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TEACH

Module Functional Evaluation: Concept and Methodology

Didactic Unit E

Topic: Importance of cognitives abilities in the performance of motor task and why it is important to include biomechanics analysis in cognitive impairments

Politechnika Śląska

IBV INSTITUTO DE BIOMECÁNICA DE VALENCIA

VNIVERSITAT DE VALÈNCIA

AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE

Index

1. Objectives

In this Didactic Unit, the learner will be acquainted with the main cognitive functions, their involvement in motor performance and what happens when one of these functions is impaired.

The objectives of this didactic unit are:

- To identify the principal cognitive functions and their brain bases.
- To analyze the implications of the impaired cognitive functions, its evaluation, and preservation in the exercise the professional health activity.
- To know the interference caused by the cognitive load in normal and pathological motor performance.
- To study motor performance in people who have impaired cognitive functions and mental disorders.
- To analyze how a motor gesture with cognitive load should be evaluated with biomechanical assessment tools.

2. Cognition

Cognition traditionally defined as the action or mental process of acquiring knowledge and understanding through experience and the senses. More precisely, cognition can be conceived as the ability to perceive and react, store and retrieve information, process and understand such information, make decisions and produce appropriate responses that guide behavior to interact safely with the environment. Since the sensory information that can be received is vast and complicated, cognition is necessary to extract the essential elements for daily functioning and survival.

2.1 Cognitive functions

Cognition as a general process depends on many other more specific, but no less complex, processes that interact with each other, called domains or cognitive functions. These higher order mental (brain) processes are jointly involved in the execution of any daily task or activity, making it possible for the human being to have an active role in the reception, storage, selection, elaboration, transformation and recovery of the information. Although the different domains or cognitive functions are not independent of each other, some can be explained separately, being a frequent object of research and practical applications in various areas of health. Figure 1 shows the main cognitive domains.

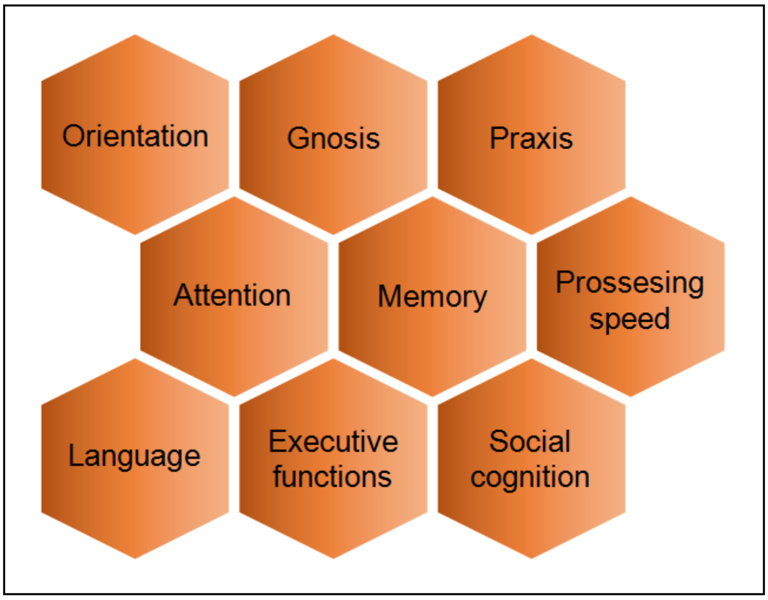


Figure 1: Main cognitive domains of humans

2.1.1. Orientation

Orientation is the ability that allows a person to be aware of himself, of others and of the context in which he is at a given time, to be able to develop the activities of that space / time situation. There are three types of orientation (Figure 2):

- ✓ **Personal orientation**: It is the ability to integrate information related to history and personal identity.
- ✓ **Temporal orientation**: It is the ability to handle information on different facts and place them in their correct chronology.
- ✓ **Spatial orientation**: It is the ability to handle information related to places.

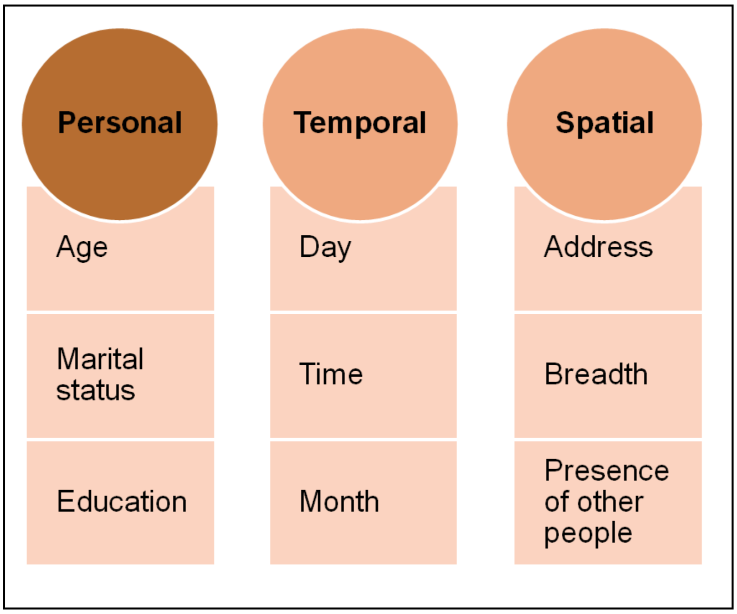


Figure 2: examples of personal, temporal and spatial orientation.

Disorientation can be a symptom of different medical conditions such as delirium and dementia. As well some physical disorders may cause disorientation: amnesia, carbon monoxide poisoning, cerebral arteritis, or inflammation of arteries in the brain, cirrhosis and liver failure, central nervous system infections such as encephalitis or meningitis, complex partial seizures, concussion, dehydration, drug overdoses, electrolyte abnormalities, epilepsy, fever, heat-related illnesses, hypo or hyper glycaemia, hypothermia, hypothyroidism or hyperthyroidism, hypoxia, a mass lesion in the brain like a tumour or hematoma, renal failure, sepsis, stroke, vitamin deficiency, vestibular disorders. Disorientation can be a side effect of some drugs, including alcohol, marijuana, prescription medications. Withdrawal from certain drugs can also cause disorientation.

The treatment of disorientation should be based on the root causes.

2.1.2. Gnosis

It is the ability of the brain to recognize elements, stimulus or any other previously learned information, through the sensitive channels and attribute meaning to them. There are various types of gnosis:

- ✓ **Simple gnosis according to the sensory channels involved**: There are visual, auditory, tactile, olfactory and gustatory gnosis.

- ✓ **Somatognosis or body scheme perception**: It is the ability to recognize and feel mentally the body as a whole and it is parts. This function allows us to know the movements we can do with each parts of the body and it is orientation in the space.

- ✓ **Visuospatial reasoning**: It is the ability to represent, analyse and manipulate objects, places, distances and spaces mentally. Two other cognitive processes are involved in this function: the spatial relationship, or ability to represent and manipulate objects in two dimensions mentally, and the spatial visualization, what it means to have the ability to represent and manipulate objects in three dimensions mentally.

- ✓ **Perception and visual construction**: It is an active brain process of reinterpretation of visual information.

Gnosis dysfunction is known as agnosia. Despite these disorders are rarely seen in isolation there are many specific names for each particular sensory channel dysfunction or some of its combinations. A visual agnosia, the most common form of the disorder, can be the inability to find the razor on the sink despite adequate scanning abilities (the razor can only be located by touch), also, when encountering the faces of familiar persons such as family members or close friends, a patient with prosopagnosia is unable to identify those persons, or even to recognize that they are familiar; a visuospatial agnosia can be the misjudging the distance while reaching for a cup resulting in an inappropriate endpoint (the hand ends up several inches from the cup) or the difficulties orienting a shirt to one's body; a tactile agnosia can be the difficulty with clothing fasteners despite intact motor function or the inability to recognize objects that are in one's pockets unless vision is also used; as well, the person with an apperceptive agnosia, which is a failure to construct an internal representation of an object, finds difficult colouring in the individual objects drawn in overlapping fashion, or copying drawings, but they cannot identify the objects in question.

Agnosia treatment usually focuses on teaching the patient to use the others intact sensory modalities. For example, in tactile agnosia, the patient is taught to use visual, olfactory, and auditory senses to recognize objects.

More importantly, the agnosia treatment should focus on teaching awareness of deficits and the consequences of the impairments, because some of the patients with lower order deficits or “pseudoagnosias” may underestimate the consequences of the deficit.

2.1.3. Praxis

It is the acquired ability to voluntarily execute organized, simple or complex movements, to perform a task, manipulate objects or achieve a specific objective (walking, dressing, eating, smiling, speaking). There are several types of praxis:

- ✓ **Ideomotor praxis**: It is the ability to perform a simple movement or gesture intentionally. Within this, there is another call Facial Praxis, that is, the ability to voluntarily perform movements or gestures with various parts of the face (lips, tongue, eyes, eyebrows, cheeks, etc.).

- ✓ **Ideational praxis**: It is the ability to manipulate objects through a sequence of gestures, which implies knowledge of the object's function, the action, and, the serial order of the acts that lead to the action.

- ✓ **Visuoconstructive praxis**: It is the ability to plan and perform the movements necessary to organize a series of elements in the space to form a drawing or create a final figure.

