

## **COGNITIVE ASSESSMENT**

### BEING INTENTIONAL IN THE APPROACH

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While a compelling argument could be made that every aspect of cognition is fundamental for supporting health and wellness; there are a few aspects of cognition that have predominately been focused upon that warrant further discussion and clarification. By better understanding some of the broader concepts that underlie the concept of cognition, we can gain a greater appreciation for some of the challenges associated with this area of study.

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**Topics:** Motor Speed — Information Processing — Attention — Cognitive Control — Neural Mechanisms of Control — Declarative Memory — Intelligence — CHC Theory of Intelligence — Psychometric Stability — Sensitivity — Saturation

**Motor Speed** — The time it takes to initiate and complete an intentional movement.

Although tests of motor speed are typically viewed as having minimal cognitive demands, they provide essential information regarding the ability to understand and carryout instructions. Thus, if an individual is unable to complete or has difficulty completing tests of motor speed, it calls into question the validity of being able to assess more complex cognitive abilities. The key issue is that the predominate way of assessing more complex cognitive abilities is through the use of speeded responding and intentional decision making based upon directions. So if an individual is unable to complete the motor movement (such as in the case with populations with motor impairments such as Cerebral Palsy), unable to follow basic instructions, or even if the movement is just slowed then that could impact upon the measurement of more complex cognitive abilities. In some context — typically sports related, motor speed is viewed as critically important to support high level performance.

While there are well-established relationships between the complexity of the stimulus and reaction time such that reaction time slows as complexity increases, this is usually attributed to information processing demands rather than being related to motor speed. Tests of motor speed typically utilize very basic assessments such as finger tapping (how many times can you tap your dominant index finger during a 15 second period, repeat for non-dominant hand), simple reaction time tasks (push a button as soon as this light turns

on), or ruler drop tests (how far does a ruler drop before it can be caught). Using such approaches, motor speed does show considerable variation across individuals but appears to have a lower bound. In these simple tasks, in the absence of anticipation responses it appears to take at least 150 milliseconds to execute a response using the dominant/preferred hand, with nondominant hand responses occurring more slowly.

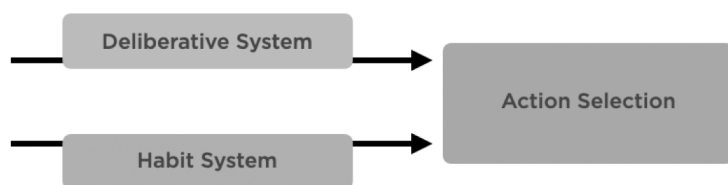
**Information Processing** — The cognitive processes involved with perceiving a stimulus, interpreting its meaning and the corresponding action, and initiating a response.

The focus on information processing ultimately reflects attempts to understand basic decision making processes — choosing a response from a set of alternatives to achieve a desired outcome. Although the nature of decision making in the context of an infinite or undefined set of alternatives (e.g., what should my major be?) is particularly expansive; in the case of information processing the focus is much more constrained. The basic situation is that in a given context, the individual is asked to take in environmental information that tells them what decision should be made. The individual must then process that information, assign meaning to it, obtain the action corresponding to the information, and then initiate the response. Although there are a number of hypothesized mechanisms that would enable such a process, it is generally thought that information processing is the result of multiple functional systems acting in parallel. The **deliberative system** (also sometimes referred to as Type 2 processing) reflects the traditional view of action-selection (choosing what to do) resulting from processing and analysis of the environmental information, consideration of alternative outcomes and potential risk-reward relationships until an action is decided upon. So if you are driving a vehicle in another country and pull up to a sign that you do not know the meaning of, you pull from various sources of information and decide on an action. But this deliberative system is slow, and grows progressively slower with decision complexity.

In contrast, the **habit system** (also sometimes referred to as Type 1 processing) is particularly fast, and requires relatively minimal cognitive effort. The characteristic of this system is that through exposure we begin to learn associations between particular situations and their associated actions. So instead of actually having to process information to determine the course of action (**action-selection**), an action can be released as soon as the situation is recognized (**situation-recognition**). So as you pull up to the sign, you recognize a pattern of behaviors that are consistent with other signs you are familiar with. Instead of having to wait until the deliberative system

finishes processing, the habit system brings online the appropriate action based upon the recognized situation. Tests of information processing are amongst the most highly varied of all cognitive assessments with virtually all cognitive assessments requiring some degree of information processing/decision making. A popular assessment of information processing utilized within intelligence test batteries is the digit symbol substitution test (given a set of digits and symbols, go through and put the symbol associated with each digit) or the trail making task (connect the dots, alternating between letters and numbers in the correct sequence).

**Figure:** Information Processing pathways.

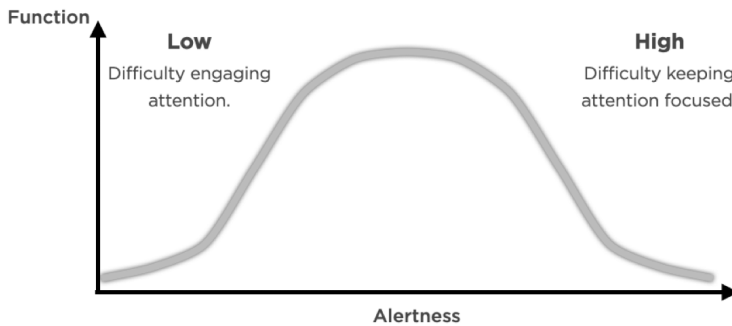


**Attention** — The cognitive operations involved with the allocation of resources towards the selection and processing of information.

Attention is generally characterized into subdomains associated with how the control of attention is implemented. Although necessarily reliant upon sensory information and associated with information processing, the concept of attention focuses on the idea of selecting out only the most relevant and important information from the sensory inputs so that it can be focused upon and utilized. At any given moment our sensory systems are taking in a great deal of information, it is therefore necessary to have some processes that help us focus on the things we are interested in while also retaining some degree of environmental awareness. **Alerting** (sometimes referred to more generally as arousal) reflects the basic attentional state that an organism exists within. This level of alertness describes the extent to which the organism is prepared to perceive and respond to a given situation. The general perspective is that the level of alertness follows a curvilinear path for optimal functioning. If alertness is too low, the organism has difficulty engaging attention and exhibits generally lethargic (sluggish, slow, lazy) responsiveness to environmental cues. If alertness is too high, the organism has difficulty keeping attention focused and exhibits hyperactive/hypersensitive responsiveness to environmental cues. While this is biologically helpful in situations where perceiving threat is

advantageous, it is generally less useful than having more moderate levels of alertness that allow for both sustained attentional engagement and shifting attention.

