BRAIN HEALTH TRAINER

Module 1:
Understanding the Course of Cognitive Aging
Handbook

In the **Course Introduction**, we **identified the types** of clients related to the various stages of cognitive decline; Worried Well, Subjective Cognitive Decline, Mild Cognitive Impairment, Dementia, and Alzheimer's Disease.

Module 1 will build on your knowledge of these terms, as we **discuss** how the **brain changes** with **age**, and differentiate normal cognitive aging from neurodegenerative conditions.

Before you begin Module 1, you should **be able to define** each of the **terms** and differentiate between the **four client types** that were discussed. An in-depth **understanding** of these **concepts** and differences among the various stages of **cognitive aging** will be **important** when making decisions on how **to individualize** a Brain Health Exercise and Physical Activity Plan (**BH-EPAP**), as well as explain how the brain may change with age.

Module 1 Overview

Introduction

Module 1 focuses on the **course of cognitive aging** and how our **brains can change** as we get older. You will learn about the **physical changes** to the brain, the differences between **normal cognitive aging versus Alzheimer's Disease**, and the four primary domains of cognition.

You will apply **need to apply this knowledge in Module 2**, where we discuss the effects of different types of exercise and physical activities on the brain. You must have a **firm understanding of the course of cognitive aging** and the **four primary domains of cognition** before we cover how to create a BH-EPAP in Module 3.

Module Agenda and Objectives

This module is divided into two sections with a total of 15 lessonss. The module ends with a quiz. You must complete both sections and score a 70% on the quiz to progress.

1

Section 1: Aging and the Brain

Lesson 1 explains the effects of aging on the human brain and the difference between the normal course of aging and Alzheimer's Disease. You will define important terms related to cognition, neuroanatomy, and different theories of cognitive aging. A key focus of this section is to compare the neurological processes during the normal course of aging and Alzheimer's Disease.

2

Section 2: Domains and Sub-domains of Cognition

Lesson 2 discusses the effects of aging on the four primary domains of cognition; Executive Functioning, Attention, Memory, and Processing Speed. You will define these four primary domains, as well as their sub-domains and components. This section will also describe how these cognitive domains interact with each other and with the other structures, networks, and processes in our brain.

Knowledge Check

Dementia (including Alzheimer's Disease), Worried Well, Subjective Cognitive Decline (SCI) or Mild Cognitive Impairment (MCI)?

Record your answers here for future reference.

No abnormal changes to the brain, motivated by family history or fear of decline .... ____________________

Changes to the brain without significant measurable decline .... ____________________

One or more cognitive domains impaired noticeably, a diagnosable condition .... ____________________

Interferes with ability to execute activities of daily living, more severe decline .... ____________________

Aging and the Brain

Introduction to Section 1: Aging and the Brain

Section 1 is divided into **7 lessons.** This section identifies the effects of aging on the adult human brain, and the difference between the normal course of aging and Alzheimer's Disease.

Lessons 1 and 2 will **define** important **terms** related to **cognition & neuroanatomy** and relate these terms to the course of **cognitive aging**. Lessons 3 identifies ways to assess brain health. Lessons 4, 5, 6, and 7 will **introduce** the concepts of **Neurodegeneration, Cognitive Reserve**, different **theories of cognitive aging,** and their relationship to **Alzheimer's Disease** and cognitive decline.

By the end of Section 1, you will be able to explain the effects of aging on the human brain, recall different theories of cognitive aging, differentiate between the normal course of aging and Alzheimer's Disease.

Lesson 1 Objectives

1. Define cognition and explain its relationship to brain health
2. Explain the role of cognition in everyday life
3. List the four primary domains of cognition

Defining Cognition

Cognition refers to mental functions that allow us to acquire knowledge and understanding through sensory input, experience, and thought. In other words, cognition allows us to interact with the world around us, and within us.

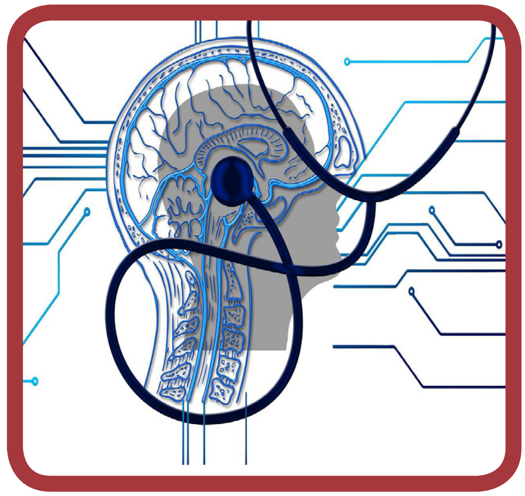
The Brain Health Trainer course will focus on four specific aspects or domains of cognition: Executive Functioning, Attention, Memory, and Processing Speed. These four domains can be used to frame a conversation around the need for a brain health-focused exercise and physical activity plan. This conversation can be an effective way to support a client's motivation and subjectively measure progress. For example, a client may mention to you they "sharper" (a general outcome) or feel that they process information faster (a specific outcome) as the result of your exercise programming.

However, given the nature of cognition and the complexity of the brain, it is not guaranteed that we can focus on these four domains of cognition as specific outcomes of our programming, although emerging research points towards the potential for "cognitive domain-specific" exercise programming as more research is conducted.

Framing Cognition for the Brain Health Trainer Course

Cognition is just **one aspect of brain health**, among some of the other brain health-related outcomes. Generally speaking, these would include Structural, Functional, Psychological, and Behavioral Outcomes.

Cognition is considered a part of **Behavioral Outcomes**, and we focus on it because it is the **most likely noticeable response** from exercise programs **without** the utilization of **neuroimaging**. For example, one might notice changes in the memory or mood, but cannot "feel neurons" or regions of their brain on a daily basis.



While mental health is an important outcome that is intertwined with cognition, the focus of this course will not be on mental health.

In addition, there are many other types of cognition not mentioned in the course, including language and metacognition.

Cognition is fluid, not fixed

Cognition is like **blood pressure**, which can change at multiple time-points. As Brain Health Trainers, we are interested in the trends of the **time-points in cognition** rather than in a single time-point.

Things that **affect blood pressure** can also **affect cognition** including:

1. Exercise
2. Sleep
3. Stress
4. Nutrition
5. Environment

There are **normal age-related changes** associated with **blood pressure & cognition**, and both can be modified by disease or co-morbidities. For example, certain changes in cognition naturally occur with age, but optimizing this process is possible through lifestyle modification.

Knowledge Check

What are the four domains of cognition framed in this course?

- ○ Attention, Executive Function, Memory, and Processing Speed
- ○ Behavioral, Structural, Functional, and Psychological
- ○ Impulsivity, Short-Term Memory, Reaction Time, and Language
- ○ Fluid Intelligence, Crystallized Intelligence, Memory, and Language

Limits to Cognitive Improvements

Continuing with our blood pressure metaphor, there is a range of acceptable values based upon age, gender, and other factors. Similar to blood pressure, cognition can be assessed both briefly and comprehensively. Achieving good blood pressure is both relevant and transient depending upon various lifestyle, environmental and genetic factors. However, blood pressure cannot continue to improve indefinitely.

Similarly, cognition cannot just continuously improve and is dependent on various lifestyle, environmental, genetic, and behavioral factors. There are limits to what an individual may be able to achieve any type of intervention for cognition, including what is covered in this course. In other words, there is a "ceiling" for cognition, which means that there is an age-related maximum score on cognitive tests that can be reached, rather than being infinite.

This concept of a "ceiling" also applies to each of the four primary domains covered in this course; attention, memory, processing speed, and executive functions. While several of these types of functions may decline with age, some remain largely unchanged but may be significantly modified by neurodegenerative diseases.

Knowledge Check

Record your answers here for future reference.

Variables that can affect cognition .... ______________________

Cognition is fluid, similar to .... ______________________

The domains of cognition focused on in this course .... ______________________

Cognitive implrovements are .... ______________________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Cognition is one aspect of brain health that allows us to think, acquire knowledge through our experiences, and interact with the world using our senses.
- [ ] There are age-related changes associated with cognition which can be modified by disease, co-morbidities, or lifestyle modification. Improvement through various interventions, including exercise and physical activity, is possible but limited by various factors.
- [ ] Improvement through various interventions, including exercise and physical activity, is possible but limited by various factors.

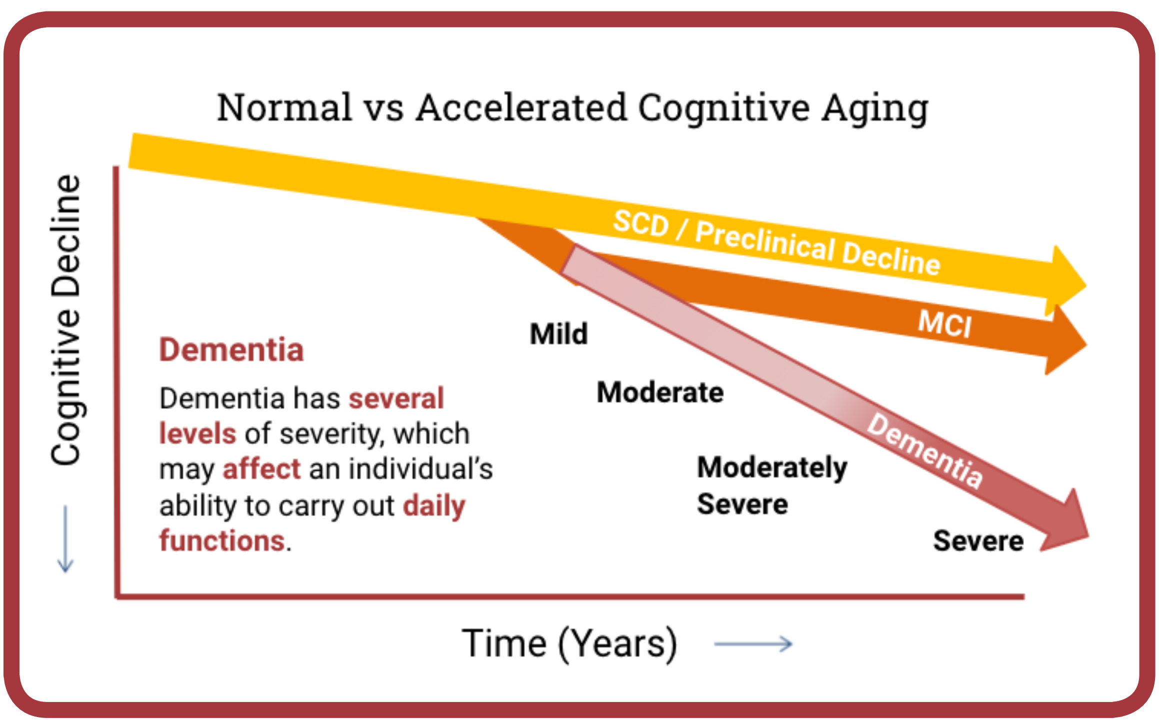
The Course of Cognitive Aging

Lesson 2 Objectives

1. Summarize the progression of normal aging in terms of normal aging, subjective (or preclinical) cognitive impairment, mild cognitive impairment, and the various stages of dementia.
2. Recall that there are changes to neurons, brain volume, and memory caused by aging.
3. Summarize the changes that occur in the brain with aging, such as brain volume and memory.

The Course of Cognitive Aging

The **chart below** provides a **graphical depiction** of the normal **course of cognitive aging**.



Normal Aging vs Alzheimer's

This **chart demonstrates** some of the **mechanisms** that occur with **normal cognitive aging versus** those that occur with **Alzheimer's Disease**, the most common subtype of dementia.

Normal Cognitive Aging	Alzheimer's Disease
Some neuronal decline	Extensive loss of neurons
Some variable changes in cognition	Severe & progressive decline
Some neurodegeneration occurs	Severe & chronic neurodegeneration
General slowing of daily activities	Worsened activities of daily living
Losing things from time to time	Misplacing things with little recall
Occasional word-finding issues	Difficulty holding a conversation
Missing a monthly bill	Inability to manage budget

Knowledge Check

Mild Cognitive Impairment, Pre-Clinical Cognitive Impairment or Dementia? Record your answers here for future reference.

General term for more severe cognitive decline .... ______________________

May include a variety of different sub-types .... ______________________

A "Silent Phase" of Cognitive Decline .... ______________________

When diagnostics would be considered preventative .... ______________________

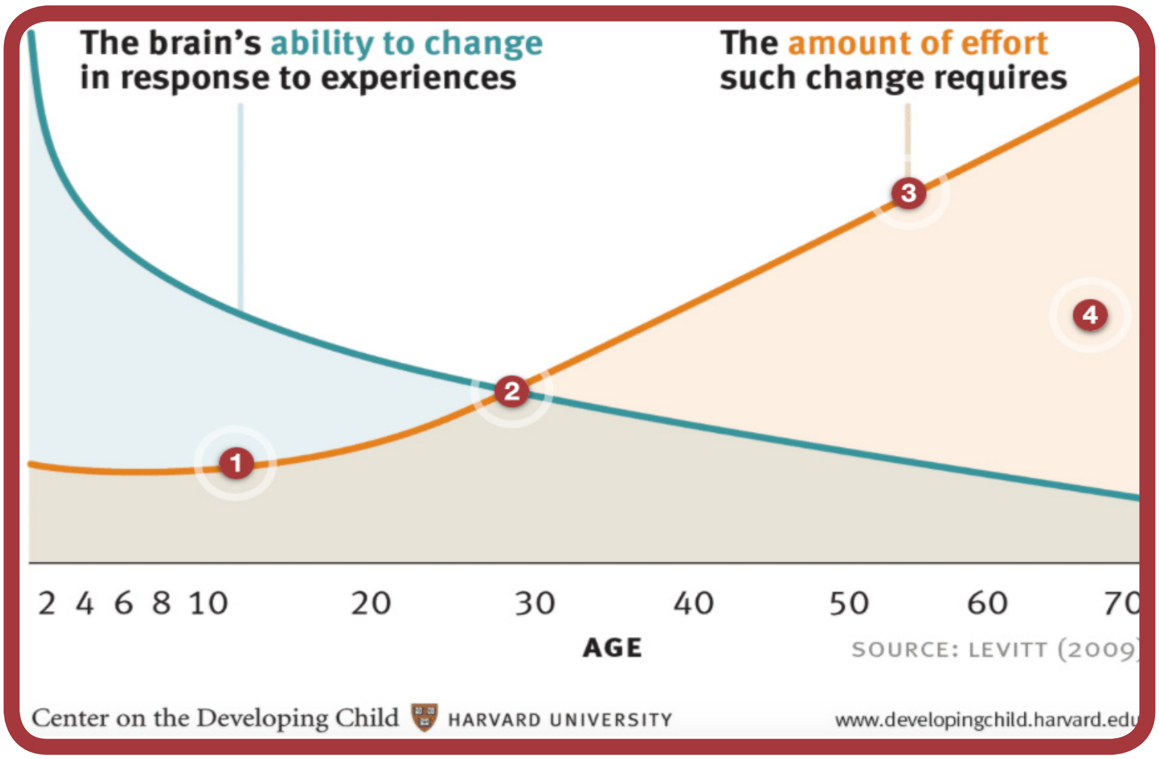
A specific disease that requires diagnosis .... ______________________

Most Common Subtype of Dementia .... ______________________

The Brain's Ability to Change with Age

The graphic below summarizes the brain's **ability** to change with age. Researchers have only recently discovered that the **brain can continue to change** into later adulthood.

Click on all the **"#"** symbol on the charts to learn more about the factors that affect our neuroplasticity over time before moving on to the next section.



1. Prevention - **Positive experiences** and lifestyle behaviors in **early-life** contribute to **slower cognitive decline** and **greater cognitive reserve**.

2. Effort and Change - The brain's **ability to change** in response to experience is **most available early in life**.

As **age increases**, the **ability** for the brain **to change** in response to experience **decreases**. At the same time, the **amount of effort** required to make these changes **increases**.

3. More Effort Required - **As individuals age**, they tend to be less eager to engage in more intense and frequent exercise.

4. Healthy Change - This curve demonstrates that with age, individuals should put more effort towards exercise and new experiences, while not exceeding stress thresholds. This will make it easier to engage in neuroplastic changes later in life.

Key Takeaways

- ☐ The brain's ability to change in response to experiences, or neuroplasticity, is available into late adulthood, but the effort required to elicit change is often greater.
- ☐ While there are changes to the brain that normally occur with age, there are modifiable risk factors, such as exercise and diet, that modify the trajectory of brain aging.

Assessing Brain Health

Lesson 3 Objectives

1. List types of brain health assessment methods.
2. List additional factors to consider when assessing brain health.

Assessing Brain Health

Brain Health can be assessed in myriad ways. The **role of a Health and Wellness Professional (HWP)** is to **refer** your **clients** to **medical professionals** that can assess various aspects of brain health. Once you refer your client to a medical professional, your client may undergo one or more of the f**ollowing assessments** to **determine** their **level of cognitive decline.**

1. **Assessments measuring Subjective Cognitive Ability**
   Subjective cognitive ability can be assessed through questionnaires, interviews, physician discussion, and accounts from a caregiver.
2. **Objective Cognitive Assessment**
   Objective cognitive abilities can be assessed through cognitive testing (either paper-based or computerized), ideally via neuropsychologists.
3. **Neuroimaging**
   Neuroimaging is used to image the brain. There is functional neuroimaging and structural neuroimaging, which clinicians may use for various reasons.

Knowledge Check

What form of assessment is most likely used to assess Subjective Cognitive Decline?

- ○ Cognitive Testing
- ○ Questionnaires & Interviews
- ○ Neuroimaging
- ○ Blood Tests

Assessments Measuring Subjective Cognitive Ability

Subjective Cognitive Decline (SCD) can occur in a variety of populations. But what is "subjective cognitive ability"? Subjective cognition refers to an individual's **experience** of their own mental **abilities**. An individual's appraisal of their own cognitive abilities may not always be **accurate**, however, it can encourage individuals to pursue **medical advice** and positively modify their lifestyle.

Cognitive Failures Questionnaire

Very often	Quite often	Occasion-ally	Very rarely	Never
4	3	2	1	0

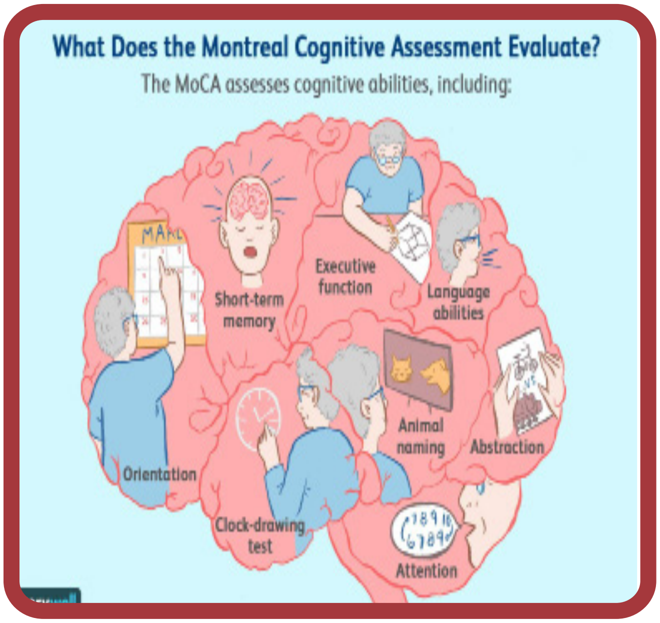
Do you find you forget appointments?
Do you forget where you put something like a newspaper or a book?
Do you daydream when you ought to be listening to something?
Do you find you forget people's names?
Do you start doing one thing at home and get distracted into doing something else (unintentionally)?
Do you find you can't quite remember something although it's "on the tip of your tongue"?
Do you read something and find you haven't been thinking about it and must read it again?
Do you find you forget why you went from one part of the house to the other?
Do you find you confuse right and left when giving directions?
Do you find you forget whether you've turned off a light or a fire or locked the door?
Do you fail to hear people speaking to you when you are doing something else?
Do you leave important letters unanswered for days?
Do you find you forget which way to turn on a road you know well but rarely use?
Do you fail to see what you want in a supermarket (although it's there)?

The **Cognitive Failures Questionnaire** is one example of a survey that can be used to assess identify and score subjective cognitive complaints.

Fewer than **50%** of individuals with SCD have consulted a medical professional. Encouraging these individuals to take a **baseline test is paramount**, especially if they are 65 years or older.

Objective Cognitive Assessment

There are three commonly used Objective Cognitive Assessments. These are different from the measurements of subjective cognitive abilities. These are provided in **medical settings** and can lead to more extensive testing.



The **Montreal Cognitive Assessment** (MOCA) is a one-page cognitive screener that is scored on the basis of 0/30 points. The assessment includes questions like drawing a clock and a 3D box, naming animals, and tests of working memory through questions on orientation (day, season, location, etc).

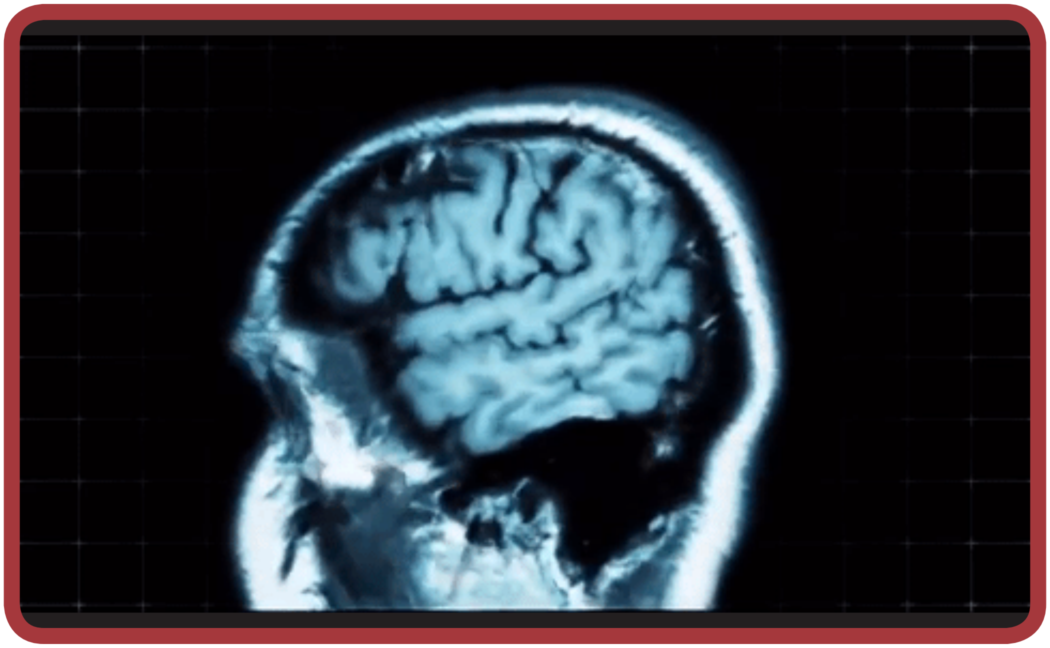
Computerized Cognitive Assessments are sometimes used, consisting of 30-60 minutes of testing multiple abilities on a computer. These can be self-administered or supervised by a medical professional.

Neuropsychological Evaluations

Neuropsychological Evaluations can be more diagnostic, specific, and sensitive, taking up to several hours using "pencil and paper testing". These are only conducted by **Neuropsychologists**, who should be referred to when evaluating or discussing cognition.

Neuroimaging

Neuroimaging is one of the most advanced way to determine a person's level of cognitive decline and is **used to diagnose advanced stages** like MCI, Dementia, and Alzheimer's Disease. There are **three common types** of Neuroimaging techniques typically used to assess the brain.



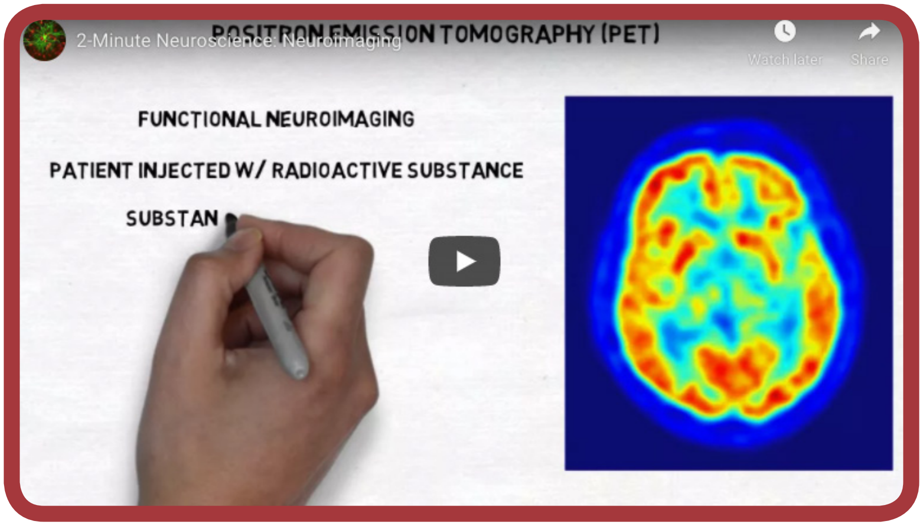
1. A **Volumetric MRI** (vMRI) looks at the size of brain structures, like the hippocampus, relative to norms. This is "structural neuroimaging."

2. An **Amyloid PET scan** uses a radioactive tracer, which is metabolized by the brain, to look for amyloid proteins that may indicate Alzheimer's Disease.

3. A **Quantitative EEG** (QEEG) observes levels of brain activity in superficial brain regions. This is "functional neuroimaging."

Neuroimaging Techniques

The optional video below will provide more information about how various forms of Neuroimaging can use to assess brain health. Clinically, volumetric MRIs are most likely utilized to assess the size of brain structures, while fMRI is used to assess brain function. fMRI is likely only to be used in a research context, not in a clinical setting.



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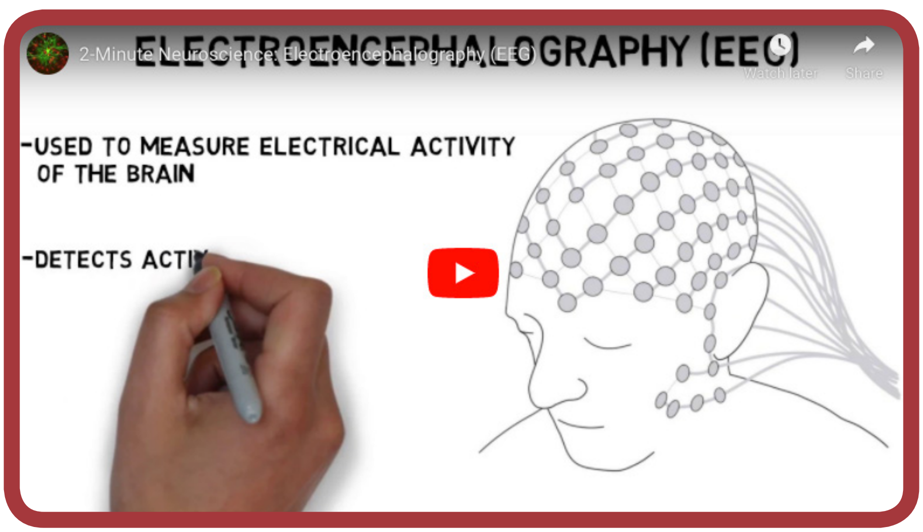
Quantitative EEG

The optional video below will provide more information how a QEEG is used to assess cognitive decline. QEEG may be utilized in clinical settings and/or research settings.



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Additional Factors in Assessing Brain Health

Other factors exist when assessing brain health-related factors that are often overlooked. The additional factors can be measured by medical professionals, both general & specialized.

Cardiovascular Risk Factors

Cardiovascular health-related measures have been strongly correlated with aspects of brain health, including cognition and brain volume. **Blood pressure**, resting heart rate, measures of **cardiorespiratory fitness**, screening for **hypertension**, and measures of heart rate variability **(HRV)** are all measures that reflect cardiovascular health and can be collected, measured, and managed by HWPs.

Sleep Studies

Sleep studies assess for **sleep disorders** that can significantly affect brain health, such as **sleep apnea, insomnia**, and issues with **sleep quality**. These are assessed by **sleep medicine doctors**. Undiagnosed sleep apnea or **sleep-disordered breathing** are common, and therefore it is worth discussing with your clients to be assessed and treated.

Hormones

Endocrinologists can assess **hormones** that affect cognitive function and brain health. The layperson is typically unaware of their hormonal health, which is why **referrals** and awareness are important. Hormones play a **significant role** in brain health, especially in **women** during and **post-menopause**, as it relates to **dementia risk.**

Blood Biomarkers

Various physicians (GPs, neurologists, functional medicine doctors) can order **lab tests** for assessing critical **biomarkers** associated with cognition, such as **Vit. B12, Vit. D, Vit. E, fasting glucose, C-reactive Protein (CRP), cholesterol, Hemoglobin A1C**, and **Homocysteine**. Sub-optimal levels of any of these blood biomarkers can affect brain health, and can often be addressed through **dietary** & **lifestyle** modifications.

Mental Health

Assessments of mental health conditions, such as **depression** and **anxiety,** are important in relation to cognitive functioning and overall brain health. **Cognitive complaints** can sometimes indicate or relate to underlying mental health issues that can be assessed by **psychologists, psychiatrists**, and other **mental health professionals**. Mental health diagnoses may also warrant **modifications** in specific lifestyle and exercise recommendations.

Genetics

Various physicians and consumers can access genetic testing for genes related to cognitive and brain health, such as the **APOE3, APOE4**, and MTHFR gene variants. The APOE3 and 4 genes are specifically related to the risk of developing dementia, specifically **Alzheimer's Disease**, and can play a role in further individualizing interventions.

Medications

Proper **medication management** is critically important in cognitive health. The assessment and management of a medication regimen are ideally conducted by a **geriatric psychiatrist** alongside neurologists & GPs and can prevent **excessive** or unnecessary medication intake **(poly-pharmacy)**.

Anthropormorphics

Body fat percentage (especially visceral **body fat)**, waist and hip **circumference,** fat mass vs. lean mass, weight, and other factors can affect brain health and cognition. The variables can traditionally be measured by HWPs, and their collection, management, and **improvement** are encouraged as part of a brain-healthy lifestyle.

Knowledge Check

Vitamin D & B12 , APOE3/4 , Estrogen, Body Fat, Hypertension, Depression, Apnea

Record your answers here for future reference.

Blood Biomarker .... ______________________

Genetics .... ______________________

Endocrine .... ______________________

Anthropomorphic .... ______________________

Cardiovascular .... ______________________

Mental Health .... ______________________

Sleep .... ______________________

Key Takeaways

- Various factors can affect brain health, such as; sleep, medications, cardiovascular health, anthropometrics, genetics, hormones, blood biomarkers, and more.
- Brain health can be assessed by subjective interpretation or observation, cognitive testing (brief or extensive), and various forms of neuroimaging.

Age Related Changes to the Brain

Lesson 4 Objectives

1. Define the levels of changes to the brain as related to cognitive aging.
2. Explain the neuronal and volumetric changes to the brain that can occur with age.
3. Explain age-related changes that occur in the major structures and lobes of the brain.

Levels of Change

Brain changes that occur throughout the course of cognitive aging can be classified at the Micro or Macro-level. These levels will also be important when you are learning about specific ways exercise can affect the brain.

1. **Micro-Level Changes**
   Changes in smaller-scale structures and functions of the brain. Examples of these structures and functions include Neurons, Dendrites, Synapses, and Neurotransmitters.

2. **Macro-Level Changes**
   Changes to the larger-scale brain structures and functions. Examples include the brain's grey matter, the Pre-frontal Cortex, the Temporal lobes, and the Hippocampus.

3 **Behavioral-Level Changes**
Changes to Behavioral outcomes, such as mood or cognition. Examples include changes in cognitive functions, such as memory or attention, or changes in mood, such as symptoms related to depression or anxiety.

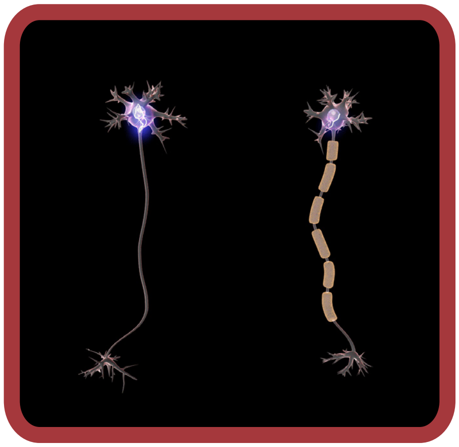
The Human Brain

This video identifies **key regions in the brain** and demonstrates how various central nervous system tissues are comprised from the **macro-level** (such as grey matter) down to the **micro-level** (such as neurons).

Watch This Video On Vimeo

Neuronal Changes to the Brain

The term **neuron** refers to **a brain cell**, or the **most basic working unit** within the **nervous system** and the brain. Both the **size** and **function** of neurons can **decline with age**, just as cells in muscle tissue change with age.



Neurons may also lose function via a reduction in the **myelin sheath**, which **surrounds neurons** and is created by oligodendrocytes to **increase signal speed.** This loss of function is especially true in the **white matter** of the brain. As myelin is reduced, brain **processing speed** slows down.
Myelin-enhanced neural processing speed peaks in the teen years, and declines thereafter.
Abnormal changes in white matter, and therefore myelin, are **often genetic, lifestyle-related**, or due to conditions such as **Multiple Sclerosis.**

Knowledge Check

Neurons, White Matter, Gray Matter, Dendrites, Hippocampus
Record your answers here for future reference.

Made up of myelinated axons that communicate between brain regions. .... ____________________

Includes cell bodies, synapses, glia, capillaries, and unmyelinated neurons. .... ____________________

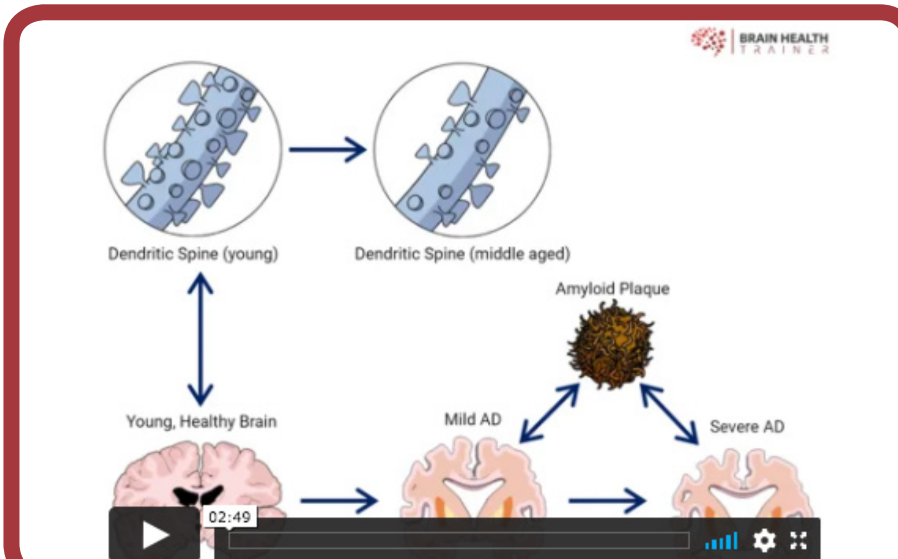
Most basic working units in the nervous system, grouped into networks. .... ____________________

A branch-like projection of a neuron, receives chemical and electrical signals .... ____________________

Structure within temporal lobe responsible for learning, memory, and emotion .... ____________________

Brain Volume Changes

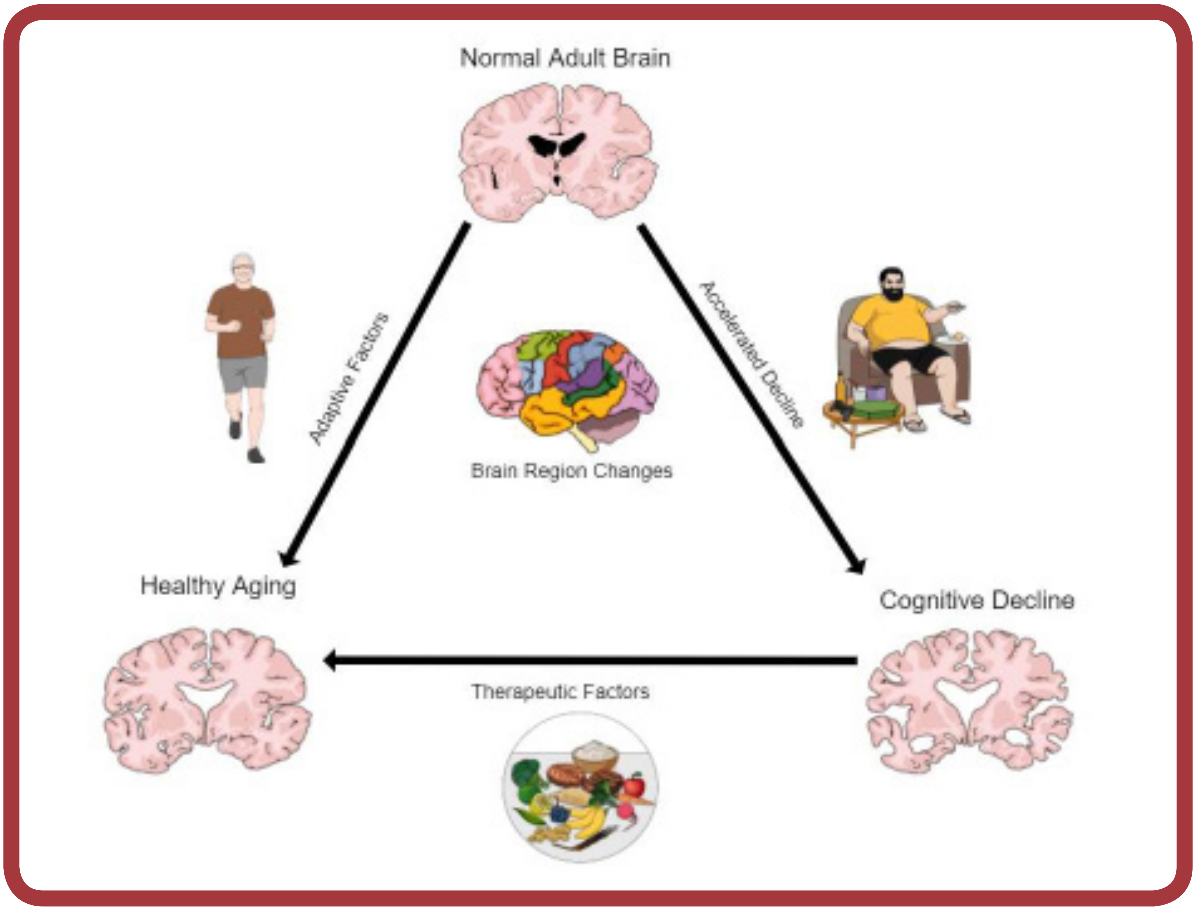
Watch the video below to learn how **micro** and **macro-level structures** can **change in parallel** with each other.



Watch This Video On Vimeo

Brain Volume Changes

As we age, decreases in brain volume normally occur, and there are **factors** that may **support healthy aging** or **accelerate decline**. The labeled graphic activity below compares the normal adult brain, a normally-aged brain, and a pathologically-aged brain. Click on all the pulsing numbered buttons below before moving on to the next section.



1 **Normal Adult Brain**

This image shows a **normal adult brain** with a healthy amount of brain volume that **has not begun to decrease**. Balance between **Adaptive** and **Accelerating factors** can reduce overall loss of brain volume caused by aging.

2 **Adaptive Factors**

Adaptive Factors are neurological and physiological **processes** of **positive brain** change that facilitates healthy aging. **Adaptive factors** include: Growth Factors, antioxidants, neurogenesis and synaptogenesis.

3 **Accelerating Factors**

There are **genetic, physiological**, and **behavioral factors** that can **contribute** to the **loss of brain volume** and increase the risk of accelerated cognitive decline. **Accelerating factors include**: cardiovascular risk, stress, depression, obesity, and **genetic** predisposition.