In the ideational and the visuoconstructive praxis, in addition to the motor skills themselves, the use of other complex cognitive processes such as planning and motor representation of the action is required, which are essential for the performance of motor tasks such as strength, speed, precision or coordination.

The inability to perform a previously learned skilled act that is unexplained by weakness, incoordination, dementia, or sensory loss, it is known as apraxia; when the deficits in skilled movement are not complete, it is called dyspraxia.

Patients with apraxia may lose the ability to manipulate commonly used tools, or the ability to perform something more complex, such as sewing or knitting. In the most common type, ideomotor apraxia, the patients cannot demonstrate skilled movements through pantomime or cannot perform single motor tasks, such as combing hair or waving goodbye. These patients make different errors such as incorrect finger configuration, improper timing, or moving the wrong joints. For example, when asked to demonstrate how to use a pair of scissors, the subject may instead hold out the index and middle fingers and scissor them together as if playing rock–paper–scissors. In the dissociation apraxia pantomiming an action to command is impaired but the subject may still imitate the examiner and use the desired object. In the conceptual apraxia, the patients are unable to associate a use with a particular tool. In the ideational apraxia, the patient is unable to sequence a series of actions such as lighting a match and then blowing it out or with multilevel tasks such as taking the proper sequence of steps for brushing teeth. Some dyspraxias are dressing dyspraxia (difficulty with dressing and putting clothes on in order), oromotor dyspraxia (difficulty with speech), and constructional dyspraxia (difficulty with spatial relations). In general, a patient with apraxia may have some of the following characteristics: coordination problems including, awkwardness in walking, clumsiness or trouble with hopping, skipping, throwing and catching a ball, or riding a bicycle; confusion about which hand to use for tasks; inability to hold a pen or pencil properly; sensitivity to touch; poor short-term memory; trouble with reading and writing; poor sense of direction; speech problems; phobias or obsessive behaviour; and impatience.

Generally, treatment for individuals with apraxia includes physical, cognitive and or occupational therapy. If apraxia is a symptom of another disorder, the underlying disorder it should be treated. To promote the independence and safety of apraxia patients, the intervention should be done in the context of the patients' homes, which provide a natural day-to-day living environment. The occupational therapy intervention should be based on combined functional rehabilitation program focusing on restorative and compensatory techniques.

2.1.4. Attention

Attention is defined as the state of observation and alert that allows awareness of what happens in the environment. It is a capacity or process by which specific mental resources are generated and directed on the most relevant aspects of the environment or the most appropriate actions, maintaining the appropriate state of activation to achieve a goal or purpose. To carry out this process, it is necessary to focus on specific stimulus, ignoring other minor ones.

It is considered as a cognitive "meta-function", since it is indispensable for the general cognitive functioning of individuals. It is responsible for selecting and filtering the information that will be processed by other complex cognitive functions such as memory.

The most cognitive systems can function more or less independently, but none could do so without "attention".

Specifically, attention is involved in processes of selection, distribution and maintenance of cognitive activity in general. It is difficult to separate attention from concentration or from mental tracking, since it is a multidimensional set of processes that involve various cognitive domains, variety of components and multiple hierarchical levels. The most traditionally studied types are:

- ✓ **Focused or sustained attention or "Surveillance"**: It is the ability to continuously maintain the focus of attention on a task or event for a certain period of time.
- ✓ **Selective attention**: It is the ability to direct attention and focus on a task or event without allowing other stimuli, external or internal, to interrupt the task.
- ✓ **Alternating or divided attention**: It is the ability to change the focus of attention from one task or event to another, in a fluid way.
- ✓ **Complex attention**: This capability includes both simple attention and the speed of information processing.

The ability to perform tasks that require attention affects various activities of daily life. For example, when reading an article in the newspaper, the ability to concentrate on the reading activity for a long enough period to read the whole article, is highly dependent on sustained attention. Also, the ability to drive a car from one point to another while avoiding hitting other cars or objects requires a high level of sustained, selective and alternating attention. The human being uses his attention to complete planned and sequenced actions and thoughts such as following a recipe, reading a map, organizing a social event, interacting socially, or writing a report. There are several factors that affect an individual's ability to sustain their attention: the nature of the task, fatigue, stress, personality, etc. Thus, lack of attention or inattention can directly interfere most activities of daily life. However, especially, lack of attention has an important and negative effect on learning. The most important disorder related to attention is Attention-deficit/hyperactivity disorder (ADHD).

The strategies for improving only the inattention are quite limited. The best strategy for avoiding the problems associated with the vigilance decrement is to redesign the task/system to avoid this requirement. More complex attention deficits such as ADHD may require pharmacological treatment, but the behaviour intervention plans long term may result in permanent improvement in concentration skills which medication cannot provide.

2.1.5. Memory

Thanks to memory you can learn, evolve, and have personality. By definition, it is often said that memory is the ability to encode, store and retrieve, effectively learned information or lived events. In the first explanatory models, the cognitive processes involved in memory were attention, coding, storage, consolidation and information retrieval. In addition, there was a distinction between sensorial memory, short-term memory and long-term memory.

Currently, neuropsychology understands that memory is a much more complex function that involves many other cognitive processes and functions, subdivided into tasks and classified in several ways:

- ✓ **By the information nature of the recall**: Verbal or nonverbal memory.
- ✓ **By the information type of the recall**: It can be "semantic" (impersonal information) that includes knowledge about the meaning of words, facts and concepts, objects and their interrelations, and general information about the world; and "episodic" (autobiographical information) or memory of the past events, specified by its time characteristics.
- ✓ **By the access method to recall**: It can be divided into "explicit" or "declarative", information that can be accessed consciously, and "implicit" or "procedural", automatic recall of actions or sequence of learned acts.
- ✓ **By the access modality to recall**: The type of sensory channel (vision, hearing, touch, taste, smell, kinesthesia), individually or in combination, and the type of task (free, guided, interfered or by recognition).
- ✓ **By the time span in which the information is recalled**: It can be divided into "immediate" or "short" (seconds or few minutes) and "delayed" or "long term" (several minutes up to several hours), with or without interference.

Everyone forgets things at times. Some degree of memory problems is a common part of aging. There is a difference, however, between normal changes in memory and memory loss associated with a disease. The first or more-recognizable signs of the clinical condition of memory loss are: asking the same questions repeatedly, forgetting common words when speaking, mixing words up, saying "bed" instead of "table," for example, taking longer to complete familiar tasks, such as following a recipe, misplacing items in inappropriate places, such as putting a wallet in a kitchen drawer, getting lost while walking or driving in a familiar area, having changes in mood or behaviour for no apparent reason, etc. Some memory problems are the result of treatable conditions: lack of sleep, medications or a combination of medications, minor head trauma or injury, emotional disorders, stress, anxiety or depression, alcoholism, vitamin B-12 deficiency, hypothyroidism, brain diseases (a tumour or infection in the brain), etc. Others are symptoms or characteristics of neurologic or neurodegenerative diseases such as severe mental disorders, Alzheimer's, Parkinson's and other types of dementia, or of permanent brain injuries.

The treatment for improving the most serious memory impairments may require pharmacological treatment but the cognitive rehabilitation or the use of memory training techniques can be very useful for medium or lower memory deficits.

2.1.6. Processing speed:

It is the ability to automatically and quickly process information, without consciously thinking. Is defined as the rate to complete a task, or the time it takes between a stimuli is received, and a response is emitted.

Slow processing speed it manifests as the difficulty to keep up with the pace of learning from others, difficulty completing tasks on time, or problems in following directions. Slow processing speed can play a part in learning and attention disabilities like dyslexia, attention deficit disorder, autism, dysgraphia, dyscalculia, and auditory processing disorder.

When mental efficiency in focusing concentration is required, students of all ages with slower processing speed have difficulty performing simple cognitive tasks fluently and automatically. In these cases, the strategies of modifying and accommodation of the environment and classroom assessment demands, and differentiating the style of instruction are appropriate to ensure that they have equal access to the curriculum. However, some of they need to be directly taught compensatory strategies that they can employ on their own across environments and encourage them to develop their own learning strategies, and to take advantage of available classroom resources.

Nevertheless the most serious cases should be evaluated and treated by an experienced neuropsychologist, who should assess the nature and the severity of the problem and identify its causes, ruling out the existence of other disorders, especially those related to learning, intellectual disability, oppositional defiant disorder, anxiety or depression.

2.1.7. Language

Language is a higher order cognitive function, the result of a complex nervous activity, which develops symbolization processes related to the encoding and decoding of information. The production of language is the materialization of signs (loud, not loud, verbal or written) to symbolize objects, ideas, etc. according to a convention of a linguistic community that allows inter-individual communication. The language is composed of several cognitive processes:

- ✓ **Vocabulary**: It is the lexical knowledge.
- ✓ **Writing**: It is the ability to transform ideas into symbols, characters and images.
- ✓ **Reading**: It is the ability to interpret symbols, characters and images and transform them into speech.
- ✓ **Naming**: It is the ability to name objects, people or facts.
- ✓ **Repetition**: It is the ability to reproduce the linguistic information received in the same way.
- ✓ **Discrimination**: It is the ability to recognize, differentiate and interpret content related to language.
- ✓ **Fluency**: It is the ability to produce linguistic content quickly and efficiently.
- ✓ **Comprehension**: It is the ability to understand the meaning of words and ideas.
- ✓ **Expression**: It is the ability to formulate ideas with meaning and grammatically correct way.