**Figure:** Optimal level of Alerting.



**Orienting** enables brief shifts in attention to occur in order to direct attention to items of interest and determine if they warrant further attention. This orienting response can occur in response to environmentally driven sensory input (footsteps or a door slamming) or in response to conscious/voluntary control. Shifts in attention therefore occur when the orienting response causes attention to disengage from what it was previously focused upon, shift to the new stimuli, and then re-engage; potentially repeating this process to return to the original thing attention was focused upon. **Executive** attention works to sustain attentional engagement despite potential distractions and reflects aspects of attention popularly known as 'concentration'. The concept of attention is sometimes described as a resource limited 'spotlight'. So long as the attentional needs are low it is possible to extend that spotlight over a larger area, but if greater attentional processing is required then that spotlight must necessarily narrow.

A common example of this is the situation of driving your car while listening to music. When the weather is nice you have no issue driving and singing along. However, when the weather gets bad, it is dark, and heavily raining what is the first thing you do? Typically turn down the music. This reflects the resource limited nature of attention, by reducing the volume of the music you enable your system to focus more attention on the primary task of driving. Thus, performance in 'dual task' situations or context in which attention is divided across multiple things is generally explained by the level of attentional/cognitive demand. So long as the total demands do not exceed capacity, it is possible to retain performance despite the dual-task situation. But if the demands exceed capacity (regardless of the reason), then performance would be expected to deteriorate. This concept underlies recommendations for avoiding distracted driving.

**Cognitive Control** — A set of goal-directed, self-regulatory cognitive operations that allow for the optimization of behavioral interactions with the environment.

The concept of cognitive control (also referred to as executive control, executive function, and sometimes self-regulation) refers to a set of processes that enable for the selection, scheduling, and coordination of processes underlying perception, memory, and action. Therefore novel tasks, tasks which require planning, problem solving, or intentional choices among alternatives all require aspects of cognitive control. Essentially, **this aspect of cognition controls the way other cognitive processes are utilized and enables the shifting of approaches/cognitive strategies to enable us to achieve our goals.** The high-level nature of these cognitive operations make it such that they require conscious awareness, are resource limited, and do not become automatic over time (you cannot eventually do it without thinking). Although the concept of cognitive control and its underlying core processes have undergone considerable revisions since it was first proposed, the core cognitive processes which collectively comprise cognitive control are generally believed to include inhibition, working memory, and cognitive flexibility.

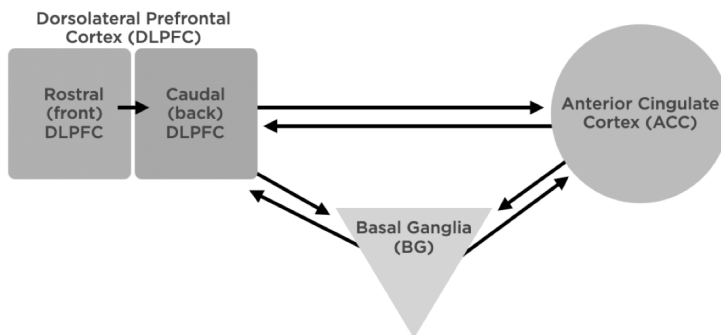
**Inhibition** relates to the ability to gate out task irrelevant information that may cause conflict with the desired goals (interference control), inhibit a dominant response to allow for the selection of the appropriate response (response inhibition), as well as to inhibit a response that has already been initiated (response suppression).

**Working memory** is sometimes also discussed in the context of short term memory; however, the key distinction is that working memory operations specifically enable the holding of multiple items of information within memory and the manipulation of those items to facilitate decision making and behavioral regulation. The term **Cognitive flexibility** refers to the capacity to alter behavioral goals, shift focus of attention, and strategically alter response behaviors. Although these core processes are functionally distinct in adulthood, they are highly integrated and in some context may not be fully dissociable.

Nevertheless, cognitive control operations are vital for maintaining control over the organisms actions despite ever-changing multifaceted environments and varied goal behaviors. During early child development these core processes are not fully differentiated/distinct; which is why research focusing on earlier developmental periods (typically under the age of eight years old) tends to use measures that treat cognitive control as a singular concept. While after this point these core processes become more distinct, they can take another

decade or so to reach full maturation. This helps explain the common occurrence during development where a young adult will engage in problematic behaviors. When confronted about those behaviors, they fully recognize that the behavior was problematic but for some reason they were unable to prevent themselves from doing it. Thus, either as a result of a failure in inhibition (to stop the problematic behavior) or working memory (to keep the idea of the behavior being problematic forefront in their mind) they still engaged in the problematic behavior.

**Figure:** Cognitive Control Network.



Neuroimaging investigations have revealed a number of anatomical structures that are consistently activated in response to tasks requiring aspects of cognitive control. Thus, convergent evidence suggests that three neural structures are particularly important to support cognitive control operations: the dorsolateral prefrontal cortex (DLPFC) which is responsible for implementing control, the anterior cingulate cortex (ACC) which is responsible for monitoring cognitive operations to reinforce behaviors and signal when adjustments in control are necessary, and the basal ganglia (BG) which is responsible for the selection of motor outputs to execute intended actions.

From a neural perspective, the dorsolateral prefrontal cortex (DLPFC) is ideally suited for the active maintenance of task-relevant goals as it routinely exhibits sustained neuronal activity over delays, suggesting the capacity to actively maintain information. The implementation of cognitive control is thought to occur through a cascade of regions in the dorsolateral prefrontal cortex (DLPFC). When exposed to a particular situation, information regarding previous experiences and previously implemented goal-sets are sent to the rostral (front) portions of the dorsolateral prefrontal cortex (DLPFC). The DLPFC integrates this information and uses this goal/strategy related information to bias decisional processes towards approaches that fit the current goal representations. The caudal (back) portions of the dorsolateral prefrontal cortex (DLPFC) uses this action-schema information along with information regarding specific environmental stimuli to make a decision to act/not act. Information regarding this decision is then sent separately to the the anterior cingulate cortex (ACC) and the basal

ganglia (BG).