4 **Lobes that Decline with Age**

Specifically the **Temporal, Frontal**, and the **Parietal lobes** decline in tissue volume and density with age. As the **Frontal lobes atrophy**, individuals may experience **decreased executive functioning.**

5 **Normal Aged Brain**

By **age 80**, a healthy brain is **5% lighter** than a brain in middle adulthood. These **decreases in volume** and weight are often **due to** changes in **gray matter**, declining **neuron numbers**, changes in **cortical thickness**, and decreased **blood flow.**

6 **Accelerated Decline**

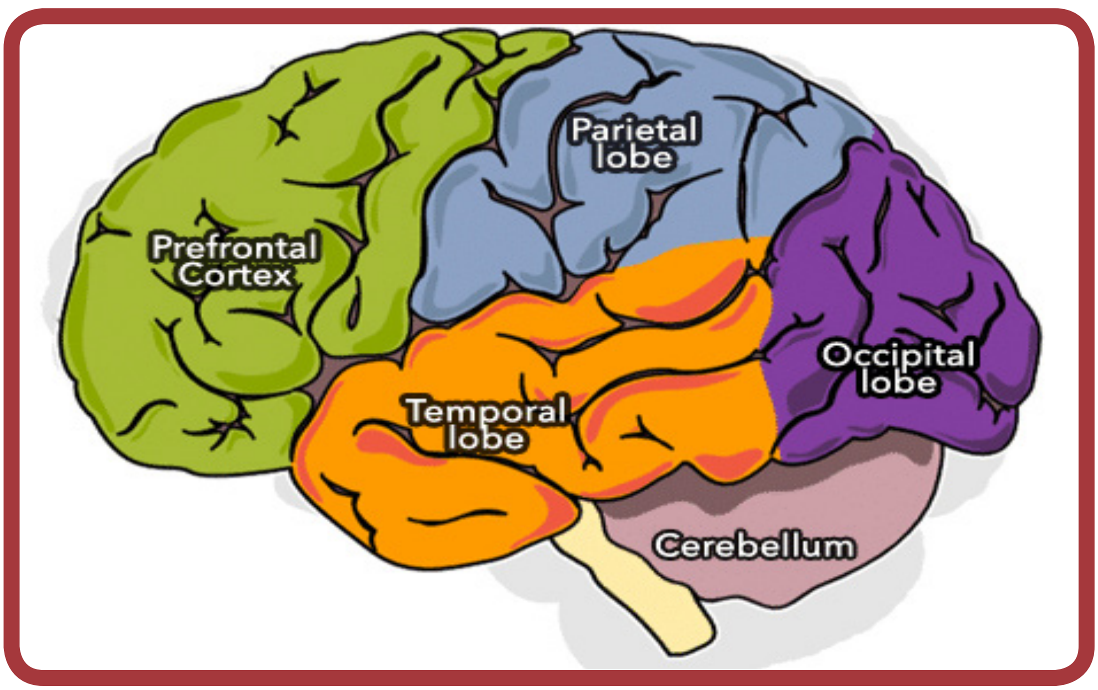
A brain that suffers from pathological **loss of brain volume** will show significant **deterioration** in both **micro** and **macro level** structures and functions.

7 **Therapeutic Approaches**

Therapeutic Approaches may **potentially reduce** the **risk** of pathological brain **volume decreases. Therapeutic Approaches** may include: Mediterranean diet, supplementation, proper lifestyle, and treatment of **cardiovascular** conditions.

Major Brain Structures

In this course, we use the term **Brain Structures** to refer to the major **regions** within the brain. Click on each numbered dot to learn more about each major brain structure. Note that some structures are **deeper** in the brain and pictures within the pop-up text will be shown for these regions.



1 **Prefrontal Cortex (PFC)**

The Pre-frontal Cortex (PFC), which covers the front of the Frontal Lobe plays a role in motor planning, executive functioning, short-term memory, and decision-making.

2 **Motor Cortex**

The Motor Cortex, also part of the frontal lobe, is responsible for the planning, execution and control of movement.

3 **Parietal Lobe**

The Parietal lobe is involved in language and processes proprioceptive & visuospatial information to create a more complete sensory picture of the world. Using this information, motoric signaling stemming from the parietal lobes allows for arm-hand-eye action and coordination.

4 **Occipital Lobe**

This area of the brain is responsible for visual-spatial processing and motor control and possesses different pathways for processing visual attention. It is associated with memory formation, face & object recognition, & visuospatial processing.

5 **Cerebellum**

The Cerebellum plays a role in motor control, attention, language, and emotion. It contributes to precision, timing, coordination & motor learning. It connects to the PFC via the thalamus.

6 **Temporal Lobe**

The temporal lobes plays a role in auditory information processing due to their proximity to the ears, and in sensory information processing and visual processing, specifically associated with object recognition.

7 **Hippocampus**

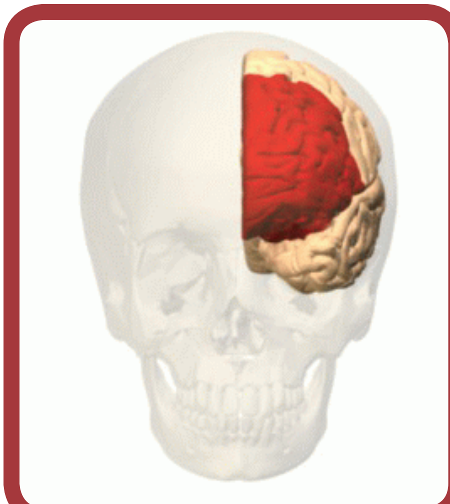
The Hippocampus is responsible for short-term, long-term and spatial memory formation and consolidation. Neurogenesis is commonly studied here. It also controls the motor circuit at the highest level, and is involved with intense muscular contractions.

8 **Basal Ganglia**

A **deeper brain structure** that consists of various nuclei-based **substructures**, rather than existing as a singular, unified structure. These include the **caudate nucleus** and **putamen** in particular. These substructures have roles in **muscle tone control and movement** due to the input received from the somatosensory and motor cortices, with output to the motor areas of the cortex.

Age Related Changes to The Prefrontal Cortex (PFC)

There are many **normal age-related changes** in the Prefrontal Cortex the can occur, including decreases in **volume**, dysfunction in motor planning, delays in response time, and changes prefrontal in **brain activity**, such as hyperactivity.



There are also changes in brain activity, specifically **Hyperactivity**, which constitutes **neural activity-based inefficiency.** For example, a younger, healthier brain uses normal levels of activity to accomplish similar tasks. This, in comparison, is less activity than an older brain, and would therefore constitute **more efficient Prefrontal Cortex activity** in the younger brain.

Higher levels of **hyperactivity** in the PFC have been associated with symptoms of **ADHD**. Conversely, **lower amounts** of activity have been associated with **depression**. Both instances can be **quite common in aging** due to these related changes in the Prefrontal Cortex over the lifespan.

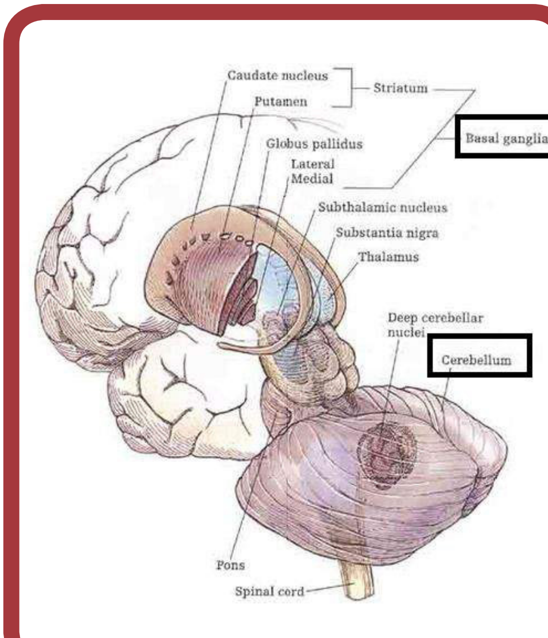
Age Related Changes to the Cerebellum

There are also significant changes within the Cerebellum and Basal Ganglia that occur during the normal course of cognitive aging.

The **Cerebellum communicates** with the **Basal Ganglia** and the **Prefrontal Cortex** via a pathway in the thalamus, lending itself to potentially **significant roles** in **learning, attention, cognition**, and **emotion**.

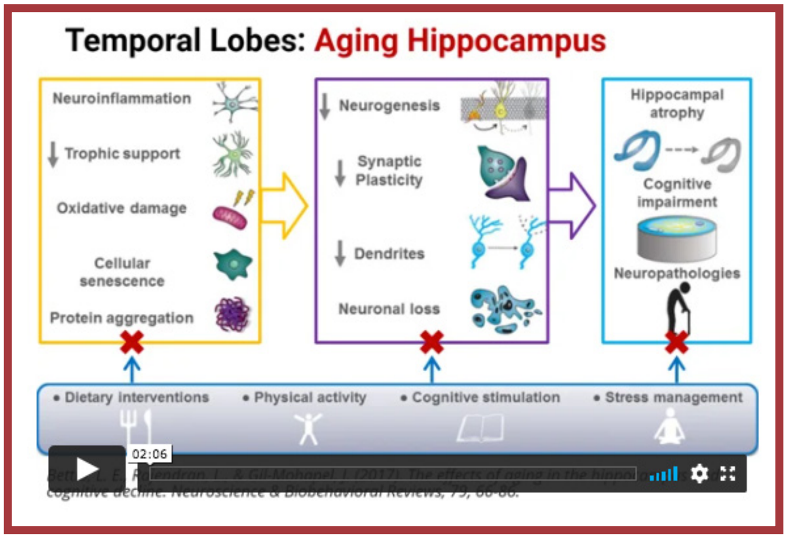
Dysfunction in these areas can lead to movement issues, such as **tremors** or **ataxia**, that can interfere with activities of daily living as seen in various neurological conditions.

In addition, the **alteration** of **neurotransmitter** levels, such as dopamine, also contribute to **motor dysfunction** and the potential onset of **Parkinson's disease.**



Age Related Changes to the Hippocampus

Watch the video below to learn more about how **age-related micro-level** changes can contribute to changes in brain structures such as the **hippocampus** and related mental functions such as **memory**.



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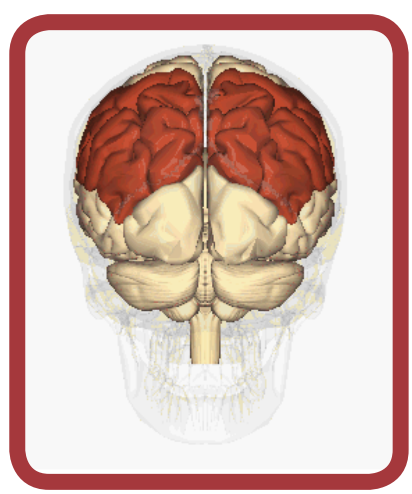
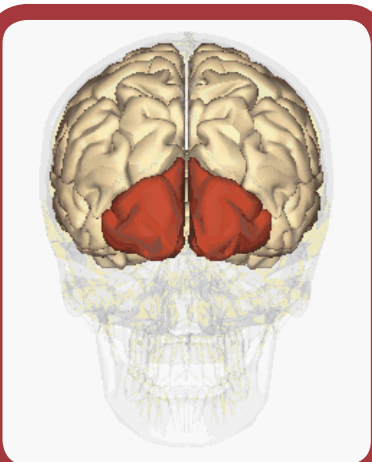
Age Related Changes to Other Brain Structures

While it is less commonly discussed, other regions of the brain can be **affected by aging** in addition to the Temporal and Frontal Lobes. The **Occipital** Lobe and the **Parietal** lobes may be subject to changes that affect **function, vision, sensation**, and **cognition**.

Parietal Lobes

The parietal lobes can change with age in both **gray matter** (atrophy) and function. Visual, auditory & verbal information is **processed** in the parietal lobes, all of which can be affected by the **aging** process. The parietal lobes work together with the **occipital** lobes in tasks of **visual attention**. Other areas of the brain, such as the **frontal** lobes, may **compensate** for suboptimal parietal lobe function.





Occipital Lobe

Occipital lobe structure and function also can change with age. Since **visual** & sensory abilities can decline with age, there can be a greater chance for increases in **fall risk** due to a reduction in sensory information processing speed, and **visuospatial** abilities. The occipital lobe may develop greater **connectivity** to the **parietal** lobes to **compensate** for sensory declines. Visual issues, such as **macular degeneration**, may also affect the occipital lobe.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Brain changes that occur throughout the course of cognitive aging can be classified at the Micro or Macro level. These levels can change in parallel to each other.

- ☐ Micro-level changes occur in smaller-scale structures and functions of the brain. Examples of these structures and functions include Neurons, Dendrites, Synapses, and Neurotransmitters.

- ☐ Macro-level changes occur to the larger-scale brain structures and functions. Examples include the the Pre-frontal Cortex, the Temporal lobes, the Cerebellum, Basal Ganglia, and the Hippocampus.

Lesson 5: Neurodegeneration

Lesson 5 Objectives

1. Define Neurodegeneration and its associated mechanisms.
2. Summarize how Beta-amyloid and Tau, along with structural changes in the brain, can contribute to Alzheimer's Disease.
3. Identify how micro-level mechanisms, such as microglial activation & neuroinflammation can contribute to neurodegeneration.

Neurodegeneration

Neurodegeneration refers to the **progressive atrophy** and **loss of function** of **neurons**, which is present in neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease.

This video illustrates how **neurodegeneration** can occur at the **neuronal level in Alzheimer's Disease** through a weakening of the dendrites that leads to a downregulation of synapses, and eventually neuronal death.

VIEW ON VIMEO >

Source: National Institute On Aging. How Alzheimer's Changes the Brain. Aug 23, 2017. https://www.youtube.com/watch?v=0GXv3mHs9AU&feature=emb_logo

Knowledge Check

Which micro level structures do the statements below describe?

Record your answers here for future reference.

Branched extensions of nerve cells that carry nerve impulses from synapses to cell body .... ____________________

Deposits of plaque that form between neurons, interrupting brain function & structure .... ____________________

Progressive atrophy and loss of function of neurons .... ____________________

Junction between two nerve cells, across which impulses pass via a neurotransmitter .... ____________________

Abnormal accumulations of protein that can collect inside neurons .... ____________________

Neurodegeneration

This video will provide you with a visualization of some of the neuro-anatomical terminology presented in this section, which will be helpful to understand the neurodegenerative aging process.

VIEW ON VIMEO >

Source: USC Stevens Neuroimaging and Informatics Institute. Neurodegeneration caused by Alzheimer’s Disease. Jun 6, 2017. https://www.youtube.com/watch?v=epa_KRnFHfE&feature=emb_logo

Knowledge Check

Do the statements below describe Normal Cognitive Aging or Alzheimer's Disease?
Record your answers here for future reference.

Misplacing things from time to time .... ____________________

Severe cognitive decline .... ____________________

Inability to converse fluently .... ____________________

Word finding issues every now and again .... ____________________

Loss of neurons at a low level .... ____________________

Severe loss of neurons .... ____________________

Some cognitive decline .... ____________________

Chronic neurodegeneration .... ____________________

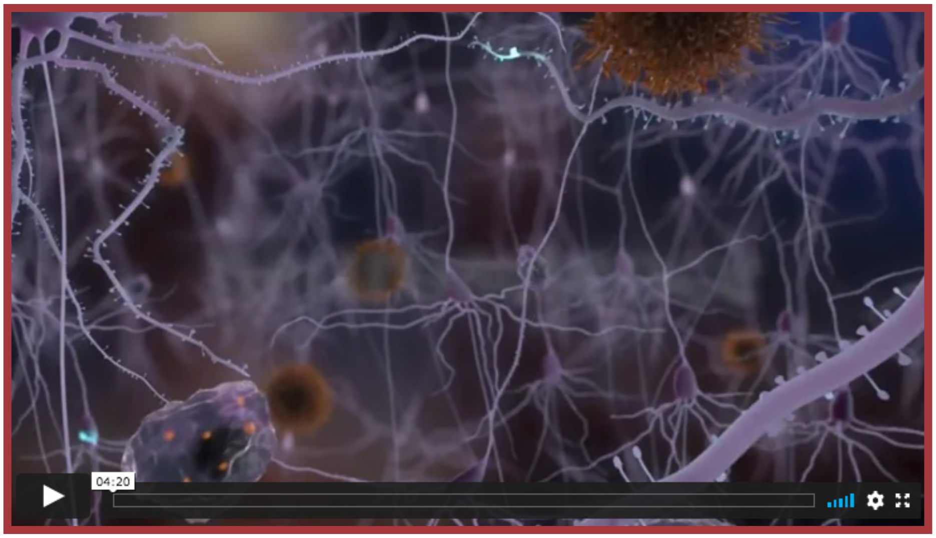
Normal brain volume, less space in sulci .... ____________________

Loss of activities of daily living .... ____________________

Less brain volume, more space in sulci .... ____________________

Inside Alzheimer's Disease

This video will further explain Microglia's role in Alzheimer's Disease, along with the processes of inflammation.



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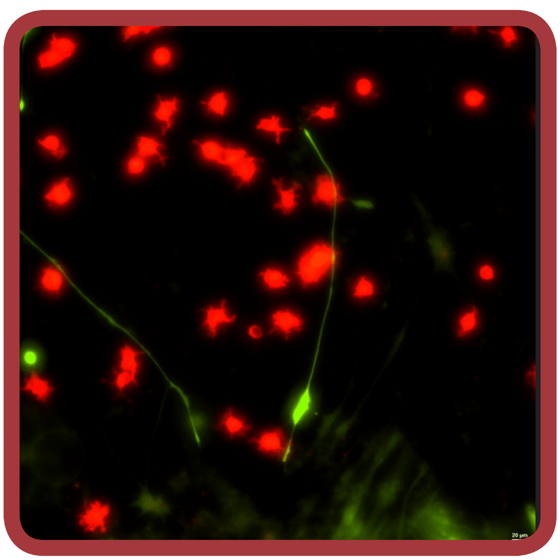
Neurodegeneration and Neuroinflammation



In their activated, **pro-inflammatory** state, **microglia** (red) attack an otherwise **healthy neuronal synapse** (neon yellow).

To further appreciate the mechanisms that may underlie negative changes to the brain, it is helpful to understand **micro-level processes** that contribute to **neurodegeneration**, one of which is **neuroinflammation**. Neuro-inflammation can be caused by **microglial activation**, as well as the build-up of **Amyloid-beta plaques** and **Tau tangles**. The process of neuroinflammation and the mechanisms that contribute to it have been correlated with various neurological issues, including **dementia** and **depression**.

Preventing Alzheimer's

Watch the video below to learn about Alzheimer's Disease, its prevalence, pathology, and how it can be prevented.

VIEW ON YOUTUBE >
TED. What you can do to prevent Alzheimer's | Lisa Genova. May 19, 2017

To learn more about the genetic risk associated with Alzheimer's Disease, including the APOE4 gene and how to screen for it, read the article below provided by the NIH's National Institute on Aging:

Alzheimer's Disease Genetic Fact Sheet

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ While there are normal changes that can occur to cognition, dementia & Alzheimer's Disease (a specific, diagnosable sub-type of dementia) involve more severe declines in cognition and activities of daily living.
- ☐ Micro-level changes, such as inflammation caused by microglial activity in the brain, alongside genetic and modifiable risk factors, can contribute to a greater risk of Alzheimer's Disease.
- ☐ Improving cognitive reserve, even in the face of neurodegenerative processes, can be a way to improve cognition and maintain functional independence, although may not prevent dementia completely.

Lesson 6: Cognitive Reserve and Neuroplasticity

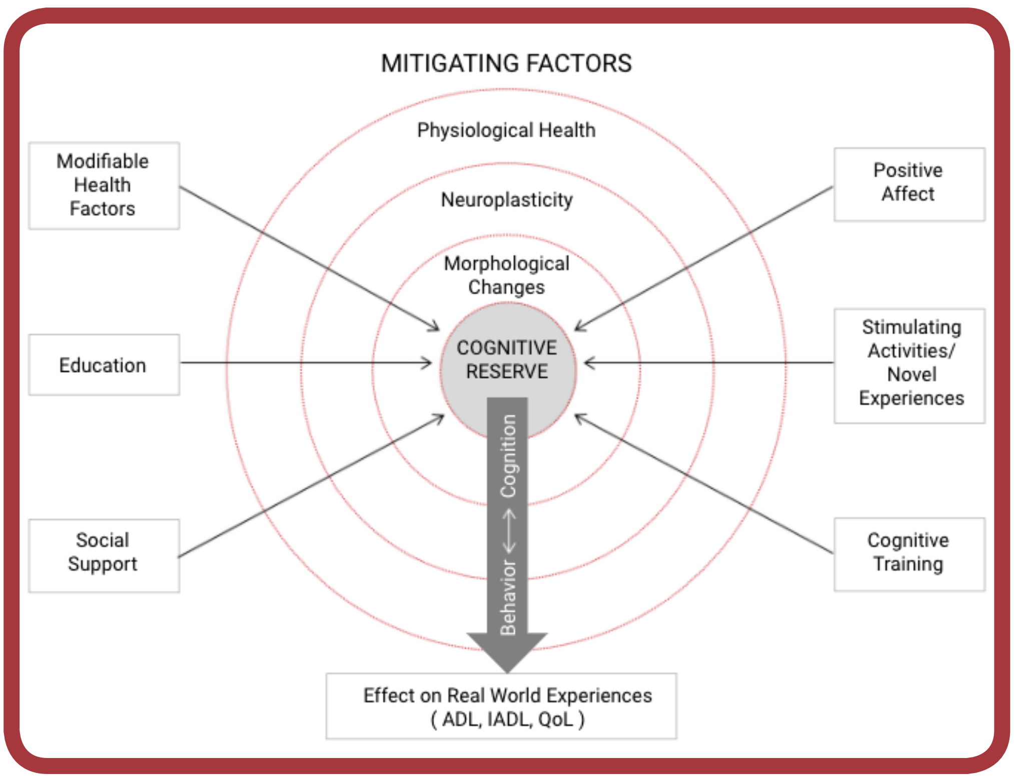
Lesson 6 Objectives

1. Define Cognitive Reserve, describe its role in cognitive aging, and list mitigating factors to increase it.
2. Define Neuroplasticity and explain the relationship between Functional and Structural Neuroplasticity.
3. Describe the bi-directional nature of Neuroplasticity and list factors that contribute to Positive and Negative Nueroplasticity

Cognitive Reserve

Cognitive Reserve is like a cognitive gas tank. It tells us **how long** we can expect good cognitive functioning and **what the course of cognitive aging** – whether normal or accelerated -- **is likely to be**.

A higher cognitive reserve yields a longer delay to dementia, more mild cognitive impairment, and may even slow the normal course of cognitive decline.



The mitigating factors shown here are more associated with bottom-up, which refers to body-based influences, and environmental influences as they relate to cognitive reserve. Modifiable health factors is of primary focus as it relates to the work we do as health and wellness professionals, and includes exercise, nutrition, sleep, and stress management. Specifically, we are interested in how exercise contributes to cognitive reserve, which research demonstrates that its effects are significant, but also how those effects can be enhanced via other mitigating factors.

Education level, both in reference to structured education and lifelong learning, has a considerable impact on cognitive reserve. In addition, social support not only insinuates cognitive stimulation via social interaction, but reflects an important domain of psychosocially-related health factors. This is especially important when seeking to avoid the immensely deletirious effects of social isolation on the brain.

The mitigating factors shown here are associated with more top-down processes, or those primarily focused on the brain and mind. Positive affect refers to positive mood states, and it would be safe to factor in additional components such as mindfulness and emotional intelligence into this category. This is important in the context of mental health, as various mental illness can take a toll on cognitive reserve.

Stimulating activities and novel expriences are a pinnacle of healthy brains, and these characteristics can be present in other mitigating factors. For example, engaging in novel movements and stimulating exercise experiences may yield enhanced benefits.

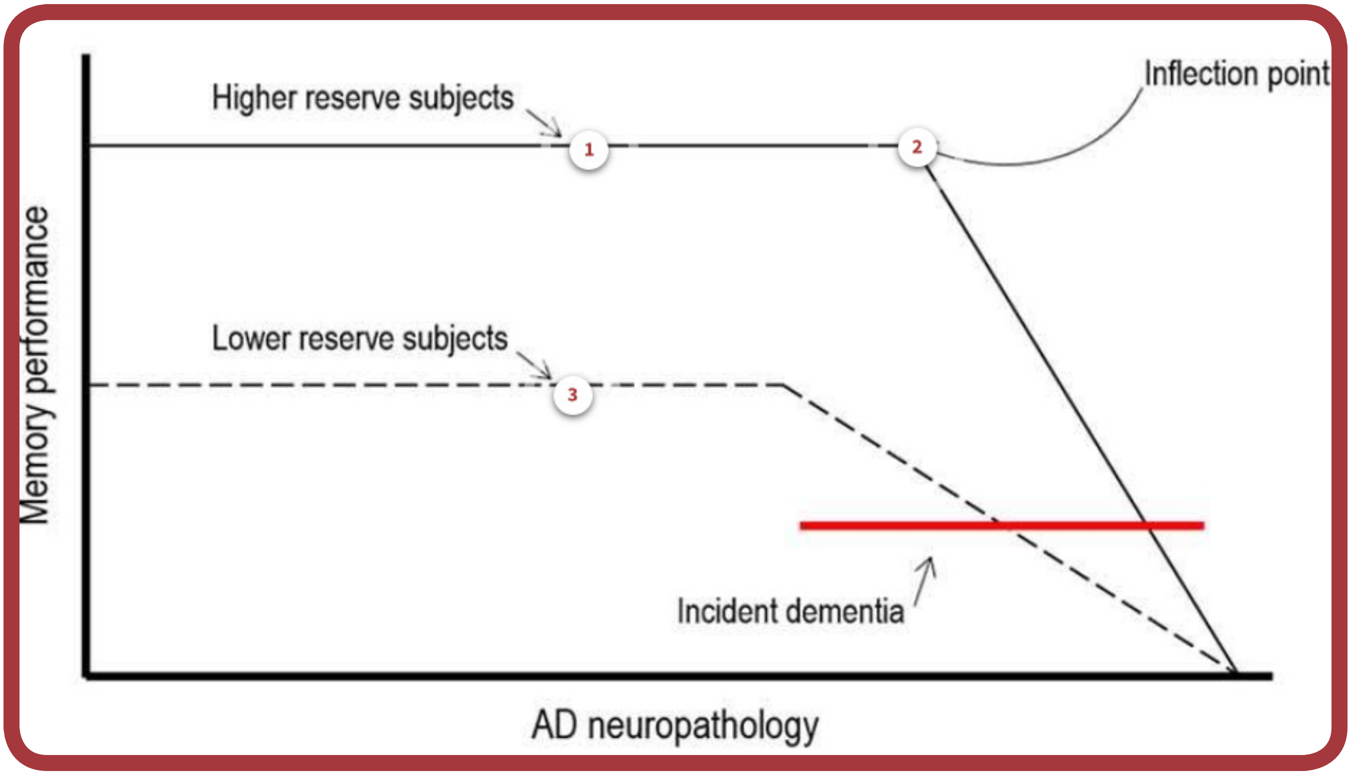
Cognitive training, which refers to cognitive stimuli that is targeted to specific domains of cognitive abilities, also may contribute to cognitive reserve, especially when combined with physical activity. As certain research has begun to point out, the combination of exercise or physical activities that possess elements of social contact, novelty, stimulation, cognitive demand, and positive mood states are hypothesized to have signficantly greater effects on cognition than any of these components alone.

Cognitive Reserve is thought to involve greater efficiency of synaptic functioning, allowing cognitive functions to endure even in the presence of amyloid plaques and tau tangles. This has been demonstrated in studies where Nuns who live an enriched lifestyle without accelerated cognitive decline donated their brains to science, only to find that despite having the structures associated with neurodegenerative disease, they did not reflect the symptoms of dementia.

The purpose of enhancing cognitive reserve is not just to extend life, but to enhance quality of life. Many individuals would agree that they would prefer quality of years versus quantity of years, and orchestrating these mitigating factors to ensure this quality of life, may be one of the most important ways a health and wellness professional can add value to a client’s life. In addition, improvements in activities of daily living and improving the way individuals interact with the world through cognitive and affective processes is a major outcome associated with improved cognitive reserve.

Cognitive Reserve & Neuropathology

The graphic below relates the theoretical concepts of the cognitive reserve (CR) to the process of neurodegeneration. In this graphic, there is a specific reference to neuropathology as it relates to Alzheimer's Disease (AD).



Arenaza-Urquijo, E. M., Wirth, M., & Chételat, G. (2015). Cognitive reserve and lifestyle: moving towards preclinical Alzheimer's disease. Frontiers in aging neuroscience, 7, 134.

1. High CR - **High cognitive reserve** (CR) is likely associated with **healthy lifestyle behaviors**, and while it may not prevent dementia all together, it can **prevent it's onset**, increase quality & quantity of life via improved **cognition** (i.e. memory).

2. Inflection Point - This inflection may represent a variety of **neurobiological occurrences**, such as build up of amyloid plaque or a neurological "**insult**" (such as a brain injury). It may also represent **Mild Cognitive Impairment** (MCI).

3. Low CR - **Lower cognitive reserve** (CR) likely leads to a **greater incidence risk of dementia**. While a lack of lifestyle modification may not seem to affect what seems to be stable cognition, it is shown here that a **sharp decline can occur with lower CR**.

Knowledge Check

Do these statements describe factors that increase or decrease Cognitive Reserve? Record your answers here for future reference.

Frequent Exercise .... ______________

Stress management .... ______________

Chronic stress .... ______________

Social isolation .... ______________

Stimulating activities .... ______________

Positive mood states .... ______________

Sleep deprivation .... ______________

Poor dietary choices .... ______________

Neuroplasticity

Neuroplasticity is the **ability** of the brain **to form and reorganize synaptic connections,** especially in response to behavior, environment, or learned experience. This term is **frequently used incorrectly** to justify a variety of products, methods, and mechanisms. Watch the video below to learn more about definitions and perspectives in neuroplasticity.

VIEW ON VIMEO >

Sentis. Neuroplasticity. Nov 6, 2012

Types of Neuroplasticity

One must exercise caution while encountering the **use of neuroplasticity in mainstream utility**, as there is **much still unknown** about neuroplasticity in humans.

1. **Functional Neuroplasticity**
   Functional neuroplasticity refers to **changes** in **synapses, brain activity**, and connections within **neuronal networks**. Functional changes often **precede structural changes** in the brain.

2. **Structural Neuroplasticity**
   Structural neuroplasticity refers to **changes** in **nerve cell number, brain volume**, or modifications to nerve **cell structures** (like dendrites). There is still much unknown about structural neuroplasticity in humans.

3. **Positive Neuroplasticity**
   Positive (or **adaptive**) neuroplasticity refers to the **creation** or **strengthening** of **synapses** and neuronal connections, nerve cell structures, and brain volume. It is important to note that the term **neuroplasticity** is often **falsely used** to **imply all changes** are **positive** and/or **permanent**.

4. **Negative Neuroplasticity**
   Negative (or **mal-adaptive**) Neuroplasticity is **not a scientific term**, but we use it through the course to **describe** the weakening or **degeneration** of **synapses** and **neuronal connections**. In addition to behavioral, environmental, and experiential factors, mechanisms like neurotoxicity partially explain the more scientific concepts related to negative neuroplasticity.

Functional Neuroplasticity

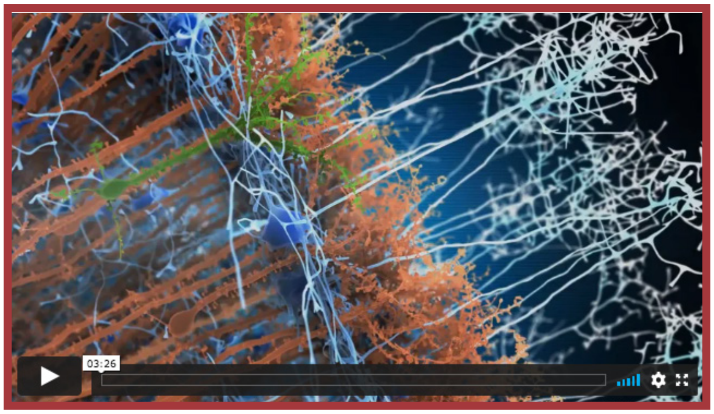
Even though it is generally assumed that neuroplastic change is only structural, **neuroplastic change can be both functional and structural.** This video discusses the role of neurons & synapses in functional neuroplasticity.

VIEW ON VIMEO >

Source: USC Stevens Neuroimaging and Informatics Institute. Neurons and Synapses. Jul 26, 2017. https://www.youtube.com/watch?v=m0rHZ_RDdyQ&feature=emb_logo

Structural Neuroplasticity

This video discusses Structural Neuroplasticity, specifically as it relates to a study of **neurogenesis** in animals within the olfactory bulb, a region of the brain responsible for smell that is **highly plastic**. **Behaviors** related to **structural neuroplasticity** are also discussed.



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Source: Demcon Nymus3D. Adult Neurogenesis. Jul 17, 201. https://www.youtube.com/watch?v=BAGomr-j_85M&feature=emb_logo

Knowledge Check

A modification in synaptic activity over a short amount of time is an example of what kind of neuroplasticity?

Record your answer here for future reference.

- ○ Executive Function, Attention, Memory, and Processing Speed
- ○ Structural Neuroplasticity
- ○ Positive Neuroplasticity
- ○ Negative Neuroplasticity

Positive and Negative Neuroplasticity

Neuroplasticity is **always in flux** and can be conceptually understood to be **bi-directional in nature**. Regardless of if the change is positive or negative our brain strengthens the synapses and **neuronal connections** that we use most. When connections are not used the brain will allow them to degenerate.

These factors can facilitate either positive or negative change based on our individual behaviors, experiences, and environmental conditions.

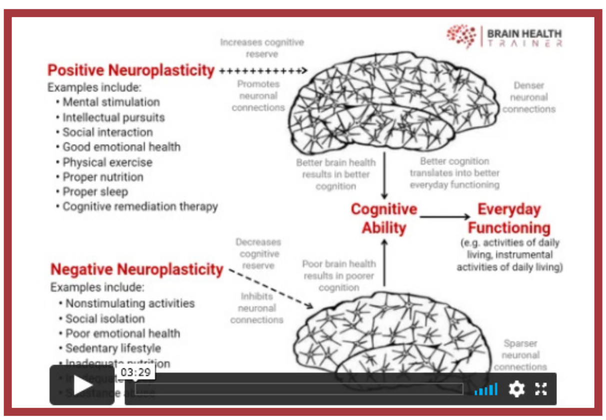
1. **Cognitively Stimulating Environments**
   Cognitively stimulating **environments** that provide **opportunities** for **learning** and **novel experience** are highly **conducive** to **positive Neuroplasticity**.

2. **Nutrition, Stress, and Sleep**
   Nutrition, sleep, and stress are all **contributing factors to neuroplasticity**. Various mechanisms underlie positive or negative changes in the brain, such as the glymphatic system, which can regulate brain toxicity and is related to sleep and exercise.

3. **Physical Activity and Exercise**
   Negative (or **mal-adaptive**) neuroplasticity can be **induced by sedentary behavior**. Some studies demonstrate that anywhere from a single session to several weeks of **exercise** can have **positive effects on the brain**. However, there are heightened benefits when we maintain consistent, yet variable, types of exercise, and physical activity throughout our lifespan.

Cognitive Reserve and Neuroplasticity

Positive neuroplasticity is **elicited** by a **similar** healthy lifestyle and environmental **variables** that **contribute** to a high **cognitive reserve**. Negative neuroplasticity can be elicited by poor lifestyle and environmental variables, which can lead to “mal-adaptive neuroplasticity” and therefore neurodegeneration.



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Vance, D. E. (2009). The emerging role of cognitive remediation therapy. Activities, adaptation & aging, 33(1), 17-30.

Knowledge Check

Do these factors contribute to positive or negative neuroplasticity? Record your answers here for future reference.

Quality Sleep .... ______________

Physical Exercise .... ______________

Sleep Deprivation .... ______________

Sedentary Behavior .... ______________

Healthy Diet .... ______________

Cognitive Stimulation .... ______________

Poor Diet .... ______________

Mindless Activities .... ______________

Social Isolation .... ______________

Chronic Stress .... ______________

Social Support .... ______________

Stress Management .... ______________

Poly-pharmacy .... ______________

Medical Management .... ______________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Cognitive Reserve could be considered a "Cognitive Gas Tank" that, if fuller, would slow cognitive decline and/or the potential onset of dementia and neurodegeneration.
- [ ] Neuroplasticity represents the brain's ability to change in response to experiences and partially explains how the brain is affected by various lifestyle and environmental factors, in addition to partly explaining how the brain ages.
- [ ] Healthy lifestyle behaviors, novel & stimulating experiences, education, positive affect, and other variables contribute to increased Cognitive Reserve, partially via neuroplasticity.

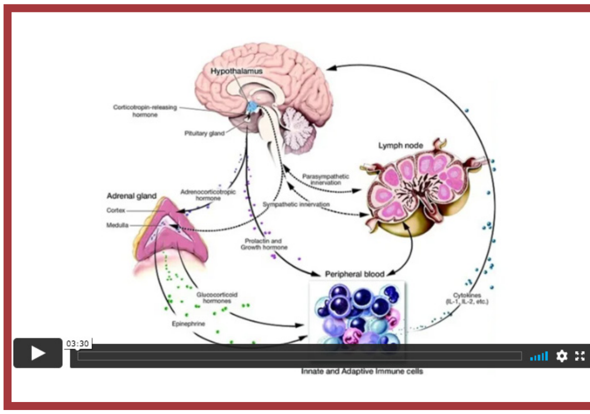
Lesson 7: Theories of Cognitive Aging

Lesson 7 Objectives

1. Recall the various theories of cognitive aging & identify their unique characteristics.
2. Relate the theories of Cognitive Aging to changes in physiology.

Theories of Cognitive Aging

There are **many theories of what causes cognitive aging**. Different theories attribute aging to different mechanisms in the mind and body. All of these theories have some validity and help us understand that **aging is complex and involves many factors**.



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Important Note: There is no single theory of aging that serves as "the single cause" of cognitive decline, accelerated or otherwise.

Knowledge Check

Which Theory of Aging matches the descriptions below? Record your answers here for future reference.

Changes in cell signaling .... ____________________

Changes in hormone function .... ____________________

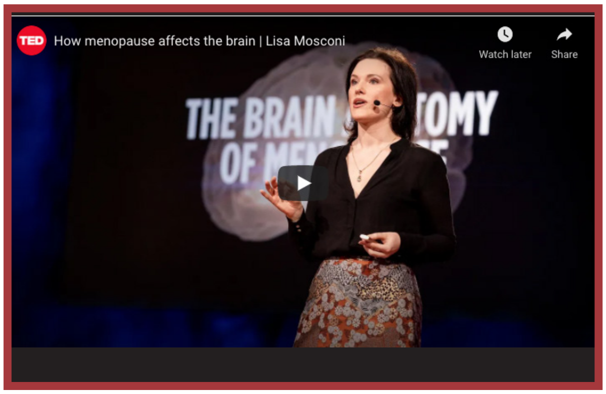
Changes in somatosensory function .... ____________________

Changes in the speed of signals in the brain .... ____________________

Menopause and the Brain

As an **example of the Neuro-endocrine Hypothesis** of aging, it is helpful to understand the recent research associated with women's hormones, **menopause**, and brain health.

An expert in this area of research, Dr. Lisa Mosconi, presents this information in the optional video below, detailing **why women may be at a higher risk for Alzheimer's** Disease.



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Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ There are various theories of aging that may partially explain how and why the brain changes with age and changes in health status. None of these theories of aging exist as the "best" or "only" theory, and likely each theory identifies one piece of a very complex neurobiological puzzle.
- ☐ Certain theories are focused more on changes in the body, while others are focused more on changes in the brain. It is likely that changes in both occur in parallel, affecting each other bi-directionally.
- ☐ Certain theories of aging, such as the Neuroendocrine Theory of Aging, are getting more attention in brain aging research, giving a greater understanding of how gender may modify how the brain changes with age.