Language disorders or language impairments is an impairment in the processing of linguistic information that affects an individual's ability to receive and/or express language. As a brain function that require a number of cognitive processes, is commonly affected by both focal brain lesions and neurodevelopment or neurodegenerative disorders. They can be classified according to the aspect of language that is impaired (phonology, syntax, morphology, semantics, and/or pragmatics), its severity (mild, moderate, or severe), and whether it affects comprehension (receptive language), production (expressive language), or both. Accordingly there are various types of language disorders: alexia, agraphia, aphasia, dyspraxia, dyslexia, and other overlapping terminology (the expressive/receptive and fluent / dysfluent divisions of aphasia). Language disorders are one of the four disorders classified under communication disorders by DSM-V along with speech disorders, central auditory processing disorders and hearing disorders.

The impact of language disorders on daily life can go from being detached from others in family, school or play environment to, lack confidence and assertiveness as a result of difficulties comprehending and expressing information. Language neurodevelopment disorders are typically identified in early childhood when a child fails to display age-appropriate language abilities.

The treatment for language disorders should be a multidisciplinary approach that involves speech-language therapists, audiologists, behavioural therapists and special education professionals, as well as physician to identify (or rule out) physical causes behind language impairments. In addition, the most effective therapies are those that are conducted in these natural environments where the patient not only learns faster in a natural environment but also more easily maintains the new behaviour and skills in these familiar settings. The use of new technologies to support treatment is currently a powerful communication tool to improve communication and social skills, however, communication and educational professionals must foremost focus on the communication needs of the individual, and ensure the tool addresses those needs. Other useful tools are play programs and music therapy programs. In any case, early identification of language disorders is key to early intervention, which will produce better long-term treatment results.

2.1.8. Executive functions

They are a set of higher order cognitive processes, or complex mental activities, that use and modify information from many cortical sensory systems in the anterior and posterior brain regions to modulate and produce behaviour. This cognitive function include both cognitive and behavioral components, related to each other, to organize, guide, review, regularize, establish and initiate activities. It also involves any other mental operation necessary to adapt effectively to the environment and to manage independent activities of daily living.

These functions, through feedback, facilitate self-regulation and the suppression of inappropriate responses or behaviours and the verification of errors or the monitoring of strategies. They also allow the resolution of complex problems, the use of abstract concepts, decision-making and the selection of correct actions. They are responsible for flexibility and cognitive change in new or complex situations, to keep the behaviour under control and oriented towards the pre-established objectives.

There are several types of executive functions:

- ✓ **Time estimation**: It is the ability to calculate approximately the time span and the duration of an activity or event.
- ✓ **Inhibition**: It is the ability to ignore impulses or irrelevant information both internally and externally, when perform a task.
- ✓ **Dual execution**: It is the ability to perform two tasks of different types at the same time, paying attention to both constantly.
- ✓ **Multitasking (branching)**: It is the ability to organize and perform tasks optimally simultaneously, intercalating them and knowing where each one is at all times.
- ✓ **Planning**: It is the ability to generate objectives, develop action plans to achieve them (sequence of steps) and choose the most appropriate based on the anticipation of consequences.

- ✓ **Reasoning**: It is the ability to compare results, draw inferences and establish abstract relationships, to solve problems of various kinds in a conscious way, establishing causal relationships between them.

- ✓ **Decision-making**: It is a mental process that allows you to make a choice between several alternatives depending on the needs, weighing the results and consequences of all options.

- ✓ **Cognitive flexibility**: It is the ability to generate new strategies to adapt behavior to changes in the demand of the environment. This ability allows changes to something previously planned, thus adapting to the surrounding circumstances. It also allows you to correct your own mistakes and modify habits.

- ✓ **Working memory or operational memory**: It is the capacity for temporary storage of information and its processing. This is one of the subtypes of the "way in which it is remembered" and represents a variant of the "immediate memory" in which not only the information is retained for a few seconds, but also a manipulation of the information is performed to issue a response. This complex cognitive function needs its own system for the maintenance, manipulation and transformation of specific information for a particular period. For this, it coordinates with other systems such as the “articulation loop” to keep verbal information active, the “visuospatial agenda” to maintain and manipulate images and the central executive system to regulate and select strategies. Although it could be considered as one of the types of memory, it should be included in the classification of executive functions since it is vital to organize future thoughts and actions from the recent past.

Executive dysfunction can refer to difficulties in any of its abilities or capacities. It can be a symptom of another condition for instance conduct disorder, depression, obsessive-compulsive disorder, schizophrenia, bipolar disorder, fetal alcohol spectrum disorders, learning disabilities, autism, Alzheimer's disease, drug or alcohol addiction, stress or sleep deprivation, and frontal lobes traumatic brain injury. In everyday life, it show up in things like: the disability to change plans, difficulties doing homework, not recalling what you need to pick up at the store, misplacing things, difficulty with time management, difficulty organizing schedules, trouble keeping places organized, constantly losing personal items, difficulty dealing with frustration or setbacks, trouble with memory recall or following multistep directions, inability to self-monitor emotions or behaviour.

The treatment depend on the conditions and the specific types of executive dysfunctions that are present; is an ongoing process that is often lifelong and can vary over time. Treatment typically includes working with various kinds of therapists such as neuropsychologists, psychologist, speech therapists, or occupational therapists. Medication can be helpful for the most severe cases. For the milder cases, treatments that focus on developing strategies to address the particular dysfunction are also helpful (sticky notes, organizational apps, timers, etc.).

What relationship exists between executive functions and motor performance?

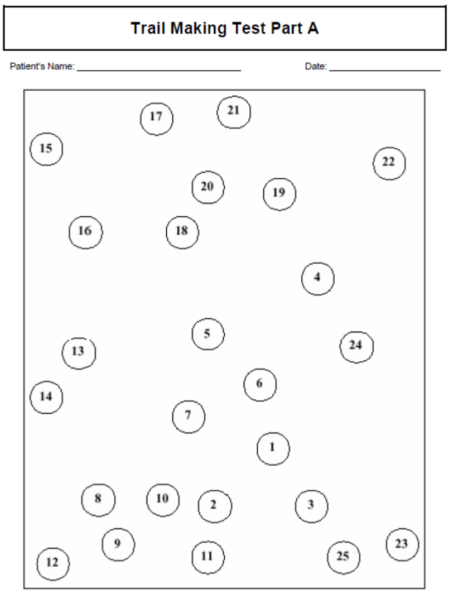
Executive function refers to a variety of higher cognitive processes that use and modify information from many cortical sensory systems in the anterior and posterior brain regions to modulate and produce behavior. They encompass a number of cognitive processes that allow for goal-directed processing of novel or complex situations.

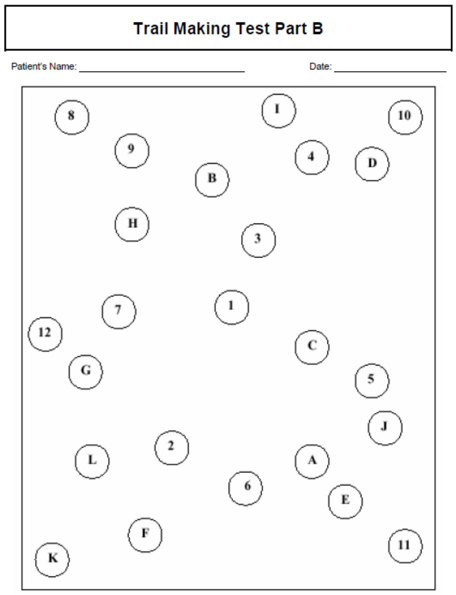
Several investigations have attempted direct study of the relationships between executive function and gait abilities. Is has been demonstrated that Poor and intermediate execution function performance is associated with decreased gait speed on gait with an obstacle. This same relationship has been seen when the gait is performed with cognitive load, showing that cognitive executive functions are critical in complex gait situations. This relationship is stronger in populations with gait disturbance such as elderly and people with neurological disorders.

In healthy elderly adults, executive functions are important for successful completion of many balance and walking task including postural maintenance, obstacle avoidance, and ambulation. This cognitive function are related to fall history, whereas other cognitive skills such as language and basic memory ability are less involved.

How are cognitive functions measured?

The most used test in research to measure execution cognitive functions is the Trail Making Test. This test is widely used in gait assessment studies in people with neurodegenerative diseases and neurological diseases. The test consists of two parts: A and B. Part A of the test requires that the evaluated person draw lines that connect sequentially twenty-five numbers in the shortest possible time. Part B requires a similar execution, with the exception that the person must alternate the sequence of numbers with letters.





2.1.9. Social cognition

It is a set of cognitive and emotional processes to perceive, remember, analyse, interpret, predict, attribute and use information about the social world. It is the ability to think and make sense of ourselves, others and their behaviour, and social relationships. Social cognition is necessary to regulate behaviour and emotions in the social context. It also facilitates the interpretation of other people's emotions, thoughts and reactions to specific situations (empathy).

This type of cognition has some components:

- ✓ **Social perception**: It is the ability to understand social reality. It refers to how others are perceived and how their behaviour is interpreted.

- ✓ **Metacognition**: It is the ability to mentally represent the intentions and beliefs of other people.