The anterior cingulate cortex (ACC) has been found to be consistently activated in response to tasks or events which are cognitively challenging, novel, or create conflict. Accordingly, the dorsal anterior cingulate cortex (ACC) is thought to integrate information from multiple areas (including the dorsolateral prefrontal cortex (DLPFC) which provides information regarding the current goal-set) in order to detect potential problems (such as conflicting action-schemas or the occurrence of errors) and signal for adaptations in behavior. In such an instance, the anterior cingulate cortex (ACC) then sends information regarding the need for greater control to the dorsolateral prefrontal cortex (DLPFC) so that the decision related process can be revised or supervised to a greater extent, and the basal ganglia (BG) which can better monitor what action was ultimately performed and delay actions if necessary.

As the basal ganglia (BG) is a vital structure in the initiation of movements, the extensive connections with both the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC) allow for modulations in the motor system to implement flexible shifts in behavior. The basal ganglia (BG) therefore takes in the information from the dorsolateral prefrontal cortex (DLPFC) about the decided upon action, in addition to information from the anterior cingulate cortex (ACC) about potential conflict or need for additional control (restraint) prior to initiating or delaying the desired action. When an action is signaled for, information is sent back separately to the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) to indicate what behavioral response was activated and what response actually occurred (as these could be different).

Although the basal ganglia (BG) is most prominently involved in motor commands, it also plays a role in providing a means of interrupting working memory. One of the core tenants of working memory is that it can rapidly update and maintain information; however, in a resource limited system these functions are ideologically at odds with each other in that if you are continuously updating information then it is not possible to maintain information within the same system. Accordingly, the the dorsolateral prefrontal cortex (DLPFC) intrinsically assumes a maintenance state (holding information within active memory), with the basal ganglia serving as a interrupt signal that enables rapid updating mechanisms to alter that information within the DLPFC when necessary (Frank et al., 2001). Interaction between these three structures therefore enable the three very different cognitive control processes to maintain control of actions despite the potential presence of conflicting, difficult, or unfamiliar

situations.

**Declarative Memory** — The cognitive processes involved with the ability to encode and recall specific facts, events, and details.

The process of memory must take meaningless sensory information and translate it into meaningful patterns, store/consolidate those patterns, and then retrieve that information at a later time. Declarative memory reflects a specific subtype of long-term memory (the ability to permanently hold information in your mind). However, unlike what is commonly represented in popular culture, this information is not stored as a perfect 'snapshot' or 'recording'. Prominent theories of memory suggest that it is largely stored relationally, encoding small bits of information that link with multiple context. The nature of declarative memory, however, makes it such that it largely requires conscious effort to encode and retain information. The concept of declarative memory is commonly differentiated into aspects related to **Episodic memory** which encompasses information regarding personal events and **Semantic memory** which encompasses information about vocabulary, everyday items, and general information (such as what you are learning in class). The encoding and retrieval of information from declarative memory is thought to be primarily supported by the hippocampus and other structures within the medial temporal lobes.

The concept of **intelligence** tries to explain why some individuals exhibit a greater ability to be successful; to judge, comprehend, and adapt to the environment; to think rationally and act purposefully. The general popularity of the concept of intelligence reflects its emergence as a solution to two issues that were particularly prominent in the early 1900's, who should be admitted to schools and who should be placed within leadership positions within the military. During this period in history there was widespread educational reform resulting in a greater number of children attaining access to school, and multiple global conflicts requiring escalation of military service.

The earliest forms of intelligence tests assessed the ability to use language, follow instructions, and remember items; characteristic abilities that generally improve over the course of childhood development. The concept of intelligence (IQ) was thus expressed as the ratio between the individual's mental abilities and their current age (multiplied by 100). So in this sense, an IQ of 70 would indicate that the individual's mental abilities are at 70% of the level expected for their current age; whereas an IQ of 130 would indicate that the individual's mental abilities are at 130% of the level expected for their current age. In this way intelligence is not about being 'smart' but rather about

having general cognitive abilities (use language, follow instructions, and remember items) consistent with or exceeding your age. Armed with this perspective, schools and the military used and promoted this concept of intelligence as a way to justify the exclusion of individuals who exhibited lower abilities to use language, follow instructions, and remember items.

Over the course of the next century, substantial research in this area began to conceptualize intelligence not as a unitary concept, but rather as a reflection of a combination of cognitive abilities. A particularly prominent perspective viewed intelligence as primarily segmented into crystallized and fluid components. **Crystallized intelligence** consists of those knowledge and abilities that an individual has already acquired. So tests of crystallized intelligence will have individuals name pictured objects and answer vocabulary related questions to assess the things that the person knows. **Fluid intelligence** consists of the individual's ability to solve novel problems through the use of reasoning. So rather than testing what the individual already knows, tests of fluid intelligence will have individuals solve pattern related puzzles to get at their problem solving ability.

### **Cattell–Horn–Carroll (CHC) Theory of Intelligence —**

Conceptualization of the structure of human cognitive abilities into narrow factors associated with specific cognitive abilities that generally cluster together into related broad categories of cognition.

The Cattell–Horn–Carroll (CHC) theory of intelligence is named in recognition of these scholars' early work and contributions in understanding aspects of cognition. This theory considers over 80 different specific cognitive abilities (such as the ability to remember auditory patterns for a short period, the ability to hear words despite background noise, the ability to remember complex patterns) which are viewed as the lowest (narrow) level of cognition. To clarify, however, this theory does not contend that these are the only aspects of cognition or that these aspects of cognition are unimportant. Rather, these cognitive abilities are those that are classically assessed by many existing test batteries generally because they have been shown to elicit deviant performance in response to particular issues (i.e., an individual with condition x should show diminished abilities on test y, so test y is used to screen for people who might have condition x).

By considering how strongly these various cognitive abilities relate to each other, broad cognitive abilities are then constructed representing the combined performance on the specific cognitive abilities within the broader ability. So the broad cognitive ability of visual processing is

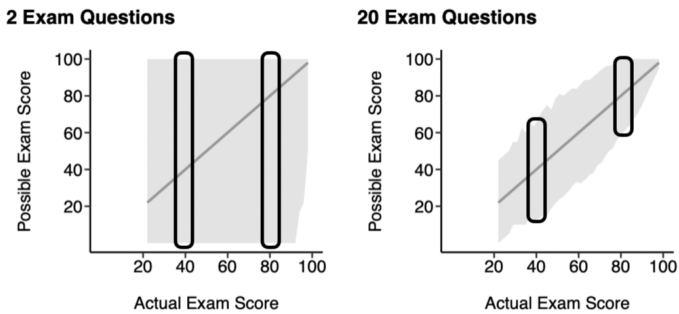
made up of performance across a variety of tests which relate together such as spatial scanning (quickly and accurately scanning a visual field), visual memory (remembering complex visual images), and visualization (perception and rotation of visual images). Performance on each specific cognitive ability is standardized against others of a similar age who completed the test and then combined to create a metric of their broad cognitive ability within a domain. By combining performance across broad cognitive abilities, a 'global' score of general intelligence (g) can then be obtained. The benefit and popularity of this model is that it enables a wide variety of traditional psychological assessment tools to be brought together despite utilizing assessments of different cognitive abilities. As long as these different psychological assessment tools ultimately characterize the same broad cognitive abilities, the fact that they test different specific cognitive abilities is irrelevant.