SECTION 2: The Primary Components of Cognition

Section 2 is **focused on** the **four primary domains of cognition**; Executive Functioning, Attention, Memory, and Processing Speed. By the end of this lesson you will be able to explain the **effects of aging** on the four **primary domains of cognitive functioning**, their sub-domains, and the **neurological structures** related to each domain.

There are many other facets of cognition to consider, and these **complex and interrelated brain functions** are **not always isolated in their functions**. We focus on these four cognitive domains because they are often the most common outcomes measured in exercise neuroscience research, and have strong relevance to **everyday life**. In addition, they can often be understood and subjectively identified by clients.

Section 2 is divided into 8 lessons, followed by a module quiz. **You are currently in Lesson 1** which will define important terms related to cognition that will be used throughout the course. The remaining sections focus on the four primary cognitive domains.

Lesson 1 Cognitive Abilities and Domains

Lesson 1 Objectives

1. Define the terms Cognitive Aging, Cognitive Domains, and Cognitive Abilities used in this course.
2. Identify the components of healthy cognitive aging and what kinds of interventions can slow cognitive decline.

Cognitive Abilities and the Aging Brain

There are three **important definitions** that you **need to understand** before continuing through this lesson: **Cognitive Aging**, **Cognitive Domains**, and **Cognitive Abilities**.

1 **Cognitive Abilities**
All the brain-based mental functions are associated with gaining understanding through life experiences, thinking, awareness, and sensory information. They have to do with how people learn, remember, process, reason, problem-solve, and pay attention.

2 **Cognitive Domains**
Cognitive Domains refer to specialized, modular functions of cognition. In this course, we focus specifically on four primary cognitive domains; Executive Functioning, Attention, Memory, and Processing Speed, all of which overlap with each other. These domains have functional and structural correlations in the brain.

3 **Cognitive Aging**
The process in which cognitive abilities, alongside their functional and structural correlations, change with age and other biological variables (such as lifestyle, gender, genetics, and environment).

The terms associated with Cognitive Abilities involve a variety of synonymous terms, including; Cognition(s), Skills, Functions, Abilities, or Capacities.

Cognition and the Healthy Brain

This video presents the **normal course of cognitive aging**, specifically giving examples in certain cognitive domains. Examples of **normal vs. accelerated aging** are presented, alongside **methods for assessing** and maintaining **cognitive health**. Finally, you will gain an understanding of what research and clinical care in **managing healthy brain aging** may consist of.

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Practice Activity

In the video above, several domains of cognition were discussed. Some of these domains change normally with age, while abnormal changes in certain cognitive abilities may be a sign of neurodegeneration.

Categorize each description as normal or accelerated cognitive aging.

Occasionally forgetting names .... ________________

Slower processing speed and problem solving .... ________________

Poor facial recognition .... ________________

Increased dependence on others for daily activities .... ________________

Able to remain independent .... ________________

Care requires an integrated team approach .... ________________

May be preventable .... ________________

May occur in all aging adults .... ________________

Key Terms Review

The terms presented in this lesson will be used throughout the rest of the course. Make sure you understand these terms prior to moving into the next section of this lesson.

Cognitive Domains, The Four Primary Domains, Cognitive Abilities or Cognitive Aging? Record your answer for each term description.

The brain-based functions related to problem solving, attention, memory, and processing. .... ______________________

Specialized functions of cognition with specific correlations in the brain. .... ______________________

The process in which cognitive abilities and the brain deteriorate with time .... ______________________

Executive Functioning, Attention, Memory, and Processing Speed .... ______________________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Research shows that participation in intellectually stimulating activities and exercise & physical activity are the two of the most effective interventions in promoting healthy cognitive aging.
- [ ] Cognitive aging, is a normal process that effects our cognitive abilities, the brain-based mental functions associated with how we process the world and our experiences. These functions can be grouped into cognitive domains which overlap with each other and have functional and structural correlations within the brain.
- [ ] Cognitive decline can only be determined through specialized assessments and neuroimaging carried out by relevant clinicians. Optimal care for accelerated cognitive decline requires an integrated team.

Lesson 2: Defining Executive Functioning

Lesson 2 Objectives

1. Define executive functioning and explain its role in the aging process.
2. Identify the regions of the brain where executive functions likely occur.
3. Identify the sub-domains of executive functioning and their relationships to other cognitive functions.

Defining Cognitive Domains: Executive Functioning

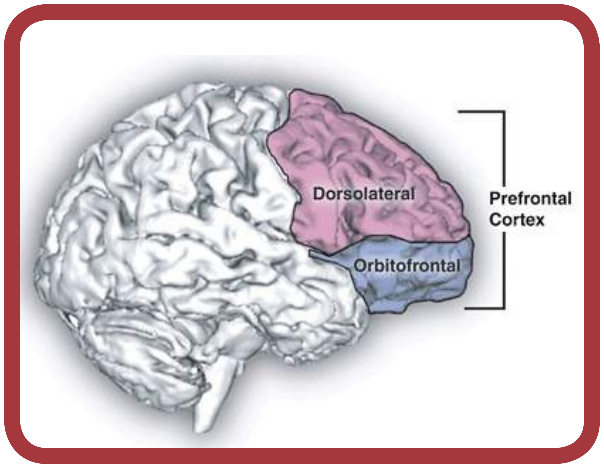
Executive functioning describes a set of **higher-level cognitive skills** that control and coordinate other cognitive abilities.

We refer to executive functions (EFs) as "**The CEO" of the brain** due to their organizing & regulatory nature. EFs play a **key role in the aging process** and are affected by a variety of conditions & diseases.

While it is often proposed that executive functions control other cognitive functions and neural resources, this theory is recently beginning to be rejected by modern neuroscience.

The role of executive functioning is likely more complex than simply the command of other brain functions, and this hierarchical relationship is less likely.

Where in the brain does Executive Functioning occur?



The Prefrontal Cortex and its Sub-regions

Executive Functioning & the Prefrontal Cortex

Executive function primarily depends on the **prefrontal cortex**, which exerts its influence via **extensive connections** with **posterior cortical regions**.

Executive function deficits in the aging brain have been associated with the **Frontal Lobe Hypothesis of Aging**.

This hypothesis **links cognitive decline** with the **decline** in the **volume and function** of **prefrontal brain regions**.

What are Executive Functions?

This video from Dr. Adele Diamond, an expert researcher in **executive functions**, gives an overview of what executive functions are and what functions comprise them. While Dr. Diamond's research & examples are primarily in children, her wisdom on the topic **applies to adults**, both young and old. As she gives examples of executive functioning in children, **think about applications** in older adults.

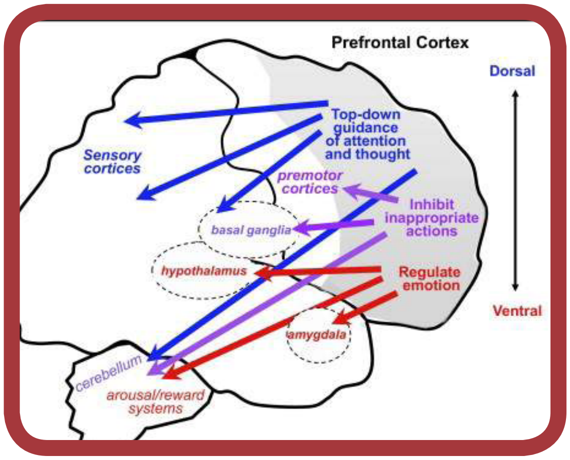
Adele Diamond: What are Executive Functions?

VIEW ON YOUTUBE >

Components of Executive Functioning

Executive Functions (EFs) can be challenging to define, and in fact there is a wide degree of variability in how various experts would define EFs. Since EFs are considered to be a Cognitive Domain, there are many **Sub-Domains** that comprise EFs.

In the text below, several Sub-Domains of EF are described. These are not the only Sub-Domains of EFs, but they have been selected in greatest relevance to this course.



Many **complex** everyday **tasks require different aspects** of **Executive Functioning**. The integration and reorganization of information required to carry out these tasks come from a variety of sources.

These "**sub-domains**" of Executive Functioning often have **close functioning relationships** with each other, but may have different associations with various brain regions.

1. Inhibitory Control

Refers to the ability to **resist** impulses, **delay** gratification, and **inhibit** responses (*verbal, motor, emotional, etc*).

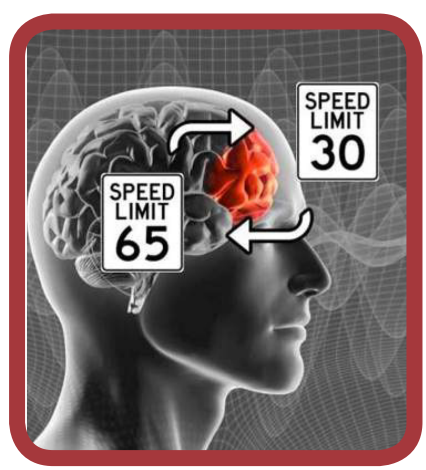
While different parts of the brain are responsible for inhibitory control, one area of the brain, the **orbitofrontal** cortex, is a part of the **prefrontal** cortex that regulates impulses during **decision-making**.

2. Cognitive Flexibility

The **ability to adapt** to **unpredictable** or new concepts or events.

How fexible certain types of thinking are (**flexibility**) and the ablility to shift from one type of thinking to another (**set shifting**) are both essential components of **cognitive flexibility**.

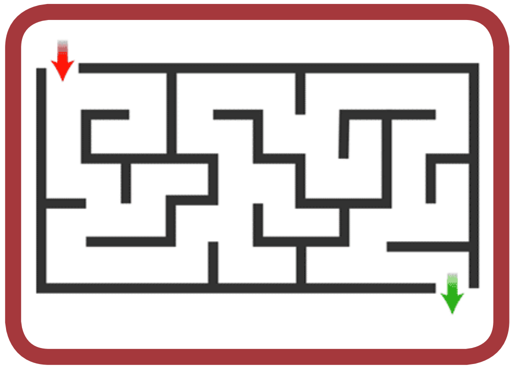
Abstract thoughts and associations and specific sets of rules are often characteristics of tasks that test cognitive flexibility.



3. Problem-Solving, Decision-Making, Reasoning & Planning

These functions rely on **active thinking** to complete tasks. They alternate individual and integrated functioning in a process called "**reflective cognition**."

All of these functions are involved in **prioritizing attention** by overlooking thoughts and behaviors irrelevant to identified goals. This allows for **goal-directed behavior** to take place.



Knowledge Check

Match the definitions of the sub-domains of executive functions to their correct definitions.

Inhibitory Control, Cognitive Flexibility, or Problem Solving? Record your answer for each term description.

Controlling responses that don't serve goals. .... ______________________

Responding to unpredictable stimuli or conditions. .... ______________________

Allocating attention for goal-oriented behavior .... ______________________

Key Takeaways

Check off each key point regarding Executive Functions (EFs) if you feel that you understand it.

- ☐ EF is a higher-level Cognitive Domain that refers to a larger category of various Cognitive Sub-Domains. While there are many Sub-Domains that are considered part of EFs, some of the ones mentioned include Impulse Control, Cognitive Flexibility, Working Memory, Decision-Making, Planning, Organizing and Reasoning.

- ☐ EFs are primarily correlated with the Prefrontal Cortices, and seem to influence other regions of the brain similar to a "CEO", although we are still learning more about how EFs may actually work.

- ☐ Certain Sub-Domains of EF are normally affected by the process of normal cognitive aging, but the significance of decline in certain sub-domains of EFs can change with various neurological conditions.

Lesson 3: Working Memory & Executive Functions

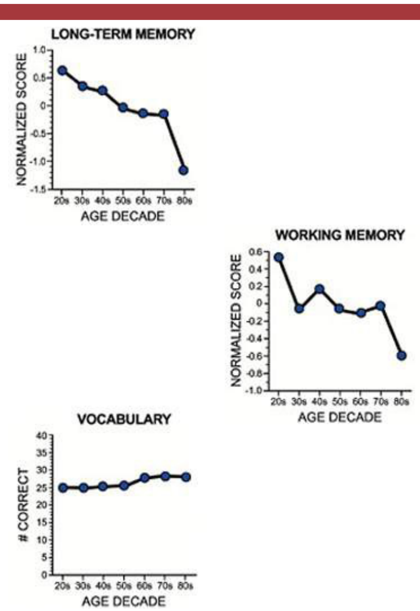
Lesson 3 Objectives

1. Define Working Memory as a part of Executive Functions.
2. Present on how Working Memory may change with age.
3. Identify how Executive Functions interact with the other primary cognitive domains.

Working Memory

The text below defines working memory, its components, how it is affected by aging, and its relationship with other domains of cognition.

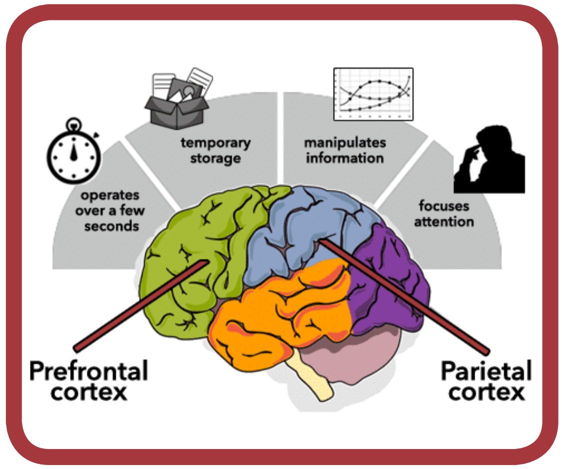
Working memory is a component of Executive Functioning that temporarily **holds, manipulates, processes**, and **stores** information.



Working Memory (WM) and Aging

Working memory is a multidimensional **cognitive construct**. It has been hypothesized as the **fundamental source** of **age-related deficits** in a variety of cognitive tasks **including** long-term memory, language, problem-solving, and decision making.

Neurological Components of the Pre-frontal Cortex and Working Memory



The dorsolateral prefrontal cortex (**dlPFC**) plays a role in the manipulation and updating of infromation in **working memory**, with the **left DlPFC** invloved more in **verbal tasks** and the **right dlPFC** in **visuospatial tasks**.

The **parietal** cortex plays a role in relating **sensory** information that is temporarily **attended** to or **organized** by working memory.

Theories of WM Deficits

There are several theories for how working memory deficits occur in cognitive aging.

- a reduction of **attentional resources**
- **reduced speed** of information processing
- problems due to a **failure of inhibitory** control.
- deficits in tasks that involve active manipulation, reorganization, and integration

Attention Demands & Working Memory

Working memory tasks, by their very nature, can involve divided attention. Since divided attention also declines with age, older adults may experience working memory limitations in distracted environments.

Appreciating how attention and working memory interact may explain why older adults (with & without cognitive impairments) may struggle with working memory, and reveal potential ways of training working memory.

Why is Working Memory an Important Executive Function?

Working Memory is a **part of Executive Functioning**, but defined **separately** from **other memory processes**.

While it involves memory, it is **more focused on** the **short-term management** and manipulation of memory. Working memory also has specific interactions with other executive functions before the relevant information becomes a part of other memory processes (such as long-term memory).

Working Memory **normally changes with age** and can be further affected through various conditions, such as mild cognitive impairment, dementia, and ADHD/ADD.

Relationships to other Cognitive Functions

Executive Functions plays a key role in virtually all aspects of cognition, and has a **direct role** in **managing attention** and **processing speed** in a variety of ways.

1. **Executive Functioning and Attention**
   Allocates attention among tasks and inhibits irrelevant information. This is important during new and complex tasks, and in environments with distractions.

2. **Executive Functioning and Memory**
   Selects, encodes and manipulates information in working memory to eventually store or retrieve from other memory processes (episodic memory, long-term memory, verbal memory, etc).

3. **Executive Functioning and Processing Speed**
   Quickly selects responses in relation to goal-directed behavior, while managing the trade-offs between accuracy and speed of processing.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Working memory is a component of executive functioning responsible for the temporary manipulation, storage, and retrieval of information.

- ☐ Working memory is affected normally by aging, and abnormally by accelerated aging and cognitive impairments, as well as in neurological and neuropsychiatric conditions.

- ☐ Working memory involves to dorsolateral prefrontal cortices and is related to functions of the parietal lobes. Visual working memory will also involve the occipital lobes, while verbal working memory will also involve the temporal lobes.

Lesson 4: Defining Attention

Lesson 4 Objectives

1. Identify the role of Attention as a primary cognitive domain and its related brain regions.
2. Recall the brain mechanisms used to rapidly focus attention and its importance in understanding cognitive decline.
3. Explain the relationships between Attention and other cognitive domains, abilities, and functions.

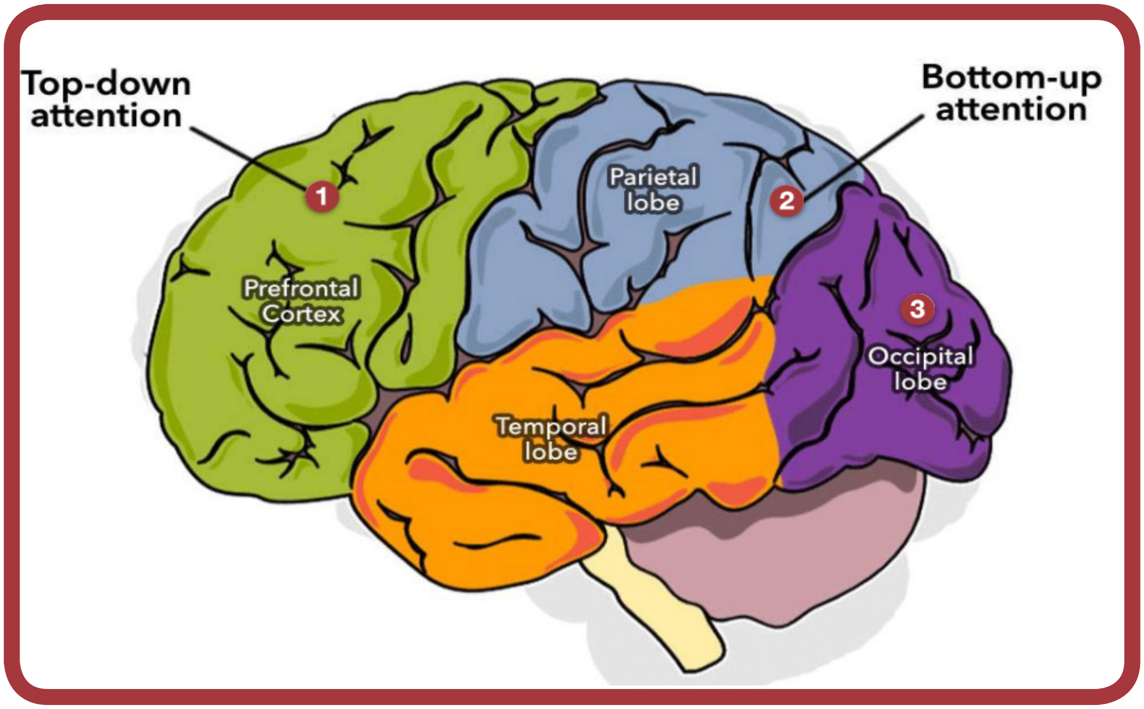
Defining Cognitive Domains: Attention

Attention refers to **goal-oriented focus**, **filtering irrelevant stimuli**, and **selecting important information**.

Attention is **critical for the purposes of filtering**, orienting and directing information, so that the **brain is not overwhelmed** by unfiltered information. Executive functioning manages attentional resources and applies them to various other functions as needed.

Where in the Brain does Attention occur?

Top-Down vs. Bottom-Up Attention



1. Endogenous Attention - Endogenous Attention (AKA Top-Down Attention) uses **existing knowledge** and **higher-level cognition** to interpret incoming sensory information.

Attention is allocated based on **choice**, and is dictated by **goal-oriented behavior**.

2. Exogenous Attention - Exogenous attention (AKA **Bottom-Up Processing**) is focused on **sensory processing** as it **enters the brain**.

This is raw sensory information, and attention is automatically allocated based on an external stimulus (emotional, reactive, novelty, etc.).

3. Ventral-Dorsal Streams - The Ventral and Dorsal streams, also called the **Two-Stream hypothesis**, is a model of the **neural processing** of **vision** and **hearing**.

Visual and **auditory** information **travels through the ventral stream** where is it processed slowly, based on object identification and recognition. Also called the "**what pathway**", this pathway **encodes the object's identity** in **long-term memory.**

The same information also travels through the **dorsal stream** (or "**where pathway**") where it **gets processed quickly**, based on the object's spatial location, and relates to the **short-term storage** of the "where" of the object.

Knowledge Check

Match the correct characteristic of each domain of cognition or type of attention to their correct definitions.

Working Memory, Attention, Top-Down Attention, or Bottom-Up Attention? Record your answer for each term description.

Holding & manipulating information .... ______________________________

The filtering of relevant stimuli .... ______________________________

Relies on higher-order cognition .... ______________________________

Relies on sensory processing .... ______________________________

Attention's Relationships to other Cognitive Abilities

Attention is involved in virtually every cognitive function, except when processes are habitual or automatic.

1 **Attention and Executive Functioning**
Different types of attention rely heavily on the involvement of executive functions. Certain types of attention, such as attention shifting, interact with EF components including cognitive flexibility and working memory in various tasks. Attentional resources can limit or enhance EFs.

2 **Attention and Memory**
How attention is allocated can determine how efficiently or accurately information gets encoded. When a person is not attending to information, he or she will be unlikely to remember it accurately. Paying attention, especially in divided or distracting environments, is key to memory consolidation.

3 **Attention and Processing Speed**
Attention can affect how quickly information is processed. This processing speed may be further modulated by the number of attentional resources available, and how long attention is required.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Attention refers to goal-oriented focus, filtering irrelevant stimuli, and selecting important information.
- ☐ Attention is critical for the purposes of filtering, orienting, and directing information so that the brain is not overwhelmed by unfiltered information. Executive functioning manages attentional resources and applies them to various other functions as needed.
- ☐ Attention occurs in various brain regions, and there are different types of attention, including endogenous (or top-down) and exogenous (or bottom-up).

Lesson 5: The Components of Attention

Lesson 5 Objectives

1. Define the four components of attention.
2. Explain the effects of aging on the four components of attention.

Components of Attention

Sustained Attention - Refers to the ability to **maintain concentration** on a task over an **extended** period of **time** (i.e. having a focused conversation)

Selective Attention - Ability to **attend to specific stimuli**, while **disregarding others** that are irrelevant to the task at hand. (i.e. searching for a person in a crowd)

Divided Attention - Attending to **multiple streams** of information at one time. This is different than switching between two stimuli (task switching) and is **expensive** to attentional resources. (i.e. talking while walking)

Attention Switching - AKA "**Task Switching**" or "**Set Shifting**" involves **shifting attention** from one task to another at varying intervals of time. This **utilizes more attentional resources**, especially with greater frequencies of attention shifting (i.e. shifting from a conversation to scheduling a meeting).

Attention Changes in Aging

The following chart summarizes how each of the four components of Attention can be modified, if at all, by the normal process of cognitive aging.

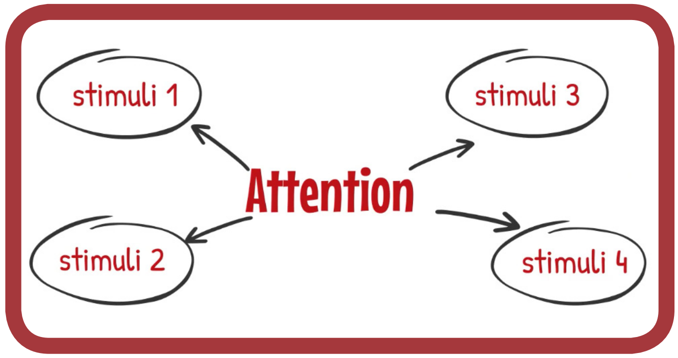
	Description	Age Effects
Selective Attention	Ability to focus despite distractions	Slight Decrease
Divided Attention	Managing multiple streams of information	Decreased
Attention Switching	Ability to switch from one task to another	Much reduced
Sustained Attention	Sustaining Attention on relevant stimuli	No effects

Note that these changes are either differentiated or significantly increased in the presenece of neurological conditions, such as certain types of MCI, dementia, Traumatic Brain Injury (TBI), Stroke, ADHD/ADD, MS, and Parkinson's Disease.

Divided Attention & Aging

From Preventing Injury to Cognitive Performance

Attention **becomes limited** when **divided between** two or more **stimuli**, particularly in older adults and those with cognitive impairments.

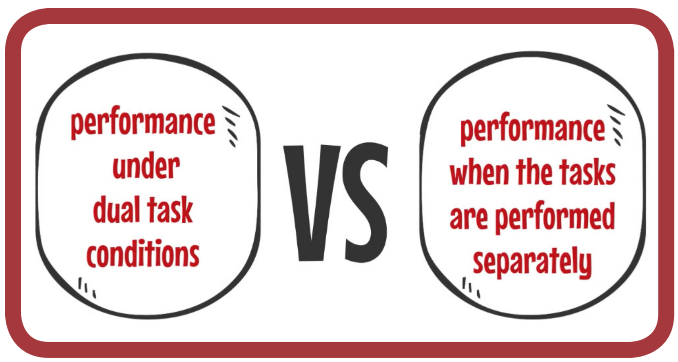


This is referred to as divided attention; and has been associated with age-related declines in performance, particularly with complex tasks.

Examples include:

- Driving while trying to listen to someone talk
- Visually scanning across a street while walking
- Monitoring stimuli at two different spatial locations

The **cost** of **dividing attention** Is assessed by comparing **Performance under dual task conditions** vs.**Performance when the tasks are performed separately.**



This is referred to as “**dual-task cost**”.

Older adults are more affected by the division of attention than young adults particularly when the attentional **demands** of the two tasks are **high**. In other words, older adults, especially those with cognitive impairments, will likely have higher dual-task cost in divided attention tasks.

Older adults can show **impairments** on **attentional tasks** that require **dividing** or switching of **attention** among **multiple** inputs or **tasks**.

The tasks on which older adults show impairments tend to be those that require **flexible control of attention**, a **cognitive function** associated with the **frontal lobes**. However, divided attention tasks that also **incorporate vision** and **task switching** may **integrate** the **occipital** and **parietal lobes**, respectively.

Research has shown that **divided attention** impairments are significantly associated with **increased automobile accidents** in older adults.

Issues also arise during gait or tasks of daily functioning that require **divided attention** that could **pose a fall risk** to older adults, and dual-task ability has been both correlated and predictive of risk of falls and cognitive decline.

Therefore the **importance of training divided attention** in an **aging population** is immense, both for the reduction of fall risk and the potential slowing of aspects of cognitive decline.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Attention refers to **goal-oriented focus**, **filtering irrelevant stimuli**, and **selecting important information**. Attention is **critical** for the **purpose** of **filtering**, **orienting** and **directing** information so that the brain is **not overwhelmed** by unfiltered information.

- ☐ **Divided Attention** normally **changes** with age, and its **decline** is more **pronounced** in those with **neurological diseases** and **conditions**. Divided Attention can be both assessed and trained.

- ☐ There are **several types of attention**; Sustained Attention, Attention (or Task) Switching, Selective Attention, and Divided Attention. All four, with the exception of Sustained Attention, are **susceptible** to **age-related declines** in performance at varying degrees.

Lesson 6: Defining Memory

Lesson 6 Objectives

1. Identify the role of Memory as a primary cognitive domain and its related brain regions.
2. Understand the role of the hippocampus in certain types of memory

Defining Cognitive Domains: Memory

Memory is the **encoding**, **retrieval**, and **manipulation** of information. Our memory storage is unlimited, but the encoding and retrieval processes are the rate-limiting factor.

Memory allows us to **recall past experiences** and **learning**. This contributes to our sense of identity, and also enables us to draw on past experience to work more effectively in the present and future.

A Historical Lesson in Memory: H.M.'s Brain

Watch the video below to learn about the history-making patient, "H.M.", and how a novel brain surgery impacted how we understand and study memory functions.

VIEW ON YOUTUBE >

Knowledge Check

Record the most correct term below based on the information presented in the video above regarding the study of H.M.'s brain:

Automatic or implicit memories. .... ______________________

Explicit memories (facts, names, events). .... ______________________

Stores Procedural Memories .... ______________________

Stores Explicit Memories .... ______________________

Temporary Memory Storage .... ______________________

Memory's Relationships to other Cognitive Abilities

1. **Memory and Executive Functioning**
Working memory is a link between executive functions and memory processes because working memory often dictates what ends up in long-term memory storage. Other EFs, such as emotional regulation and cognitive flexibility, can play a role in memory by altering the emotional context and the novelty of stimuli that are processed.

2. **Memory and Attention**
Various types of memory can determine how attention may be allocated. For example, visual memory may direct attention through the visual system. In addition, previous memories may cause attentional biases, and novel stimuli may change the way attention and memory interact.

3. **Memory and Processing Speed**
The speed at which memories can be encoded and retrieved depends on the processing speed associated with the neural circuits that support memory. The speed of recall, alongside the accuracy of recall, can be a major determinant in memory performance.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Memory is the encoding, retrieval, and manipulation of information.
- [ ] There are various types of memory, including; short-term, long-term, working memory, spatial, verbal, visual, procedural, declarative, and semantic memory.
- [ ] Memory interacts with attention, processing speed, and executive functioning. Changes to any of these other cognitive domains may also affect memory.

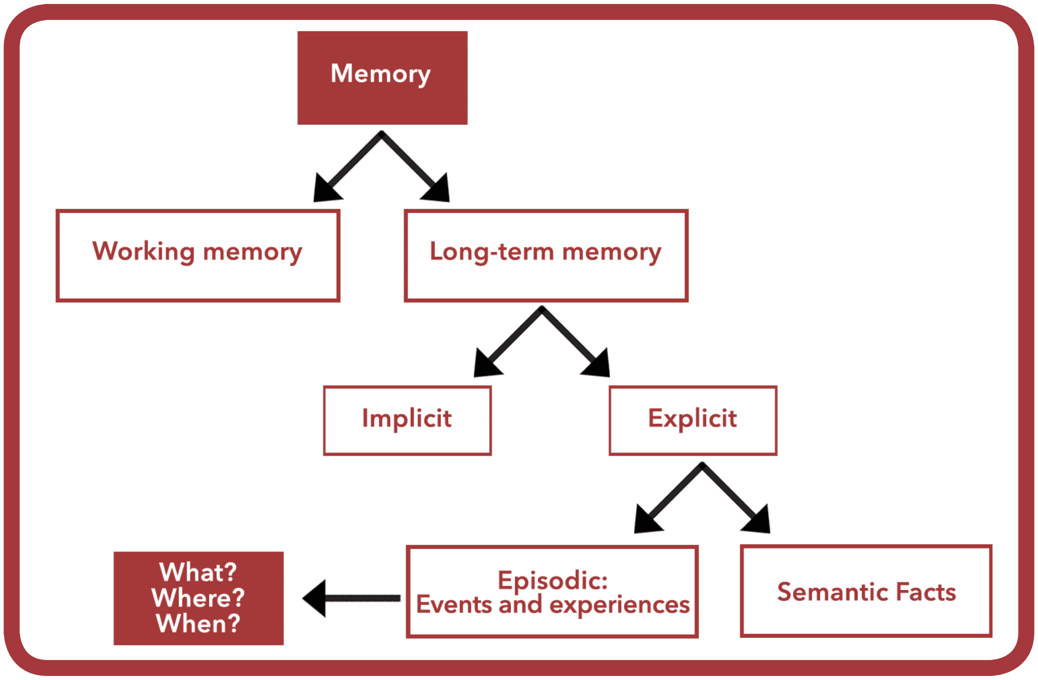
Lesson 7: The Components of Memory

Lesson 7 Objectives

1. Define the different types of memory.
2. Summarize the Multi-store Model and its relationship to memory consolidation and retrieval, and compensatory memory strategies.
3. Recall environmental, biological, cognitive, and psychological factors.

Types of Memory

Previously, you have learned about memory in the context of the changes that occur with age. This section will further elaborate on the different kinds of memory, and how they are affected by aging.



Long Term Memory - Long-term memory **requires** the **retrieval of information** that is no longer present or being maintained in an active state. This information could have occurred a few **minutes** ago or been acquired many years ago.

Long-Term Memory and Age - Failures of long-term memory have generally been attributed to **reduced use of effortful encoding strategies**, which depend particularly on **prefrontal brain regions**. Long-term memory processes **can decline with age, alongside working memory** deficits.

Implicit Memory - Acquired and used **unconsciously**, and can affect thoughts and behavior. Includes **procedural** memory, which allows performance of certain tasks without conscious awareness, such as **walking** (except in certain **conditions**, such as Parkinson's).

Explicit Memory - The **conscious**, intentional recollection of **factual information**, previous experiences, and concepts. Learning explicit memories requires **repetition** of both **stimulus & response gradually**.

Semantic Facts - Refers to **generalized world knowledge** that is accumulated throughout life. This knowledge includes facts, ideas, meaning and concepts. This information is intertwined in **experience** and dependent on **culture**.

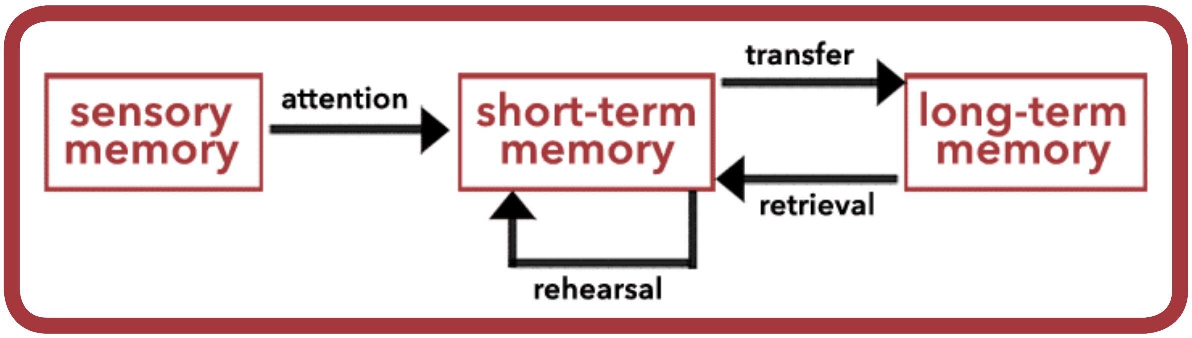
Episodic Memories - The memory of **autobiographical** events and experiences, including **time, location**, emotions, experiences, and involved **visual** imagery.

Memory Consolidation and Retrieval

Consolidation is the binding of various aspects of experience into a composite memory trace. This strategic storage process depends on the **prefrontal cortex**, as well as the **medial temporal lobe** structures, particularly the **hippocampus**.

Older adults may experience problems with this **storage** or **consolidation** process. Nonetheless, the organization of the **knowledge** system seems unchanged with age. In addition, **autobiographical** memory is largely preserved with age.

Multi-Store Model



What Can Affect Memory?

Memory consolidation and retrieval can be affected by various environmental, **biological**, cognitive and **psychological** factors.

1. Sleep - The quantity, quality, and consistency of sleep can affect memory consolidation, from the encoding of the previous day's experiences to the "cleansing" of the brain's microglial networks.

2. Psychological State - Motivation, rumination, perceived threat, emotional state, and apathy are examples of various psychological states that can affect the consolidation of memory. Negative psychological states can increase memory in ways that are not always positive, as in the case of PTSD, for example.

3. Attention - Attention, alongside other cognitive processes, can determine what memories are effectively encoded. Environments that are distracting or threatening, quiet or safe, can differentially affect memory processes.

4. Biology - Biomarkers, sometimes those as simple as blood pressure or insulin sensitivity, can affect memory consolidation and cognition. Specific nutrient deficiencies, caloric intake, and medications may further interact with memory, either for better or for worse.

5. Medication - Changes in medication, especially blood pressure medication and anti-psychotics, can affect memory. With the brain being a highly sensitive end-organ, changes in biochemistry are reflected in abilities such as memory performance.

Knowledge Check

Record the type of memory associated with each description below:

Experiences & Autobiographical Events. .... ____________________

Facts, figures, & data .... ____________________

Words, language & faces .... ____________________

Mental objects & images .... ____________________

Procedures & automaticity .... ____________________

Declarative information, explained .... ____________________

Temporary manipulation of information .... ____________________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] There are many different kinds of memory, all of which are differentially affected by the aging process.
- [ ] Various environmental, biological, cognitive, and psychological factors can influence the short and long-term encoding and retrieval of memory.
- [ ] The hippocampus plays a significant role in memory and learning, as illustrated by the famous case of patient “H.M.’s” hippocampus being removed.
- [ ] The basal ganglia and cerebellum store procedural memories, while the prefrontal cortex is involved in working memory, and the hippocampus is involved in declarative memory.

Lesson 8: Defining Processing Speed

Lesson 8 Objectives

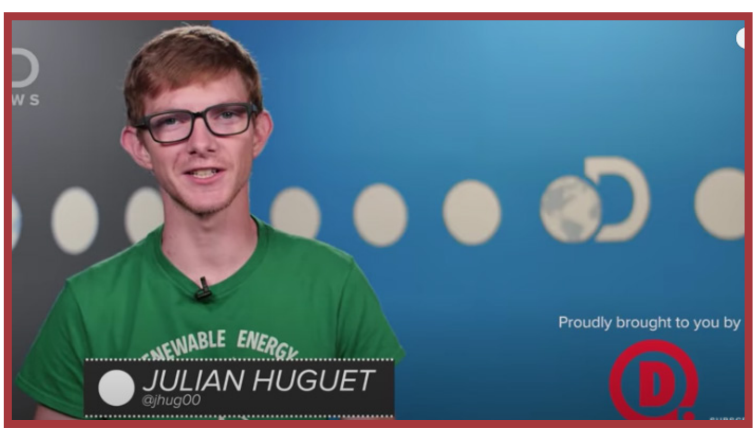
1. Explain the role of Processing Speed as a cognitive function and list its sub-domains.
2. Identify the brain structures associated with processing speed.
3. Summarize how processing speed is affected as we age.

Defining Cognitive Domains: Processing Speed

The ability to process information rapidly. Cognitive aging can be partially characterized by a "general slowing" of information processing & the speed of motor output. Processing speed is one of the leading **indicators** of age-related changes in **memory** and **spatial** ability.

Generally speaking, aging is associated with shifts in the timing and level of transmission in neurons. Still, there are several theories describing how processing speed might change with age.

Video: How Fast Does A Thought Travel?



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Components of Processing Speed

Technically, all cognitive abilities rely on processing speed to be accomplished quickly and accurately. Modern society places a high value on fast and efficient processing speed, whether the task requires recall, problem-solving, or decision-making.

Key sub-domains associated with processing speed include:

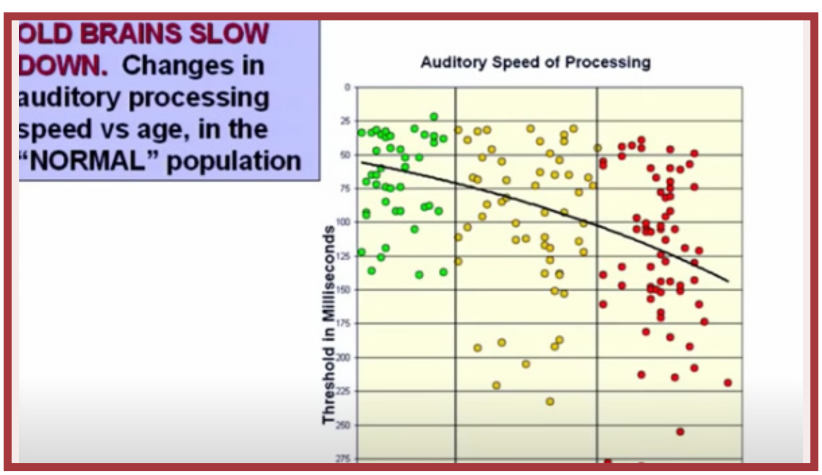
1. **Visual Perceptual Speed**
   The ability to analyze, interpret & act upon visuospatial information quickly, which may decline with age.

2. **Auditory Processing Speed**
   The ability to analyze, interpret & act upon auditory information quickly, which may decline with age.