- ✓ **Theory of mind**: It is the ability to automatically be aware of the differences that exist between the point of view of the others and ourselves, almost unconsciously.

- ✓ **Emotional processing**: It is a process in which, situations, things, people, etc., they are put on a scale of values. From the analysis performed, the quality and intensity of the associated emotion will emerge, resulting in a subjective assessment, changes in physiological activation and / or behavioural mobilization.

- ✓ **Attributional style or attributional bias**: These are the differences with which people attribute causes to what happens to them. Attributions are a series of internal messages, not unconscious, but sometimes it is difficult to detect. There are different types of attributions: global or specific, stable or unstable, and, internal or external control locus.

In everyday life the constant interact between people include cooperate, compete, or simply to go about day-to-day business. Those interactions, to be successful must include the ability to understand and predict the actions of the other people in terms of beliefs, desires, and intentions. People while interact with others, read their signals and send back signals for others to read, thus mutually sharing their mental states, actively responding in order to change them: to make them trust or fear. For example, in an action in which two people cooperate in order to achieve some common goal, participants must understand how they and their partner view each other's roles within the partnership, being able to understand the intentions of our partner and predict his actions. This process involves at least four levels of mentalizing: (1) our belief about our partner's role, (2) our belief about how our partner views his role, (3) our belief about how our partner believes we view our role, and finally (4) our belief about how our partner believes we view him (Figure 3).

Figure 3: Levels of mentalizing

Social impairments are common and contribute a great deal to the burden of mental illness or disability. Autism is one developmental disorder that is defined by social and communication impairment as well in certain types of schizophrenia, psychopathic and borderline personalities. Patients with psychosis has shown a clear deficit in social cognition across its multiple domains playing an important role in the etiology of both positive and negative psychotic symptoms. For example, experiences of paranoia have been related to deficits in emotion recognition and attribution biases, that is, misattributing neutral stimuli to be negative. Asocial behavior (such as social isolation and social anhedonia) can be partially explained by social impairments.

Treating social disability may include socially-focused behavioral interventions, interaction training, cognitive-behavioral treatments, and pharmacological treatments for more severe cases.

In summary, the cognitive domains and subfunctions involved are show in diagram 1.

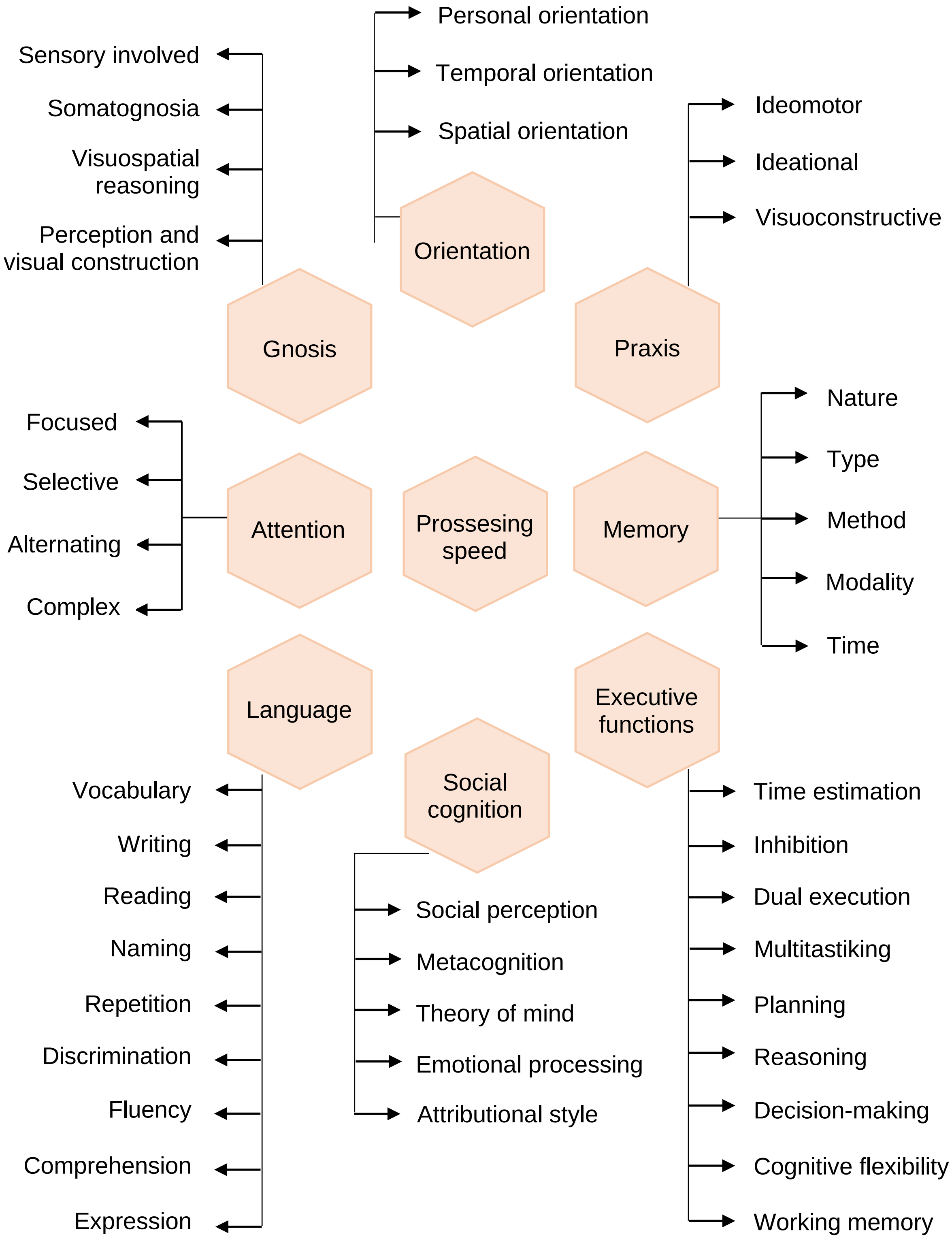


Diagram 1: Summary of the cognitive domains and subfunctions involved.

2.2. Brain bases of cognitive functions

Traditionally, neuroscience has focused mainly on the topological organization of cognitive functions in specific brain regions (Figure 4).

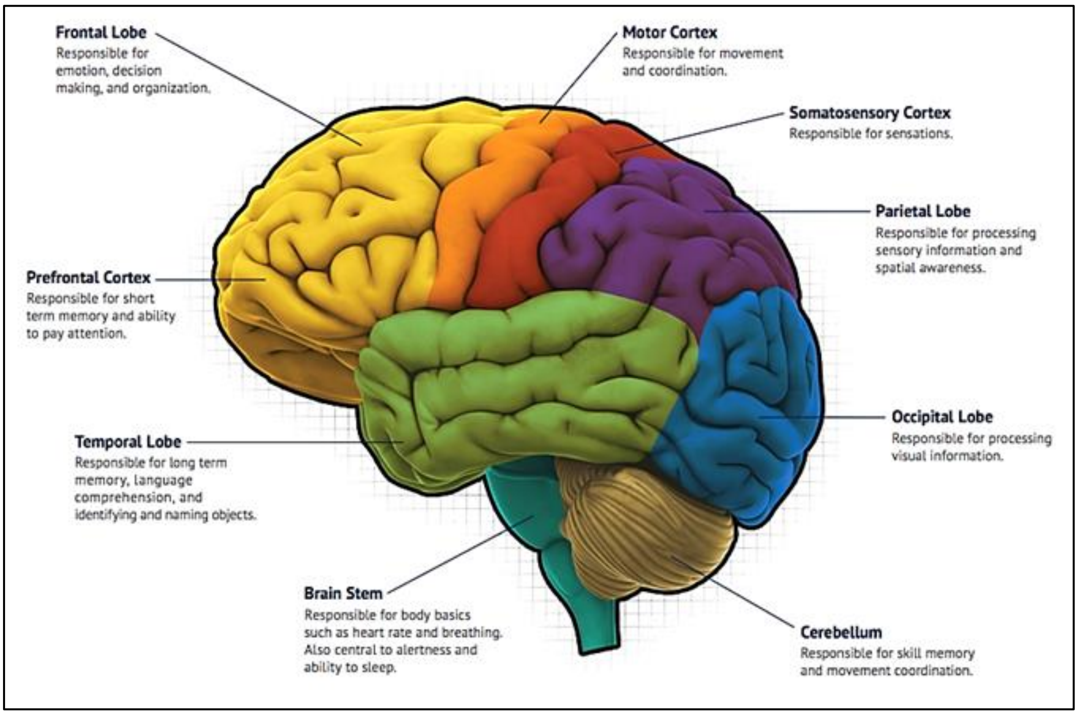


Figure 4: Brain mapping (From North Jersey Health & Wellness)

However, actually there are a new "network paradigm" to understand the neuronal basis of cognition: the key to understanding the functions of any specific brain region lies in understanding how its connectivity differs from the pattern of connections in other functionally related brain areas. Shifting neuroscientific interests towards the development of a deeper understanding of how the intrinsic architecture of the brain influences the processing of cognitive information.

According to Mesulam (1990), the human brain contains at least five major core functional networks:

I. A spatial attention network anchored in posterior parietal cortex (PPC) and frontal eye fields.
II. A language network anchored in Wernicke’s and Broca’s areas.
III. An explicit memory network anchored in the hippocampal–entorhinal complex and inferior parietal cortex.
IV. A face-object recognition network anchored in midtemporal and temporopolar cortices.
V. A working memory–executive function network anchored in prefrontal and inferior parietal cortex.

