major compendia for neuropsychological assessment (Lezak et al<sup>1</sup> and Strauss et al<sup>15</sup>) do not list procedural memory in their index sections,

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suggesting that this is an area that is still largely under development and requiring development of more standardized tests.

### **Semantic memory**

This refers to the process of long-term storage of verbal information, often referred to as long-term memory. Such information has been processed through the declarative memory system, and stored. It is of interest that semantic memory appears to remain intact over the lifespan and continue to accrue new information even into late life.<sup>47</sup> Semantic memory is often accessed in the performance of new declarative memory tasks, in that information that is previously stored in semantic memory is more easily attended to, encoded, and recalled for short-term use than completely novel information.

### **Prospective memory**

This is the ability to remember to perform tasks in the future, such as taking medication at scheduled times, performing sequences of functional activities such as preparing meals, and other sequential tasks requiring timing and performance of tasks at specific time periods.<sup>48</sup> Prospective memory operates in two different formats: event-based and time-based. Event-based prospective memories consist of responses that are triggered by a stimulus. An example would be to remember to “take the cake out of the oven when the timer sounds.” Time-based procedural memories are triggered by specific times, such as “take my medicine in the morning.” Prospective memory is implicated in a variety of functional impairments in people with psychiatric conditions.<sup>49</sup>

Procedural memories can additionally be separated into immediate and delayed response prospective memories. Often it is not possible to perform an action at the specific time required or when the cue occurs, because of situational factors. Being able to remember to perform a delayed response to a time or event cue is one of the challenges in prospective memory.

### **Assessments of memory-disordered populations**

While fully addressing this topic is beyond the scope of this paper, assessment strategies can be used to reveal the specific and potentially diagnostic impairments of memory-disordered populations. For instance, in cortical dementia and amnesic conditions encoding, delayed recall, cued recall, and delayed recognition are all impaired, while in

frontostriatal conditions encoding and delayed recall are impaired, but delayed recognition and cued recall are typically spared.<sup>50-51</sup> The same is true for neuropsychiatric populations such as schizophrenia spectrum conditions.<sup>52-53</sup> Further, in amnesic populations with complete impairments in declarative memory, both procedural learning (as described above) and affective memories can be fully spared.<sup>54</sup> In conditions such as schizophrenia, prospective memory<sup>49</sup> is often substantially impaired in addition to the impairments in episodic memory described above. Another substantial impairment seen in neuropsychiatric populations are impairments in working memory, particularly manipulation working memory, including sorting demands, or trying to “look back” to previously presented information in a stream of information held in memory.<sup>55</sup>

### **Executive functioning**

This cognitive domain is also referred to commonly as reasoning and problem solving. The global concept of executive functioning is the set of processes that manifest control over other component cognitive abilities, such that cognitive resources can be effectively utilized to solve problems efficiently and plan for the future.<sup>56</sup> Thus, tasks of problem solving, planning, manipulating mazes, and other complex tasks where management of multiple cognitive abilities are required, fall under the domain of executive functioning.<sup>57</sup> Executive functioning is the definitional set of top-down processes, because effectively using simpler cognitive abilities is required for real-world adaptive success. Thus, executive functioning also requires cognitive flexibility, in that problem solving, particularly of novel tasks, requires consideration of new strategies and rapid rejection of failed efforts. Classical executive functioning tests such as the Wisconsin Card Sorting Test (WCST<sup>58</sup>) require problem-solving in response to feedback. One of the classical failures on the WCST is the generation of perseverative errors, which are errors that arise when the person solving the test should already know from feedback that their response choice will lead to another error.

There are some definitional challenges associated with executive functioning, possibly because of the older notion that executive functioning consists of “frontal lobe” tasks.<sup>59</sup> Thus, other tasks such as working memory, where activation of the frontal lobe has been repeatedly demonstrated, are often designated as executive functioning tasks. An intact

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frontal cortex is certainly critical for performance of executive functions; however, many working memory tasks, such as simple delayed response tasks, involve essentially no problem solving or management of cognitive resources. Following instructions such as ignoring distractors, dividing attention to process one of two concurrent information streams, or following other instructions in processing speed tasks (eg, alternate between letters and numbers) are clearly executive or “cognitive control” demands as described above. Thus, careful assessment strategies are required in order to separate working memory, processing speed, attention, and executive functioning and some of these cognitive abilities may not be clearly separable into one domain or another.

Prospective memory is certainly one of the tasks on the boundary of executive functioning, because of the strong planning component associated with task outcomes. Further, Trail-Making Part B, wherein alternation between letters and numbers is required, is often viewed as an executive functioning task, while dividing attention in response to external instructions has strong executive components as well. A further important element of executive functioning is inhibition/response management. As noted above in the section on attention, failures to inhibit when performing an attentional task are common feature of attention deficit disorders.