3. **Response Time**
   The amount of time required to respond to a stimulus, which may decline with age. This may also be referred to as Reaction Time, but this depends upon the context of the task.

Changes in Processing Speed with Age

Watch the video below to hear how a type of Processing Speed, Auditory Processing Speed, may change in older adults, and how it may represent changes in information processing abilities.



VIEW ON VIMEO >

Speaker: Dr. Michael Merzenich, Ph.D. from Google Tech Talks, “Think faster focus better and remember more Rewiring our brain to stay younger” (https://youtu.be/UyPrL0cmJRs)

How does age affect Processing Speed?

There are several theories of how processing speed declines with age, which were mentioned in the prior module. The theories that may be specific to processing speed declines include:

1. **Sensory Deprivation Hypothesis**
2. **Common Cause Hypothesis**
3. **Information Degradation Hypothesis**
4. **Myelination**

Changes in visual and auditory processing speed are often tied to the sensory systems, such as the eyes and ears. As individuals age, it is critical to work with an integrated medical team to keep vision and hearing assessed and treated for any impairments, as research is finding the untreated visual, vestibular and auditory deficits can increase risk of cognitive decline & falls.

Processing Speed's Relationships to other Cognitive Abilities

1. **Processing Speed and Executive Functioning**
   How efficient an executive function is, is often determined by the speed that it can be performed. For example, for impulse control to be effective, a person must inhibit the impulse quickly. Likewise, without quick cognitive flexibility in the face of adversity, a person may experience bouts of emotional dysregulation. Fast problem-solving and decision-making likewise are highly valued in work, sport, and leisure activities.

2 **Processing Speed and Attention**

Processing speed can dictate how quickly various stimuli are attended to. For example, in a healthy brain, a novel visual stimulus should be quickly responded to. General slowing, on the other hand, may increase the amount of time it takes to attend to this stimulus. Cognitive slowing also reduces the speed at which a person can alternate attention between tasks.

3 **Processing Speed and Memory**

When the neural circuits supporting memory operate quickly, memories can be encoded and retrieved quickly too. When these neural circuits slow, memory processes can slow as well. The speed of recall, alongside the accuracy of recall, are major components of good memory performance.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Various types of processing speed change normally with age, and likely affect various other cognitive domains, such as working memory and components of attention.

- ☐ Information processing speed is closely related to the sensory systems of the body. Keeping up-to-date assessments and treatments (like hearing aids) for these systems is an important component of brain health.

- ☐ Clients that experience slight changes in processing speed may be experiencing normal aging, but early changes in processing speed might precede cognitive decline by many years, warranting referrals to medical professionals (such as neurologists) whenever a client has a subjective cognitive complaint with the goal of early assessment, diagnosis and/or monitoring of cognitive brain health.

Reflection

Take a moment to reflect on all that you have learned in this module. Use the space below to record your thoughts.

BRAIN HEALTH
TRAINER

Module 2:
Exercise and The Brain
Handbook

Introduction

Module 2 **builds upon** the concepts of **cognitive aging, cognition**, and **neuroplasticity** to present the general and specific **benefits of exercise on the brain**. This section will present how **exercise can change the brain**, at what levels, and the **acute variables within a Brain Health Exercise and Physical Activity Plan**. This information will set you up for Module 3, which will focus on integrating this information in the development of a BH-EPAP for a client.

Module 2 includes **5 Sections**, with a total of **19 Lessons**, and a **quiz**. **Before you continue** into Module 2 you should be able to **explain** the natural **course of cognitive aging**, differentiate between the **stages of cognitive decline**, and explain the relationship between **Neurodegeneration** and **Alzheimer's Disease**.

Module 2 Overview

Introduction

Congratulations on completing Module 1! Now, you will build on your understanding of cognitive aging as we begin to discuss the role of exercise as a factor in promoting healthy brain aging.

In **Module 2**, you will be learning about the myriad **effects of exercise on the brain**. To effectively explain how exercise affects the brain, you must understand **the mechanisms** and **processes of change**, including the types of **neuroplasticity** and different **neurotransmitters**.

Module 2 will also present on the **effects of exercise on cognition**, their **mechanisms** and processes of change, as well as the larger regions and networks of the brain. Finally, you will learn that **various** types of **exercise variables** and **modalities** have both **shared & differential effects on the brain**.

By the end of the module, you will be able to **classify** categories and **modes of exercise by specific** micro (growth factors & neurotransmitters), macro (brain regions and networks), and behavioral (including cognitive) **changes to the brain**.

Module Agenda and Objectives

This module is divided into five sections with a total of 19 lessons. The module ends with a quiz. You must complete both sections and score a 70% on the quiz to progress.

1 **Section 1: Mechanisms of Neural Change**
This section will identify and define the different ways in which the brain can change. “Neural Change” refers to how the brain can change, and “mechanisms” refers to the ways the brain can change. This section will identify 3 different “levels” in which the brain can change, from the smallest level of the brain (the micro-level) to the largest level of the brain (the macro-level). These changes will be related to manifestations of changes in cognition and mood, which are behaviors, therefore occurring at the “behavioral-level.”

2 **Section 2: Growth Factors and Neurotransmitters**
This section will review the ways that exercise can affect the brain at the “micro-level”, specifically in regards to growth factors and neurotransmitters. Different types of growth factors and neurotransmitters will be explored, as will the ways that exercise affects them. These changes at the micro-level will be related to changes at the macro-level and the behavioral-level of the brain.

3 **Section 3: Macro-Level Changes**
This section will review the ways that exercise can affect the brain at the “macro-level”, specifically in regards to brain structures (regions) and functional brain networks. The mechanisms by which exercise can affect brain structures and functional brain networks will be explored. These changes at the macro-level will be related to changes at the micro-level and the behavioral-level of the brain.

4 **Section 4: Exercise and Cognition**
This section will review the ways that exercise can affect the brain at the “behavioral-level”, specifically in regards to cognition. The mechanisms by which exercise, both generally and specifically can affect cognition will be explored. These changes at the macro-level will be related to changes at the micro-level and the macro-level of the brain.

4 **Section 5: Modalities of Exercise and Cognition**
This section will continue to review the ways that exercise can affect the brain at the “behavioral-level”, specifically in regards to cognition. However, more specific information will be given about how different modalities of exercise affect these outcomes. These changes at the macro-level will be related to changes at the micro-level and the macro-level of the brain.

Knowledge Check

Which of the 4 primary cognitive domains matches the description?
Record your answers here for future reference.

Includes working memory, which can decline with age .... ________________

Filters stimuli and when divided, declines with age .... ________________

Processes, encodes and retrieves information .... ________________

Underlies virtually all cognitive functions, declines with age .... ________________

SECTION 1: MECHANISMS OF NEURONAL CHANGE

Lesson 1: The Levels of Change in the Brain

Introduction to Section 1: The Levels of Change in the Brain

Section 1 is divided into **4 Lessons**. This section identifies the different levels in which exercise can affect the brain. You are currently in **Lesson 1**, which will give you a brief overview of the **multi-level** and complex effects of exercise on the brain. Lessons 2-4 will review each level of the brain individually.

Lesson 2 will define **micro-level** changes in the brain, which include **smaller structures** such as **neurons, synapses, growth factors**, and **neurotransmitters**. Lesson 3 will define **macro-level** changes in the brain, such as **brain structures (regions)** and **functional brain networks**. Lesson 4 will define the **behavioral** changes that can result from exercise, including changes in **mood** and **cognition**.

By the end of Section 1, you will be able to differentiate the effects of exercise at multiple levels of the brain and relate them to each other. This information is fundamental to learning how exercise can comprehensively affect the brain, and differentiate the unique effects certain modalities of exercise may have on the brain, which is explored further in Sections 4 and 5.

Lesson 1 Objectives

1. Explain how exercise can affect the brain at the micro, macro, and behavioral levels
2. Identify commonly shared and select mechanisms in which exercise can change the brain at multiple levels
3. Define neurogenesis, angiogenesis, and synaptogenesis and relate these to exercise

---

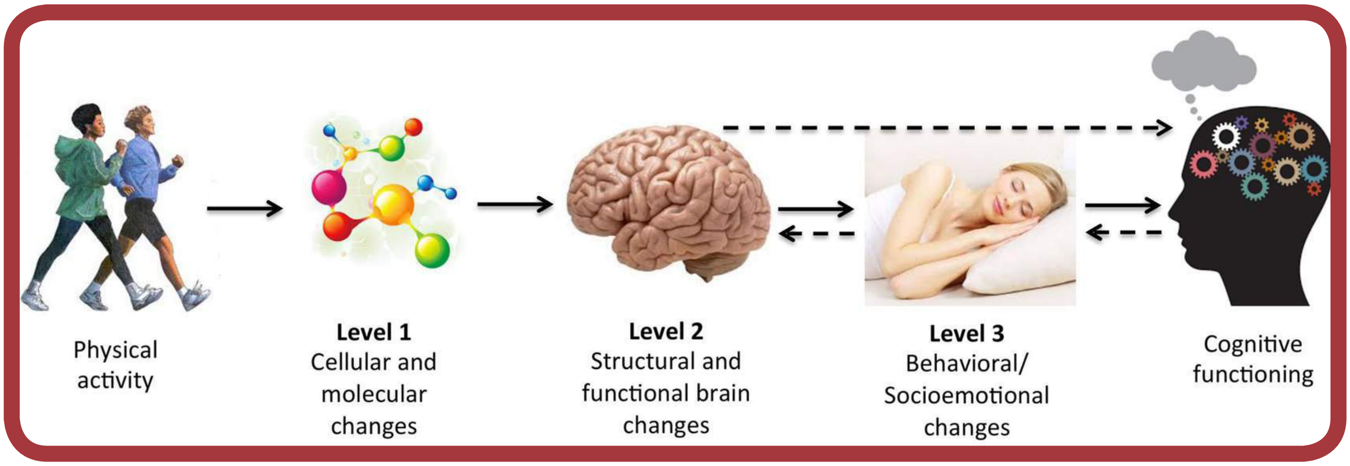
Introduction to Mechanisms of Brain Change

Watch the video below to gain an overview of what will be covered in this next section, including neuroplasticity, growth factors, & other mechanisms of brain change.

VIEW ON VIMEO >

Exercise and the Brain

Exercise and physical activity are **associated** with a **broad array** of **neurological** and **physiological processes**. We refer to these processes generally as **mechanisms of brain change**. Similar to the course of cognitive aging, changes to the brain caused by exercise occur at the **Micro** and **Macro levels**. These micro and macro level changes may support **behavioral changes** and **improvements** in **cognitive abilities**. It is important to note that this is a **simplified presentation of exercise neuroscience**, and the reality of these effects likely involves more complex dynamics.



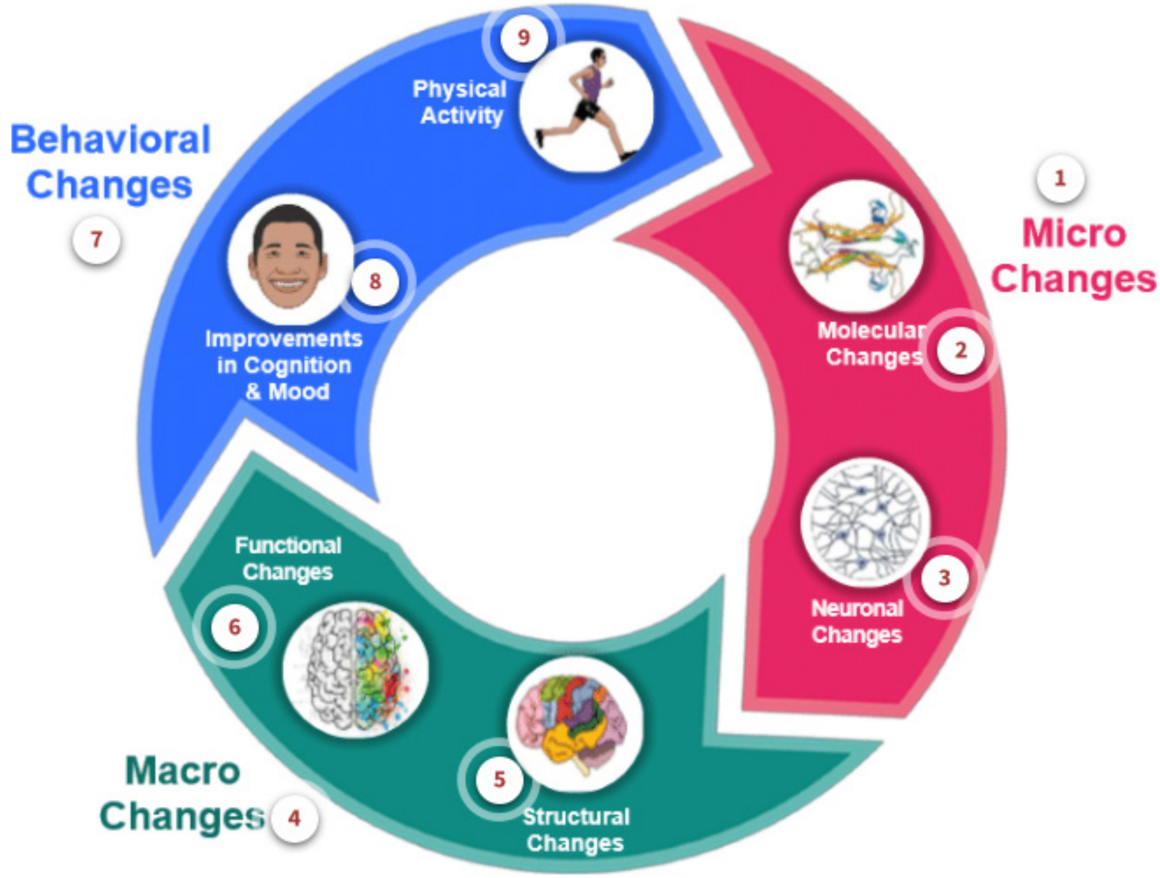
Stillman, C. M., Cohen, J., Lehman, M. E., & Erickson, K. I. (2016). Mediators of physical activity on neurocognitive function: a review at multiple levels of analysis. Frontiers in human neuroscience, 10, 626.

It is **insufficient** to **explain** the **benefits of exercise** on the brain by way of any **single mechanism**. This difficulty is compounded because “**exercise neuroscience**” is an **ever-changing field of study**. We are still discovering new mechanisms underlying changes in the brain and our understanding of existing mechanisms continues to be improved upon. **Some mechanisms** by which the brain changes may **seem simple**, while others **may function** in seemingly **contradictory** or **complex ways**. These **mechanisms require** various **multi-level**, collaborative **processes** in order to **change the brain** in any way.

These changes are all related and do not necessarily occur in a step-wise or isolated manner. In fact, they are all interconnected and the relationships between these mechanisms require much more research.

Micro, Macro, and Behavioral Level Changes

Exercise and physical activity **affects the brain** in myriad ways through **three levels** of neurological and physiological mechanisms. Exercise and physical activity can affect the brain at the **Behavioral** Level, the **Micro-level**, and the **Macro-level**.



1. Micro-level Changes - Micro-level changes specifically refer to the **molecular** and **neuronal** effects of exercise on the brain. This includes the interaction of **growth factors**, neurotransmitters, **electrical brain changes**, and changes in blood flow.

2. Molecular Changes - Molecular Changes include increases in the expression of the **growth factors** such as **BDNF** and **VEGF**. They also include smaller-level changes in **blood** flow & **neurochemistry**.

3. Neuronal Changes - Neuronal changes include modification in the **size**, **function** and/or **number** of **neurons**, **synapses**, **glial cells** and the networks they comprise. The level comprises **functional** & **structural** neuroplasticity at a smaller-level.

4. Macro-level Changes - Macro-level changes include modifications in brain **structure** and/or **function** in one or more brain regions or networks. These changes could be **volumetric** (change in size) or **functional** (change in connectivity).

5. Structural Changes - Structural changes involve change in **volume**, size, or cortical thickness in one or more **regions** of the brain. For example, the change in volume of the **hippocampus** as a result of exercise is a structural, regionally-specific change. Improvements in **whole-brain grey matter** is also a structural change.

6. Functional Changes - Changes in **brain function** at the macro-level include changes in **regional brain activity**. As different brain regions connect to each other via **functional brain networks**, the activity of efficiency of these **networks** can be modified by exercise.

7. Behavioral Level Changes - Changes in behavior are often the outcomes that are **noticeable** by individuals, and include changes in mood (**positive affect**) and cognition (such as attention and **memory**).

8. Cognition & Mood - Changes in cognition include modifications to **domains** such as **memory**, **attention**, executive function, **processing speed**, and other domains of cognition. Changes in mood could manifest as increased **energy**, the amelioration of stress, or the **management** of **depressive** or anxious symptoms.

9. Physical Activity - While physical activity and exercise can initiate these micro, macro and behavioral changes, it is also influenced **bi-directionally** via these modifications. As these changes occur, the **increasing** physical activity and exercise **behavior** also increases.

Key Neurobiological Processes

There are three critical **neurobiological processes** that **facilitate** the **micro-level changes** to the brain caused by exercise.

Neurogenesis - Neurogenesis is the process of growing new neurons in the brain.

Synaptogenesis - Synaptogenesis is the process of the formation of new synapses in the brain.

Angiogenesis - Angiogenesis is the process through which new blood vessels and connections are made.

Knowledge Check

Which key mechanism of brain change matches the description?
Record your answers here for future reference.

Creation of new brain cells .... ____________________

Creation of new synapses .... ____________________

Creation of new blood vessels .... ____________________

The ability of the brain to change .... ____________________

The resiliency of the brain .... ____________________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Neurogenesis refers to the creation of new brain cells, Angiogenesis refers to the generation of new blood vessels, and Synaptogenesis refers to the generation of new synaptic connections.
- [ ] Exercise can affect the brain at the micro-level, including changes in neurons, synapses, blood vessels, neurotransmitters, growth factors, and local brain activity.
- [ ] Exercise can affect the brain at the macro levels, including brain structures and networks, and at the behavioral level, which includes mood and cognition.

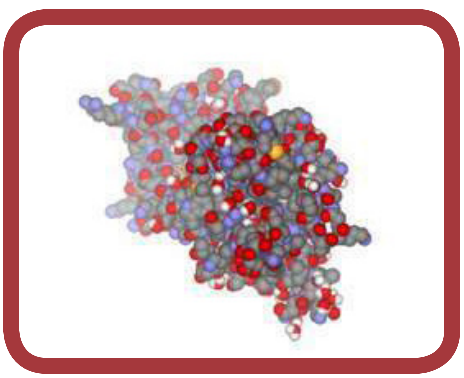
Lesson 2: Micro-Level Changes

Lesson 2 Objectives

1. Identify the molecular and neuronal changes that can occur in the brain due to exercise.
2. Summarize the effects of exercise, enriched environments, and cognitively stimulating activity on Neurogenesis and Neuroplasticity.
3. Summarize the effects of exercise on Synaptogenesis.

Micro-level Changes

Micro-level changes occur when there are modifications in molecules, neurochemicals, growth factors, hormones, blood flow, and brain activity at a smaller level of the brain.



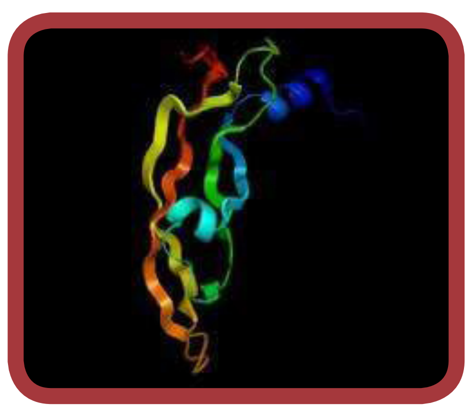
BDNF's molecular structure

Increase in BDNF

One of the most well-replicated findings of a **molecular change** in **response** to **exercise** is an increase in the expression of a protein called **BDNF**. **BDNF** stands for **Brain-Derived Neurotrophic Factor** and facilitates **neuroplasticity**. Increases in BDNF also affect **behavioral changes**, including **improved learning** and **memory**.

Increase in VEGF

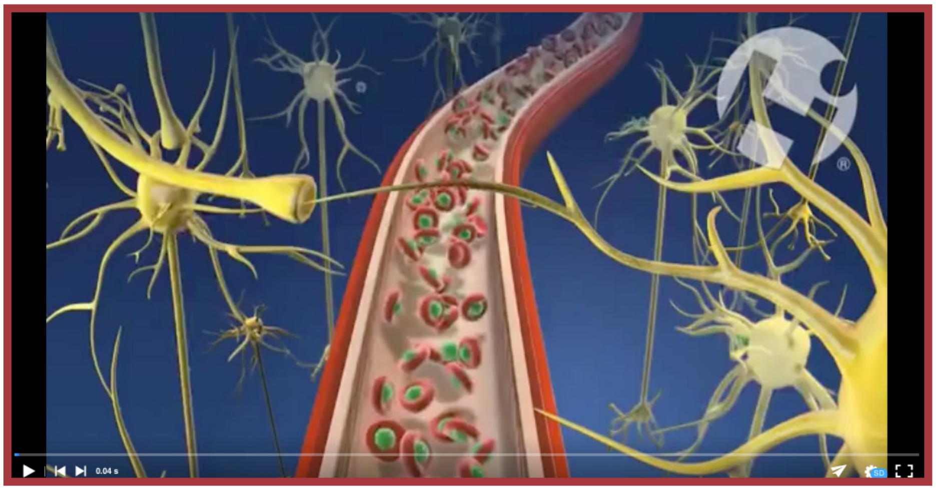
Vascular Endothelial Growth Factor (VEGF) has been found to **stimulate angiogenesis**. Exercise increases VEGF, which in turn **increases** the **vascular density** in the brain. This may be important for **maintaining cognitive performance** during normal aging and **preventing neurodegeneration.** It is important to note that VEGF has no direct control over neurogenesis.



VEGF's molecular structure

Brain Activity and Metabolism

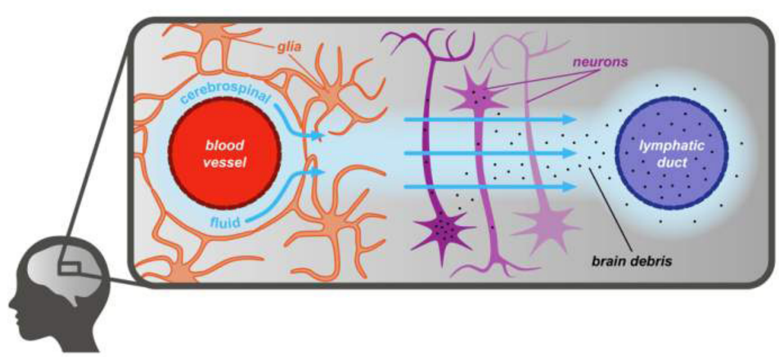
Metabolic changes in the brain occur in response to **brain activity** and brain **blood flow**. When the brain becomes more active, either locally or within a network, blood flow delivers **oxygen** and **nutrients** to the active regions. This signaling is paralleled with **electrical impulses** that result from **neurochemical signals**, which result in brain activity.



View on Gfycat >

Exercise and Glymphatic Function

The **glymphatic** system refers to a network of **vessels** that **clear waste** from the brain. Exercise has demonstrated to have beneficial effects on **mechanisms** that contribute to **neuroinflammation** and **glymphatic** function, especially when combined with other modifiable healthy lifestyle behaviors (such as **sleep**).



Knowledge Check

Neurotransmitters, VEGF, Neuroplasticity or BDNF?
Which term matches the description?
Record your answers here for future reference.

Protein associated with facilitating neuroplasticity .... ____________________

Protein that have been found to stimulate angiogenesis .... ____________________

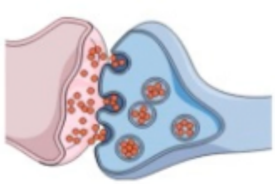
Chemical substances that allow neurons to communicate .... ____________________

The ability for the brain to change .... ____________________

How Quickly Can the Brain Change?

When it comes to neuroplasticity, there are various levels of change that can occur in the central nervous system, from changes at the synpatic level, to modifications in brain morphology. Each of these changes has different time-periods in which they can change, and this is important to define, as neuroplasticity from one perspective may not mean significant neuroplasticity in another.

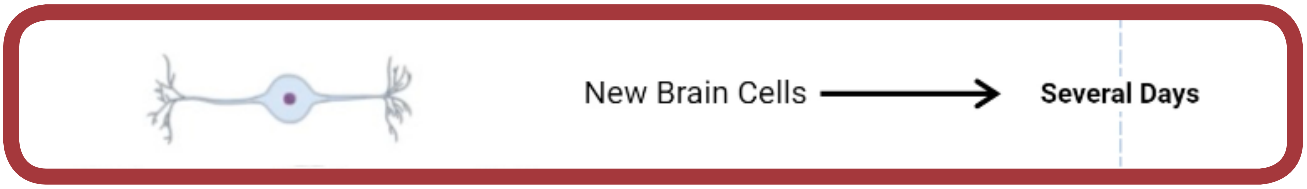
Let's begin with talking about the synapses, a space between at least two neurons that passes on electrical signals or chemical signals through charged ions and neurotransmitters, respecitively. When synapses are modified, the function and structure of the synapse can be changed. In the case of synaptogenesis, which occurs with exercise, new synpases are formed between other neurons. While the degree of synaptogenesis depends upon the variables of exercise and cognitive stimuli, changes at the synaptic level can occur in milliseconds.



Synaptic Modification → **Milliseconds**

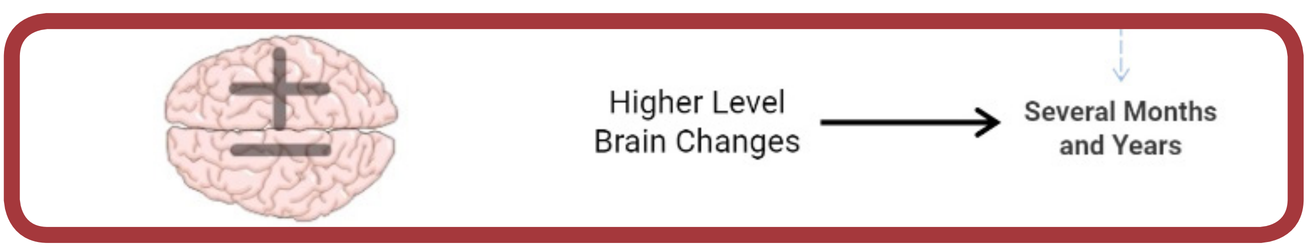
Synaptogenesis will continue to occur over longer time periods at greater degrees. As this happens, dendrites, the branch-like extensions along neurons that carry electrical signals, continue to grow and split into more variable directions. A common metaphor is that of a tree growing new branches that connect with others, and this process can occur over several hours.

The process of neurogenesis, the creation of new brain cells, is critical to various improvements in brain health. Contrary to common belief, the bulk of the neurogenesis process does not occur right away. Rather, it occurs over the process of several days. This timeline establishes an argument for introducing additional factors that can enhance the survival and function of these new neurons over the course of several days.



As new neurons get created, and as their sub-structures grow to faciltiate greater connectivity, changes of entire neuronal networks begin to take place. This is important as certain neuronal networks correlate to specific neural circuits, which may be a part of certain mental functions. Changes in neuronal networks requires more consistent and possibly targeted effort, as these changes occur over several weeks and months.

Specific regions of the brain are comprised of many neuronal networks and consist of different types of brain tissues. These tissue types include gray matter and white matter, and changes in their volumes often occur with chronic exercise and physical activity. These changes are not short term, and occur over several months and years.



Knowledge Check

Days, Months and Years, Weeks and Months, Milliseconds, or Hours?
What is the timing associated with each process?
Record your answers here for future reference.

Synaptic Modification .... ______________________

Branching of Synapses & Dendrites .... ______________________

New Brain Cells .... ______________________

Neuronal Network Changes .... ______________________

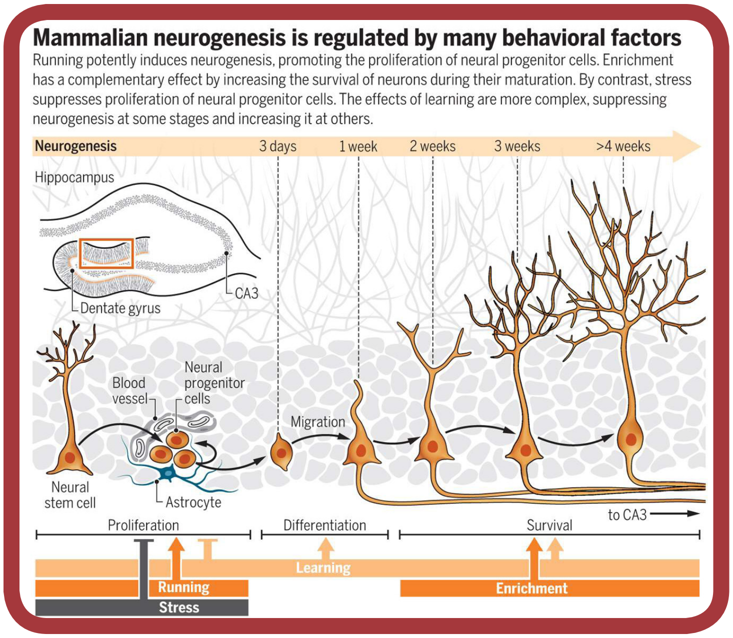
Higher Level Brain Changes .... ______________________

What About Changes at the Genetic Level?

Individuals who possess the **APOE4 gene variant** have a **higher risk** of developing **Alzheimer's Disease** and **cardiovascular disease**. Individuals with this **genetic profile** tend to develop a greater **burden** of **amyloid** plaque and **vascular** issues in the brain. One theory is that humans **evolved** to be more physically **active** alongside the development of these **genes**, which may explain why **sedentary** lifestyles increase **Alzheimer's** Disease, **dementia**, and **cardiovascular** disease **risk**.

- Individuals with greater **genetic risk** of **Alzheimer's** Disease **significantly benefit** in **cognition** and **physical function** from higher levels of **physical activity** when compared to those who **exercise less**.
- Engagement in **higher** levels of **exercise** in those with the **APOE** genotype may lead to the **lessened deposition of amyloid plaques** in the brain
- Seeking **genetic assessments** via a doctor or **neurologist** may allow for identification and specific lifestyle **recommendations** (such as **exercise**) for **dementia prevention**.

Effects of Exercise on Neurogenesis



Gage, F. H. (2019). Adult neurogenesis in mammals. Science, 364(6443), 827-828.

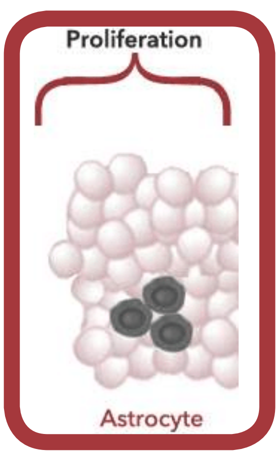
Neurogenesis is the **generation of new neurons** or brain cells. **Exercise** has demonstrated the ability to **facilitate neurogenesis** in animals & humans, which is one of the mechanisms thought to influence brain health positively. While neurogenesis can happen in a short amount of time (**3 days**), **significant effects** resulting from the **survival & integration** of these new neurons can take longer (**>4 weeks**).

Neuronal Proliferation and Survival

New cells undergo two crucial phases: proliferation and survival. Making new cells alone isn't enough, the cells must be incorporated in the existing brain tissue to survive.

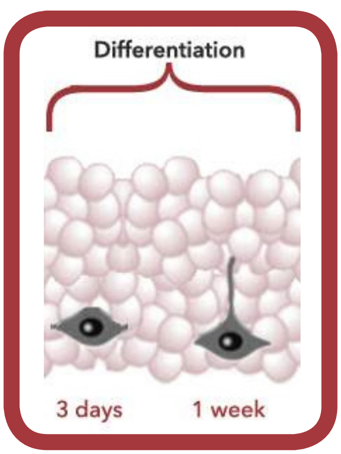
1

Proliferation (Cells Divide)



2

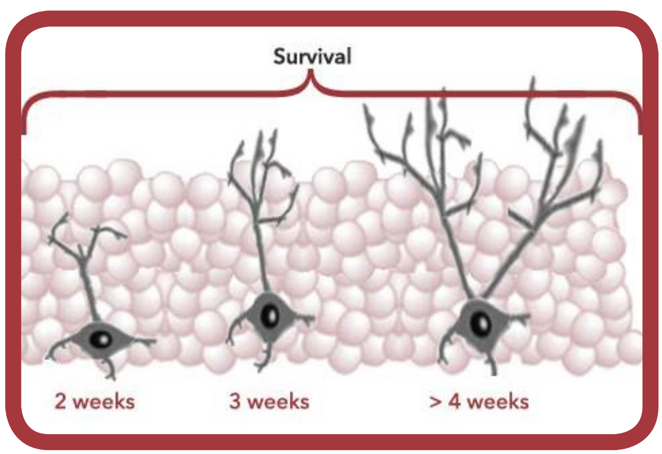
Differentiation & Maturation



Cells develop characteristics specific to adult neurons.

3

Survival



Cells grow and extend toward other neurons.

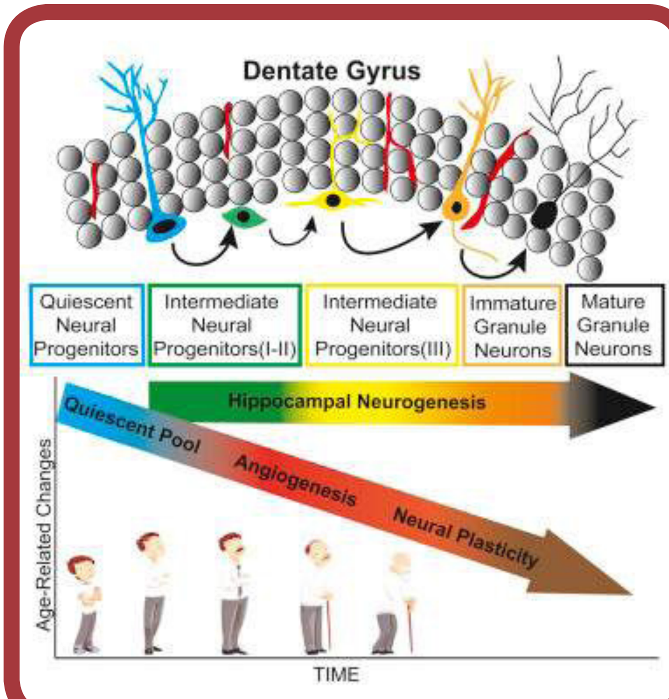
Neurogenesis in Mental Health & Cognitive Decline

Studies show that even with **neuropsychiatric & neurodegenerative conditions** (such as dementia and depression) individuals can **still benefit** from **exercise** and physical activity programs. These programs can alleviate many symptoms associated with various health conditions & improve cognition. It is thought the micro-level mechanisms play a role in these beneficial effects, from altering **brain activity** to reducing brain **inflammation**, or increasing **neurogenesis** that would otherwise be negatively affected in such conditions, although their significance requires more research.

Neurogenesis

Rates of neurogenesis can **decline with age**, especially among the presence of various risk factors. Several behaviors can foster and promote neurogenesis, specifically in the **hippocampus** (a specific region is called the **dentate gyrus**).

Some of the behaviors that may better facilitate neurogenesis include **aerobic exercise**. Some research has hypothesized that exercise performed at **60-80% of Heart Rate Max**, or moderate to vigorous intensity, may release higher amounts of **BDNF** and therefore potentially higher rates of neurogenesis.



Knowledge Check

Structural Neuroplasticity, Differentiation, Functional Neuroplasticity, Proliferation or Apoptosis. Which term matches each description?

Record your answers here for future reference.

Nerve cell(s) created .... ______________________

Nervel cell(s) function splits .... ______________________

Nerve cell death .... ______________________

Changes in synapses & connections .... ______________________

Changes in brain cells & brain volume .... ______________________

Modalities of Exercise & Neurogenesis

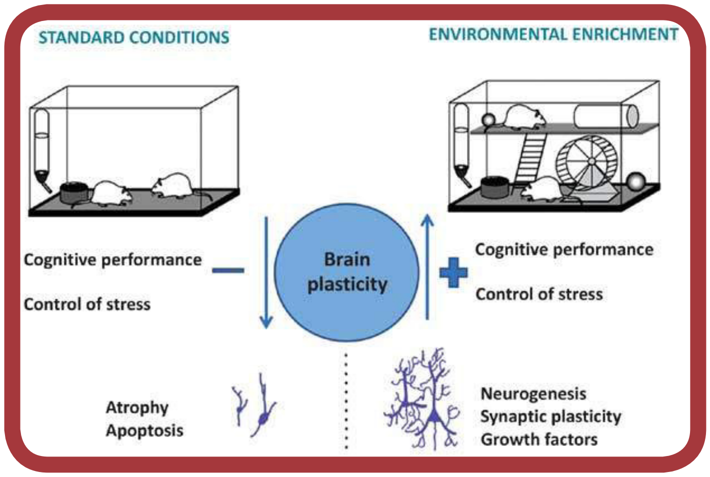
Higher intensities of aerobic exercise is not the only way to facilitate neurogenesis. Releasing a greater variety of growth factors may also be helpful, which may be done by **adding in other modalities** of exercise, such as **resistance training**.

Incorporating **skill-based demands** that incorporate **effortful learning** and cognitive demands may affect the rate of neurogenesis, but also potentially affect the "**integration**" and survival of these new neurons.

Cognitively Enriching Environments

Environments consisting of complex stimuli also affect neuroplasticity. Similarly, "**cognitively enriching environments**," or environments that impose intellectual demands, can also facilitate neuroplasticity.

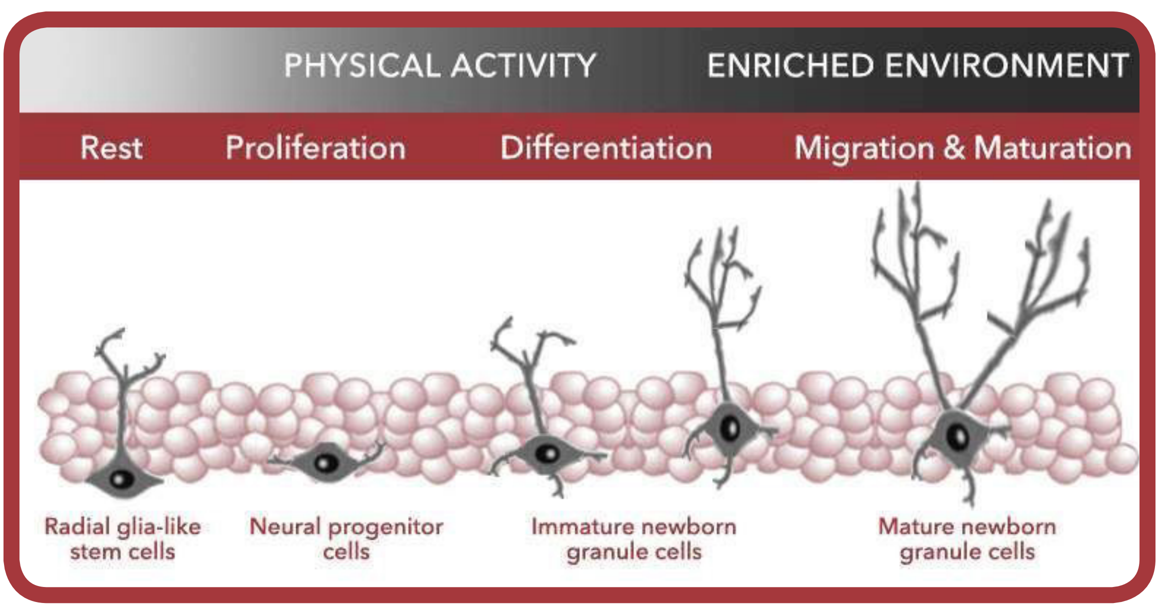
Experiences that lead to changes in the brain often involve several stimuli, such as **sensory** and **motor**. Higher degrees of changes have been thought to occur when **multiple** stimuli are present simultaneously, such as **sensory-motor** instead of the two in isolation. Greater change may also occur in response to a greater **novelty**, **variability**, & **challenge**.