In addition, Independent Component Analysis (ICA) has been used to identify intrinsic connectivity networks involved in executive control, episodic memory, autobiographical memory, self-related processing, and detection of salient events. This studies has revealed a sensorimotor network anchored in bilateral somatosensory and motor cortices; a visuospatial attention network anchored in intraparietal sulci and frontal eye fields; a higher-order visual network anchored in lateral occipital and inferior temporal cortices; and a lower-order visual network anchored in the striate and extrastriate cortex. Those network modules can vary their intraconnectivity and the intermodule connectivity. Figure 5 shows a topology example of the modular organization of functional brain networks, demonstrating the communication between computational resources of different types: (A) brain regions are organized into cytoarchitectonically distinct areas, (B) each cytoarchitectural configuration has structural properties with different implications for computational functions, (C) cytoarchitectural regions can be represented as nodes in a network, (D) the nodes have functional associations, represented as edges that extend beyond spatial boundaries evident in cytoarchitectural organization.

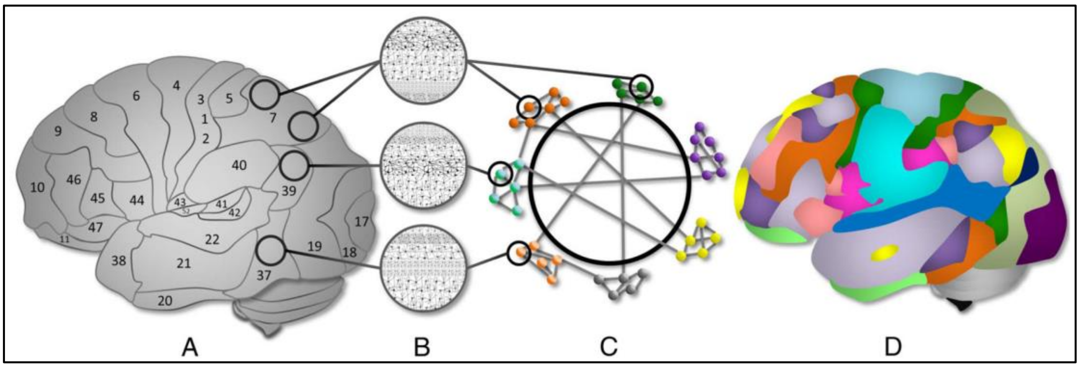


Figure 5: From nodes to networks (Medaglia et al., 2015). (A) brain regions organized into cytoarchitectonically distinct areas, (B) cytoarchitectural configuration with structural properties, (C) nodes in a network, (D) functional associations of the nodes.

2.3. Impaired cognitive functions

As mentioned earlier, the loss of cognitive abilities is due to the natural aging process. However, the way in which this degenerative process develops depends on multiple conditions: health, functional capacity, genetic structure and environment. In addition, other factors can alter cognitive abilities acutely or chronically: neurodegenerative diseases, neurodevelopmental disorders, intellectual disabilities, mental illnesses, addictions, severe physical or mental traumas, etc. The affectation in one or more of the cognitive functions has a direct implication on the daily functioning of people, individually or in interaction with others and the environment. Table 1 shows the implications of some of the cognitive function in carrying out activities of daily life.

Table 1: Implications of cognitive deficits in carrying out activities of daily life

Cognitive function	Activities of daily life
Recognition of the body scheme	Difficulties in dressing, using objects in relation to the body (comb, toothbrush, cutlery, etc.).
Sustained attention	Difficulties in following a movie or book, studying, etc.
Selective attention	Difficulties in working in an environment with other people, with noise or other possible distractions.
Divided attention	Difficulties in driving a vehicle, home care or children, etc.
Semantic memory	Forgetting previously acquired knowledge, forgetting the name of known people.
Episodic memory	Forgetting where you left your car, keys or glasses, forgetting itineraries (holidays, visits, etc.)
Prospective memory	Forgetting the next day's appointments, forgetting what you want to buy, etc.
Executive functions	Difficulties to plan and carry out the meal, to use the computer, to control expenses, to organize trips or trips, to solve problematic situations, etc.

In recent years and through multiple studies worldwide, it has been shown that deterioration can slow down or make cognitive deficits lighter, maintaining an active and healthy life, in stimulating environments, and if it continues to stimulate or develop these functions through cognitive stimulation practices and exercises.

How the exercises can improve the cognitive function?

A promising non-pharmacological intervention for cognitive problems is physical exercise. In healthy older adults and people with mild cognitive impairment, evidence of positive effects of exercise on cognition is accumulating. In the published studies, the evidence indicates that memory, executive function, attention, and processing speed are cognitive function that has been improving after physical training in elderly people.

The mechanisms underlying the effects of physical exercise are related to neurogenesis, vascular changes such as increased oxygen saturation, the promotion of angiogenesis and increased cerebral blood flow. Also, changes in neurotransmitters and inflammatory factors have been studied. Behind this, is the evidence that states that the exercise leads to increased levels of neurotrophic factors, which in turn have a positive influence on neurogenesis. Brain-derived neurotrophic factor (BDNF) is increased after aerobic exercise and has been implicated in the differentiation, extension and survival of neurons in the hippocampus, cortex striatum, and cerebellum.

2.4. Evaluation of cognitive functions

An adequate cognitive or neurocognitive evaluation may involve the application of observation, interviews, clinical and psychosocial scales, cognitive tests, neuroimaging techniques, or any other appropriate form of evaluation. Focusing also on the specific treatment needs of the affected person.

In general, the neurocognitive evaluation should include at least the study of general intellectual performance, temporal and spatial orientation, attention, speed of information processing, learning and memory capacity, visuospatial abilities, perceptual and motor skills, language and communication, reasoning, the ability to solve problems and some of the executive functions.

There are currently multiple evaluation instruments, intended for the evaluation of one or more cognitive functions and for the general population or specific groups of patients with impairment.

I. Short scales or cognitive tracking tests

These tests are easy to apply and require little time for application (5 to 20 minutes). Most of them were originally designed to assess cognitive deficits in elderly patients, although they have been applied in general to patients with all types of both acute and chronic cognitive deficits. The overall score obtained allows obtaining a "cut-off point" between normal and pathological, allowing the remission of those who need a more detailed neuropsychological evaluation. Its main utilities are limited to providing a quick view of the patient, monitoring patients, and establishing correlations between this global score and other relevant variables. E.g. Mini-Mental State Examination (MMSE): evaluate Orientation to time, Orientation to place, Registration, Attention and calculation, Recall, Language, Repetition, and, Complex commands (Figure 6-left).

II. General evaluation batteries

Those are a set of tests or elements that explore the main cognitive functions systematically. The main advantages of its use is the opportunity to have a large database that facilitates obtaining a profile that characterize different levels of people cognitive domains, and a greater control over a set of variables that may affect the performance of individuals (age, educational level, etc.). They identify not only the main deficits but also the skills preserved in each person, essential for the establishment of a subsequent personalized rehabilitation program. E.g. Weschsler Adult Intelligence Sacale (WAIS): evaluate Vocabulary, Similarities, Information, Comprehension, Arithmetic, Digit Span, Letter-number sequencing, Picture completion, Block design, Matrix Reasoning, Digit symbol coding, Symbol search (Figure 6-middle).

III. Specific tests of neuropsychological evaluation

These tests are focused on examining specific cognitive function deterioration. Used to develop a realistic work plan for the patient. E.g. Conners CPT – CATA: measures sustained and selective attention. (Figure 6-right).

Although the cognitive or neurocognitive evaluation should be done by a neuropsychologist, the cognitive screening tests, are accessible to all health professionals, who, with minimal preparation, and in a short time, can make a previous evaluation that allows them refer a patient to the appropriate professional.

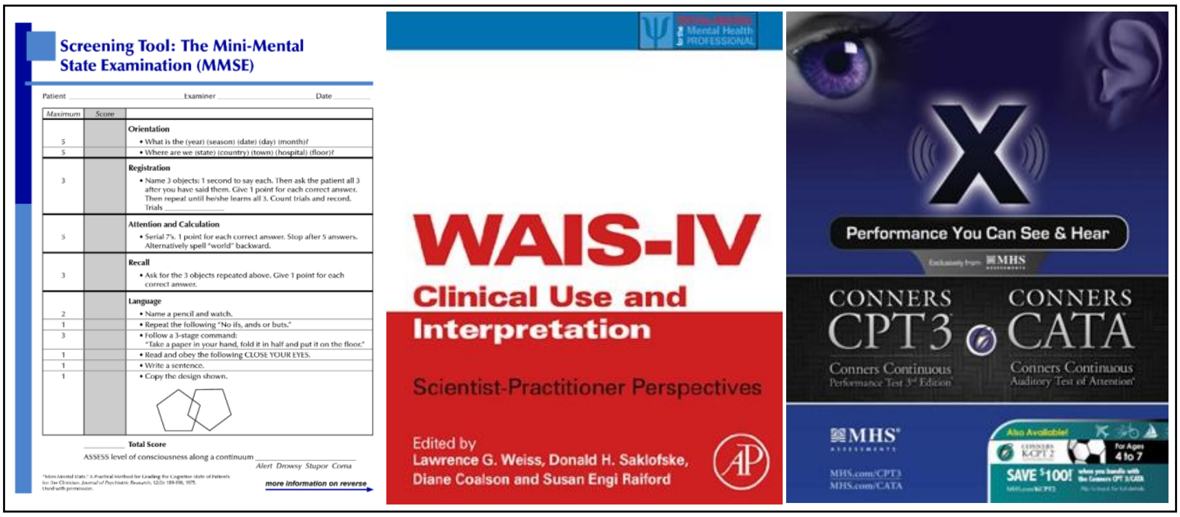


Figure 6: Test for neurocognitive assessment. (left) Mini-Mental State Examination (MMSE), (middle) Weschsler Adult Intelligence Sacale (WAIS), (right) Conners CPT - CATA.