Although the assessment of intelligence is critically important given state and federal mandates that have integrated these assessments into processes for securing additional funds for student services, equal rights provisions, and even mental-health diagnosis; it is important to also understand that the very nature of such a concept is debated; as is the way it is assessed. Amongst one of the many criticism of typical intelligence based views on cognition, is that to assess this concept you have to utilize broad based cognitive batteries which attempt to assess cognition across too many cognitive abilities. This is not unique to just intelligence tests, but also applies to popular 'neuropsychological assessment batteries' which assess multiple aspects of cognition and then attempt to combine performance to create a singular usable metric, as well as tests of academic achievement. Such batteries must navigate multiple competing issues.

First, is the issue of **psychometric stability**. In order to provide a usable measure of a cognitive domain, it is necessary to have multiple questions, attempts, or trials. Although there is no set 'minimum', having very few questions increases the relative influence of performance on that question. If you were to take an exam with only two questions on it (each question worth 50 points), your performance on each question would be weighted more heavily than on an exam with 50 questions (each question worth 2 points). So an error on a single question would have drastically different implications. Similarly, if we were interested in assessing your visual search abilities, having a greater number of trials on a given test increases the stability of the assessment. You might be particularly fast on one trial, very slow on another, but with multiple trials we could obtain an assessment of your general abilities. A general rule-of-thumb — which is based upon motor based assessments — is that you should obtain at least 30 samples of something to reduce the potential for any one individual sample to skew the result. However,

there are a variety of arguments for why that should or should not apply outside of motor responding.

**Figure:** Psychometric Stability.

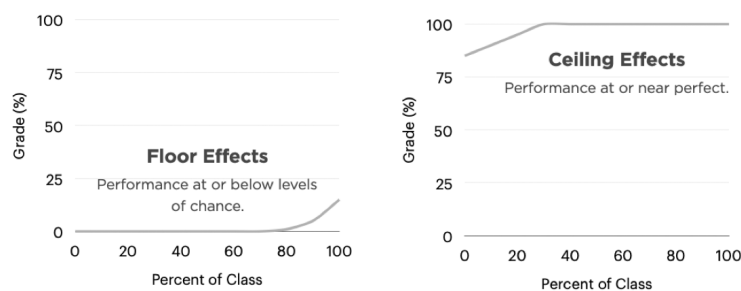


However, more trials means that the assessment will take longer. The issue of **assessment duration** is not just of practical importance — it is more difficult to schedule very long duration testing sessions, but also relates to issues such as cognitive engagement and fatigue. A comprehensive intelligence battery can take over 4 hours. Although traditional cognitive views treated these concepts as highly stable with very little day to day variation; those views have gradually been replaced in recognition that cognitive function can change over a period of only a few minutes. Consider how your cognitive function changes following consuming a cup of coffee or caffeine. Classic research from radar operators indicates that sustained cognitive engagement rapidly declines following a period of only 20 to 40 minutes. So assessments that last longer than this would have to manage if reduce performance was the result of lower cognitive abilities or the long assessment duration. The more cognitively demanding, the sooner assessment duration would likely have an effect.

Finally, it is also important to consider the **sensitivity** of the given assessment — what is ultimately being assessed? Consider a test of mathematical ability. Is the test trying to determine differences in performance associated with age/grade, if so then there can be relatively large jumps in question difficulty (addition, subtraction, algebraic expression, matrix multiplication, calculus). Or is the test trying to determine understanding of a specific type of mathematical ability such as calculus, if so then the questions would be more specific to limits, derivatives, and integrals. But if the test is too sensitive, you increase the risk of **saturation**. If you give a calculus-focused test to 3rd graders, it is very likely that you will run into **floor effects** where performance is all at the level of chance (or even below). If you give a test of addition–subtraction to college–students, it is very likely that you

will run into **ceiling effects**.

**Figure:** Saturation Effects.



In either case there is very little meaningful variation in performance to look at, as the measurements become saturated and unable to differentiate what you are interested in assessing. So there must be a balance of the sensitivity of the instrument: very insensitive instruments tend to be applicable to a wide variety of populations but may miss important differences, very sensitive instruments tend to be able to detect even small differences but only if properly tailored to the group of interest. Since we would need to have a sufficient number of questions on each mathematical concept being assessed to obtain a stable measure, but not so many that the individual would fatigue or that it would take too long to administer; we have to be intentional about the sensitivity of the assessment.

When put into practice, assessments of cognition make intentional choices reflecting a balance of these issues. Take for instance the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) program that is widely used to assess cognitive functioning of athletes before and after a concussion. This test is designed to be completed in under 20 minutes, and uses 8 cognitive assessments; meaning each aspect of cognition is allocated less than 3 minutes for assessment. The test is further designed to be completed by those age 12 to 80, which represents a substantial broad range of assessment for aspects of attention and memory. Thus, while this assessment is good at identifying major deviations in cognitive abilities following a concussive injury, the sensitivity of the measure is quite poor for detecting smaller persistent deficits that may remain.

Again this is not unique to this one tool, and there are a variety of reasons to explain why organizations might mandate the use of tools that lack sufficient sensitivity — it may be to reduce the occurrence of false positives (where the individual may be prevented from participating), it may be to focus efforts on only those with the most severe issues (because there is often not enough money to help everyone), or it may be intentional to enable claiming that there is no issue to be worried about (such as what is alleged to have occurred in

the NFL). As most popular 'neuropsychological assessment batteries' and intelligence tests were designed to pick up large scale differences that might represent grade level or clinically significant impairment, it is important to understand that they may lack the nuance to capture smaller changes in cognition which might be observed in response to several weeks or months of a given treatment.

### Relevant Domains of Cognition

**Motor Speed**

**The time it takes to initiate and complete an intentional movement.**

- Motor speed is typically viewed as having minimal cognitive demands.
- Provides essential information regarding the ability to understand and carryout instructions.
- The predominate way of assessing more complex cognitive abilities is through the use of speeded responding and intentional decision making based upon directions.
- If an individual is unable to complete or has difficulty completing tests of motor speed, it calls into question the validity of being able to assess more complex cognitive abilities.