Additionally, **psychological** states such as **enjoyment**, **motivation**, and **exploration** as well as levels of practice and relative cognitive and physical demands can affect neuroplastic outcomes. These variables can guide us to modify **environments** for exercise programs that may enhance outcomes of neuroplasticity, although this cannot be measured practically.

Effects of Enriched Environments

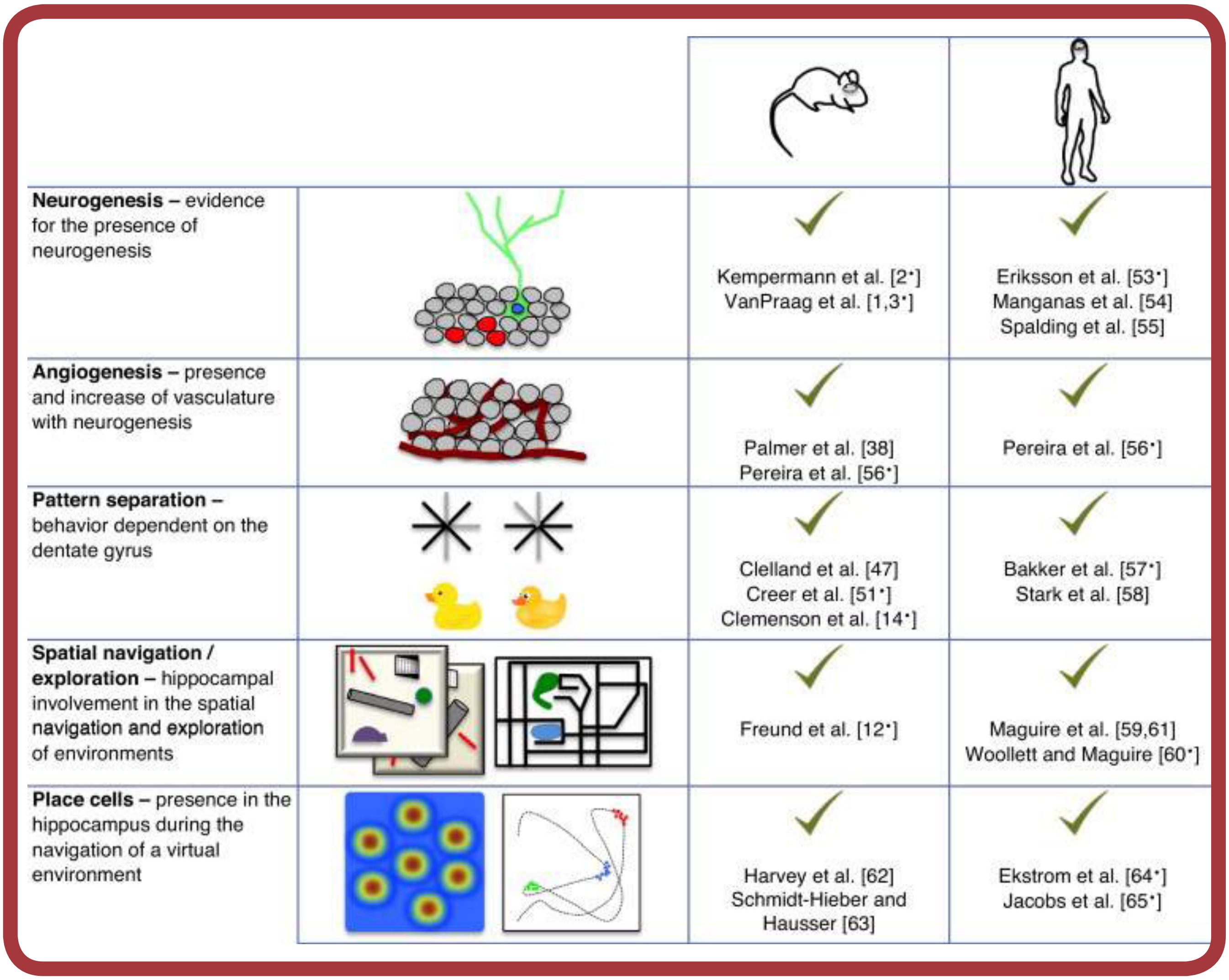
When combined with physical activity, environmental enrichment may have profound effects on neurogenesis. Environmental enrichment facilitated the proliferation of newborn cells and led to a higher degree to the integration and survival of neurons. Thus, for the integration and the survival of newly generated neurons, additional stimuli seem to be crucial.



Kempermann, G., Fabel, K., Ehninger, D., Babu, H., Leal-Galicia, P., Garthe, A., & Wolf, S. (2010). Why and how physical activity promotes experience-induced brain plasticity. Frontiers in neuroscience, 4, 189.

Does Environmental Enrichment Research Apply to Humans?

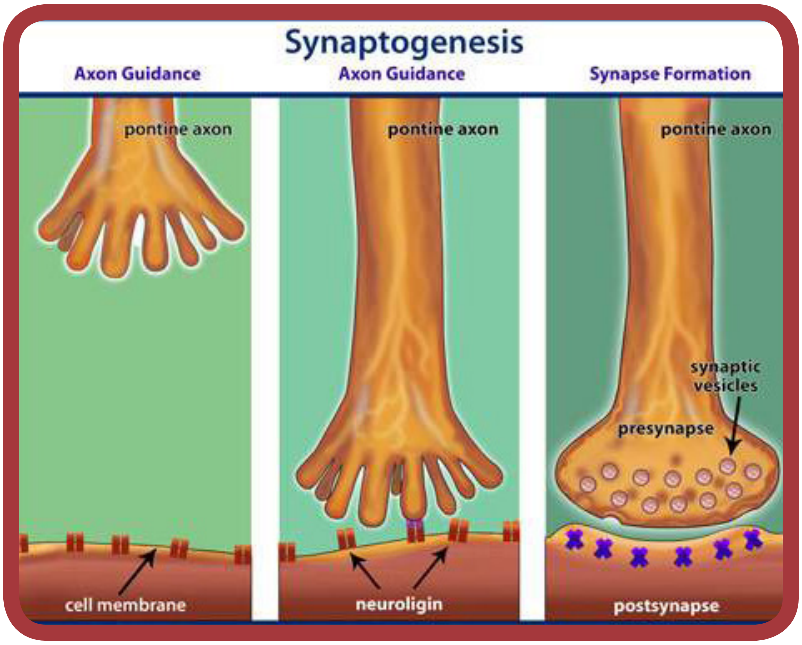
While Environmental Enrichment research is encouraging, do these studies on animals really apply to **humans**? The image below demonstrates various results from **enriched environments**, from neurogenesis to changes in behavior, in **both animals and humans**, citing research authors demonstrating potential evidence for each adaptation.



	Mice	Humans
Neurogenesis – evidence for the presence of neurogenesis	✓ Kempermann et al. [2•] VanPraag et al. [1,3•]	✓ Eriksson et al. [53•] Manganas et al. [54] Spalding et al. [55]
Angiogenesis – presence and increase of vasculature with neurogenesis	✓ Palmer et al. [38] Pereira et al. [56•]	✓ Pereira et al. [56•]
Pattern separation – behavior dependent on the dentate gyrus	✓ Clelland et al. [47] Creer et al. [51•] Clemenson et al. [14•]	✓ Bakker et al. [57•] Stark et al. [58]
Spatial navigation / exploration – hippocampal involvement in the spatial navigation and exploration of environments	✓ Freund et al. [12•]	✓ Maguire et al. [59,61] Woollett and Maguire [60•]
Place cells – presence in the hippocampus during the navigation of a virtual environment	✓ Harvey et al. [62] Schmidt-Hieber and Hausser [63]	✓ Ekstrom et al. [64•] Jacobs et al. [65•]

Clemenson, G. D., Deng, W., & Gage, F. H. (2015). Environmental enrichment and neurogenesis: from mice to humans. Current Opinion in Behavioral Sciences, 4, 56-62.

Synaptogenesis



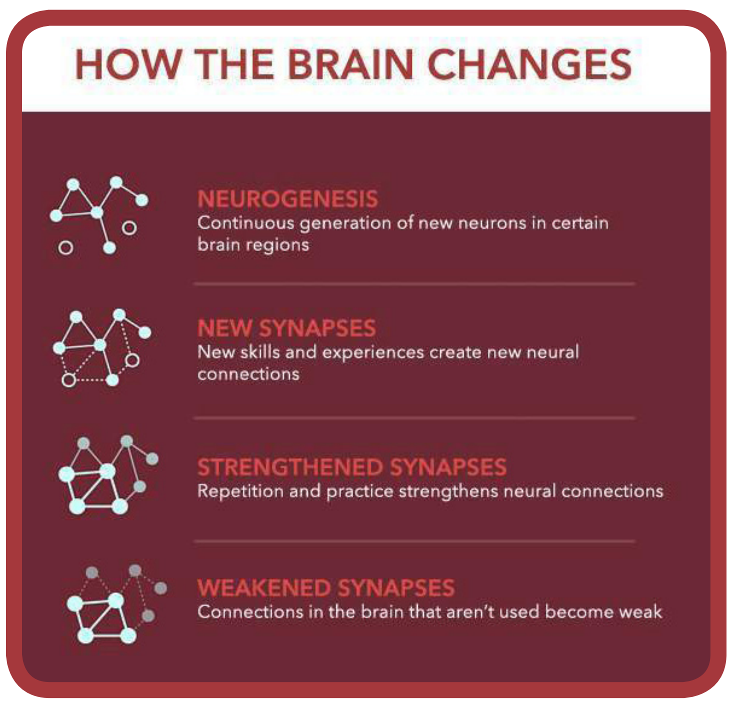
Jin, Y. (2005). Synaptogenesis. In WormBook: The Online Review of C. elegans Biology [Internet]. WormBook.

Exercise and **physical activity** also **aid in synaptogenesis**, the formation of new synaptic connections between neurons.

Synaptogenesis is **rampant** during **early brain development**, to accommodate the acquisition of skills and knowledge, and slows later in life.

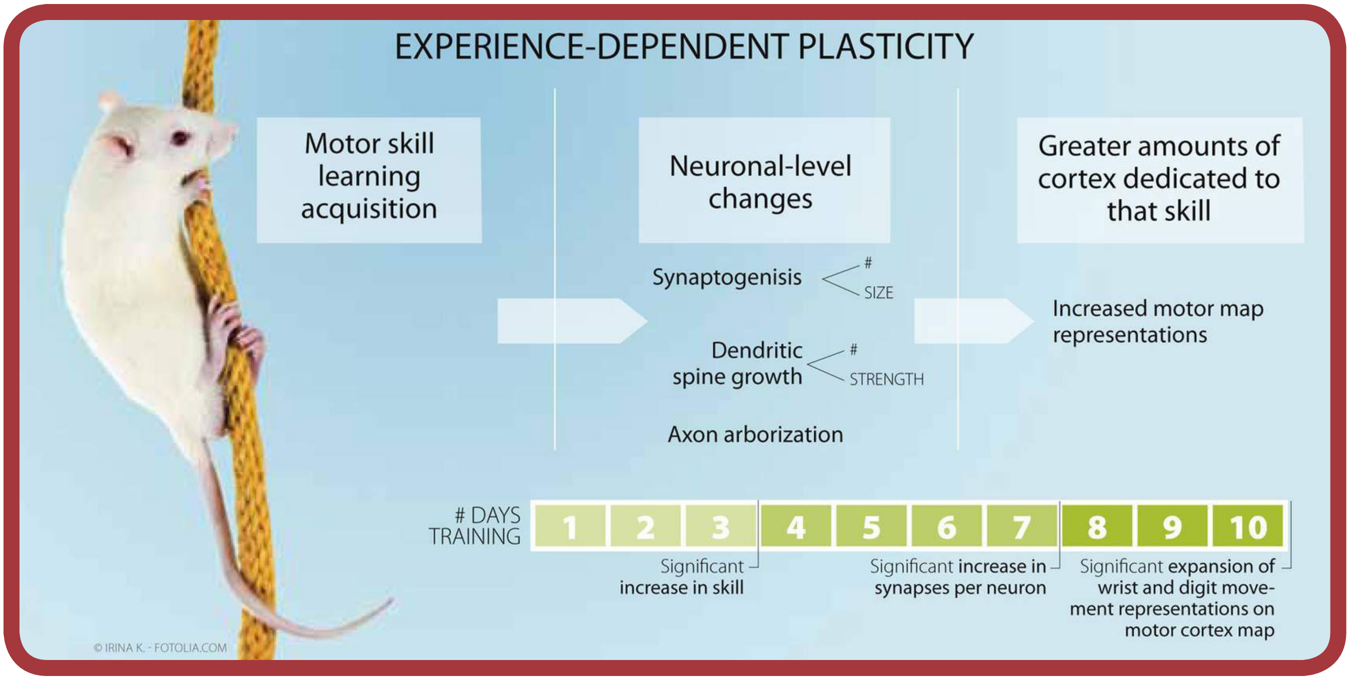
Increases in synaptogenesis can lead to an overall change in **function** within certain brain regions, which may **eventually** contribute to **volumetric changes** in the brain.

Synaptogenesis is rampant during early brain **development** and slows later in life. Increases in synaptogenesis and neurogenesis can lead to an overall increase in **brain volume**, specifically in the gray matter areas of the cortex and cerebellum. Both aerobic exercise and cognitive **challenges** have been shown to increase brain volume through the mechanisms described.



Regional Synaptogenesis

Synaptogenesis may also occur in certain brain regions more readily than in neurogenesis since **synaptogenesis** is a **functional change**. This is likely to happen during skill-training, by which brain regions, such as the cerebellum, may increase their rates of synaptogenesis through effortful learning.



Synaptogenesis through effortful skill-learning is most readily studied in rats. This graphic shows how **motor skill learning acquisition** can lead to micro-level changes.

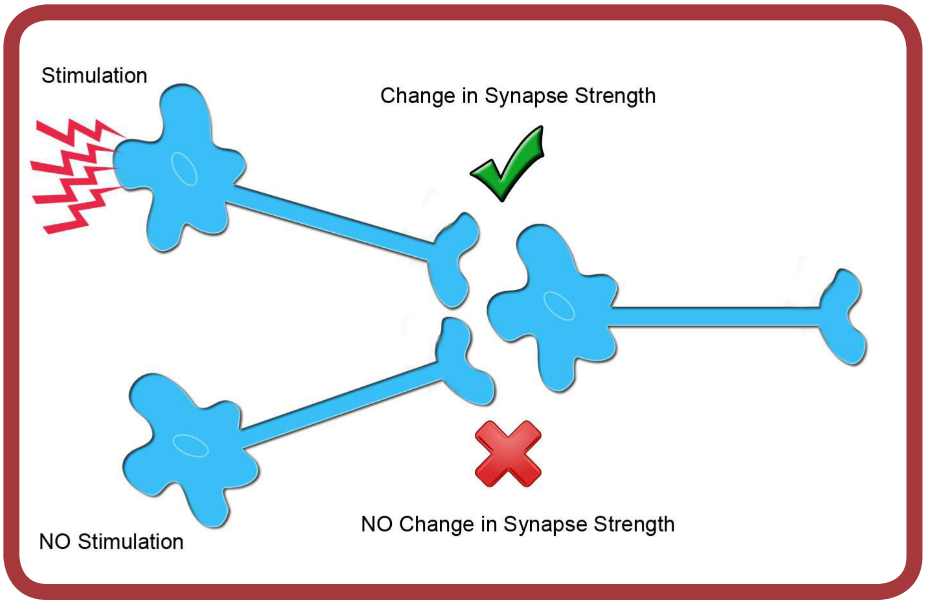
Incorporating elements such as **mental effort**, **novelty**, and **goal-oriented attention** may further affect the rates of synaptogenesis. **All** of these elements are **present during motor-learning** activities.

Hebbian Theory

Hebbian Theory attempts to explain that **stronger synaptic connections** lead to **stronger connections** between **pre-synaptic** and **post-synaptic** cells. Synaptic connections are strengthened when the pre-synaptic cell persistently and repeatedly stimulates the post-synaptic cell.

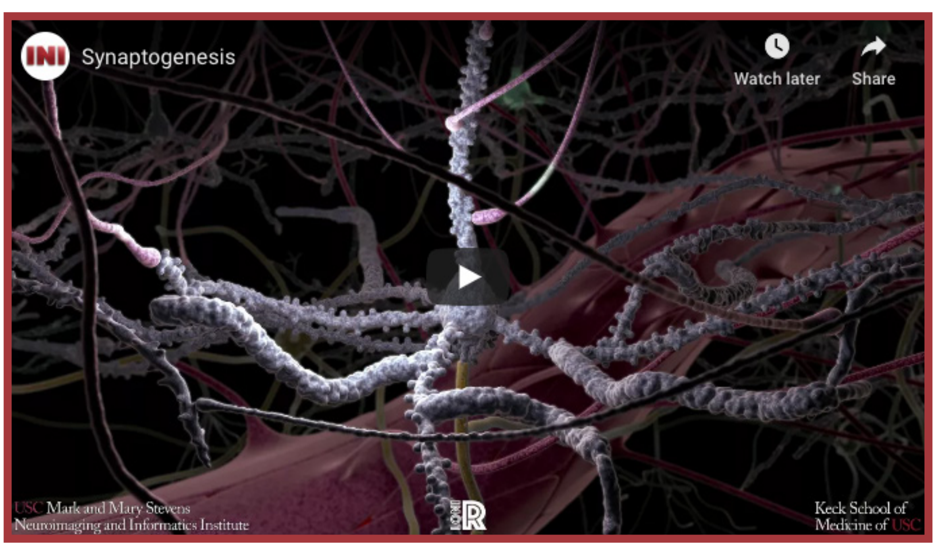
While synaptic plasticity depends on the timing that cells activate, **Hebbian Theory** provides an interesting perspective on **neuronal network coordination**.

The more a synapse is used, the stronger it becomes. This demonstrates one of the many ways that behavior and neurophysiology are linked. Circuits that are frequently used get stronger and those that are used less or not at all atrophy.



Synaptogenesis

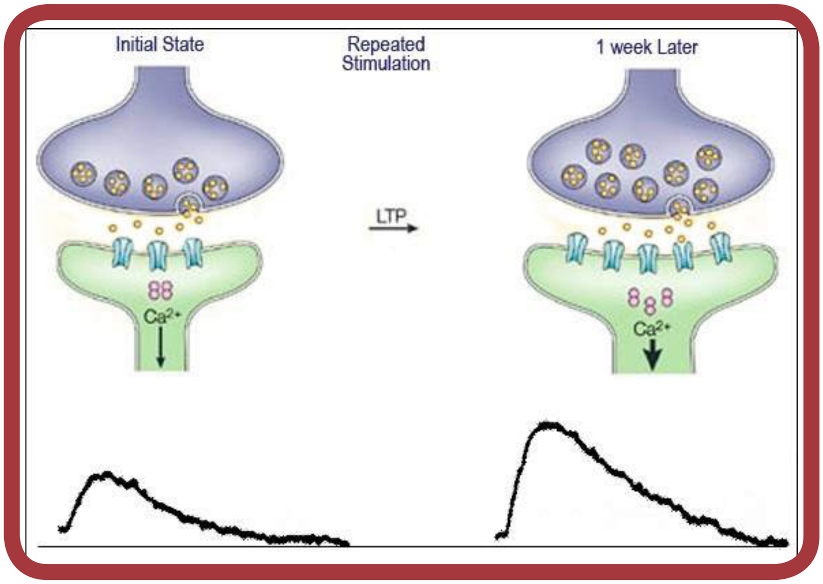
Watch the video below to learn more about dendrites, how synaptogenesis may occur, and its relationship to neuroplasticity.



VIEW ON YOUTUBE >

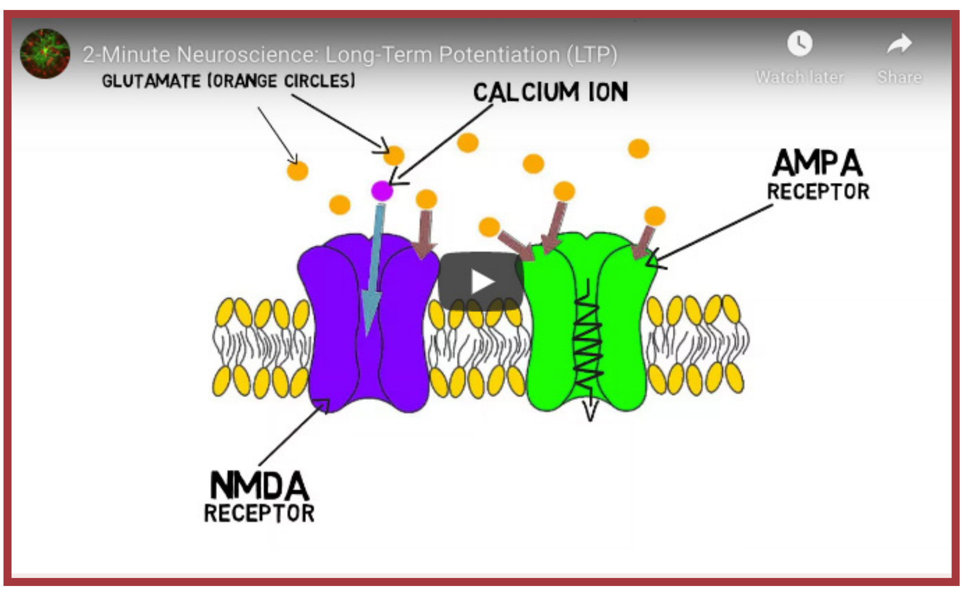
Long-term Potentiation and Long-term Depression

Neuroplasticity may also be defined as an **increase** or **decrease** in the **strength** of the connections between synapses, and therefore between neurons, in response to experiences.



The increase in strength in synaptic transmission due to prolonged strengthening via coordinated activation is called **long-term potentiation (LTP).** Conversely, **long-term depression (LTD)** is a reduction of synapses due to reduced transmission because of a lack of coordinated activation. Both LTP and LTD **underlie changes in brain activity** and cognition.

Watch the video below to learn more about Long-Term Potentiation (LTP)



VIEW ON YOUTUBE >

Knowledge Check

Synaptogenesis, Synapses, Hebbian Plasticity or Dendrites. Which term matches each description?

Record your answers here for future reference.

Receive & transmit signals from other brain cells .... ______________________

The creation of new neural connections .... ______________________

Connections between neurons .... ______________________

Repeated stimulation increases plasticity between neurons .... ______________________

Knowledge Check

Select the best single option from the four choices. Long-term Potentiation (LTP) is best described as:

Record your answer here for future reference.

- ○ How neuronal connections become stronger through experiences
- ○ How neurons that wire together fire together
- ○ How neuronal connections become weaker through experiences
- ○ How neuronal connections are unaffected by experiences

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Synapses can change in both number (synaptogenesis) and function (Hebbian Plasticity) based on the stimulus that is (or is not) repeated in certain connections between neurons.
- ☐ At the micro-level, exercise can release growth factors such as BDNF and VEGF, as well as release beneficial neurotransmitters.
- ☐ Long-term potentiation (LTP) explains how neuronal connections become stronger through repeated experiences, while Long-term depression (LTD) demonstrates how they can become weaker in absence of those experiences.
- ☐ Synaptogenesis, LTP, LTD, and Hebbian Plasticity all relate to different types and proposed mechanisms of functional neuroplasticity.

Lesson 3: Macro Level Changes

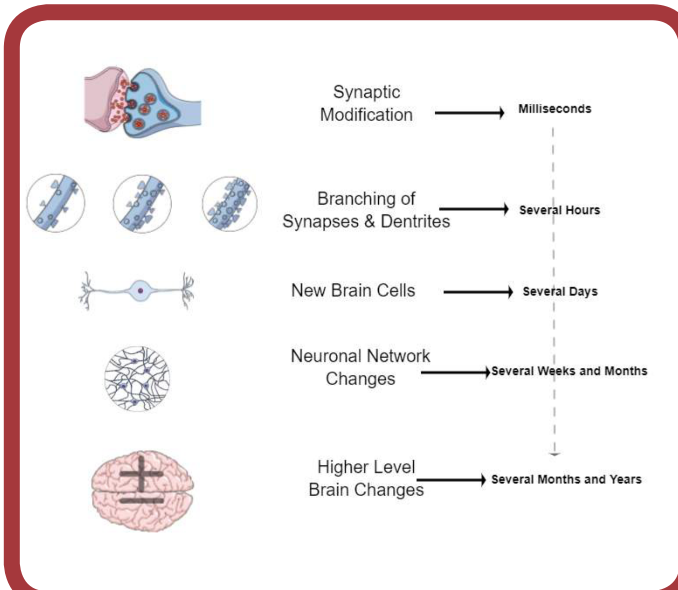
Lesson 3 Objectives

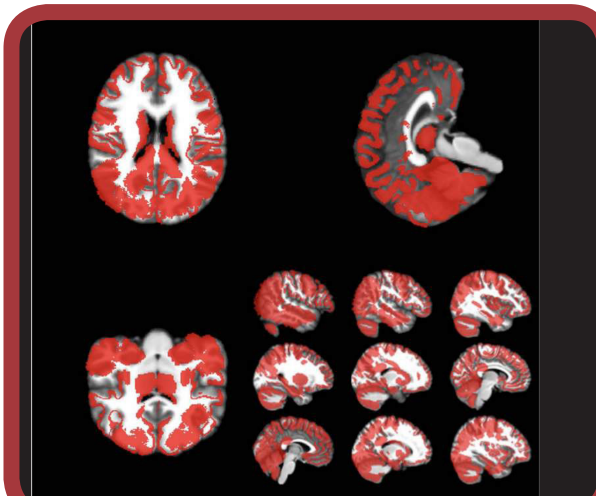
1. Identify examples of changes to the brain at the macro level, including modifications in brain structure and brain function.
2. Identify the ways in which exercise can affect specific brain regions.
3. Understand the different types of brain activity, from brain metabolism to electrical activity.

Macro-Level Changes: Structural Adaptations

Changes at the micro-level are thought to, over time, contribute to changes at the Macro-level. Macro-level changes specifically refer to changes in brain structure and function at a higher level. For example, changes in regional brain volume or changes in brain network activity.

Structural adaptation is likely to occur over the **long-term**, rather than the short-term. It is often incorrectly assumed that because changes occur on the **neuronal level**, they are quickly reflected on the structural levels. This is unlikely because the need for growth factors, metabolism, and brain activity for changes to occur, need to occur **repetitively over a longer period of time** in order to generate a significant response at the structural level, even though certain aspects at the micro and behavioral level can occur acutely and effect each other **bi-directionally**.



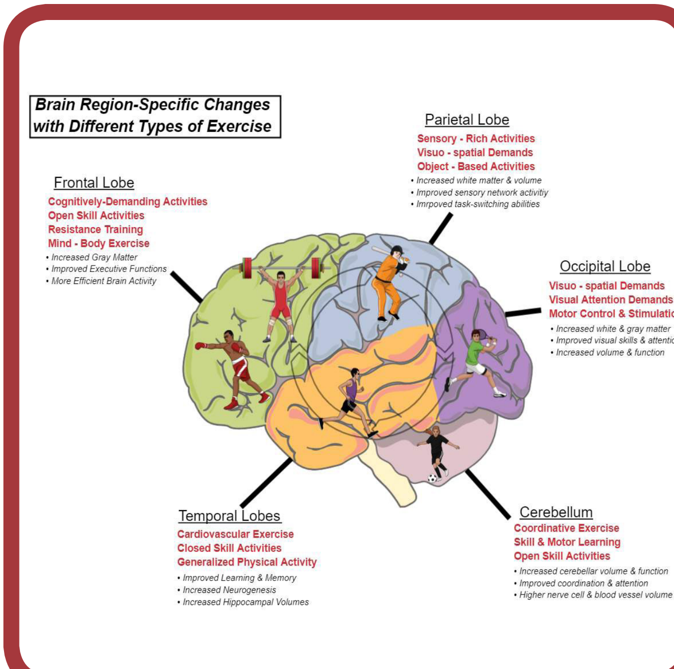


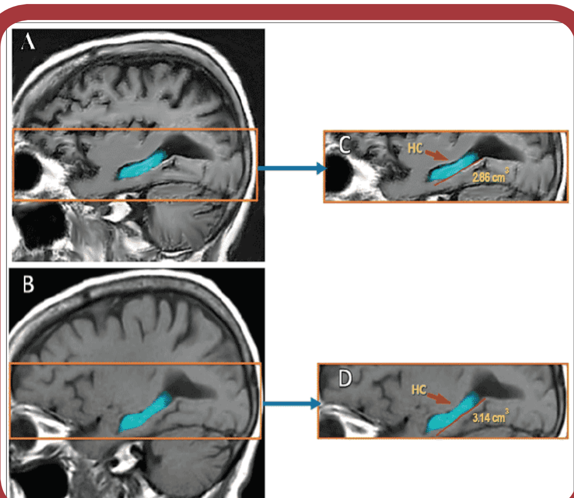
Batouli, S. A. H., & Saba, V. (2017). At least eighty percent of brain grey matter is modifiable by physical activity: a review study. Behavioural brain research, 332, 204-217.

Structural changes are alterations in the overall brain regions or tissue types as a result of exercise and physical activity. This is referred to as **volumetric changes**, or changes in **cortical thickness**, specifically in different types of brain tissue such as **grey matter (80% of which may be modifiable by exercise and physical activity**) and **white matter** (whereby exercise and specific aspects of skill acquisition have shown to affect **white matter tract integrity**).

Studies that have been conducted on various **modalities of physical activity**, as well as modifications to their variables (intensity, frequency, and duration), have demonstrated **differential changes** in regional brain structures, such as in regions of the **hippocampus, prefrontal cortex, cerebellum**, and **basal ganglia**.

These changes can occur in **parallel** with changes on the micro and behavioral levels, which are critical for countering the **age-related decline in brain volume** and addressing certain neurological insults and **neurodegenerative diseases**.





Fotuhi, M., Lubinski, B., Trullinger, M., Hausterman, N., Riloff, T., Hadadi, M., & Raji, C. A. (2016). A personalized 12-week" Brain Fitness Program" for improving cognitive function and increasing the volume of hippocampus in elderly with mild cognitive impairment. The Journal of Prevention of Alzheimer's Disease, 3(3), 133-137.

The most common way of **assessing structural changes** in the brain is through neuroimaging, specifically **volumetric MRIs**. We cannot sufficiently claim or suggest that individualized EPAPs will have a structural effect, without **referring** clients to physicians (e.g. **neurologists**) that can order and interpret neuroimaging-based tests.

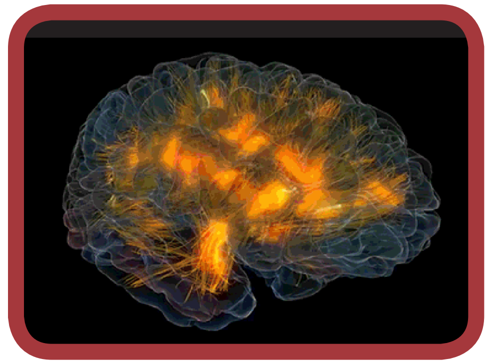
Such tests can demonstrate changes as a result of lifestyle interventions, such as increasing **hippocampal volume**. However, the amount of evidence that exists on exercise and physical activity increasing overall and **regional brain volumes** is quite convincing, and therefore could be assumed after **several months** of training.

Macro-level Changes: Functional Changes

In addition to structural changes, functional changes also occur in the brain. These functional changes can be **local** to a **specific brain region**, such as seen in changes in prefrontal cortex activity. Changes in brain activity can also be reflected within **functional brain networks**, which involve **multiple brain regions** that **spontaneously activate**.

Functional changes may include alterations to brain **activity** and **metabolism**, but on a larger scale than that of the **micro-level** (within **smaller networks** of neurons or at the **synaptic** or **cellular level**).

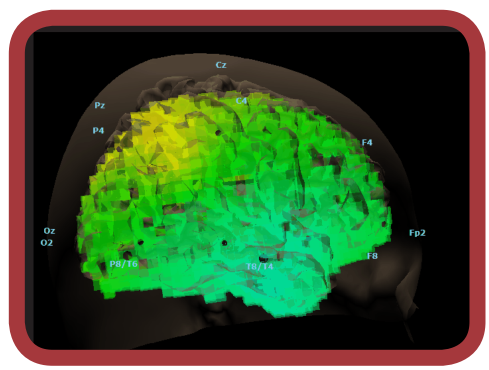
For example, changes in larger **neuronal networks** (**locally in a brain region** or within a **functional brain network**) may take place due to the alteration of **neurochemical**, **metabolic**, or **electrical activity** in various brain regions.



Credit to: The Neuroscape Lab at UCSF, The Glass Brain

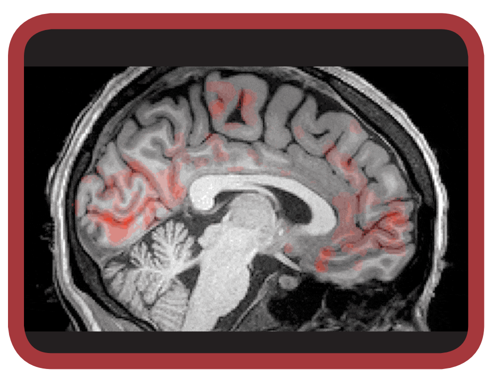
Types of Functional Changes

Functional brain activity changes are often understood as changes in **electrical** brain activity on a **regional** or **brain-network level**.



Brain activity changes can be measured with **neuroimaging techniques**, such as **EEG** or **fMRI**, while **metabolic** changes (or changes in blood flow) can be observed with neuroimaging techniques such as **fNIRS** or **SPECT** scans.

Both **metabolic** and **electrical** changes occur in **parallel**. The electrical activity requires changes in metabolism, and metabolism also requires changes in electrical activity.



Changes in the function of brain structures can be measured by different types of **neuroimaging**. Cerebral blood flow and neuronal activation are thought to be coupled, which is identified by the "**neurovascular coupling**" hypothesis.

Knowledge Check

Do the statements below describe Structural Change or Functional Change?

Record your answers here for future reference.

Volumetric Change .... ____________________

Cortical thickness .... ____________________

Changes in brain blood flow .... ____________________

Changes in electrical brain activity .... ____________________

White matter tract integrity .... ____________________

Changes in synaptic plasticity .... ____________________

Key Takeaways

Check off each key point if you feel that you understand it.

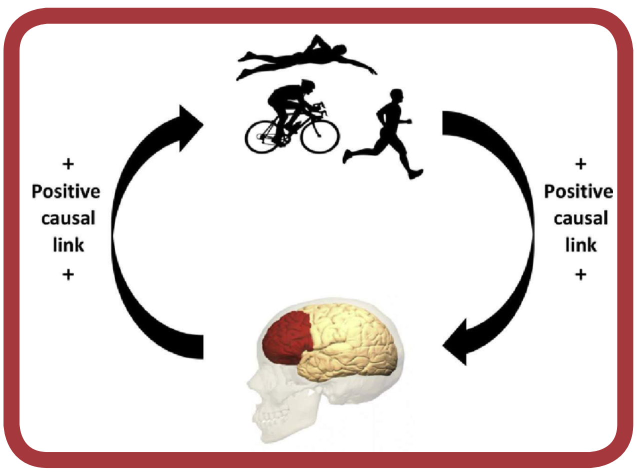
- ☐ **Exercise can modify** brain structures, both in terms of total **brain volume** and specific **brain regions**, as well as brain functions, which include localized changes in **brain activity** to modifications in larger-scale **brain networks**.
- ☐ **Changes** at the synaptic level, the neuronal level, the neuronal network level, and at the structural level of the brain **occur at different time points**, with **functional changes preceding** larger and more significant **structural changes**.

Lesson 4: Behavioral Level Changes

Lesson 4 Objectives

1. Identify examples of changes at the behavioral level of the brain with exercise, including modifications in mood, stress, cognition, and psychology.
2. Understand the bi-directional relationship between exercise and physical activity behavior, mood, and cognition.
3. Differentiate behavioral changes from micro-level and macro-level changes in the brain as a result of exercise & physical activity.

Improvements in Cognition and Mood



This graphic demonstrates how exercise and physical activity can improve cognitive functions, which in turn can improve the rates of adherence of participation of exercise and physical activity.

Cognition - Mood Relationships

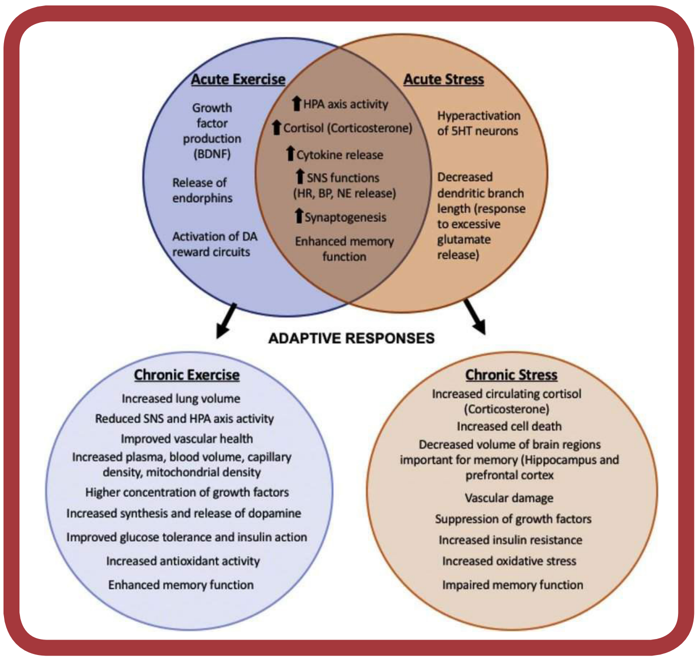
Via the occurrence of various **mechanisms**, exercise and physical activity can have significant and positive outcomes on **cognition** and **mood**.

Cognition and mood are **related** via several common **pathways**, which may be why **exercise** has profound impacts on **both**.

Subjective Cognitive Improvements

Improvements in **cognition** may yield better performances in work or life settings, situations requiring learning, or in **tasks of daily functioning**. This improves **mood**, in response to what may be considered relative “**successful performance**” or improved ability to mentally or intellectually in various settings. Positive feedback in performance scenarios is likely to **increase buy-in** to further EPAP or lifestyle modifications.

Improvements in Stress & Mood



Yuede, C. M., Timson, B. F., Hettinger, J. C., Yuede, K. M., Edwards, H. M., Lawson, J. E., ... & Cirrito, J. R. (2018). Interactions between stress and physical activity on Alzheimer’s disease pathology. Neurobiology of stress, 8, 158-171.

Improvements in **mood** may allow better cognitive performance via the **amelioration of stress**, which may positively affect the brain at the **micro and macro levels**, and also improve other cognitively-enhancing behaviors (e.g. **sleep**).

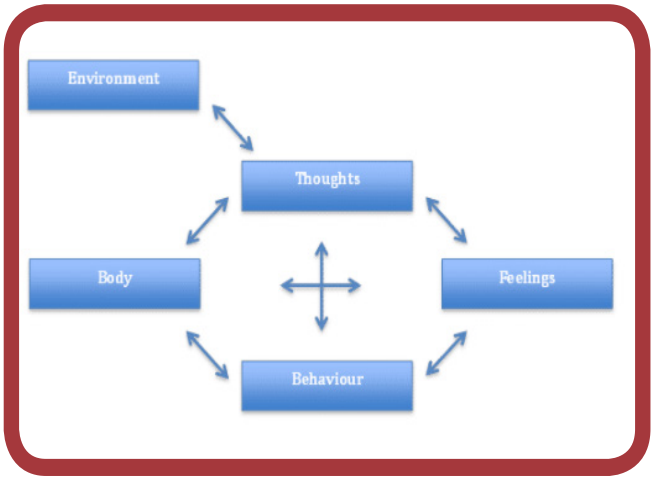
By modifying the hypothalamic-pituitary-adrenal axis (**HPA Axis**) and the associated levels of **neurotransmitters**, such as **cortisol**, exercise, and physical activity also improves the underlying biological mechanisms of stress.