2.5. Progress toward objective cognitive assessment

The cognitive evaluation has always been carried out through standardized tests and scales in which an observer scores the performance of the person evaluated while answering their questions. The possible errors derived from this methodology are endless. For example:

- The observer or evaluator may err in the scaling of responses. As such, the scales and cognitive assessment test are subjective, because they depend on the criteria of a person. Although these criteria are standardized, it is normal that in some cases the evaluator may misinterpret the instructions or simply make a mistake when rating a result.

- The evaluated person may feel uncomfortable in the presence of the evaluator and make a poor perform because of the lack motivation.

- In neurological diseases, motor and verbal function is often compromised, so the results of some cognitive tests may be inferior because of the concomitant physical disorder of their disease. For example, in tests such as the Trail Making Test, a trace must be made on the paper while numbers and letters are being joined in order. In this test, the result is the time it takes for the person to finish the test. In people with Parkinson's disease it is a test widely used to measure executive functions, however, the slowness of movement of the disease itself may be masking a possible cognitive slowness during the test.

In order to objectify the cognitive evaluation, technology has been developed that is still innovative. Eye-tracking is a non-invasive method to gain a deeper understanding of cognitive processes, such as problem-solving and decision making. By measuring eye movements, it is possible to get insight into the ongoing mental processes during tasks and to dispense with the motor functions of speech or the mobility of the upper limbs to develop a clinical test in paper-pencil format. The eye-tracking system allows to register the eye movement through an intelligent camera and thus obtain objective parameters on how patients develop a certain mental task. In previous studies, it has been determined that as a bio-marker.

The system is basically composed of a screen that has an integrated smart camera that tracks the pupil movement of the evaluated subject. This technique works similarly to the way photogrammetry does in the human movement register. In the case of the eye-tracker, the pupil is the "marker" that allows to evaluate the desired movement. Thus, the objective of this technique is to evaluate eye movement as a clinical indicator of cognitive disorders and to analyze the visual strategy and the follow-up of the gaze in response to a certain stimulus. This technology allows to calculate the situation to which the user is directing his gaze (Figure 7) without the need for physical contact, allowing to identify his visual strategy and follow-up of the gaze in order to characterize his response to certain visual stimuli (colors, photographs, etc.) and textual (comprehension and reading of texts). The objective variables that can be studied with this system are shown in Table 2.

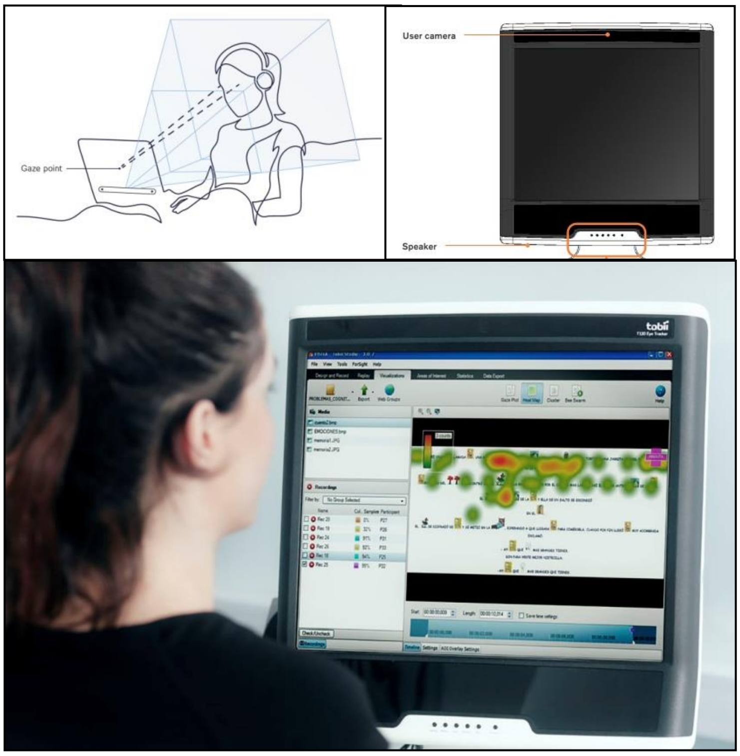


Figure 7: Eye gaze assessment with the eye-tracker system Tobii studio 120, software release 2.2. (Upper images from Tobii user manual).

Table 2 - Results from eye-tracking system assessment

Outcome	Description
Number of gaze fixations	A high number of fixations indicates a lower search efficiency of items on the screen.
Average time of gaze fixation	Long fixations are usually indicative of the difficulty of the participant in extracting the stimulus information.
Number of fixations of the gaze in each area of interest	The number of gaze fixations in a special element of the stimulus should reflect the importance of that element. Most important elements will receive a greater number of fixations.
Time percentage of the gaze in each area of interest	The proportion of time looking at a particular element of the stimulus could reflect the importance of that element.
Spontaneous eye-blink rate	Correlates with levels of dopamine in the central nervous system and can reveal processes underlying learning and goal-directed behavior.
Pupil dilation	The pupils of the eye not only constrict in response to light and dilate in response to darkness; in children as well as adults, they also dilate during autonomic arousal and mental activity. Thereason that the pupil responds to arousal and mental activity is thatpupil dilation is modulated by the noradrenergic locus coeruleus, implied on the regulation of physiological arousal and cognitive functioning.
Gaze trajectory	Circuit of the tracked look during a test. It allows obtaining an order of the places in which the person fixes the sight on the screen.
Blink rate	Frequency at which the eyelids open and close. Serve as a non-invasive, indirect measure of dopamine activity in the central nervous system. This neurotransmitter is involved in learning, working memory, and goal-oriented behavior.

Taken together, gaze, pupil dilation, and blink rate are three non-invasive and complementary measures of cognition with high temporal resolution and well-understood neural foundations.

Eye Tracking can be used in the evaluation, diagnosis and rehabilitation of cognitive performance, thus its applications are diverse in areas such as cognitive development and social psychology, among others.

3. Cognitive load interference on motor performance

In usual contexts, we do several tasks at the same time. Some situations that exemplify this are:

- When we walk, we can be doing a multitude of cognitive tasks: think about how to go to our destination, to observe the objects in the environment, to have a conversation with another person, or to search for something in our purse.
- When we have a conversation we do the motor task of "talking" while planning what we want to say to the other person.
- When we cook, at the same time that we handling objects in the kitchen, we are ordering the series of steps to follow to carry out a recipe.

This cognitive load can interfere with the motor task we are developing, which has been the topic of studies in recent times. This interference will vary according to the type of population studied, whether young healthy subjects, healthy older people, people with neurological disorders or people with other pathologies that, due to their disease or treatment, generate metabolic toxicity that alters their cognitive or motor functioning, issue that we will explain later.

In healthy people, the cognitive load can be measured because the performance of the primary task is not the same as when a cognitive load is not included. This difference in performance is more severe in healthy elderly. An example of this is the study of MacPherson (2019) in which determined the impact of cognitive load imposed by a speech production task on the speech motor performance of healthy older and younger adults. The experiment of this study consisted in repet senteces thre times: pre-, during-, and post stroop task. The stroop task is about reed a word with a stroop task in 2 cognitive conditions: congruent and incongruent, which required participants to suppress orthographic information to say the font colors in which color words were written. The results from this study is an increased cognitive load in the incongruent condition was associated with increased articulatory coordination variability and movement duration, compared to the congruent Stroop condition, for both age groups. The effect of increased cognitive load was greater for older adults than younger adults and was greatest in the portion of the sentence in which cognitive load was manipulated (during-Stroop), followed by the pre-Stroop segment. Sentence production accuracy was reduced for older adults in the incongruent condition.

Although the MacPherson study (2019) uses a cognitive task of great difficulty and a motor task feasible to be interfered (speaking) by the cognitive task used, the study by Chatain C. et al. (2019) uses a completely different methodology. In this study, it uses sometric quadriceps contractions at 15% of maximal voluntary contraction (blocks of 170 s interspaced by neuromuscular evaluations) until exhaustion as a motor task, and two memorization conditions as a cognitive task. All condition, (i.e. without cognitive task and with each memory task) were performed in different days. The researchers noted that the endurance time was shorter during both memory conditions, compared with control. Additionally, other measures such as the voluntary activation level, sympathetic activity, and perceived muscular exertion were compromised during the performance with cognitive load. The study of Chatain C. et al. (2019) shows that cognitive load can interfere with motor tasks that do not need cognitive functions for their development. It is important to differentiate at this point the cognitive load from the mental load. It is well documented that mental fatigue has a negative impact on subsequent endurance performance during whole-body exercises as well as during isometric contractions. In the case of mental fatigue, the performance impairment is mainly explained by the fact that mentally fatigued subjects reached their maximum level of perceived exertion faster, leading to earlier task disengagement. The mental fatigue implies mental block, lack of motivation, irritability, stress, etc., which have an impact in multiplies system. On the other hand, Motor performance reduced by cognitive load in the study by Chatain C. et al. (2019) can be explained by the interaction of various psychological and neurophysiological factors including higher perceived exertion, greater perturbations of autonomic nervous system activity, and cerebral impairments leading to earlier onset of central fatigue.