### Relevant Domains of Cognition

**Motor Speed**

**The time it takes to initiate and complete an intentional movement.**

- In sports-related context, motor speed is viewed as critically important to support high level performance.
- There is a need for being able to respond quickly.
- The more complex the stimulus, the longer it takes to respond.
- This is not actually a function of motor speed as it reflects the information processing demands.

### Relevant Domains of Cognition

**Motor Speed**

**The time it takes to initiate and complete an intentional movement.**

- Tests of motor speed typically utilize very basic assessments.
- Motor speed does show considerable variation across individuals but appears to have a lower bound.
- In these simple tasks, in the absence of anticipation responses it appears to take at **least 150 milliseconds** to execute a response using the dominant/preferred hand, with nondominant hand responses occurring more slowly.

### Relevant Domains of Cognition

**Information Processing**

The cognitive processes involved with perceiving a stimulus, interpreting its meaning and the corresponding action, and initiating a response.

- The focus on information processing ultimately reflects attempts to understand basic decision making processes
- Choosing a response from a set of alternatives to achieve a desired outcome.
- Specifically focused on constrained choices (limited options).

### Relevant Domains of Cognition

**Information Processing**

The cognitive processes involved with perceiving a stimulus, interpreting its meaning and the corresponding action, and initiating a response.

- In a given context, the individual is asked to:
  1. Take in environmental information that tells them what decision should be made.
  2. Process that information
  3. Assign meaning to it
  4. Obtain the action corresponding to the information
  5. Initiate the response

## Information Processing

The mechanism is thought to be the result of multiple systems acting in parallel.

<p style="text-align: center;"><b>Deliberative System</b> Type 2 Processing</p> <p>Reflects the standard idea of action-selection that results from:</p> <ul style="list-style-type: none"> <li>Processing and analysis of the environmental information</li> <li>Consideration of alternative outcomes</li> <li>Consideration of potential risk-reward relationships</li> </ul> <p>Slow processes that takes longer with decision complexity.</p>	<p style="text-align: center;"><b>Habit System</b> Type 1 Processing</p> <p>Reflects situation-recognition:</p> <ul style="list-style-type: none"> <li>When patterns of behaviors/situations are consistent with things you are familiar with, actions can be brought online based upon what has been done before.</li> </ul> <p>Very fast process that greatly reduces cognitive effort.</p>
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### Relevant Domains of Cognition

**Attention**

The cognitive operations involved with the allocation of resources towards the selection and processing of information.

- Attention is generally characterized into subdomains associated with how the control of attention is implement.
- The concept of attention focuses on the idea of selecting out only the most relevant and important information from the sensory inputs so that it can be focused upon and utilized.
- It is therefore necessary to have some processes that help us focus on the things we are interested in while also retaining some degree of environmental awareness.

### Relevant Domains of Cognition

**Attention**

- Describes the extent to which the organism is prepared to perceive and respond to a given situation.
- The level of alertness follows a curvilinear path for optimal functioning.

**Alerting**

The basic attentional state the organism exists within. Sometimes called Arousal.

### Alerting Attention

Moderate levels of alertness allows for both sustained attentional engagement and shifting attention.

### Relevant Domains of Cognition

**Attention**

- Enables brief shifts in attention to occur in order to direct attention to items of interest and determine if they warrant further attention. Can occur in response to:
  - Environmentally driven sensory input
  - Conscious/voluntary control

**Orienting**

Shifting of attention.

### Relevant Domains of Cognition

**Attention**

- Shifts in attention therefore occur when the orienting response causes:
  - Attention to disengage from what it was previously focused upon
  - Attention shifts to the new focus point
  - Attention re-engages

**Orienting**

Shifting of attention.

### Relevant Domains of Cognition

**Attention**

- The focus of attention on a given task despite potential distractions.
- Sometimes described as an attentional 'spotlight.'
  - Is resource limited.

**Executive**

Sustained attentional engagement.

Also known as Concentration.

## Cognitive Control

Cognitive control refers to a subset of self-regulatory processes involved in the goal-directed selection, scheduling, coordination, and maintenance of computational processes that underlie perception, memory, and action.

Situations which require cognitive control include:

- Novel tasks
- Planning
- Problem solving
- Conscious choices among alternatives



## Cognitive Control

Component abilities that comprise what is known as cognitive control include:



**Inhibition**

The ability to ignore distraction & stay focused.



**Working Memory**

The ability to hold information in the mind and manipulate it.



**Cognitive Flexibility**

The ability to switch perspectives, focus of attention, or response mappings.

## Cognitive Control

Cognitive control operations are vital for maintaining control over the organisms actions despite ever-changing multifaceted environments and varied goal behaviors.

### Early Childhood

These core processes are not fully differentiated/distinct.

Research on earlier developmental periods usually therefore treats cognitive control as a unitary concept.

Can they engage in self-regulation?

### Adolescence

Around the age of 8 to 12, these core processes begin to differentiate.

Although they can be separately assessed, they are not fully operational.

### Adulthood

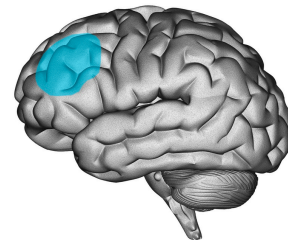
Around the age of 20 to 25, these core processes reach levels of optimal functioning.

## Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

### Dorsolateral Prefrontal Cortex (DLPFC)

Responsible for implementing control.

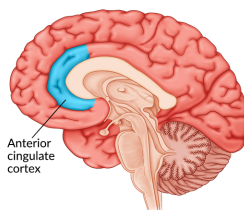


## Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

### Anterior Cingulate Cortex (ACC)

Responsible for monitoring cognitive operations to reinforce behaviors and signal when adjustments in control are necessary.



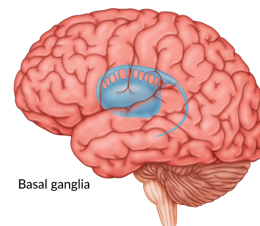
Anterior cingulate cortex

## Cognitive Control

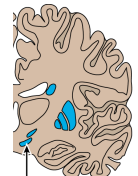
Neuroanatomical structures that are particularly important to support cognitive control operations.

### Basal Ganglia (BG)

Responsible for the selection of motor outputs to execute intended actions.



Basal ganglia



### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

Receives information regarding previous experiences and previously implemented goal-sets.