Executive functioning is also an ability, like semantic memory, that can be less affected by aging than other ability domains such as processing speed.<sup>60</sup> Large-scale studies of cognition over the lifespan have found increases in wisdom and semantic memory over the lifespan, with decreases in processing speed and working memory span tasks.<sup>47</sup> Thus, the end products of executive functioning tend to accumulate over time, while the cognitive abilities that executive functioning supervises may actually worsen, often to a considerable extent.

### **Populations with executive functioning deficits**

These include ADHD, mental illnesses such as schizophrenia and depression, and obsessive-compulsive disorder (OCD).<sup>61</sup> All of these conditions manifest executive functioning deficits in slightly different ways, with ADHD manifesting impulsivity and inattention, people with schizophrenia showing marked problem-solving and organizational deficits, and OCD patients having very ineffi-

cient cognitive processing. Both cortical and fronto-striatal degenerative conditions also present with severe deficits in executive functioning. In fact, like list learning, free recall, and working memory impairments, executive functioning deficits are shared across these conditions with different CNS etiology.<sup>51</sup>

### **Processing speed**

Processing speed refers to cognitive processing assessments that require rapid performance of tasks that range from very simple to complex. Prototypical processing speed tasks include various coding tasks (Symbol Coding),<sup>62</sup> as well as tasks requiring rapid performance of simple tasks such as connecting numbers or letter sequences such as the Trail Making Test.<sup>12</sup> The critical feature of processing speed tasks is that participants are instructed from the outset to solve the task as rapidly as possible. Scoring is often in terms of elapsed time or number of correct responses. These tasks are intentionally simple, but may have some learning requirements (matching symbols with digits) or executively-oriented performance demands (alternation between letters and numbers).

Processing speed is a particularly important cognitive ability that is the most impaired domain of functioning in several neuropsychiatric conditions. For instance, performance on various coding tasks is not only the most significant impairment in schizophrenia<sup>63</sup> but is also the cognitive ability domain that is most strongly correlated with impairments in everyday functioning. Another critical feature of processing speed is that it tends to be the strongest predictor of overall cognitive performance, on cognitive assessment batteries, loading most highly on single factor solutions of cognitive ability.

Cognitive speed is required for performance of many other tasks, in that even tasks without explicit speed demands have stimuli presented in a fixed rate, such as one word or digit per second in list learning and memory span tasks. If cognitive speed is excessively slow, then performance of “non-speeded” tasks acquire an additional challenge and may lead to challenges in access correct strategies in a timely manner.<sup>64</sup> Populations with challenges in processing speed include major depression, severe mental illnesses, Parkinson’s disease, and both cortical and frontostriatal degenerative conditions.



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## Language skills

Language skills include receptive and productive abilities and the ability to understand language, access semantic memory, to identify objects with a name, and to respond to verbal instructions with behavioral acts. There are multiple characterizations of aphasia, with Lezak et al<sup>1</sup> describing eight different kinds. Language skills are assessed with measures of fluency (eg, name as many animals as possible), object naming, and responding to instructions. Language abilities can be impaired in neuropsychiatric conditions but are much more commonly impaired in conditions involving brain damage, stroke, or degenerative dementia. Some patterns of performance on language tasks differentiate between frontostriatal and cortical dementia. For example, both cortical and frontostriatal conditions adversely impact verbal fluency, but naming deficits are more commonly seen in cortical dementia.<sup>50</sup> Within neuropsychiatric conditions, language deficits may be associated with either deficits in executive functioning (eg, the ability to successfully access semantic storage) or slowed processing speed. By virtue of the fact that fluency tasks are speeded in terms of their instructions, cognitive slowing can have an adverse impact on performance.

## Comments on the validity of cognitive domains

There is considerable evidence that in many populations, including schizophrenia and bipolar disorder, that conventional domains of cognitive dysfunction are not truly separable.<sup>65</sup> The larger the study of the factorial structure of cognitive performance, the more likely it is that a single, global ability factor arises from factor analyses.<sup>66-67</sup> In addition, in healthy individuals, studies that have focused on global abilities have found robust genomic correlates of global cognitive performance defined with both intelligence and neurocognitive tests.<sup>68</sup> That said, the signature of cogni-

tive deficits in cortical dementia vs frontostriatal conditions has been validated in both these neuropsychiatric populations and in other populations such as populations with subjective memory impairment. Most importantly, the rapid forgetting of adequately learned information, specifically defined as lack of perseveration of recognition and cued recall, is a robust finding in populations who have medial temporal lobe brain dysfunction. Cognitive domains should not be viewed as lacking validity if they are intercorrelated. Executive functioning by definition requires the intactness of component cognitive skills. Finding a strong correlation between global executive functioning measures and other tasks that require executive control (eg, selective attention) is actually evidence of the validity of executive functioning.

## Conclusion

Historical domains of cognitive functioning are still examined to this day, but now through the lens of a considerably more information about underlying brain structure and function. Also, brain imaging allows for the differentiation of impairments in different brain regions. As a result, current uses of cognitive assessment are often oriented at identification of patterns of performance that give clues as to the breadth of any functional deficits and their potential for treatment. ■

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