Mental Health

The **positive psychological effects** of exercise and physical activity are paramount for the management of conditions associated with **mental health**, **neurodegenerative diseases**, and **neurological changes** throughout the lifespan. **Exercise** and **physical activity** have consistently demonstrated positive changes on **most measures of mental health** and are becoming a critical component in managing a variety of mental illnesses.

Exercise, Cognition & Behavior

The **neurophysiological** changes that occur in the body and brain during and after physical activity work in concert to mediate changes in **cognition**, **mood**, and **behavior**. It is helpful to understand how cognition and mood can affect lifestyle choices in behavior.

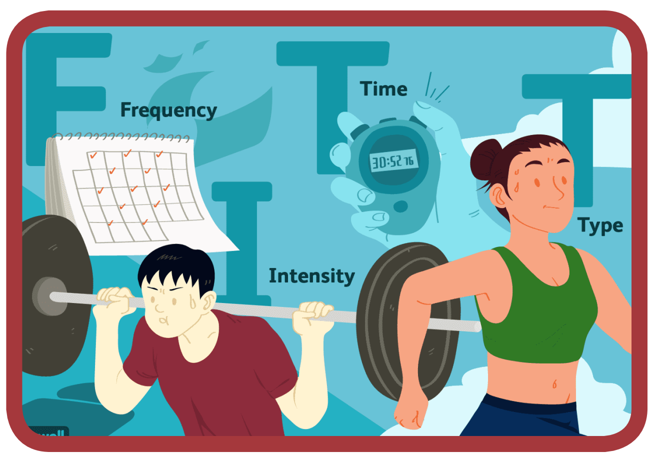


1. Cognition and Adherence

It is important to note that **cognition directly relates to behavior**. Cognitive functions such as controlling **impulses, planning, organizing & initiating** affect the **adherence** to lifestyle behaviors, such as exercise and physical activity. Difficulties with sleep, stress, **cognitive impairment**, or chronic health conditions can all make it more challenging to adhere to a program.

2. Variable Modifications

BH-EPAPs consist of many **different variables**, such as intensity, duration, type, frequency, and volume. Changes in these variables may facilitate **adherence**, cognitive benefits, and various physiological changes. While leveraging "routine" can be helpful for greater adherence, certain variables such as **novelty & variability** may need to be manipulated to elicit greater cognitive demands. The tradeoff between adherence & optimal programming is a constant challenge for HWPs.



3. Guidance and Accountability

Working with **one or more HWPs** will increase BH-EPAP initiation and adherence through **education, coaching & accountability**. These HWPs can include personal trainers, health coaches, doctors, specialists & more.

As described in this presentation, changes at the **Behavioral** level are associated with the interactions between **cognition, behavior, and mood**.

In the next section, you will learn about how behavior changes are related to molecular changes.

Knowledge Check

Select the best single option from the four choices. Which of the following is an example of change at the behavioral level with exercise?

Record your answer here for future reference.

- ○ Modifications in mood and cognition.
- ○ Molecular changes in the brain.
- ○ Changes in cortical thickness.
- ○ Alterations to brain activity and metabolism.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Based on both micro-level and macro-level changes, behavior can change. Such behavioral outcomes include changes in mood and cognition.
- ☐ Exercise and physical activity, via several shared mechanisms, can impact mood and cognition positively.
- ☐ Exercise and physical can improve mood and cognition indirectly, by improving sleep, ameliorating stress, and serving as a medium for social contact.

SECTION 2: GROWTH FACTORS & NEUROTRANSMITTERS

Lesson 1: Growth Factors

Introduction to Section 2: Growth Factors and Neurotransmitters

Section 2 is divided into **5 lessons**. This section identifies some of the effects that exercise can have at the micro-level, specifically in regards to **growth factors** and **neurotransmitters**. You are currently in **Lesson 1**, which will give you a brief overview of the effects of exercise on various **growth factors**, which in turn impact brain health in a myriad of ways. Lessons 2-4 will define **neurotransmitters**, differentiate between excitatory and inhibitory neurotransmitters, and discuss their interactions with exercise. Lesson 5 will connect all of the concepts from the previous lessons and breakdown the complexities underlying the **neurophysiology of exercise**.

By the end of Section 2, you will be able to define various growth factors & neurotransmitters and identify how they may be affected by exercise and physical activity. You will be able to relate these **micro-level changes** to neurophysiological processes that lead to **macro-level changes** in the brain, which is explored further in Section 3.

Lesson 1 Objectives

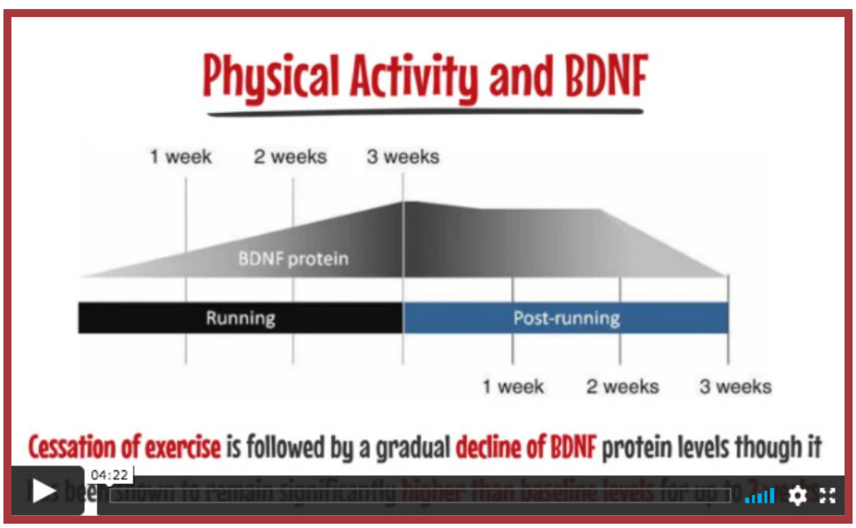
1. Define growth factors, identify how they are released by exercise, and how they may affect the brain.
2. Identify how growth factors may facilitate neurogenesis, angiogenesis, and synaptogenesis, or modify both functional and structural neuroplastic changes.
3. Identify how growth factors from exercise may modify the vascular system in the brain and the body, linking cardiovascular (or metabolic) adaptations to changes in the brain.

Growth Factors

Growth (or **bioenergetic**) factors are a group of molecules, proteins, hormones, and metabolic elements that may occur in the body and/or brain. They can directly or indirectly trigger the **function, growth**, or **maintenance** of various brain structures at the micro-level, eventually contributing to changes at the macro level, and may explain changes at the behavioral level. Growth factors that affect the brain are typically referred to as "**neurotrophins**."

Growth Factors Video

Watch the video below to learn more about some of the main growth factors released by exercise in relation to improvements in brain health & cognition.



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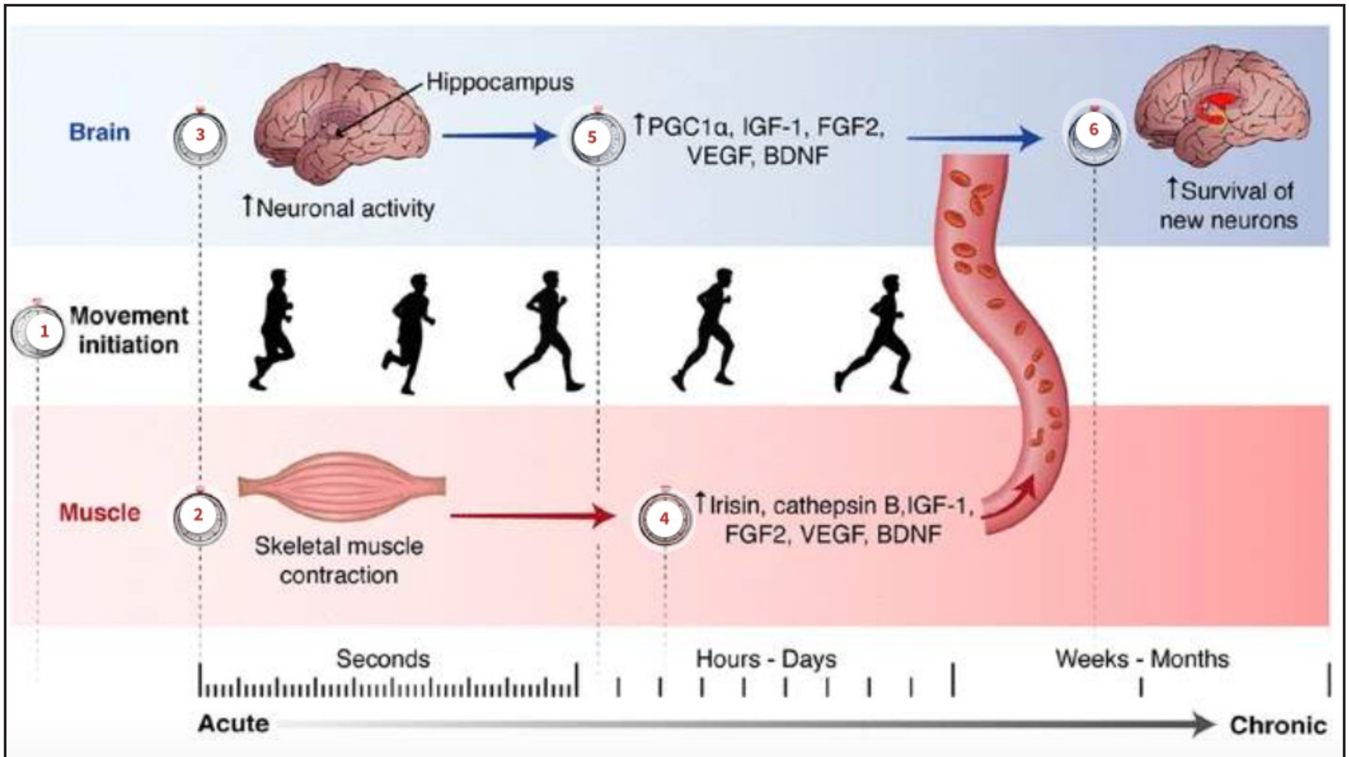
Multi-level Effects of Exercise and the Brain

The image below relates the timing of mechanisms of neural change with micro and macro-level changes to demonstrate the **time course** in which exercise and physical activity can affect **growth factors, blood flow, hippocampus neurophysiology**, and **neuronal survival**.



Rendeiro, C., & Rhodes, J. S. (2018). A new perspective of the hippocampus in the origin of exercise–brain interactions. Brain Structure and Function, 223(6), 2527-2545.

1. Movement Initiation - The central nervous system (CNS) initially communicates with the **peripheral skeletal muscle** to initiate movement which will generate skeletal muscle **contractions**.

2. Myokine Production - The repeated contraction of skeletal muscle during physical activity will further produce **myokines**, also called "**exerkines**". Not shown are changes in **metabolic** processes and related signaling that also are thought to affect brain function.

3. Neuronal Activity - Repeated **neuronal activity** within the **hippocampus** and neuronal activation of the hippocampal within the **same time** frame of muscular contraction & aerobic stimulus lead to increased **neurotrophic & growth factors**.

4. Myokines - The **myokines** released by skeletal muscle and aerobic stimulus include **irisin, cathepsin B, IGF-1, FGF-2, VEGF**, and **BDNF**. These reach the brain via the circulatory system by crossing the **blood–brain barrier (BBB)**.

5. Growth Factor Expression - The processes of **cardiovascular** and **neuromuscular** stimulus, combined with **peripherally**-delivered myokines, likely play a role in the long-term and **neurogenic** effects of exercise.

6. Neuronal Survival - The chronic **neurogenic** effects of exercise, ideally after weeks and months of training, include **neurogenesis, angiogenesis, synaptogenesis, gliogenesis**, and overall neuronal **survival**.

Cerebral Blood Flow

One benefit of exercise, physical activity, and cognitive challenges is an increase in **cerebral blood flow or CBF**. Blood flow is vital to the overall function and health of the brain. Exercise can increase CBF volume, as well as physically change the vascular network in the brain through **angiogenesis**, or new blood vessel formation.

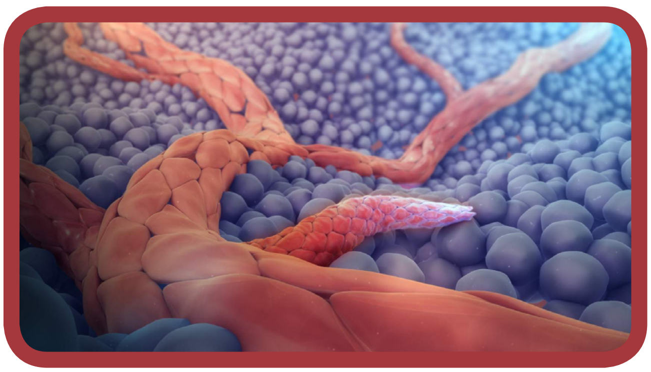
Research demonstrates that dementia **symptoms** may be partly due to age-related **decreases** in new **blood vessel formation**, which diminishes blood flow and reduces cerebral microcirculation. Controlling for cardiovascular risk factors, such as **blood pressure**, can have an immense impact on brain health.

Watch the video below to learn about the brain's blood **supply** and how brain blood flow is **regulated**. You will learn about the relationship between brain blood supply and brain health, the connection between **muscle** and brain blood flow, and how changes in blood pressure can affect the brain.

VIEW ON VIMEO >

Angiogenesis

Angiogenesis (the creation of new blood vessels), is an important process in brain health. Blood supply is critical for brain **metabolism**. The creation of new blood vessels not only improves blood supply but can improve cerebral blood **volume** and contribute to healthy brain volumes in the long-term.

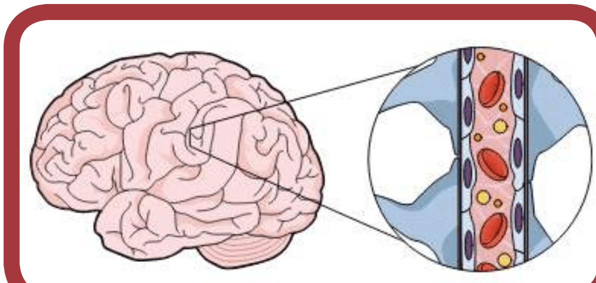


1. Stimulus for Angiogenesis (Exercise)

Exercise that stimulates the heart rate to **exceed average resting levels** may be enough to stimulate angiogenesis. **Complex environments** also may contribute to angiogenesis.

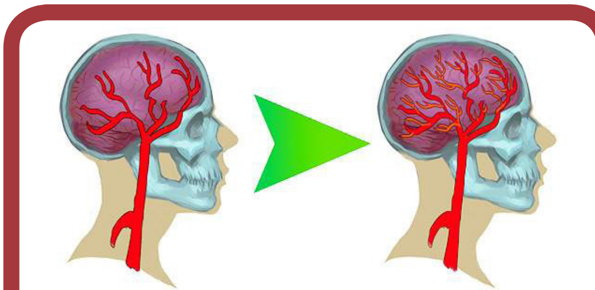
Similar to what is required for optimal **BDNF** release, **65-75% of Max HR** (or moderate to vigorous-intensity cardiovascular exercise) is most likely to be sufficient.

2. Increase in Cerebral Blood Flow (CBF)



When blood flow improves **peripherally**, it acutely increases blood flow to various **regions** of the brain.

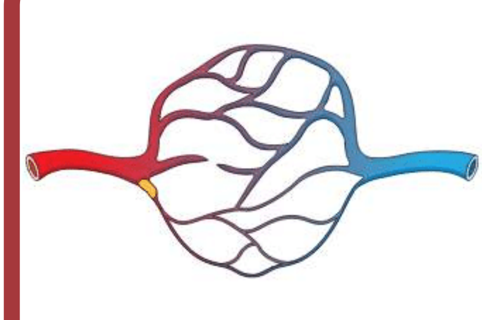
3. The Brain's Vascular Network



Angiogenesis - the formation of new blood vessels - can occur even in adulthood and is correlated with neurogenesis.

Over time, increases in blood flow can lead to a more dense **capillary network**. When considering the **400 miles** and a **surface area** of **100 square feet** of blood vessels in the human brain, this is a significant mechanism for increasing the delivery of **oxygen** & nutrients throughout the brain.

4. Effects of Angiogenesis



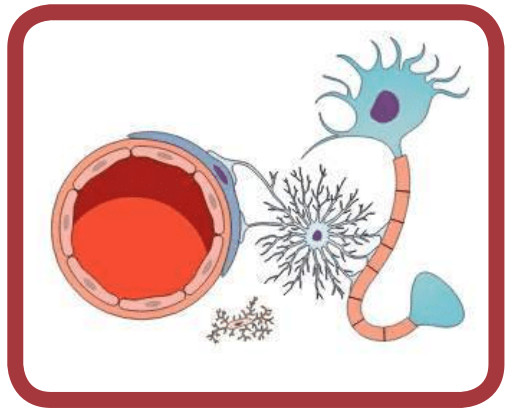
Some effects of angiogenesis include:

- Increased capillary **density**
- Responsiveness to metabolic demands
- Improved **connectivity** of the vascular network

5. Synergistic Effects

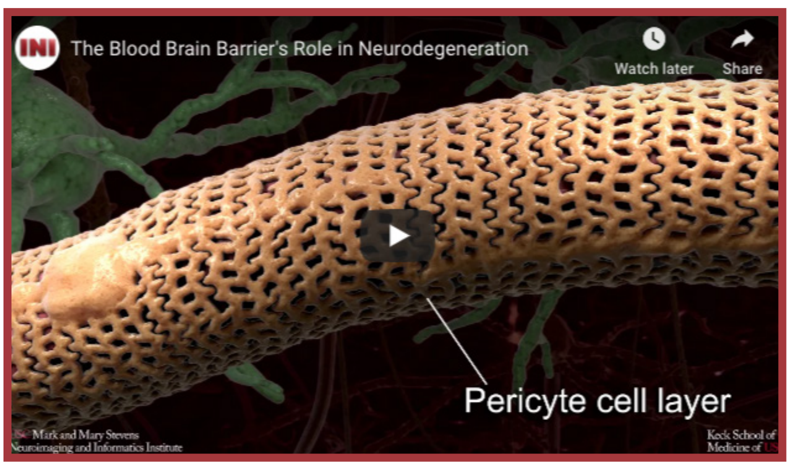
Some synergistic effects of angiogenesis include:

- Neuroprotective & **Neurogenic**
- **Synergistic** to learning & memory
- Promotes growth factors (i.e. **BDNF**)



The Blood Brain Barrier's Role in Aging

The Blood-Brain Barrier (**BBB**) is a network of microvasculature that **protects** the brain from neuro-toxic substrates and permits the entry of beneficial compounds.



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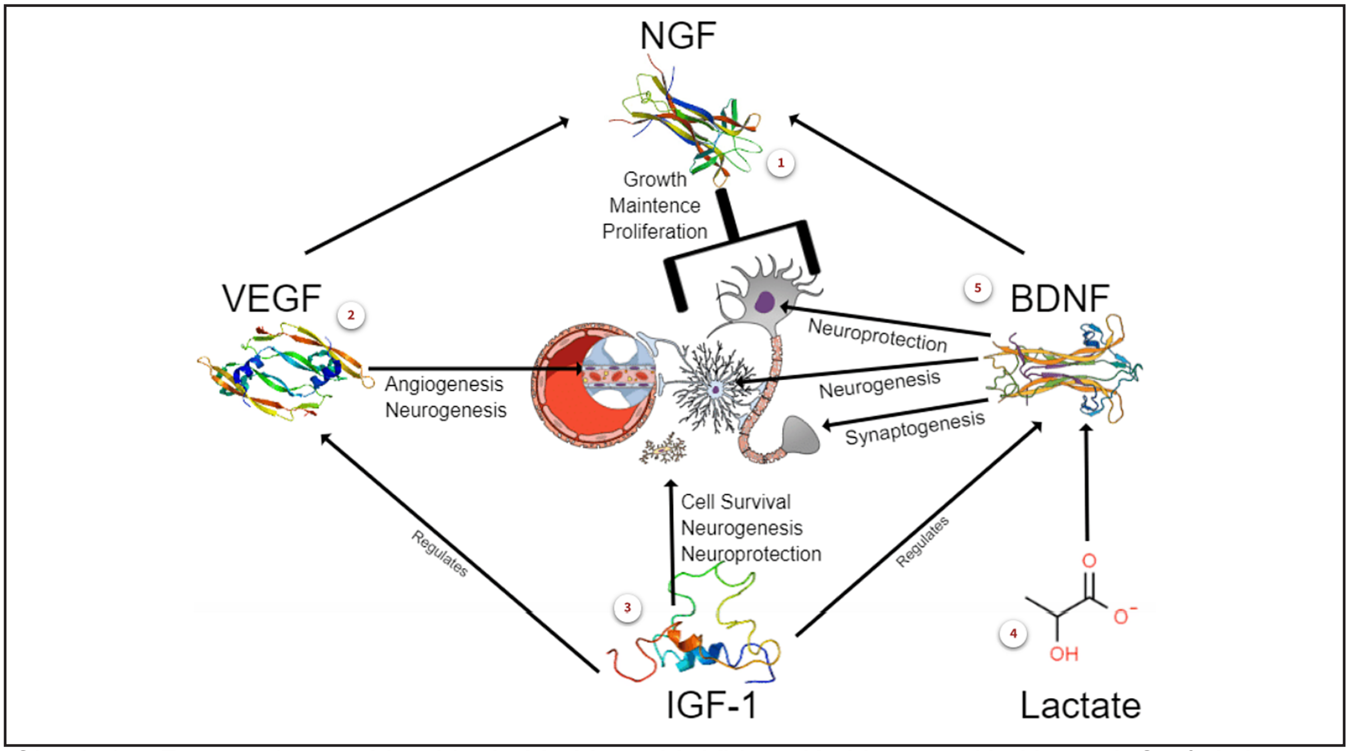
Interactions Between Growth Factors

The photo below illustrates the potential relationships between various **growth factors**, as well as their **direct and indirect effects** on the brain at the micro-level. You will see that many of these functions overlap, as no one specific growth is responsible for the plethora of **beneficial adaptations** in the central nervous system.



Circulating Factors" image: Vecchio, L. M., Meng, Y., Xhima, K., Lipsman, N., Hamani, C., & Aubert, I. (2018). The neuroprotective effects of exercise: maintaining a healthy brain throughout aging. Brain plasticity, 4(1), 17-52.

1. Nerve Growth Factor - Nerve growth factor (**NGF**) is a part of the "neurotropin" group and stimulates the **growth, maintenance**, and **proliferation** of new nerve cells. Exercise can stimulate the expression of NGF and therefore **regeneration** of nerve cells. NGF can also control the differentiation (**specialization**) and apoptosis (death) of neurons.

2. VEGF - Vascular endothelial growth factor (**VEGF**) can be secreted by skeletal muscle cells and circulate in the brain. Lactate can induce **angiogenesis** alongside VEGF, which is a process of creating new blood vessels and **networks**. Via the delivery of blood, it can support neurogenesis.

3. IGF-1 - **Insulin-like growth factor-1** (IGF-1) is increased quickly during and after exercise, and is associated with improvements in cognition. The permission of IGF-1 in the brain **upregulates nerve cell survival** and neurogenesis. The role of IGF-1 is controversial in current research, and considered to be "**a double-edged sword**."

4. Lactate - Increased levels of **lactate**, which is released into the blood stream as a metabolic **by-product** of exercise (especially **higher-intensities**), is associated with increased levels of **BDNF**. Lactate occurs in the body peripherally, but is able to cross the Blood-Brain-Barrier (**BBB**).

5. BDNF - BDNF (**Brain-derived Neurotrophic Factor**) is a protein that belongs to the "**neurotropins**" group. Microglial cells and skeletal muscle cells can **synthesize** and release BDNF, which occurs both centrally and peripherally to the brain. BDNF mediates neuroplasticity via **neurogenesis**, **synaptogenesis**, and protects existing neurons. BDNF is also closely related to memory processes.

Knowledge Check

Match the growth factors with their primary relationship with a mechanism of brain change:

Record your answers here for future reference.

Angiogenesis & Neuroprotection .... ____________________

Neurogenesis & Stem Cell Growth .... ____________________

Improves Brain Metabolism .... ____________________

Myelination & Axonal Growth .... ____________________

There are many other growth factors that are not mentioned or emphasized thus far. These include; Nerve Growth Factor (NGF), Cathepsin B, IL-6, Lactate, Kynurenine, Glial-Derived Neurotrophic Factor (GDNF), and several others.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Exercise releases a variety of growth factors, including **BDNF**, **VEGF**, **IGF-1**, **Irisin**, and others. These growth factors influence brain function and structure in various ways and interact in a complex system of **inter-relationships**.
- ☐ Since exercise is a **metabolic stressor**, a common adaptation of exercise (especially aerobic exercise) is a modification of **blood flow** in the brain. Over time, this can lead to changes in the number and density of blood vessels via **angiogenesis**.
- ☐ Circulation of the blood in combination with growth factors is necessary for signaling the brain to change. **Myokines** (or **exerkines**) released from the body can travel through the bloodstream, cross the **blood-brain-barrier**, and affect the brain.

Lesson 2: Introduction to Neurotransmitters

Lesson 2 Objectives

1. Define neurotransmitters, the different types of neurotransmitters, and identify how they enable communication between neurons.
2. Identify the primary categories of neurotransmitters.

Neurotransmitters

Neurotransmitters are **brain chemicals** that are released by a nerve fiber following a nerve impulse. They can affect motor behavior via sensory perception, sensory-motor integration, and motor effector mechanisms.

These chemicals travel across a junction, synapse, or another space in between nerves to enable **communication** between one muscle fiber and another.

Specific receptors on the receiving end of the fiber bind to the neurotransmitters. These receptors can change in number and in their sensitivity to the neurotransmitter.

Neurotransmitters and Chemical Synapse

Please watch the following video to learn more about types of **Neurotransmitters** and **Chemical Synapse**.

VIEW ON VIMEO >

Types of Neurotransmitters

Amines - The most **well-known** category of neurotransmitters because of their role in the treatment of **mental** and physical diseases. Examples include **depression**, anxiety, **Parkinson's disease**, and psychiatric illness.

Monoamines - Monoamines have **one amino group** in their chemical make-up and they act as **slow-acting** neurotransmitters and neuromodulators in the brain. Examples include **dopamine, serotonin, adrenaline, histamines**, etc.

Catecholamines - **Catecholamines** are a group of monoamine neurotransmitters. They include; **epinephrine, norepinephrine**, and **dopamine**.

Excitatory - Excitatory Neurotransmitters "**excite**" neurons by increasing the likelihood that neurons will send an action potential, or an electrical signal, to another neuron via the synapse. These include **dopamine**, **glutamate**, and **noradrenaline**.

Inhibitory - Inhibitory Neurotransmitters "**inhibit**" neurons by decreasing the likelihood that neurons will send an action potential, or an electrical signal, to another neuron via the synapse by stopping, **slowing** or discouraging the signal. These include **GABA** and **serotonin**.

Effects of Exercise

A majority of these neurotransmitters are "**excitatory**." This means that they typically trigger an increase in a **neuron's electrical potential and** the **speed** of the electrical signal.

Acute bouts of exercise increase the presence of **monoamines** in the bodily systems, which lead to benefits in **mood** and **alertness**. Physical exercise influences the central **dopaminergic**, **noradrenergic**, and **serotonergic** systems. Exercise itself could be considered an excitatory or "**up-regulating**" activity in these neurotransmitter systems.

To better understand the various neurotransmitters associated with exercise, we will explore the function and role of several neurotransmitters and neuroendocrine systems and their relationships to exercise.

1. **Excitatory Neurotransmitters**
   Dopamine, Noradrenaline/Adrenaline, Acetylcholine, Glutamate

2. **Inhibitory Neurotransmitters**
   GABA and Serotonin

3. **Cortisol, the HPA Axis, & Endorphins**
   Stress, mood, and hormones

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Neurotransmitters are neurochemicals that are released by a nerve fiber following a nerve impulse.

- [ ] Monamines are a larger group of neurotransmitters including dopamine and noradrenaline, which are also called catecholamines.

- [ ] Neurotransmitters can be excitatory or inhibitory, and the ratios of these signals can fluctuate.

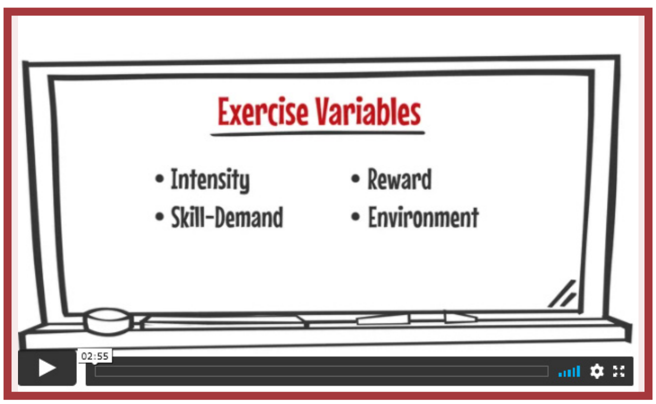
Lesson 3: Excitatory Neurotransmitters

Lesson 3 Objectives

1. List the Excitatory Neurotransmitters and explain the role of each of them in the brain.
2. Understand the relationship between glutamate, an excitatory neurotransmitter, and GABA, an inhibitory neurotransmitter.

Dopamine

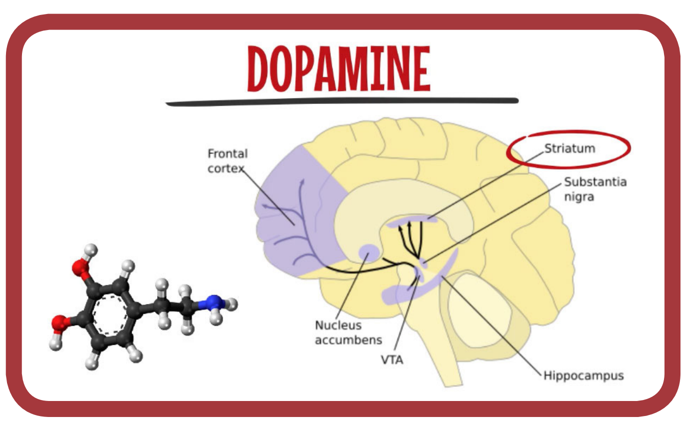
The video below will present a major excitatory neurotransmitter, dopamine, which plays several important roles within the central nervous system.



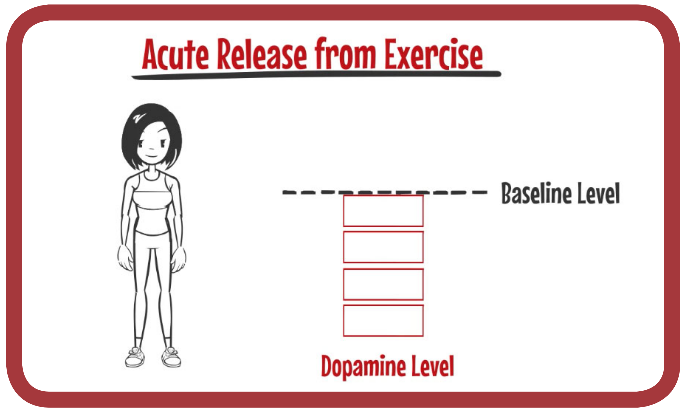
VIEW ON VIMEO >

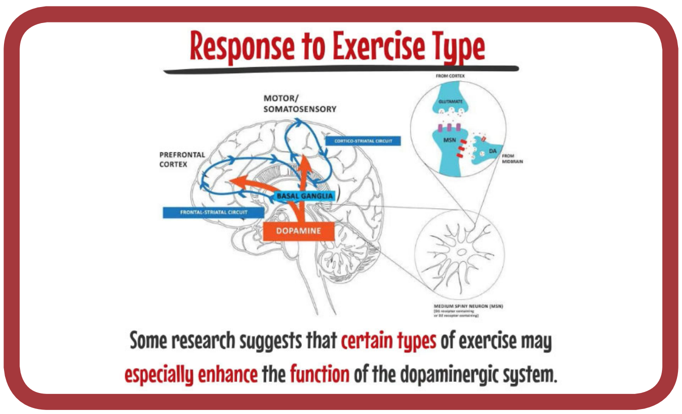
Key Takeaways

1. Dopamine is an excitatory neurotransmitter that makes up 80% of catecholamines in the brain. It affects the striatum (including the basal ganglia), prefrontal cortex, and other areas of the brain involved in motivation, reward, and motor pathways. nervous system.



2. Dopamine levels can increase immediately after exercise and seems to be mediated by exercise intensity. This increase in dopamine, which later returns to baseline levels, may underly improvements in mood and certain aspects of cognition.

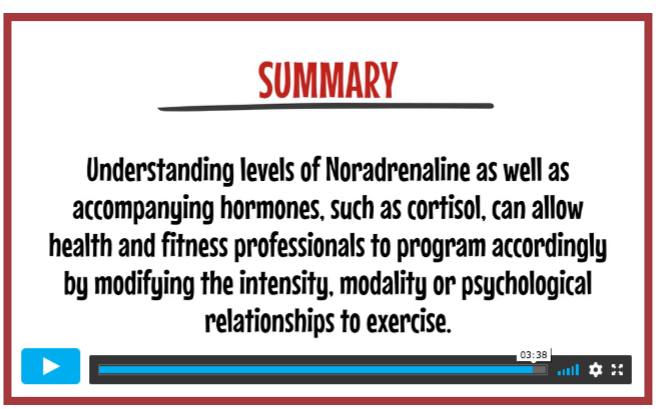




3. Exercise over time, especially with exercise that involves motor learning, positive affect, cognitive demands, and reward, may improve the efficiency of the dopaminergic system. This has valuable implications for neurodegenerative diseases, such as Parkinson's Disease.

The Noradrenergic System

The video below will teach you about the Noradrenergic system, which includes norepinephrine and noradrenaline, and the effects of exercise.



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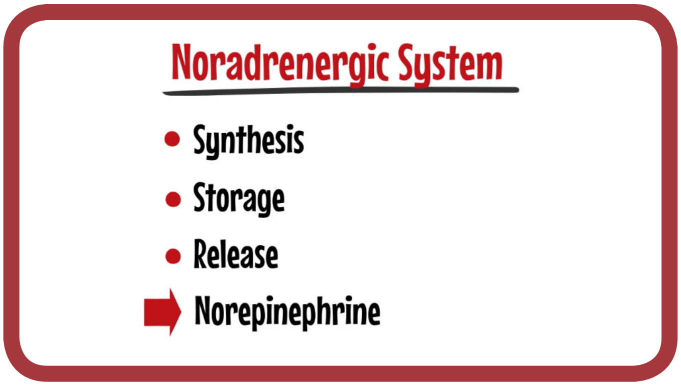
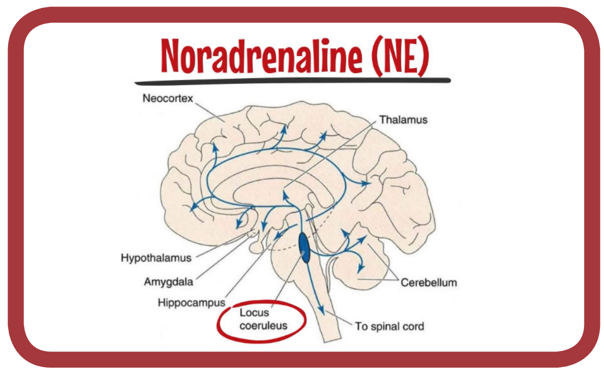
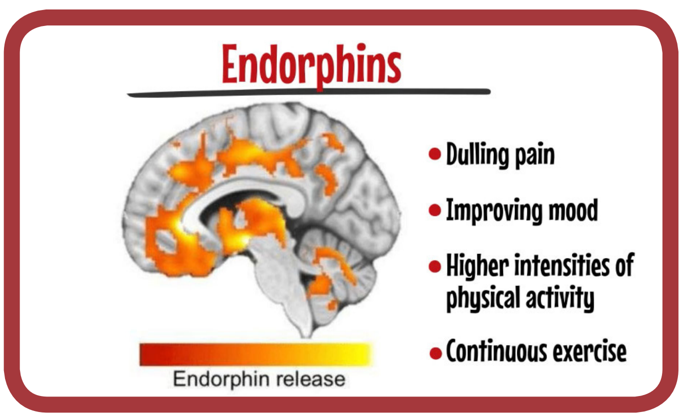
Key Takeaways



1. The Noradrenergic system is responsible for the synthesis, storage, and release of norepinephrine, which plays a role in paying attention to sensory information.

2. Noradrenaline is produced by the locus coeruleus, which projects into a majority of the brain and plays a role in attention and mood. With dopamine as a precursor to noradrenaline, these systems regulate cognition and stress.



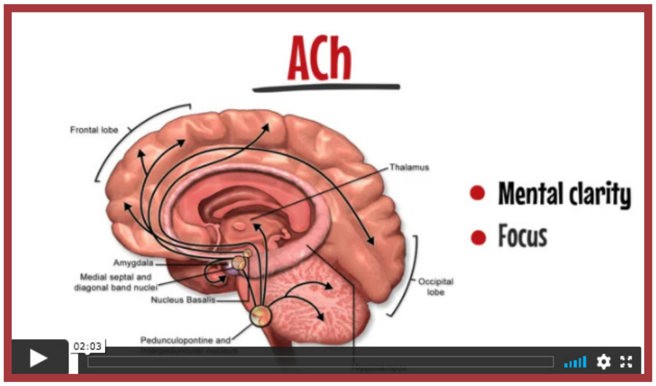


3. Endorphins, a group of approximately 20 neurotransmitters, are released with physical activity and exercise, and account for “feel-good” sensations from exercise, dull pain, and affect mental health. Activities with higher senses of reward and social contact may elicit or enhance these effects.

Acetylcholine

Watch the video to learn more about Acetylcholine and how its system, the Cholinergic system, is affected by exercise and physical activity.

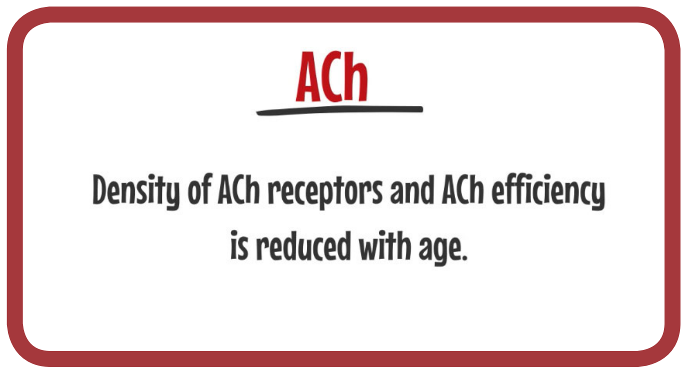
Note that Acetylcholine is EXCITATORY in the Central Nervous System (CNS), but INHIBITORY in cardiac and muscle tissue. We present it in the excitatory category since we are primarily interested in Acetylcholine’s role in the CNS.

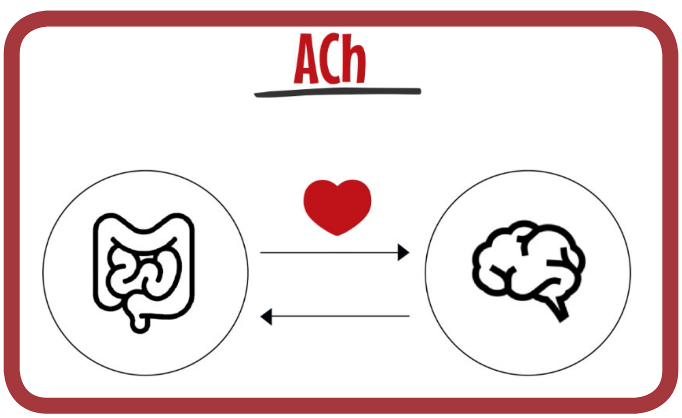


VIEW ON VIMEO >

Key Takeaways

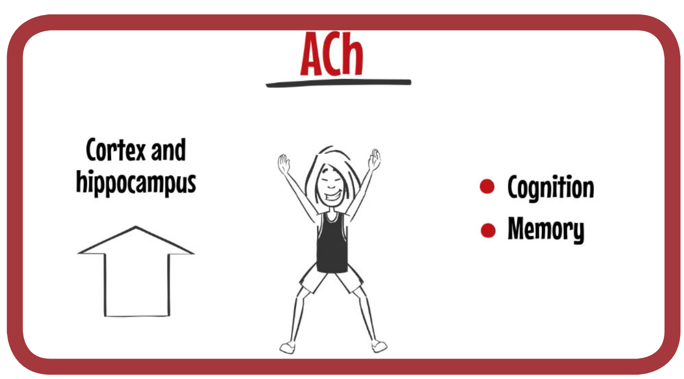
1. Acetylcholine (ACh) is a part of the Cholinergic group of neurotransmitters that is involved in controlling movement and the selecting of attention in the central nervous system. The density of ACh receptors is generally reduced with age.