Uses this goal/strategy related information to bias decisional processes towards approaches that fit the current goal representations.

Allows for overriding habit-system.

### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

→

**Caudal (back) DLPFC**

Uses this action-schema information along with information regarding specific environmental stimuli to make a decision to act/not act.

### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

→

**Caudal (back) DLPFC**

Conveys information about what the decision is.

**Anterior Cingulate Cortex (ACC)**

**Basal Ganglia (BG)**

### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

→

**Caudal (back) DLPFC**

The ACC monitors for situations that are cognitively challenging, novel, or create conflict.

By integrating information across many systems, the ACC monitors to detect problems.

**Anterior Cingulate Cortex (ACC)**

**Basal Ganglia (BG)**

### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

→

**Caudal (back) DLPFC**

If necessary, the ACC can then signal the need for greater control:

Tell the DLPFC to revise or better supervise decision related process

Tell the BG to better monitor what action was ultimately performed and delay actions if necessary.

**Anterior Cingulate Cortex (ACC)**

**Basal Ganglia (BG)**

### Cognitive Control

Neuroanatomical structures that are particularly important to support cognitive control operations.

**Dorsolateral Prefrontal Cortex (DLPFC)**

**Rostral (front) DLPFC**

→

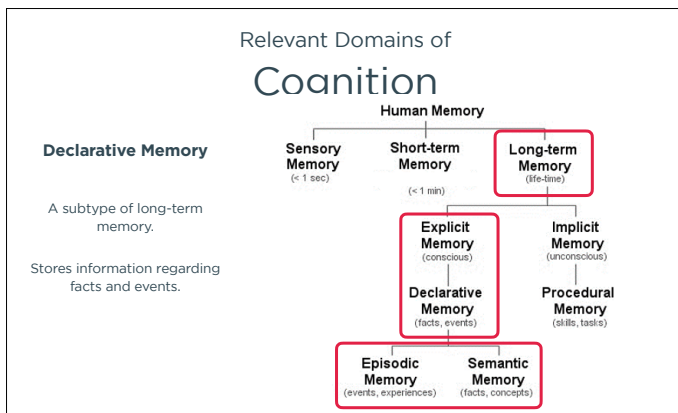
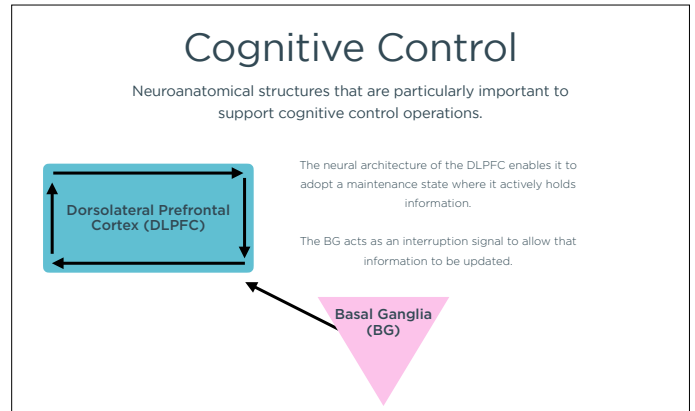
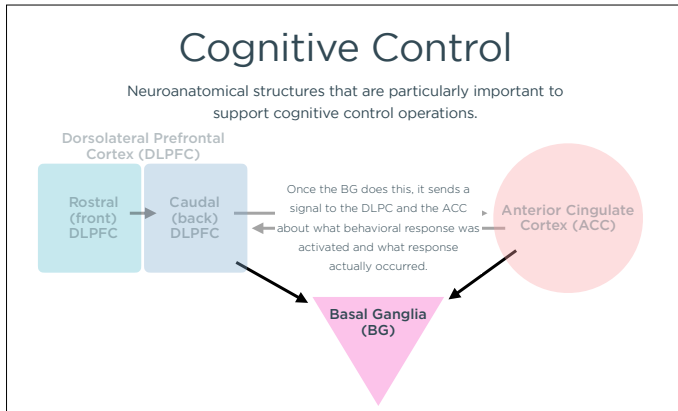
**Caudal (back) DLPFC**

The BG takes in information from the DLPFC about what to do, and the ACC about potential issues.

It can then initiate or delay activation of the motor pattern.

**Anterior Cingulate Cortex (ACC)**

**Basal Ganglia (BG)**



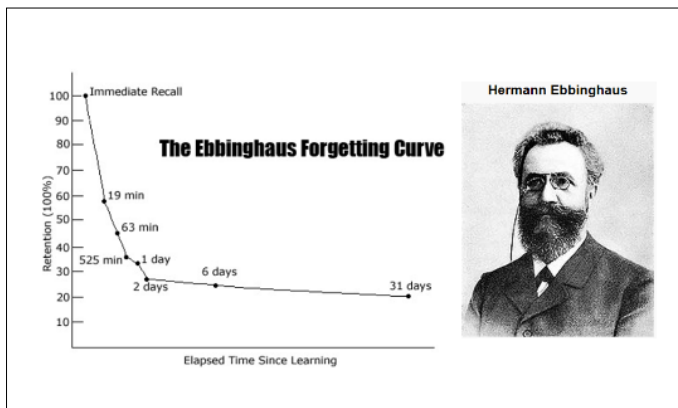
### Relevant Domains of Cognition

**Declarative Memory**

- The process of memory must take meaningless sensory information and translate it into meaningful patterns, store/consolidate those patterns, and then retrieve that information at a later time.
- Declarative memory is primarily stored relationally.
  - Not as a snapshot, video, or recording.
  - Small elements of the information to be stored are linked with existing context.
  - Only that information which cannot be linked to existing elements is needed to be stored.

A subtype of long-term memory.

Stores information regarding facts and events.



### Relevant Domains of Cognition

**Declarative Memory**

The encoding and retrieval of information from declarative memory is thought to be primarily supported by the hippocampus and other structures within the medial temporal lobes.

A subtype of long-term memory.

Stores information regarding facts and events.

**HIPPOCAMPUS**

### Clarifying Some Cognitive Concepts

- The concept of intelligence tries to explain why some individuals exhibit a greater ability to be successful; to judge, comprehend, and adapt to the environment; to think rationally and act purposefully.
- The popularity of intelligence reflects its emergence as a solution to two issues that were particularly prominent in the early 1900's:
  - Who should be admitted to schools
  - Who should be placed within leadership positions within the military

**What is intelligence?**

### Clarifying Some Cognitive Concepts

- Since these abilities gradually improve over the course of development, the concept of intelligence (IQ) was expressed as:
  - The ratio between the individual's mental abilities and their current age (multiplied by 100).
  - An IQ of 70 would indicate that the individuals mental abilities are at 70% of the level expected for their current age.
  - An IQ of 130 would indicate that the individuals mental abilities are at 130% of the level expected for their current age.