Another important theory than explain the poor motor performance when a cognitive task is developments at the same time is the "bottleneck" theory that suggests that both task (motor and cognitive), compete for similar resources when they develop at the same time. This theory could explain the cases in which motor and cognitive tasks are related in some way, as could be the case of a functional task such as gait and a cognitive task such as visual recognition. However, this approach differs from the methodology used by Chatain C. et al. (2019).

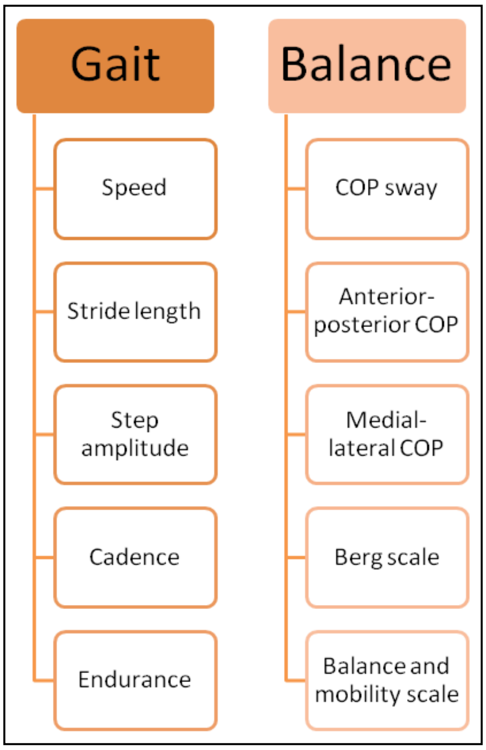


Figure 8: Gait and balance outcomes commonly altered when both motor tasks are developed with cognitive load. COP, centre of pressure.

What we explain previously is much more severe when there is an additional pathology with motor disturbance. The studies of motor performance with cognitive load in people with traumatic brain injury, acquired brain injury, multiple sclerosis, Parkinson's disease, stroke, and Alzheimer's disease have demonstrated a significant deterioration of differents motor function when it develops along with another cognitive task. The main motor tasks studied is gait and balance and the principal impairment characteristic are shown in Figure 8. These studies have allowed proposing a new methodology of motor rehabilitation in people with the pathologies mentioned above. This new approach consists of include cognitive load in motor rehabilitation of gait and balance, in order to perform motor training in a more common context and promote the practice of probable situations in daily life. The literature supports this methodology as it has been shown that challenging cognitive load training improves gait performance and balance to a greater extent than usual motor rehabilitation without cognitive load.

4. Motor performance in people with cognitive impairment and mental disorders

In the previous section, we have reviewed how cognitive load affects motor performance in healthy, elderly and with neurological motor disorders. If we study this paradigm in an inverse situation, that is, people with a pathology that implies cognitive disorders, we will also find poor motor performance. Physical health is increasingly recognized as a determining factor of neurocognitive status in psychiatric and nonpsychiatric populations. For instance, higher body mass index is associated with poorer cognitive performance and reduced gray matter in healthy samples.

In the study of this approach, it should be taken into account that age must be a factor to control since aging can be a factor of motor impairment different from cognitive impairment itself. The pathologies in which this has been studied are of two types: 1) Pathologies in young-adults or adults people that involve a cognitive alteration, such as Bipolar disorder, Schizophrenia and Depression, 2) Pathologies that in a secondary way, either by a natural course of the disease or by treatment aggressive, develop a secondary cognitive disorder, like occurs in people with Hepatic damage and Cancer. Hereunder, each of these examples is reviewed in depth.

Bipolar disorders and major depression

Cognitive impairment is a stable and lifelong feature of bipolar disorder (BD) that persists during the acute and euthymic mood phases. In particular, verbal memory, psychomotor speed, executive functioning (e.g., planning and inhibition), and to a lesser extent, visual memory and attention have been shown to be greatly impaired in acutely ill BD patients. These cognitive deficits also impair social and occupational functioning, contributing to the personal, social, and economic burden associated with mood disorders.

These findings can be interpreted based on the theory of neuroprogression which has been linked to an increase in the individual’s vulnerability to psychological stress, brain atrophy, and ultimately cognitive impairment. Closely related is the concept of “staging” which has been applied to the pathophysiology of BD to explain the progressive decline in mental health, psychosocial functioning and cognitive performance over the course of the disease. Another potential explanation for the findings of this review could be related a recent hypothesis suggesting that the structural brain abnormalities in gray and white matter observed in BD are linked to a process of accelerated brain aging. These findings suggest that increased inflammation may lead to neuronal loss in gray and white matter brain regions similar to that observed in age-related neurodegenerative diseases such as dementia.

This cognitive alterations in people with bipolar disorders can give way to a series of motor signs related with physical frailty, such as lower speed gait, balance problem during gait and sit-to-stand and loss of muscle force. For example, the study of Firth et al. showed that maximal handgrip strength held significant associations with greater performance in tasks of reasoning, reaction time, and immediate and delayed memory measures in people with major depression, bipolar disorder, and the general population. On the other hand, a growing number of publications describe cerebellar abnormalities in patients with bipolar disorders, which could affect the implicit motor learning that allows improving a sequence of motor acts through their repetition without conscious awareness of the exposure to the task. Chrobak et al. found that patients with bipolar disorders are not able to acquire procedural knowledge while performing a serial reaction time task with both hand in front of a computer with four buttons (Figure 9), compared to controls without disease.

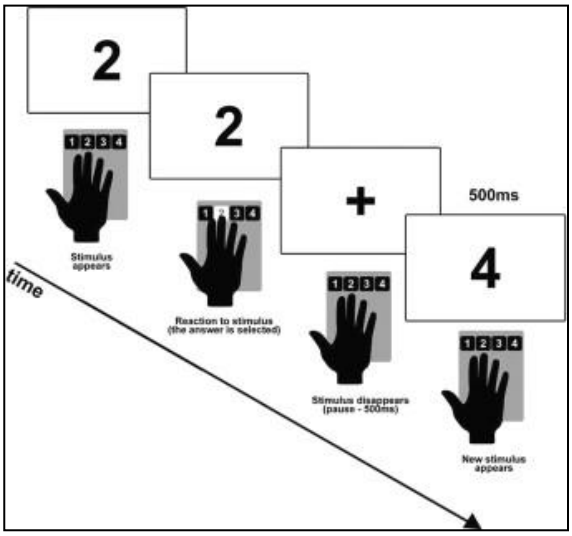


Figure 9: Serial reaction time task for implicit motor learning assessment. The task from the study of Chrobak et al. consisted in to react to different numbers from one to four with a suitable button on a response pad.

Schizophrenia

Schizophrenia is a devastating disorder thought to result mainly from cerebral pathology. Neuroimaging studies have provided a wealth of findings of brain dysfunction in schizophrenia. In addition to the mental and cognitive signs known in schizophrenia, there is a high prevalence of motor symptoms such as catatonia, neurological soft signs, parkinsonism, and abnormal involuntary movements. Although in some pathologies the affectation of cognitive functions predisposes to the affectation of motor performance due to the implication that cognition has in the development of movement, in the disease of schizophrenia, the neuroimaging methods have allowed us to establish that hypokinesia is suggested to result from insufficient interaction of thalamocortical loops within the motor system. This thalamic-cortical insufficiency causes poor communication from the motor cortex with the entry nucleus of the basal ganglia circuit (striatum), which deteriorates the feedback of this subcircuit to the control of movement originated in the cerebral cortex (Figure 10).

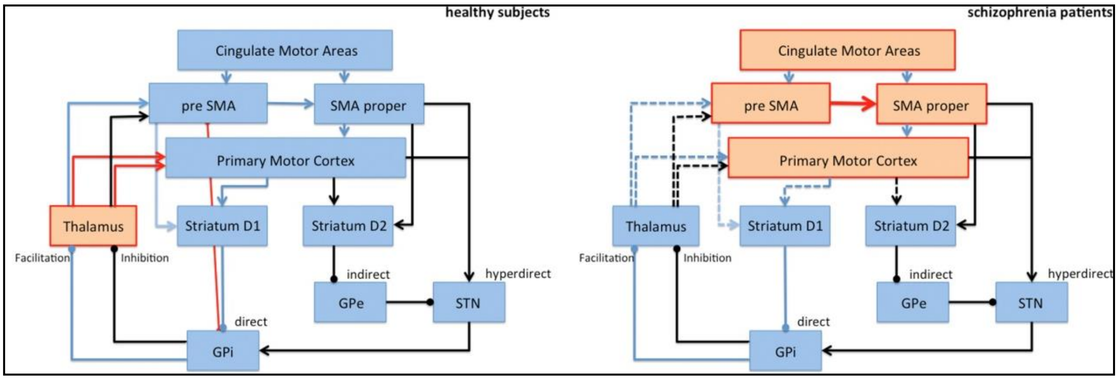


Figure 10: Connections between cortical and subcortical components of the motor loop. (Left) Circuit of Healthy subjects, (Right) Altered circuit of people with schizophrenia. Image from Walther S. 2015.