2. ACh communicates works with the vagus nerve to regulate stress and inflammation. The intensity of exercise can modulate vagal tone, and affect the gut-brain axis.

3. ACh may be affected by the attentional demands of exercise, as well as the novelty of activities. ACh may also affect the survival and specialization of neurons into different regions of the brain.



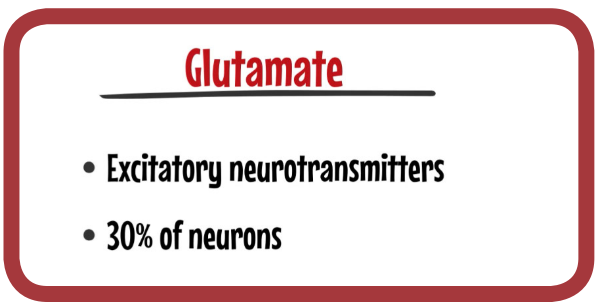
Glutamate & GABA

Watch the video below to learn more about how Glutamate (a primary excitatory neurotransmitter) and GABA (a primary inhibitory neurotransmitter) interact with each other in the context of exercise.

Glutamate is an EXCITATORY neurotransmitter, while GABA is an INHIBITORY neurotransmitter. We present them alongside each other due to their close interactions.

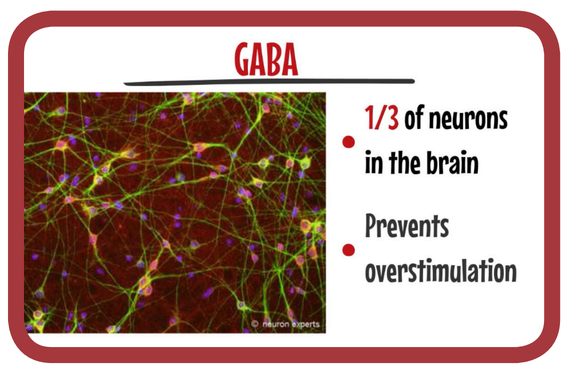
VIEW ON VIMEO >

Key Takeaways



1. Glutamate is one of the most common excitatory neurotransmitters, used by approximately 30% of neurons, and is the primary neurotransmitter in the cerebellum. It has a role in synaptic plasticity and cognition.

2. GABA is the primary inhibitory neurotransmitter in the brain and is used by 1/3 of neurons. It prevents excessive brain activity, and its metabolism allows for synaptogenesis, neurogenesis, and BDNF synthesis.



3. An imbalance of excitatory-inhibitory activity can cause excessive inflammation or hypoactivity in the brain, whereas exercise can help to regulate the levels of both Glutamate and GABA.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Dopamine levels can increase immediately after exercise and seems to be mediated by exercise intensity.
- [ ] The Noradrenergic system is responsible for the synthesis, storage, and release of norepinephrine, which plays a role in paying attention to sensory information.
- [ ] Acetylcholine (ACh) may be affected by the attentional demands of exercise, as well as the novelty of activities. ACh may also affect the survival and specialization of neurons into different regions of the brain.
- [ ] An imbalance of excitatory-inhibitory activity can cause excessive inflammation or hypoactivity in the brain, whereas exercise can help to regulate the levels of both Glutamate and GABA.

Lesson 4: Inhibitory Neurotransmitters

Lesson 4 Objectives

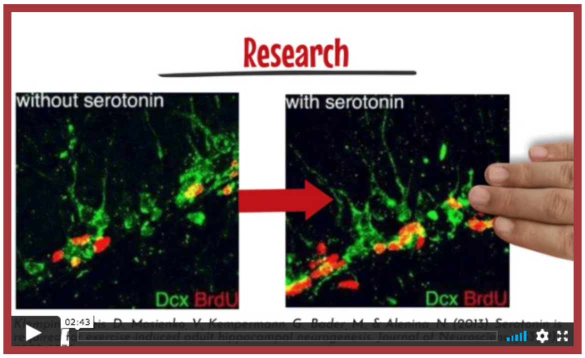
1. Identify the role of inhibitory neurotransmitters.
2. Understand the mechanisms and effects of exercise on GABA, serotonin, cortisol, and beta-endorphins.

Inhibitory Neurotransmitters

Inhibitory Neurotransmitters “**inhibit**” neurons by decreasing the likelihood that neurons will send an action potential, or an electrical signal, to another neuron via the synapse by stopping, slowing, or discouraging the signal. These include GABA and serotonin.

Serotonin

Watch the video below to learn about Serotonin, an inhibitory neurotransmitter, and how it is affected by exercise and physical activity.



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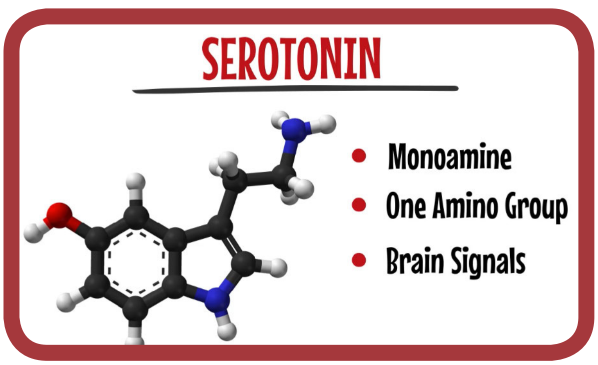
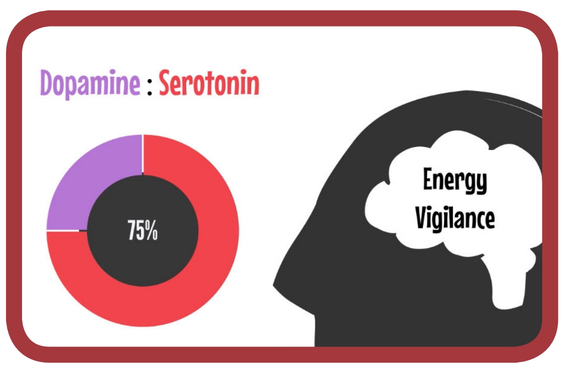
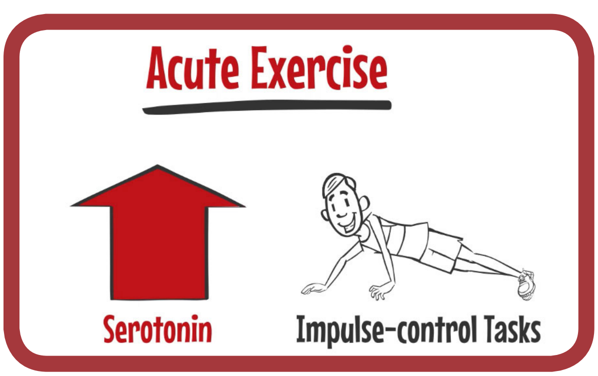
Key Takeaways



1. Serotonin is an inhibitory, monoamine neurotransmitter that plays a role in sleep, emotion, cognition, and pain perception. 90% of serotonin is present in the body and has more pathways in the brain than the noradrenergic system.

2. Serotonin and dopamine ratios may play a role in cognition and emotion. Serotonin levels are highest during alert states and lowest during REM sleep. It affects during acute exercise mimic that of SSRIs, affecting mood and cognition positively.

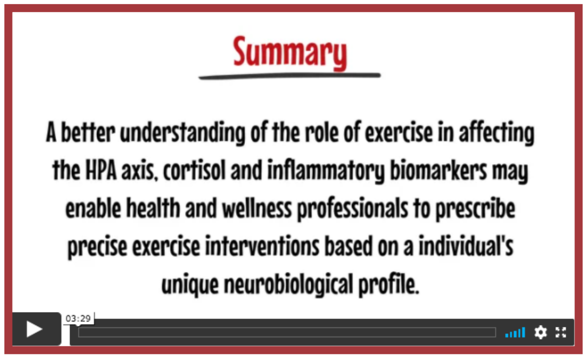




3. Higher intensity of acute exercise has been found to improve impulse control in correlation with serotonin levels, while acute, low-intensity exercise may produce higher levels of serotonin and improved mood states.

HPA Axis & Cortisol

Watch the video below to learn about the central stress response system, the hypothalamic-pituitary-adrenal (HPA) axis, and a primary stress hormone, cortisol, and how they are affected by exercise.



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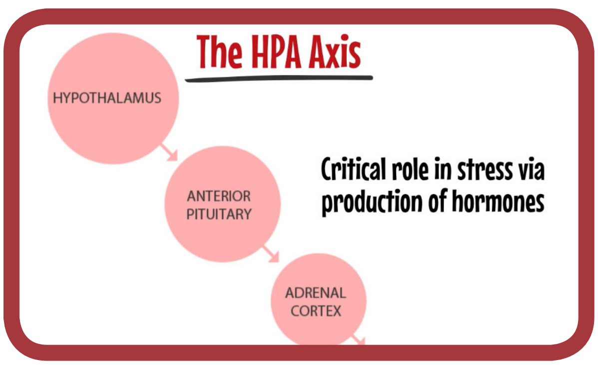
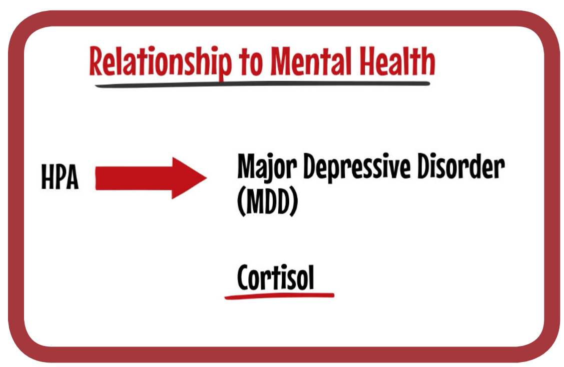
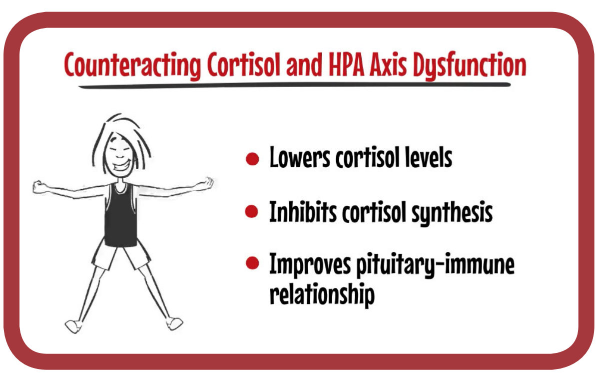
Key Takeaways



1. The hypothalamic-pituitary-adrenal (HPA) axis plays a critical role in stress via the production and release of CRH and cortisol, which are involved in cognition, immune function, mood, and inflammation.

2. The dysfunction of the HPA is correlated with neuropsychiatric and mood disorders, such as depression. Chronic stress can reduce hippocampal function and volume, as well as increase the level of circulating neuroinflammatory markers.

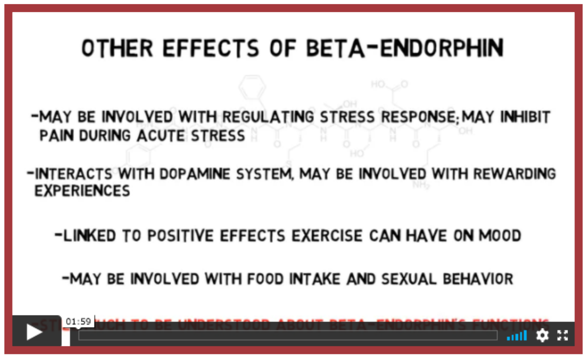




3. The HPA axis and levels of cortisol are positively affected by exercise by improving levels of stress and regulating stress hormones by inhibiting their synthesis and negative effects on the nervous system.

Beta-Endorphins

Watch the video below to learn about beta-endorphins, which are amino-acid peptides that are released by the pituitary gland and into various brain pathways, and are stimulated by exercise.



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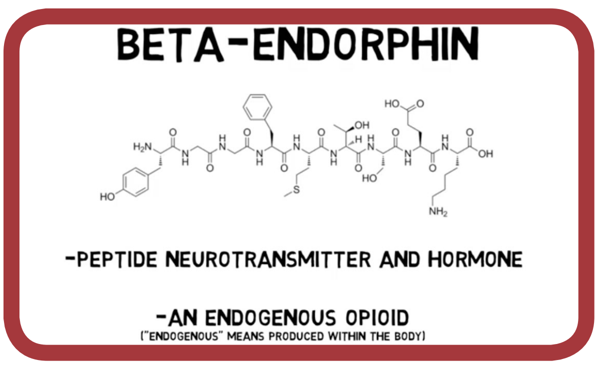
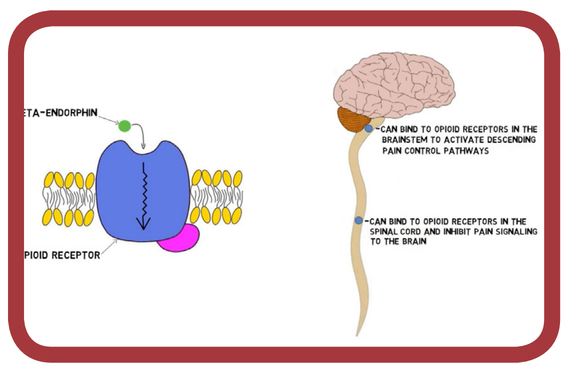
2-Minute Neuroscience: Beta-Endorphin: https://youtu.be/tsjwHWDCT0Q

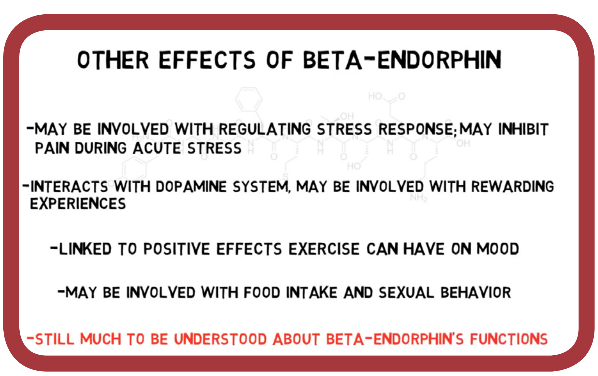
Key Takeaways



1. Beta-endorphins has also been called endogenous opioids, and bind to opioid receptors in the brain stem, spinal cord, and brain.

2. Beta-endorphins have been found to play a role in pain modulation, improvements in mood, the modulation of stress, and interacts with the dopamine system.





3. While beta-endorphins are thought to be the primary mechanisms underlying pain, pleasure, and reward, more research is needed to clarify their roles.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Higher intensity of acute exercise has been found to improve impulse control in correlation with serotonin levels, while acute, low-intensity exercise may produce higher levels of serotonin and improved mood states.

- [ ] The HPA axis and levels of cortisol are positively affected by exercise by improving levels of stress and regulating stress hormones by inhibiting their synthesis and negative effects on the nervous system.

- [ ] Beta-endorphins, which are released during and after exercise, have been found to play a role in pain modulation, improvements in mood, the modulation of stress, and interacts with the dopamine system.

Lesson 5: Neurophsyiology of Exercise

Lesson 5 Objectives

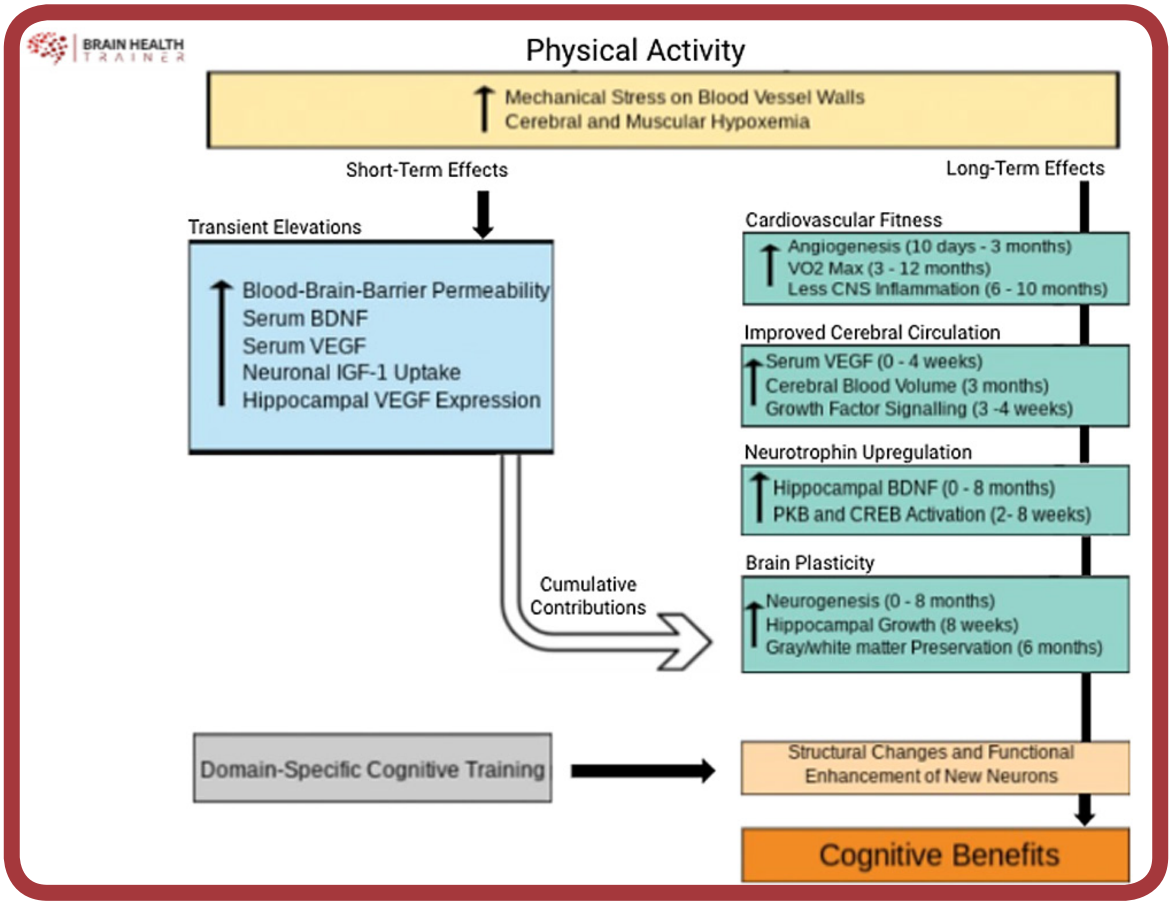
1. Understand the complexities underlying the neurophysiology of exercise.

2. Identify the multiple neurophysiological systems and levels on which exercise can act upon.

3. Identify the acute effects of exercise and the time-course in which they act, as it relates to various cognitive and micro-level changes.

Neurophysiology of Exercise

The image below summarizes the many mechanisms triggered by both chronic and acute exercise.



Stimpson, N. J., Davison, G., & Javadi, A. H. (2018). Joggin'the noggin: towards a physiological understanding of exercise-induced cognitive benefits. Neuroscience & Biobehavioral Reviews, 88, 177-186.

Let's review some of the micro level changes as they relate to physical activity and exercise, and break them up into separate categories of mechanisms, observing effects in both the short-term and the long-term.

It is thought that one of the most important mechanisms of physical activity and the brain has to do the physiological effects surrounding the cardiovascular system. As shown here, exercise and physical activity increases the mechanical stress on blood vessel walls in both the body and the brain. This increase in blood flow flow leads to temporary increases in hypoxemia, or decreased blood oxygen levels, in both cerebral and muscular tissues. This is of course only temporary as a result of exercise-induced physiology, but let us observe what else happens in the short term.

There are various acute mechanisms that occur with exercise and physical activity. There are increases in certain growth factors, that lead to long-term changes at both the micro and macro levels.

An important acute change is an increase blood-brain-barrier (or “BBB”) permeability, which is influenced by neurons, astrocytes, vascular endothelial cells, and the extracellular matrix. This permeability allows for a better exchange of fluids and chemicals that contribute to healthy brain structure and function.

In terms of acute growth factors, serum levels (components of the blood that do not include white or red blood cells) of BDNF and VEGF.

Neurons also express a greater uptake of IGF-1, and IGF-1 levels may be further increased by changes in exercise variables such as type, as demonstrated by resistance training.

The hippocampus also expresses greater VEGF expression, which enhances the effects of neurogenesis in this brain region, as well as others. These mechanisms, alongside others, are crucial processes for enhancing cognitive function.

There are many potential acute cognitive changes as a result of exercise, some beneficial and some detrimental, across various cognitive domains. The research on the acute cognitive effects stemming from exercise is limited and complex, and chronic changes in cognition are the primary interest of this course.

One of the most recognized mechanisms that can lead to improved brain health is associated with “Cardiovascular Fitness Hypothesis”, which states that higher levels of cardiovascular fitness lead to greater cognitive reserve over the lifespan, primarily due to cardiovascular mechanisms.

One of these mechanisms is an increase in Angiogenesis, the creation of new blood vessels in the brain, which occurs over a period of 10 days - 3 months, with each time point increasing in the potential significance in the number, size, or connectivity of blood vessels.

Another familiar measure of cardiorespiratory fitness, VO2 Max, which has been associated with greater levels of cognitive reserve and lower risks of dementia, occurs over training periods of 3 - 12 months. This timelines provides a significant argument for EPAP adherence and the presence of substantial cardiorespiratory training.

Cardiovascular fitness is also thought to reduce Central Nervous System inflammation, which occurs acutely, but more significantly over a period of 6 - 10 months. A reduction of inflammation is known to have a critical role in brain health, and some research demonstrates that a reduction in CNS inflammation earlier in life, perhaps decades earlier, profoundly reduces the risk of neurodegeneration.

Additional benefits of long-term exercise include increases in cerebral circulation, which is essentially more blood flow throughout the brain. Increases in serum VEGF (vascular endothelial growth factor) occurs immediately and up to 4 weeks, acting in parallel to allow angiogenesis to occur.

Increases in the total blood volume in the brain, also referred to as cerebral blood volume, occurs in a 3 month time period. This occurs in parallel with increases in cerebral blood flow (CBF).

As a result of increased CBF, other growth factors are signaled to become unregulated, which occurs in 3 - 4 weeks of training. The signaling of different growth factors is associated with different timelines, and are likely to be affected by exercise variables, such as modality, duration and intensity.

Neurotrophins, proteins that facilitate the creation, development, survival, and function of neurons, are growth factors that also increase with exercise. Brain-derived neurotrophic factor, or BDNF, begins to be detectable almost immediately, and increases its presence more significantly along a period of 8 months or more. This is especially true in the hippocampus.

Neurotrophins are also unregulated via signaling pathways that promote neuronal survival and growth, as seen with activation of the PKB and CREB pathways. This occurs between 2 and 8 weeks of exercising.

The accumulation of all these growth factors, physiological changes, and signaling pathways leads to overall changes in brain plasticity. This includes neurogenesis, the creation of new neurons, occurring over periods of several days to 8 months.

This can lead to growth in various brain structures, such as the hippocampus, in as little as 8 weeks.

Total brain volumes also become affected as a result of exercise, which is demonstrated by the increases in gray Matter and white matter preservation, occurring within a period of 6 months.

The transient elevations in various growth factors occurring with acute exercise can lead to changes in brain plasticity in the long-term, assuming that an EPAP is properly adhered to. This can provide motivation for getting another workout in, as cumulative effects lead to highly beneficial central nervous system adaptations.

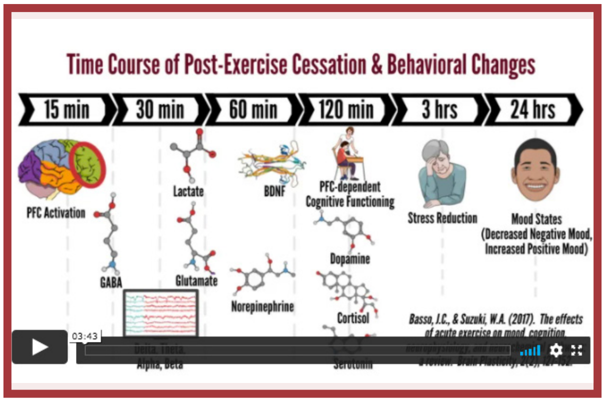
As brain structures become modified and new neurons appear in the brain, an opportunity arises to integrate or functionally engage these neurons.

This is where domain-specific cognitive training can come into play. Cognitive stimuli can come in many forms and can be present in various modalities. Adding cognitive stimuli to plastic brain regions and new neurons may enhance neuronal survival and functional levels of brain activity, a concept we will explore in later modules of the course.

Functional, structural, and physiological changes as a result of exercise lead to enhanced cognitive benefits. These cognitive benefits may be enhanced through additional cognitive stimuli, and these cognitive benefits may be general or selective.

The Effects of Acute Exercise

The video below will demonstrate some of the mechanisms that can occur at the micro, macro, and behavioral level of the brain after acute (or short-term exercise). This video will cover the effects of acute exercise on certain growth factors, neurotransmitters, cognitive functions, mood, and brain activity changes.



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General Exercise Effects on Neurotransmitters & Growth Factors

The table below presents select neurotransmitters & growth factors, and the effects of acute (short-term) and chronic (long-term) exercise. While this table is not extensive, it demonstrates that exercise acutely increases (or regulates) the concentrations of a majority of these, with chronic exercise increasing the signaling and/or concentrations of these neurotransmitters & growth factors.

Name	Acute Exercise	Chronic Exercise
Catecholamines	Transiently increased concentrations	Increased signaling
VEGF	Transiently increased concentrations	Increased concentrations
BDNF	Transiently increased concentrations	Increased concentrations
IGF	Transiently increased concentrations	Increased concentrations

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ The neurophysiology of exercise consists of complex, multi-level, and inter-related processes.
- ☐ Acute exercise elicits various changes in neurophysiology, including the transient increase in certain neurotransmitters, growth factors, brain waves, cognitive functions, and mood.
- ☐ Exercise acts at the micro, macro, and behavioral levels both in the short and long term. However, outcomes in cognition and brain health depend upon the “dosage” of exercise, consideration of multiple acute variables, timelines, and cognitive load.

SECTION 3: Brain Structure & Functional Brain Networks

Lesson 1: Brain Structures & Exercise

Introduction to Section 3: Brain Structure & Functional Brain Networks

Section 3 is divided into **2 lessons**. This section identifies the effects of exercise at the **macro**-level, which include changes to brain **structures** and functional brain **networks**. You are currently in **Lesson 1**, which will give you a brief overview of the effects of exercise on various **brain structures**, which in turn can affect behavioral outcomes, such as mood and cognition. Lessons 2 will define the **functional brain networks**, and relate them to various brain regions and domains of cognition, as well as discuss their relationship with exercise.

By the end of Section 3, you will be able to define several brain structures and functional brain networks and identify how they may be affected by exercise and physical activity. You will be able to relate these **macro-level changes** to behavioral outcomes that lead to **changes** in mood and **cognition**.

Section Objectives

1. Identify the specific effects of certain exercise modalities as they relate to brain regions.
2. Understand the complexities behind the neurobiology of exercise, and its effects of multiple neurobiological systems.

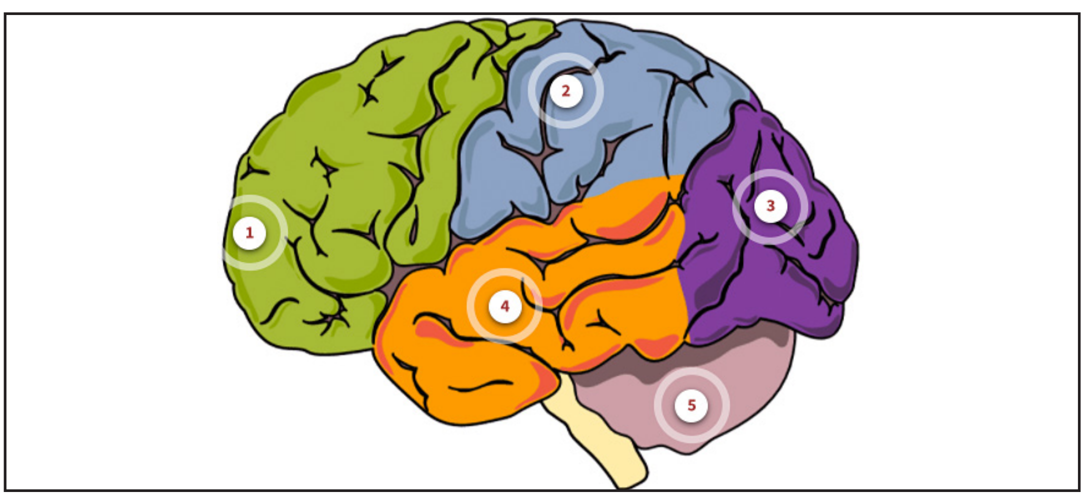
Brain Structures and Functional Networks Introduction

Watch the video below to gain an overview of this section:

VIEW ON VIMEO >

Region-Specific Brain Changes

The numbered image below will guide you through some of the major regions of the brain, and explain how they may be affected by certain types of exercise and physical activity.



1. **Frontal Lobe** - Exercise increases **gray matter,** improves **executive functions**, and improves the **efficiency** of brain activity. Modalities of exercise that target this area may include:

2. Cognitively-Demanding Activities
3. Resistance Training
4. Mind-Body Activities

2. **Parietal Lobe** - In the parietal lobe, exercise may increase **white & gray matter volume**, improves **sensory network activity** and **task-switching** abilities. Modalities of exercise that target this area may include:

3. **Sensory**-rich Activities
4. **Visuospatial** Demands
5. **Object-based** Activities

3. **Occipital Lobe** - In the occipital lobe, exercise may increase **white & gray matter**, improve **visual attention**, and functional activity. Modalities of exercise that target this area may include:

4. Visuospatial demands
5. Visual Attention demands
6. Motor Control & Stimulation

4. **Temporal Lobes** - In the temporal lobe, exercise improves learning and **memory** and increases neurogenesis and **hippocampal** volumes. Modalities of exercise targeting this area include:

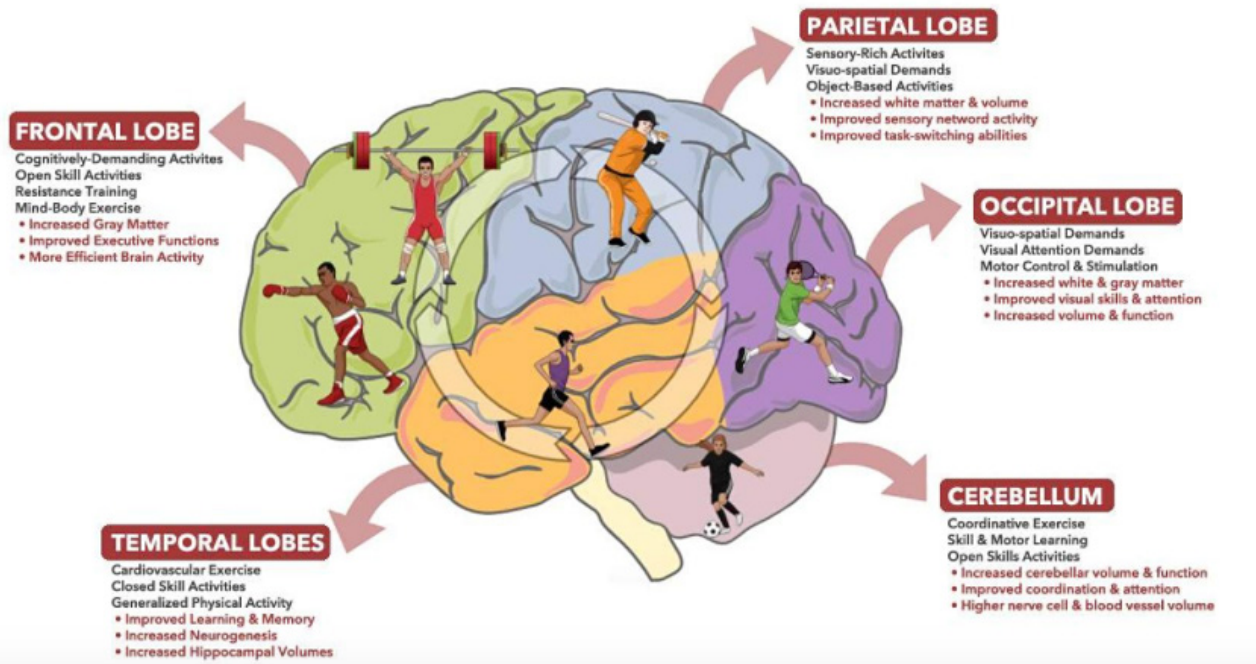
- Cardiovascular Exercise
- Resistance Training
- Physical Activity

5. **Cerebellum** - Exercise may increase **cerebellar volume** and **function**, improves **coordination** and attention, and increases **nerve cell** and **blood vessel volume**. Modalities of exercise targeting this area include:

6. Coordinative Exercise
7. Skill & Motor Learning
8. Neuromotor Activities

Brain Region-Specific Changes with Exercise Types

The graphic below summarizes the potential selective, regional effects of different exercise modalities on various brain regions based on the interactive graphic above. While not exclusive nor conclusive, this information provides a comprehensive perspective on the value of integrating various modalities of exercise, skill learning, and sensory stimuli in order to create a well-rounded BH-EPAP.



Knowledge Check

Which brain region is likely involved with the exercise stimulus on the left?

Record your answers here for future reference.

Coordination Exercise .... ____________________

Cognitively Demanding Exercise .... ____________________

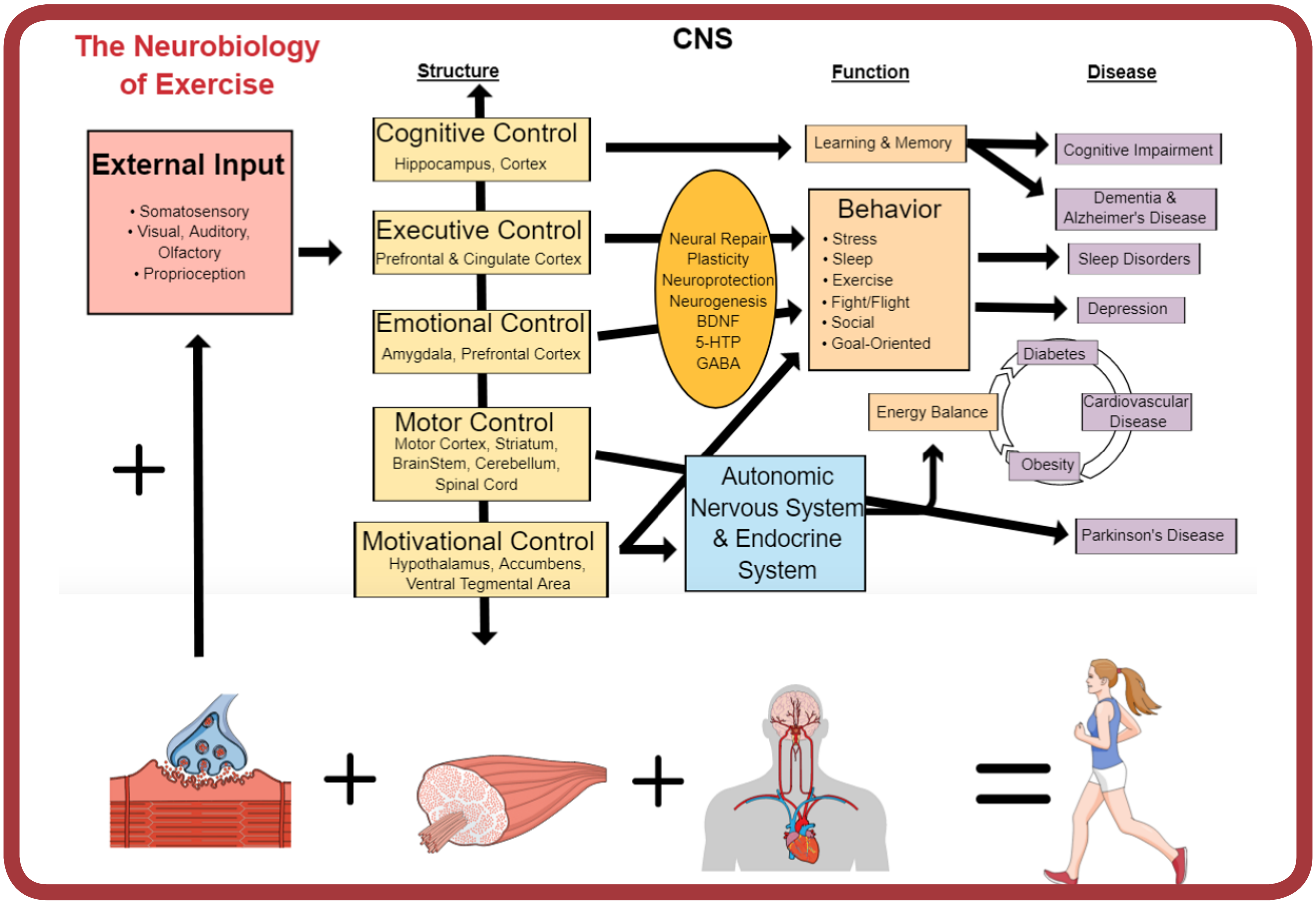
Sensory-Rich Activities .... ____________________

Cardiovascular Exercise .... ____________________

Motor Fitness .... ____________________

Neurobiology of Exercise: An Overview

The image below to learn how the stimulus from exercise affects and is processed by the brain, its various regions and networks, their associated cognitive functions and neurobiological systems, and their relationships to health and disease.



Dishman, R. K., Berthoud, H. R., Booth, F. W., Cotman, C. W., Edgerton, V. R., Fleshner, M. R., ... & Kramer, A. F. (2006). Neurobiology of exercise. Obesity, 14(3), 345-356.

The neurobiology of exercise is complex and constantly-evolving. We have discussed the role of neurotrophic factors, but that is only a piece of the puzzle. Let us observe the interactions between the neuromuscular system, the sensory systems, brain structures, cognition, and the risk of disease.

We know that when we exercise, there are metabolic and cardiovascular changes that occur, leading to changes in muscle physiology, activation of the peripheral nervous system, specifically at the neuromuscular junction, and increases in blood flow systemically and to the brain. It is interesting to note that certain growth factors come from each of the system-based changes. For example, the growth factors irisin and IGF-1 are stimulated by muscle activity, and VEGF and BDNF are stimulated by cardiovascular activity.

In addition to these “bottom-up” mechanisms occurring during exercise, human movement includes the integration of external sensory inputs. This includes information through the visual system, the somatosensory system, the auditory system, the proprioceptive system, and the olfactory system. Various parts of the brain help to process and integrate all of this stimuli, especially the parietal lobes. These external inputs that can occur also provide an argument for what we call “environmental enrichment”, which refers to presence of multiple and variable stimuli that may contribute to cognitive benefits.

As we relate external inputs and bottom-up effects associated with exercise to the brain, let us review some of the structural hierarchies that are responsible for critical, high-level functions of cognition. As we covered in the Adaptive Capacity Model, one of the functions that occurs with novel, movement-based input is Executive Control. This involves the prefrontal cortex and the cingulate cortex, and what this means is that executive functions may be recruited to help process this information. Imagine Executive Control as the CEO of this process; directing, interpreting, and organizing incoming information.

As Executive Control kicks in, Cognitive Control adds additional neural resources to the mix, via recruitment of the Hippocampus and the Cortex. This includes the integration of additional cognitive abilities that work in partnership with executive control, such as spatial memory, sensory processing, and various types of attention. Keep in mind that the Hippocampus and the Prefrontal cortex are positively affected by exercise given the right conditions.