**What is intelligence?**

**Early 1900's view:**  
The ability to use language, follow instructions, and remember items.

### Clarifying Some Cognitive Concepts

- In this view, intelligence has nothing to do with being 'smart', only your ability to use language, follow instructions, and remember information.
- Armed with this perspective, schools and the military **used and promoted this concept of intelligence** as a way to justify the exclusion of individuals who exhibited lower abilities to use language, follow instructions, and remember items.

**What is intelligence?**

**Early 1900's view:**  
The ability to use language, follow instructions, and remember items.

### Clarifying Some Cognitive Concepts

- Crystallized intelligence - the knowledge and abilities that an individual has already acquired.
  - Tests of crystallized intelligence will have individuals name pictured objects and answer vocabulary related questions to assess the things that the person knows.
- Fluid intelligence - the individuals ability to solve novel problems through the use of reasoning.
  - Tests of fluid intelligence will have individuals solve pattern related puzzles to get at their problem solving ability.

**What is intelligence?**

**Late 1960's view:**  
The combination of two distinct aspects of cognition: crystallized intelligence and fluid intelligence.

### Clarifying Some Cognitive Concepts

- Cattell-Horn-Carroll (CHC) Theory of Intelligence attempts to combine performance across 80 different specific cognitive abilities.
- The cognitive abilities are those that are classically assessed by many existing test batteries generally because they have been shown to elicit deviant performance in response to particular issues.
- Essentially, "how does all the stuff we do actually fit together?"

**What is intelligence?**

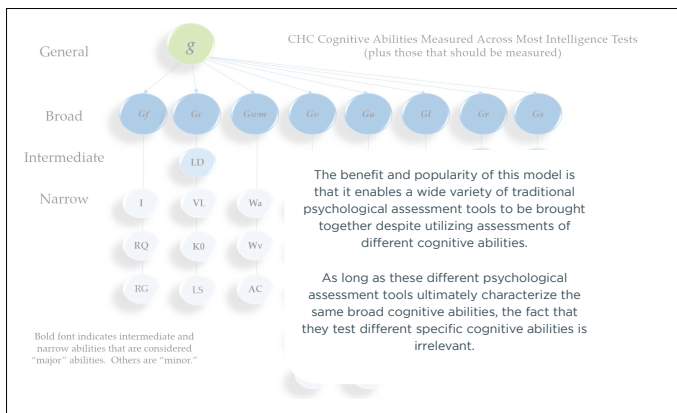
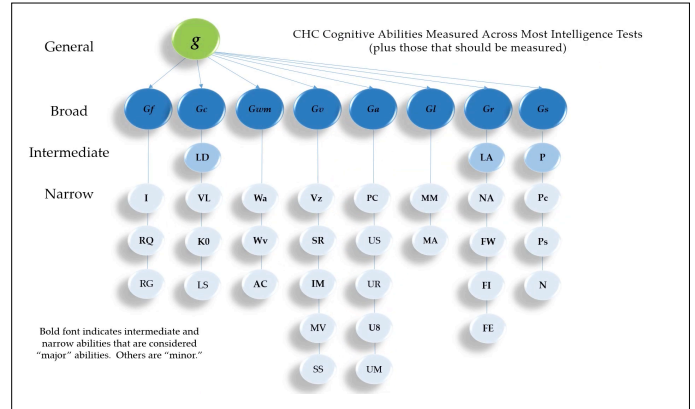
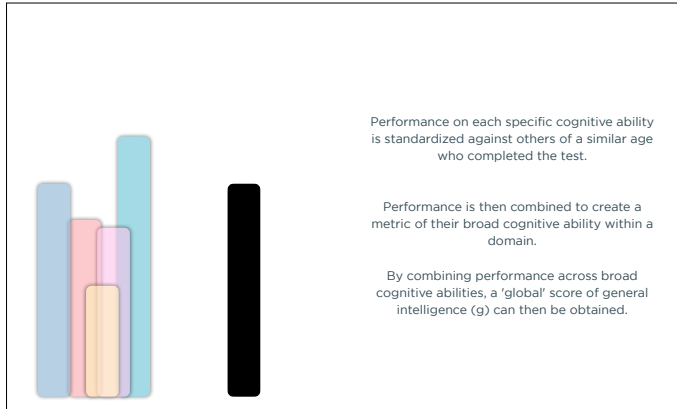
**Late 1990's view:**  
The combination of many specific cognitive abilities that generally cluster into broad cognitive abilities.

### Clarifying Some Cognitive Concepts

- The lowest (narrow) level of cognitive abilities reflect performance on each specific task.
- Broad levels of cognitive abilities reflect the combined performance across specific tasks that tend to be highly correlated.

**What is intelligence?**

**Late 1990's view:**  
The combination of many specific cognitive abilities that generally cluster into broad cognitive abilities.



Although the assessment of intelligence is critically important given state and federal mandates that have integrated these assessments into processes for securing additional funds for student services, equal rights provisions, and even mental-health diagnosis,

It is important to also understand that the **very nature of intelligence as a concept is debated; as is the way it is assessed.**

### Issues in the study of Cognition

**Psychometric Stability**

- To assess intelligence you have to utilize broad based cognitive batteries which attempt to assess cognition across many cognitive abilities.
- Similarly popular 'neuropsychological assessment batteries' and tests of academic achievement assess multiple aspects of cognition and then attempt to combine performance to create a singular usable metric.
- Although there is no set 'minimum', having very few questions increases the relative influence of performance on that question.

To provide a usable measure of a cognitive domain, it is necessary to have multiple questions, attempts, or trials.

### Issues in the study of Cognition

**Psychometric Stability**

- Tests with very few items tend to have a high degree of variation on a day to day basis.
- A general rule-of-thumb is that you should obtain at least 30 samples of something to reduce the potential for any one individual sample to skew the result.
- Based upon research on motor responding.
- However, there are a variety of arguments for why that should or should not apply outside of motor responding.

To provide a usable measure of a cognitive domain, it is necessary to have multiple questions, attempts, or trials.

### Issues in the study of Cognition

**Psychometric Stability**

To provide a usable measure of a cognitive domain, it is necessary to have multiple questions, attempts, or trials.