In addition to the above, patients with schizophrenia commonly suffer from impairments in various aspects of cognition. These deficits were shown to have detrimental effects on daily life functioning. Cognitive impairments in processing speed, attention, executive control functions, and memory have been well documented as a core feature of schizophrenia, and they are associated with reduced quality of life, functional disability and poor prognosis. They are associated with reduced quality of life, functional disability and poor prognosis.

Hepatic Damage

Liver failure may affect cerebral function, leading to hepatic encephalopathy (HE), a neuropsychiatric condition that may present different forms and grades of severity. Liver failure may be acute or chronic (for example, cirrhosis), and each condition induces different neurological alterations. Ammonia and inflammation are main contributors to this brain impairment. Due to liver metabolism in a disease situation, a metabolic toxicity is generated that ends up altering the brain functioning, which gives way to the signs of cognitive deterioration observed in the hepatic encephalopathy. Overt HE is frequently preceded by minimal hepatic encephalopathy (MHE), with attention deficits and mild cognitive impairment unveiled by psychometric tests.

Because cognitive impairment and neuropathy in patients suffering from liver disease trigger the onset of physical frailty, some authors aimed to determine a specific cognitive and physical profile in these patients with the final goal of identifying early indicators of the progressive deterioration. Until now, the relationship between cognitive and motor deficits in patients with liver damage has been reported in a very limited way. One line of this research is related to the assessment of frailty from scales or psychometric tests. For example, Ney et al. described a composite score from the Montreal Cognitive Assessment and the Clinical Frailty Scale to predict hospital admission of patients with HE at 6 months. However, motor evaluations like clinical tests or scales have some limitations as results can be biased by evaluators subjectivity or inaccuracy of patients reports. In this regard, including the assessment of motor signs in the study of early indicators in patients with MHE is a step forward insofar biomechanical tools allow the researcher to check objective measures of frailty. At the same time, these precise evaluations enable us to better prove risk in nondisabled patients. In this line, Mechtcheriakov et al. analyzed the kinematics of handwriting in patients with hepatic cirrhosis and found that handwriting movement performed by patients was markedly slower and less efficiently coordinated than that from healthy control subjects. Moreover, Urios et al. found that cirrhotic patients with MHE showed impaired balance, mainly on an unstable surface with eyes open, compared to cirrhotic patients without MHE. Also, parameters of the posturography test correlated with other biomechanical parameters like motor coordination and the cognitive domains like attention.

A possible explanation for the physical deterioration concomitant to the cognitive impairment observed in patients with MHE is that the function of neuronal circuits between the basal ganglia, thalamus and cortex that modulate motor activity are altered in MHE owing to altered dopaminergic, glutamatergic and GABAergic neurotransmission.

Cancer

After treatment with chemotherapy, many patients with breast cancer experience cognitive problems. Chemotherapy is an important pillar in the treatment of primary breast cancer, which impairs cognition by several mechanisms. Preclinical studies showed that chemotherapy agents can disrupt various neurobiological processes, which can lead to cognitive impairment. Effects of cellular toxicity on cognitive impairment are described (neurons, glial cells, progenitor and stem cells), but also reduced white matter integrity and inflammatory reactions as vascular toxicity and oxidative stress. These mechanisms are not mutually exclusive and one can also influence the other.

The observed cognitive changes frequently concern learning and memory functioning, speed of information processing and executive functioning. The cognitive problems are generally mild to moderate and can adversely affect work ability, interpersonal relationships and leisure activities. Although cognitive impairment in itself has an implication in motor impairment related to activities and functioning, the toxicity of the treatment of cancer patients can reinforce the detriment of movement. A systematic review evaluated empirical studies examining motor skills in children during and following treatment for acute lymphoblastic leukemia. Most studies indicated that children on-treatment display poorer gross and fine motor abilities than healthy peers, but generally have intact visual-motor integration skills. Studies have reported gross motor difficulties in 5–54% of survivors.

5. Dual-task assessment

The proper way to assess cognitive load in a motor task or, conversely, is to develop a dual-task. The dual-task or dual-tasking is the term used in the scientific literature to refer to the simultaneous development of two tasks with different objectives and that require attention for their execution. One of the tasks is called as primary task and the other as secondary task.

Traditionally, when we evaluate a motor task, we do it in a single-task condition, in which the evaluated person is only aware of the way in which performs the motor gesture that is being evaluated. However, in daily life we do several tasks simultaneously, such as walking and having a conversation at the same time or cooking while listening to television. There is scientific evidence indicating that our motor performance is not the same if we do an additional task or not. Because of this, the evaluation of a motor function under a dual-task can provide us with information on how the people "move" in a functional and usual context.

In recent times, the evaluation of dual-tasks is very frequent in studies with older people or who suffer from motor impairment, with gait being the most evaluated motor gesture in dual conditions. In this context, the gait (or other motor gesture objective of study), corresponds to the primary task. As secondary tasks a cognitive or a motor task with the arms are used. The methodologies used for evaluation under dual conditions vary between studies. Currently, both, the performance of the primary task and the performance of the secondary task, are monitored and recorded. For this, the standardization of the instructions and the evaluation procedure are essential, and they have as an objective that all the participants of a study carry out with the same procedure the execution of the parts that compose the dual-task.

One of the most important parts of the standardization of the dual task measurement protocol is to control where the patient fixes his attention. Depending on where the person directs or focuses his attention, he will determine the level of the central nervous system that controls the primary task. For example, when we walk without thinking about it, we walk automatically, whose nervous control is in charge of lower structures such as spinal or mesencephalic control centers. On the contrary, if we need to change the gear pattern to adapt the speed, the length of the step or any other characteristic of it, we will do it in a "conscious" way and the change will be regulated by the motor areas of the cerebral cortex. This is known as dual gait control and is as flexible as it is effective.

A clear example of the development of dual tasks in daily life is when a person walks looking at the mobile phone. While walking, he performs a secondary motor task with the hands of manipulation, and at least an additional cognitive attention task (Figure 11). The importance of the evaluation in dual or multitasking conditions is not only useful and necessary because it is a habitual context of daily life but in many pathologies, as we have seen throughout this didactic Unit, they have some degree of detriment of both domains, cognitive and motor. One way to carry out this type of evaluation is with biomechanical assessment tools that allow to objectify motor dysfunction. In fact, the literature exists only uses objective assessment tools with which gait deficiencies, balance, muscle strength, motor reaction speed, among others have been characterized.

Figure 11: Dual-task assessment. In this example the primary task is the gait and the secondary task is the manipulation of the mobile phone. The gait assessment is performed with a photogrammetry system which allows register the cinematic outcomes of the evaluation, such as gait velocity, spatiotemporal parameters and joint angles.

Once a dual evaluation is carried out with objective tools, we will obtain two types of parameters, those performed in the single condition, that is, only by developing the motor task under evaluation and the parameters obtained from the motor task with cognitive load or in dual conditions. The interference of secondary task, either cognitive or motor, it is obtained through a variable called "dual-task cost", which is calculated from equation 1.

$$DTC(\%) = \frac{(ST\ score - DT\ score)}{ST\ score} * 100$$

Equation 1: Dual-task cost. Interference rate of dual tasks during a motor task performance.

For example, if an older person walks at a speed of 1.10 m/s but, when performing the same walking while talking slows his gait to 0.98 m/s, the dual-task cost is 10.9%. Which means that the gait of the person evaluated has a deterioration of eleven percent during the dual-task condition.

6. Key Ideas

- The cognitive functions in the human being allow to carry out effectively all kinds of activities, both mental, social and motor. Within cognitive functions, executive functions are widely studied because they allow the performance of multiple tasks efficiently and because of their involvement in the movement.

- The evaluation of cognitive functions is traditionally mediating scales and psychometric tests that have a subjective component because the response observed by the evaluator or given by the patient comes from a subjective perception. Tools such as the eye-tracker allow us to objectify a cognitive response through the monitoring of eye movement, identifying the pupil.

- Cognitive burden has an impact on the motor performance of healthy people, elderly or with neurological disorders. The most studied functions under cognitive load are gait and balance, finding a worse performance when an additional task is performed at the same time.

- People with diseases that implies to cognitive impairment show motor impairment for two reasons mainly: 1) because altered cognitive functions are involved in motor activities such as work or driving, and 2) because, in addition to the brain abnormalities that show cognitive damage, there are mechanisms where motor circuits are also affected. Examples of these pathologies are bipolar disorder, schizophrenia, chronic liver damage and patients with cancer and chemotherapy treatment.

- The way to evaluate the cognitive load in a motor task, or vice versa, is through a dual-task, where the attention of the person evaluated fluctuates between the development of the primary task and the secondary task. The indicator of this interference is the *dual-task cost parameter*, which indicates the percentage of deterioration of the additional load to the primary task.

- The importance of biomechanical evaluation under dual conditions is that, on the one hand, they are a functional and habitual context for people, and on the other hand, many mental or cognitive pathologies, in turn, cause motor damage, may require medical attention in this domain.

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