- The length of the test also increases the likelihood that cognitive fatigue will occur.
- Although traditional cognitive views treated these concepts as highly stable with very little day to day variation; those views have gradually been replaced in recognition that cognitive function can change over a period of only a few minutes.
- Research from radar operators indicates that sustained cognitive engagement rapidly declines following a period of only 20 to 40 minutes.

### Issues in the study of Cognition

**Psychometric Stability**

To provide a usable measure of a cognitive domain, it is necessary to have multiple questions, attempts, or trials.

- Assessments have to manage if reduce performance was the result of lower cognitive abilities or long assessment duration.
- The more cognitively demanding the test, the sooner assessment duration would likely have an effect.

### Issues in the study of Cognition

**Sensitivity**

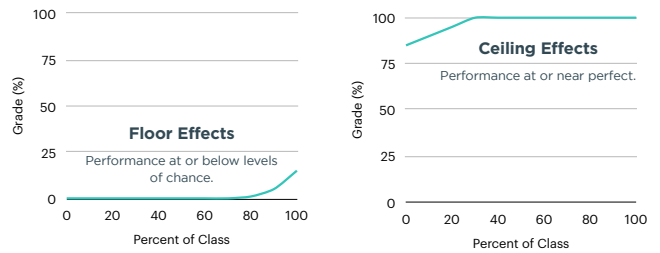
Can the assessment detect the differences/changes of interest.

- If a math test is trying to determine differences in performance associated with age/grade, then there can be relatively large jumps in question difficulty.
  - Questions can include addition, subtraction, algebraic expression, matrix multiplication, calculus.
- If the test is trying to determine understanding of a specific type of mathematical ability such as calculus, then the questions have to be specific.
  - Questions would be more specific to limits, derivatives, and integrals.

### Issues in the study of Cognition

**Saturation**

Lack of variation due to lack of alignment between sensitivity of measure and group performance.



### Issues in the study of Cognition

**Sensitivity**

Can the assessment detect the differences/changes of interest.

- There must be a balance of the sensitivity of the instrument:
  - Very insensitive instruments tend to be applicable to a wide variety of populations but may miss important differences,
  - Very sensitive instruments tend to be able to detect even small differences but only if properly tailored to the group of interest.

### Issues in the study of Cognition

**Sensitivity**

Can the assessment detect the differences/changes of interest.

- We need to have a sufficient number of questions on each concept being assessed to obtain a stable measure,
- But not so many that the individual would fatigue or that it would take too long to administer
- While also being intentional about the sensitivity of the assessment.

### Issues in the study of Cognition

- Assessments of cognition make intentional choices reflecting a balance of these issues.
- The ImPACT test is designed to be completed in under 20 minutes, uses 8 cognitive assessments, and in those 12 to 80 years of age.
  - - 3 minutes for each aspect of cognition.
  - 12 to 80 is a massive age range for cognitive abilities.

**Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)** program that is widely used to assess cognitive functioning of athletes before and after a concussion

### Issues in the study of Cognition

- This assessment is good at identifying major deviations in cognitive abilities following a concussive injury.
  - Assuming the individual did not try to intentionally perform poorly at their baseline assessment.
- The sensitivity of the measure is quite poor for detecting smaller persistent deficits that may remain.
  - Athletes then are returned to play while still impaired.

**Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)** program that is widely used to assess cognitive functioning of athletes before and after a concussion

### Issues in the study of Cognition

- This is not unique to this one tool, and there are a variety of reasons to explain why organizations might mandate the use of tools that lack sufficient sensitivity:
  - It may be to reduce the occurrence of false positives (where the individual may be prevented from participating)
  - It may be to focus efforts on only those with the most severe issues (because there is often not enough money to help everyone)
  - It may be intentional to enable claiming that there is no issue to be worried about (such as what is alleged to have occurred in the NFL).

### Issues in the study of Cognition

- As most popular 'neuropsychological assessment batteries' and intelligence tests were designed to pick up large scale differences that might represent grade level or clinically significant impairment,
- It is important to understand that they may lack the nuance to capture smaller changes in cognition which might be observed in response to several weeks or months of a given treatment.

### Cognitive Assessment Worksheet

1. Beyond providing an assessment of an individuals basic level of neuromotor speed (i.e., the time necessary to send a signal to initiate and complete a movement), tests of motor speed provide what information?
  
2. Complete the following table (<https://www.omniathlete.life/finger-tap-test>)

	Left Hand	Right Hand
Finger Tapping attempt 1		
Finger Tapping attempt 2		
Finger Tapping attempt 3		
Average		
10 second period / Average (seconds per tap)		

3. What is the typical lower boundary (i.e., fastest we might expect) for motor speed (in the absence of anticipation responses)?
  
4. In the context of information processing, what system describes the typical process of taking in information, assigning meaning to it, obtaining the action corresponding to that information and then initiating a response? What system describes the process whereby the information taken in is recognized and a response is initiated without having to fully process it?
  
5. Complete the following table ([https://www.psytoolkit.org/experiment-library/experiment\\_digit\\_substitution.html](https://www.psytoolkit.org/experiment-library/experiment_digit_substitution.html))

	Attempt 1	Attempt 2
Points		

6. Based upon the following information, how would you assess your performance?
  - Adults: average score 48 points (range: 25 to 82)
  - Older Adults: average score 44 points (range: 25 to 63)
  - Patients with Alzheimer’s disease: average score 17 points (range: 2 to 47)

7. What three core cognitive abilities comprise what is known as Cognitive Control?
  
8. What three anatomical structures are particularly important to support cognitive control and what are those structures responsible for?
  
  
  
  
  
  
  
  
  
  
9. Based upon evidence regarding declarative memory, how is this information stored?
  
  
  
  
  
  
  
  
  
  
10. Based upon this, rather than just memorize the words in a definition of a concept, what strategy might better allow this information to be stored?
  
  
  
  
  
  
  
  
  
  
11. Early concepts of intelligence focused on what abilities and were expressed as a ratio of what?
  
  
  
  
  
  
  
  
  
  
12. What is the difference between Crystallized intelligence and Fluid intelligence?

13. If someone is concerned about a tests psychometric stability, what are they referring to?
  
  
  
  
  
  
  
  
  
  
14. If someone is concerned about a tests sensitivity, what are they referring to?
  
  
  
  
  
  
  
  
  
  
15. In the context of test sensitivity, a situation whereby nearly everyone who does the test receives a perfect score would be referred to as what? While a situation whereby nearly everyone who does the test receives the worst possible score would be referred to as what?