Speaking of the Prefrontal Cortex, it is also involved in emotional control. The Prefrontal cortex partners with the Amygdala in order to manage emotional processes, and other parts of the brain, like the hippocampus, can also be involved here. Emotional control’s significance is in the interpretation of stimuli. Is it safe, is it fun, is it boring? Determining mood and affect is incredibly important to brain health, especially to executive functions. This is important to keep in mind when delivering exercise interventions.

Then we have Motor Control, which involves the Motor Cortex, the Striatum, the Brain Stem, the Cerebellum, and the Spinal Cord. Some of these structures we do not address in depth within this course, but are critically important in the bridge between brain health and movement. Many of these regions have been thought to only carry signals from the more “cognitive” parts of the brain to the body, but are now being found to be responsible for complex functions of cognition and mood.

Lastly, we have Motivational Control. These regions interact with the emotional, motor, executive and cognitive systems to drive or inhibit behavior. The associated brain regions include the hypothalamus, the nucleus accumbens, and the ventral tegmental area. The amygdala and hippocampus can also play a role in motivation. Do not forget that the hypothalamus is a part of the HPA axis, which is critical in the role of stress regulation. This motivational control is absolutely critical for understanding a client’s behavior, or lack thereof.

This relationship brings us to the Autonomic Nervous System and the Endocrine System. These two vital systems have associated connections, such as the HPA axis, the vagus nerve, and the gastrointestinal system. These systems can significantly impact brain health, as well. The effects of hormones, such as cortisol and estrogen, and vagal tone, all have been shown to play important roles in modulating cognition and brain health.

When we look at these structures working together to process exercise-related information, we should also recognize the role of the micro level mechanisms. These mechanisms include neural plasticity, neuroprotection, neurogenesis, and BDNF. Neurotransmitters are of course also affected, and listed here we have 5-HTP and GABA, important neurotransmitters that we have not presented on, but play a serious role in various behaviors and cognitive abilities.

Now that we have spent time on the brain structures associated with the neurobiology of exercise, let's look at the functions. As we know by now, exercise-based changes to the hippocampus and other structures associated with cognitive control lead to improvements in learning and memory.

Maintaining these functions are vital for the prevention and management of neurological conditions such as cognitive impairment, dementia, and Alzheimer's Disease.

The Executive, Motivational and Emotional Control centers play a big role in the management of behavior. Executive functions, motivation and emotional regulation can determine either direct or indirect adherence or abstinence of various lifestyle behaviors. These lifestyle behaviors include stress, sleep, exercise, fight/flight responses, social behavior, and goal-oriented behavior. We have discussed how all of these can significantly impact cognitive reserve, and therefore brain health, but also have an impact on quality of life. If any of these behavioral functions are disturbed they can lead to conditions such as sleep disorders or depression, both of which can affect brain health, both on the macro and micro levels. Of course, there are many more examples of diseases and conditions that can arise from poor lifestyle behaviors, but these examples should give you an idea of their potential relationships to various brain structures and functions.

Other neurological conditions can stem from dysfunction of the Motor systems, and this includes Parkinson's Disease. Part of Parkinson's Disease is the dysregulation of autonomic functions, and there are cognitive issues and neurotransmitter changes, such as decreased dopamine, that accommodate such disorders. There are other conditions that are associated with motor and cognitive dysfunction, such as multiple sclerosis.

When Autonomic and Endocrine functions are disrupted, there can also be changes in Energy Balance. Lifestyle factors play a big role in energy balance. Fluctuations can lead to metabolic and physiological dysfunctions. This can give way to conditions such as diabetes, cardiovascular disease, and obesity, all of which have been demonstrated to affect cognition and brain health negatively.

Luckily, with structured and varied exercise plans, we can tip the structural and functional scales in favor of positive effects. This can lead to the improvement in some of the various brain structures presented here, improve neurobiological functions, and prevent or ameliorate some of the diseases we have presented on here.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Regionally-dependent structural changes may occur with different modalities of exercise, although this is not exclusive nor conclusive.
- [ ] The neurobiology of exercise is complex and multi-level, interacting with structures, functional pathways, behavior, & potential disease

Lesson 2: Functional Brain Networks

Lesson Objectives

1. Define functional brain networks and how they are measured and studied.
2. Relate the effects of aging on various functional brain networks.
3. Relate the effects of exercise on various functional brain networks.

Introduction to Functional Brain Networks

Brain structures **do not work independently** most of the time. Rather, different regions play different roles and work together with other brain regions to accomplish tasks.

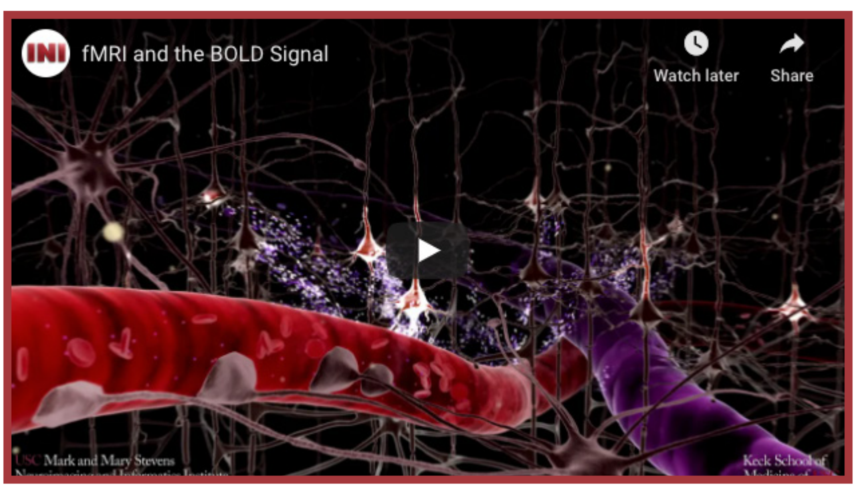
Because brain structures do not work independently, most approaches in neuroscience consider brain function in terms of **functional brain networks**. These are **connected brain regions** that will all "**activate**" during certain **tasks** and **work together**.

Studying functional brain networks allows for a deeper understanding of brain **functionality** and can offer helpful insights into cognition, mental illness, and neurodegeneration.

Measuring Brain Activity

One way to think about functional brain network activity is to consider how "neural resources" are used. All brain activity requires **oxygen, blood flow**, and other factors that **support brain metabolism**. These are examples of neural resources.

The video below demonstrates how a type of **functional neuroimaging, fMRI**, can measure brain activity through what is called BOLD signaling:



VIEW ON YOUTUBE >

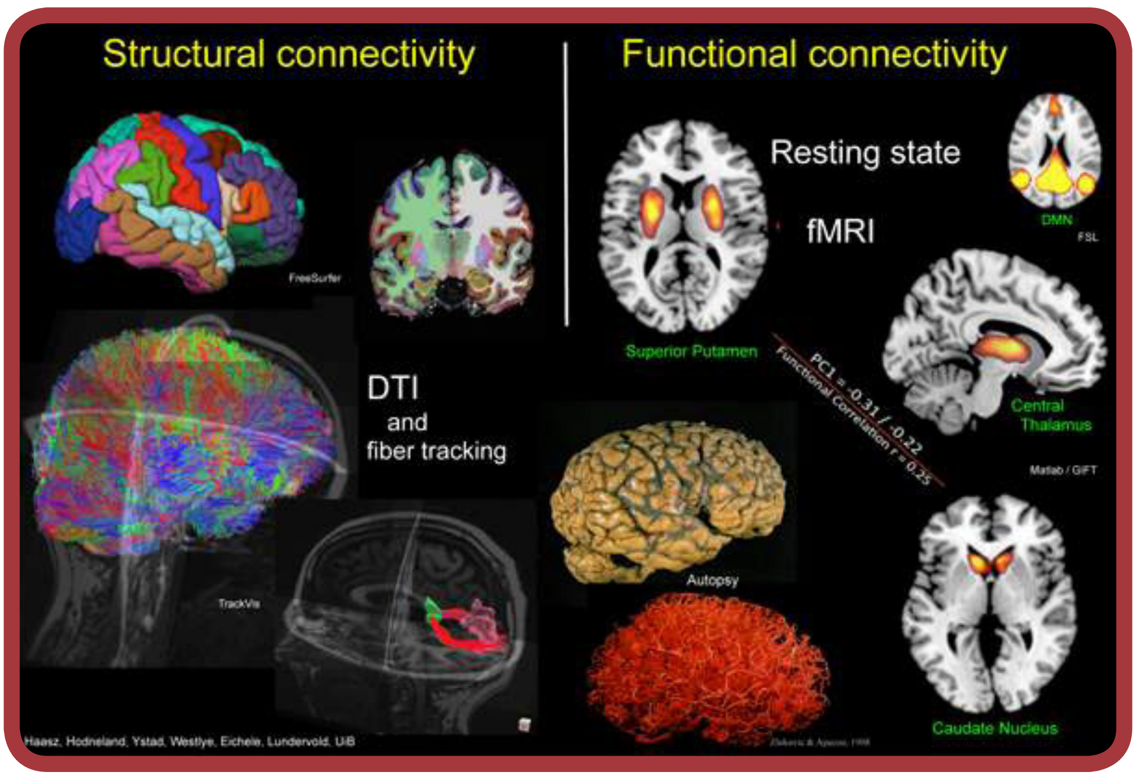
Resting-state fMRI techniques

Using **resting-state fMRI** techniques, we can correlate the health and function of functional brain networks to **resting-state functional connectivity**, which can also serve as a biomarker for neurodegenerative disease and mental health conditions.

There are at least two different kinds of brain connectivity, both of which will be affected by exercise: **structural connectivity (SC)**, and **functional connectivity (FC)**.

SC refers to the physical or **anatomical** connections between different brain regions. SC is identified by tracking **water molecules along axonal tracts** which can be done by Diffusion Tensor Imaging (DTI).

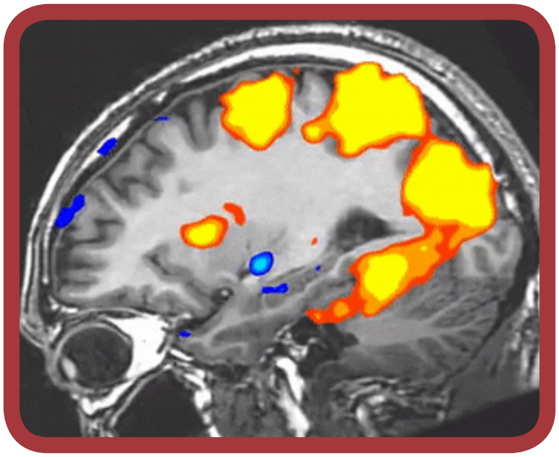
FC refers to the **functional connectivity** between brain regions either when the brain is at rest, or performing a **task**. Various brain regions that are active at the same time share a functional relationship.



Lundervold, A. (2010, June). On consciousness, resting-state fMRI, and neurodynamics. In Nonlinear Biomedical Physics (Vol. 4, No. S1, p. S9). BioMed Central.

Resting-state "rs-fMRI" is an fMRI scan that occurs in the absence of a cognitive task. Usually, the person being scanned is told to have their eyes open (so not to fall asleep) and just focus on a "+" in the middle of a screen. This allows the mind to be at rest and not have a specific cognitive task to attend to.

Exercise & Neural Resources



Exercise and physical activity influence the way neural resources are allocated. Research is finding that **exercise and physical activity** may **improve the efficiency** in which **neural resources are allocated**. This can improve the cognitive functions related to the areas or networks in the brain where this occurs.

The study of brain networks provides a different perspective on studying the effects of exercise and physical activity.

The Default Mode Network (DMN)

The Default Mode Network (DMN) is mostly involved in tasks of **autobiographical memory** and **spatial processing**. This proposes an interesting relationship between **episodic memory** and other social and self-related cognitive functions.

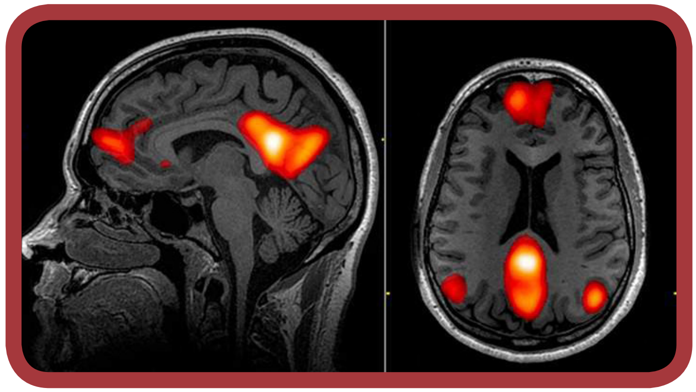
The **DMN** is a set of brain regions that are **active at rest** and demonstrates decreased activity during most tasks. **FC** of the DMN seems to **decline with age**, especially amidst cognitive impairments.

- The DMN's sites include the **frontal, parietal, temporal,** and **visual** areas.
- **Better DMN FC** seems to improve performance on certain cognitive tasks associated with **spatial memory** and **executive functioning**.
- The connections between **frontal** and **temporal** sites in the DMN are most sensitive to the changes associated with **aging**.

The DMN and Exercise

The DMN seems to be sensitive, both acutely and chronically, to exercise.

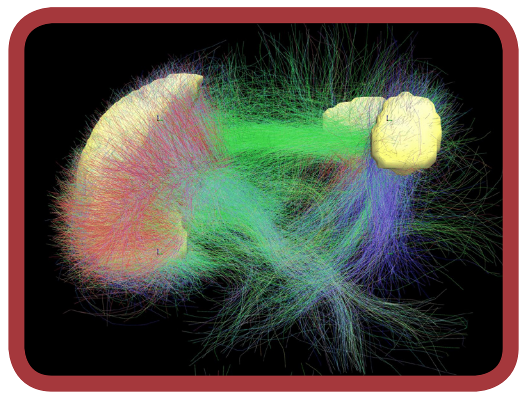
FC of the DMN (specifically in the **hippocampal, parietal**, and **prefrontal** regions) seems to be enhanced **acutely** and **after one year** of moderate-intensity **aerobic exercise**. Higher levels of aerobic exercise have been associated with higher **DMN FC** in the **frontal** and **temporal** regions in older adults.



A static view of the Default Mode Network in an active state

Longer interventions seem to have more "**network-wide**" effects (more areas more positively affected) on the DMN, as revealed by studies observing 12-month interventions vs. 6-month interventions.

DMN Functional Connectivity & Exercise



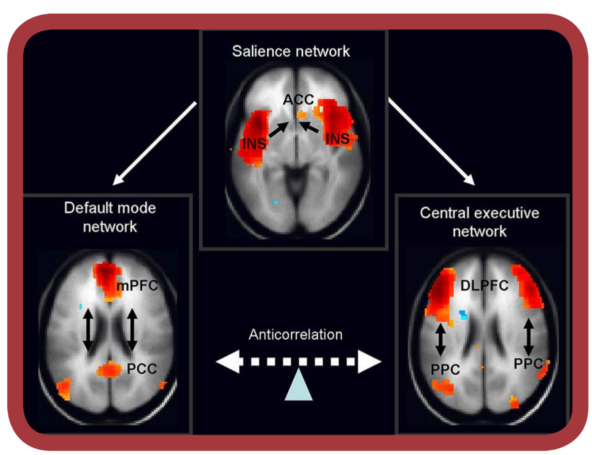
Similar to other fitness-induced adaptations in brain structure, the **prefrontal cortex** and the **temporal** lobes have higher functional connectivity (FC) with each other with higher levels of **cardiorespiratory fitness**.

Cognitive Changes Associated with DMN and Exercise

Increased **FC** in the **DMN** may also play a role in improved **executive functioning** and selective attention. **Dysregulation** of the DMN has been associated with sub-optional cognitive functioning. The CEN modulates or "**inhibits**" the DMN. By improving the **regulatory relationship** of these networks, **cognition** may **improve**.

The Salience Network

The **salience network** is another functional brain network that **filters** important information and "**recruits**" other brain networks, also acting as a "**switch**" between the CEN and DMN. These beneficial changes also occur with **mindfulness** interventions.

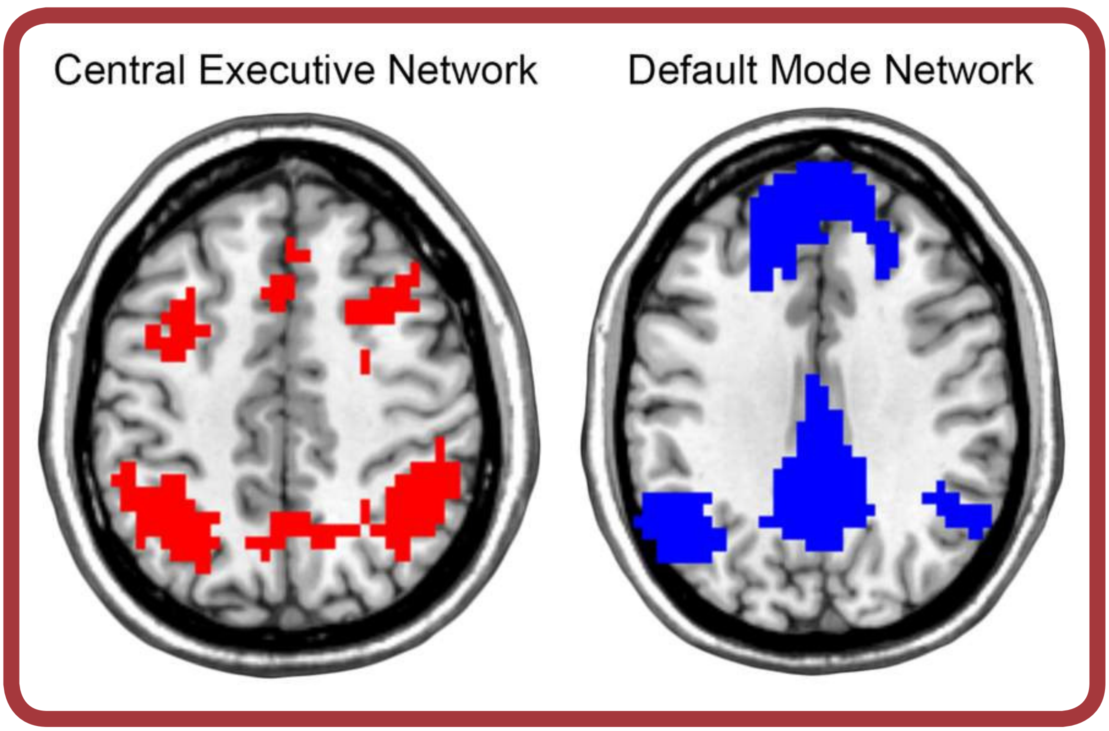


Growth Factors, Functional Connectivity, and the DMN

FC is also correlated with higher levels of **BDNF**, **IGF-1**, and **VEGF**, and higher levels of physical activity are achieved. In addition, improved **DMN FC** is often interconnected with **hippocampal** growth.

The Central Executive Network

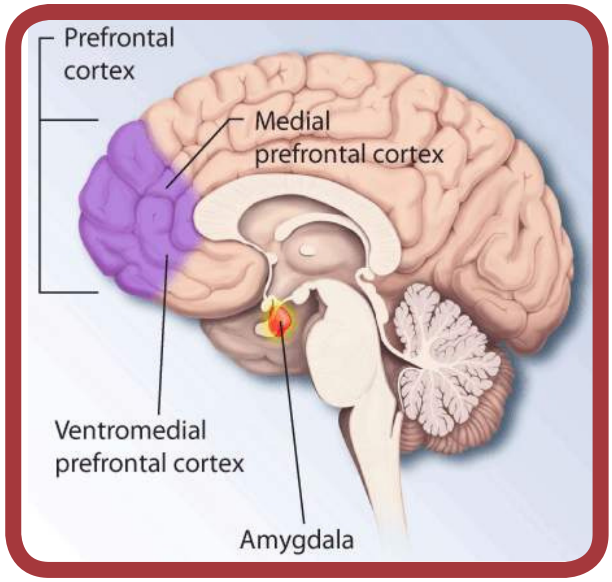
The **Central Executive Network (CEN)**, also known as the executive control network or the **frontoparietal network (FPN)**, co-activates several prefrontal and parietal brain regions. It is associated with **executive functioning tasks**, and its functional connectivity has been shown to **improve with exercise**. This may counteract the decrease in functional connectivity in the CEN that occurs with age.



Mayhugh, R. E., Moussa, M. N., Simpson, S. L., Lyday, R. G., Burdette, J. H., Porrino, L. J., & Laurienti, P. J. (2016). Moderate-heavy alcohol consumption lifestyle in older adults is associated with altered central executive network community structure during a cognitive task. PloS one, 11(8), e0160214.

The CEN and Executive Functioning

The **frontal regions** of the brain associated with the CEN and increased FC of the frontal aspects of the CEN can lead to improvements in **attention, working memory, task switching**, and **inhibition**.



Parietal Lobe Involvement

The **parietal lobes** are also a part of the CEN, and higher FC in the parietal regions typically leads to increasing **visuospatial processing abilities**. This is why the CEN is also called the **frontoparietal network (FPN).**

The CEN and Exercise

Cardiovascular and **coordinative** training has been shown to improve the utilization of neural resources, and therefore increase cognitive performance, primarily through more **efficient brain activation** in the **frontal regions** of the brain associated with the CEN/ FPN.

Skill-Based Interventions

Increased FC in the CEN has also been demonstrated in **resistance training**, **coordination training**, and **dance interventions**. This provides an interesting perspective on how **skill-based training** may target functions associated with the CEN.

Other Brain Networks

There are other brain networks aside from the CEN and DMN, including the **visual, auditory, motor,** and **sensory networks**. We will not define each of these networks in detail. Instead, we will present general principles regarding how they respond to exercise. For example, activities that involve more **visual stimuli** may affect the **visual brain networks**, more **sensory activities** affecting the **sensory networks**, and so on.

Overall, we now know that all cognitive processes are subserved by **large-scale brain networks**. Scientists now employ the study of these networks to understand the brain and its inner-workings. Moreover, these networks are **dynamic**, that is, they change over time (short, medium, and long time scales). As in the case of many of the findings presented in this course, more research is needed to clarify the effects of exercise on specific networks.

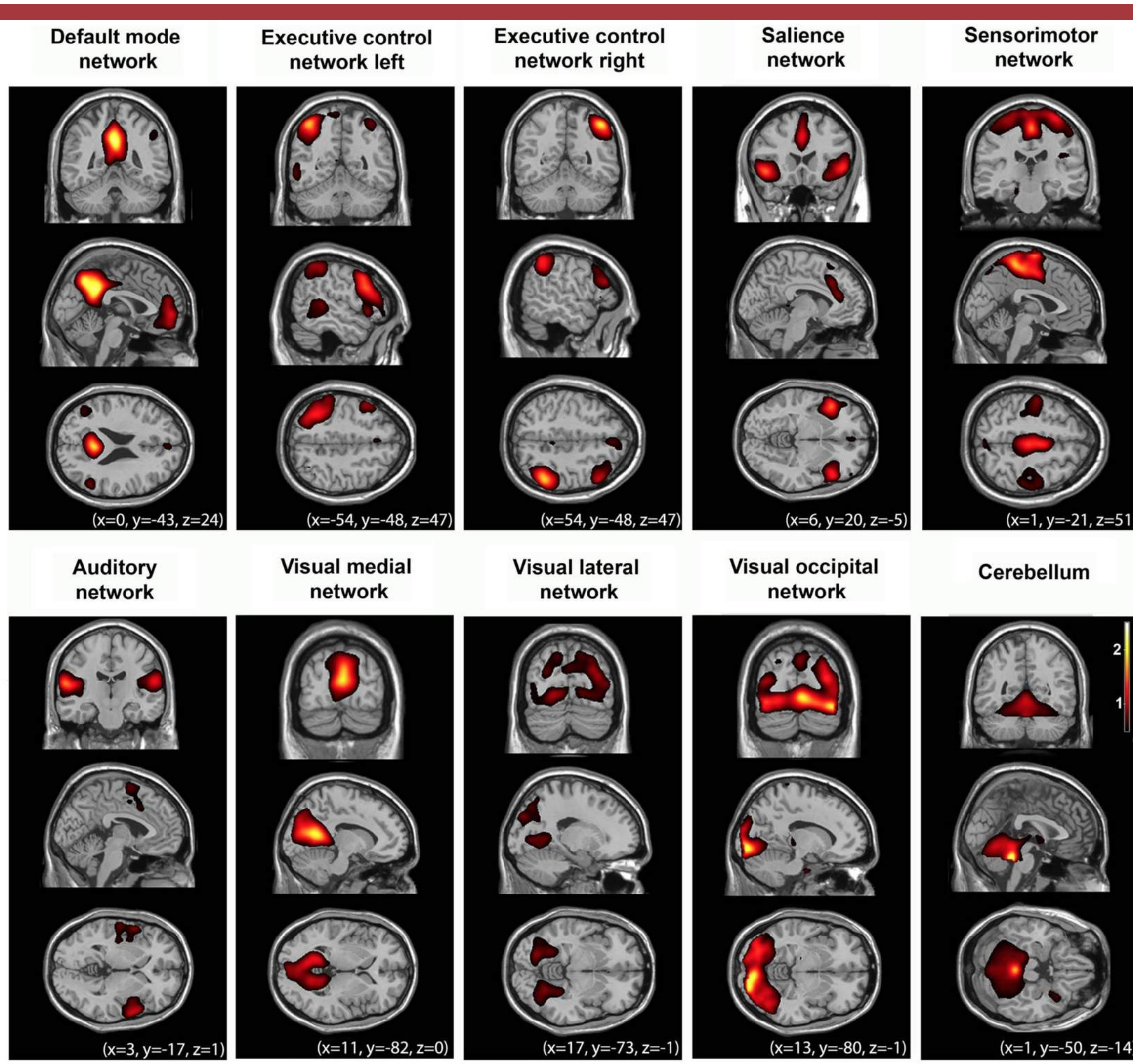
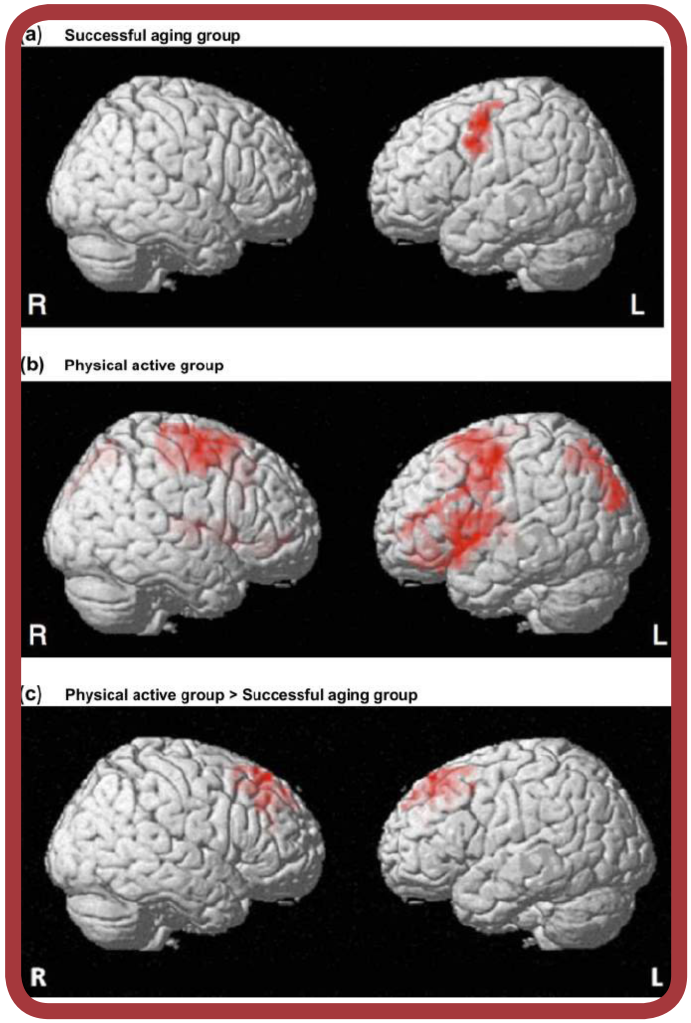


Figure 1. Cerebral networks identified with fMRI. ***Resting State Networks and Consciousness*** *(2012) Lizette Heine, Andrea Soddu, Francisco Gómez, Audrey Vanhaudenhuyse, Luaba Tshibanda, Marie Thonnard, Vanessa Charland-Verville, Murielle Kirsch, Steven Laureys, and Athena Demertzi doi:10.3389/fpsyg.2012.00295*

Aging and Functional Brain Networks

During childhood, brain networks are **optimized** (pruned) and re-wired, going from longer to shorter-range functional and structural connectivity pathways. During **later stages** in life, as the brain ages and neuronal connections are lost, the brain once again needs to **re-wire** to compensate for **lost neurons**. This can lead to less efficient brain connectivity pathways.

Some functional brain networks are **not as significantly** affected by normal cognitive aging as the **CEN** and **DMN** are, although **specific** changes may occur to various **adverse changes** that occur with aging. For example, changes to **sensory** systems, such as the **visual** and **auditory** systems (as seen with vision or hearing loss), will likely affect their **correlated** brain networks, such as the **visual** and **auditory networks**.



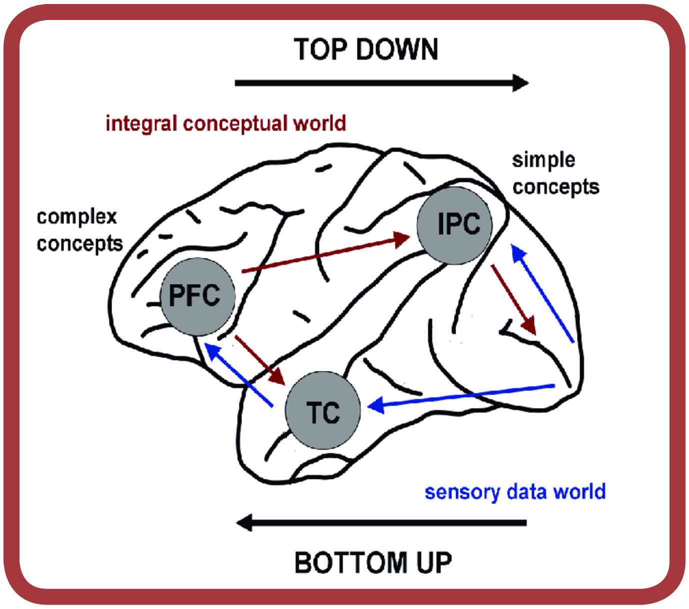
Rosano, C., Venkatraman, V. K., Guralnik, J., Newman, A. B., Glynn, N. W., Launer, L., ... & Aizenstein, H. (2010). Psychomotor speed and functional brain MRI 2 years after completing a physical activity treatment. Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 65(6), 639-647.

Top-Down vs. Bottom-Up Processing

The involvement of brain networks changes based on the way sensory information is processed and how that information interacts with cognition.

Bottom-up processing refers to **organizing information** as it comes in **from the senses**. It is associated with "**lower-level**" cognitive functions, such as basic attention processes.

Top-down processing refers to processes associated with “**higher-level**” cognitive functions, such as **executive functioning**. Top-down processing **uses existing knowledge** and experience to interpret information and thought.



Sinke, C., Neufeld, J., Zedler, M., & Emrich, H. M. (2013). Synaesthesia: a conceptualization (‘synthesis’-) phenomenon. Philosophical and neurobiological aspects. Theoria et historia scientiarum, 10, 37-54.

Some research has found that **skill-based training**, such as coordinative or motor training, **improves top-down** and goal-directed functional **brain networks** responsible for **complex processing** such as the **CEN**. On the other hand, **aerobic exercise** is more **bottom-up** and **improves basic** functional brain networks that are focused on “**internal processing**”, associated with **simple processing** including the **DMN**. The areas of the brain responsible for both bottom-up and top-down processes can **overlap** significantly and may not be as differentiated as theorized.

Knowledge Check

Do the items below describe DMV or CEN?
Record your answers here for future reference.

Associated with "internal processing" .... ____________________

Associated with bottom-up processing .... ____________________

Associated with "external processing" .... ____________________

Associated with top-down processing .... ____________________

Likely more affected by cardiovascular exercise .... ____________________

Activity is highest during rest .... ____________________

Likely more affected by skill-based training .... ____________________

Activity is highest during a task .... ____________________

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] In addition to regional brain activity, brain networks can communicate via functional networks. Functional brain activity can be measured with different types of functional neuroimaging.

- [ ] The Default Mode Network (DMN) is most active at rest, while the Central Executive Network (CEN) is most active during tasks. Both the DMN and CEN are sensitive to aging, exercise, and correlated with changes in cognition & brain structure.

- [ ] Different types of exercise may affect functional brain networks uniquely. Top-down exercise, such as skill-based exercise, may affect the CEN, whereas bottom-up exercise, such as aerobic exercise, may affect the DMN more.

SECTION 4: EXERCISE AND COGNITION

Lesson 1: Exercise Variables and Cognition

Introduction to Section 4: Exercise and Cognition

Section 4 is divided into **3 lessons**. This section identifies the effects of exercise at the **behavioral**-level, specifically **cognition**. You are currently in **Lesson 1**, which will give you a brief overview of the different types of exercise and the **minimum recommended levels** of physical activity. Lesson 2 will define specific **acute variables** in exercise and physical activity programming, and identify some of their potential interactions with cognition. Lesson 3 will define **Open and Closed skill activities**, and relate their potential differential effects on cognition and the brain.

By the end of Section 4, you will be able to define several modalities of exercise & their acute variables and classify activities as open or closed skills. You will learn about the Physical Activity Guidelines for Americans, which serves as a foundation for creating a brain health exercise and physical activity plan (BH-EPAP). Specific modalities of exercise and their effects on the brain will be explored in Section 5.

Lesson Objectives

1. Identify the generalized effects of exercise on cognition and the brain.
2. Identify the different types of exercise and physical activity.
3. Identify the exercise and physical activity guidelines that generally include cognitive and brain health benefits.

Introduction

We have discussed in detail how exercise may effect brain structures, networks, and influence the related neural mechanisms of change. This module will elaborate on how different types of **exercise and physical activity** can **affect certain cognitive domains**.

1. As with most topics on exercise and the brain, **more research** is needed to replicate findings and explore the nuances within the exercise-cognition interaction.

2. In addition, **research is inherently complicated**. One research study may claim cognitive benefits of one type of exercise, only to be criticized for a lack of significance in the results, or issues with research design or data analysis.

3. This may **confuse** the well-meaning health and wellness professional, as they encounter **contradictory messages** from different research findings.

4. Finally, many variables including age, gender, comorbidities, cognitive status, prior levels of fitness, and other demographics also affect how an individual responds to certain interventions. **Individual differences and acute variables must be considered**.

Exercise and Cognition

Watch the video below for an overview of the section, “Exercise and Cognition”

VIEW ON VIMEO >

The Role of Multimodal & Cognitively-Demanding BH-EPAPs

Aerobic Exercise seems to improve the **majority** of the cognitive domains involving attention, executive function, **memory**, and information processing, although to what significance requires more research.

In order to theoretically emphasize the **enhancement** of one or more of these cognitive domains specifically, we may 'layer' **skill** training, **resistance** training, **motor** training, and/or **coordinative demands** in addition to aerobic training, or **simultaneously** combine some of these modalities to create a **multimodal** approach to cognitive and brain health.

Minimum Required Exercise Dosage

At all times, we want to be confident that an individualized EPAP that meets certain minimum requirements will lead to cognitive benefits for an individual, likely in multiple domains, more than if that individual did not have an EPAP that met these requirements.

According to the *Physical Activity Guidelines for Americans, 2nd Edition*, the minimum requirements of exercise and physical activity to glean a variety of health benefits, including cognitive benefits, are as follows:

> "For substantial health benefits, adults should do at least:
>
> **150 minutes** (2 hours and 30 minutes) to **300 minutes** (5 hours) a week of **moderate intensity**
>
> **-- or --**
>
> **75 minutes** (1 hour and 15 minutes) to **150 minutes** (2 hours and 30 minutes) a week of **vigorous-intensity** aerobic physical activity
>
> **-- or --**
>
> An equivalent combination of moderate- and vigorous-intensity aerobic activity. Preferably, **aerobic activity** should be **spread** throughout the week."
>
> - *Physical Activity Guidelines for Americans, 2nd Edition*

Click the button to the right to download the **Physical Activity Guidelines**

PA GUIDELINES

Additional Health Benefits

- **Additional** health benefits are gained by engaging in physical activity **beyond** the equivalent of 300 minutes (5 hours) of moderate-intensity physical activity a week.

- Adults should also do **muscle-strengthening** activities of **moderate** or greater intensity that involve all **major** muscle groups on **2 or more** days a week, as these activities provide additional health benefits.

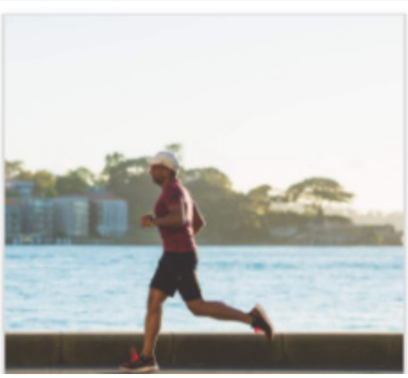
- Additional benefits have been noted by adding **neuromotor training**, which we refer to as **motor and coordination training**, which includes **balance, hand-eye** coordination, **coordinative** exercise, and dual-task training.

Categories of Exercise and Physical Activity

There are **various** types of exercise and physical activity that health and wellness professionals should consider. By considering various types of exercise, HWPs have a higher chance of finding something that meets client preferences.

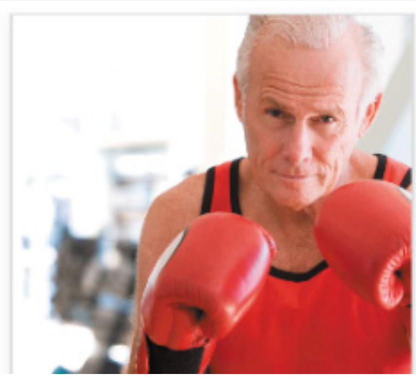
Varying exercise also enhances EPAPs and can increase enriched experiences. This course covers four modalities of exercise that are used as part of a variable Brain Health Exercise and Physical Activity Plan (BH-EPAP).

Primary modalities of exercise



Cardiovascular Exercise

Resistance Exercise



(Neuro)Motor & Coordinative Training

Knowledge Check

Select the minimum required dosage of exercise & physical activity (or equivalent) assumed to provide cognitive (not mental health) benefits as currently understood:

Record your answer here for future reference.

- ○ 150 minutes of low intensity physical activity
- ○ 150 minutes of moderate-vigorous activity
- ○ 75 minutes of moderate intensity activity
- ○ 75 minutes of low intensity activity

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] The primary categories of exercise and physical activity include Aerobic (or Cardiovascular) Exercise, Resistance (or Strength) Training, and Motor (Coordinative or Neuromotor) Training.
- [ ] The Physical Activity Guidelines for Americans recommends 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity exercise, with additional benefits for strength training and neuromotor training. These guidelins include cognitive and brain benefits.
- [ ] A recent systematic review suggests that 52 hours of exercise was required to achieve significant improvements in executive functioning and processing speed in older adults with and without cognitive impairments.

Lesson 2: Acute Variables

Lesson 2 Objectives

1. Identify how frequency, intensity, duration, time, and type of exercise play a role in a BH-EPAP.
2. Differentiate between open skill and closed skill activities.

Acute Variables

Frequency, duration, type (or modality), intensity, and training **volume** will also have differential effects on cognitive outcomes of exercise. Given this, it is hard to describe a clear relationship between EPAPs -- when combined with specific variables and highly varied **individual differences** -- and cognitive outcomes.

Since no guarantee can be made, the only recourse is to use information that has been published so far to create an EPAP that is **evidence-based**, and when evidence may be lacking, **evidence-led**.

Key Terms Knowledge Check

Match the acute variables of exercise and physical activity term to the definitions.

Record your answers here for future reference.

How often sessions are repeated .... ______________________

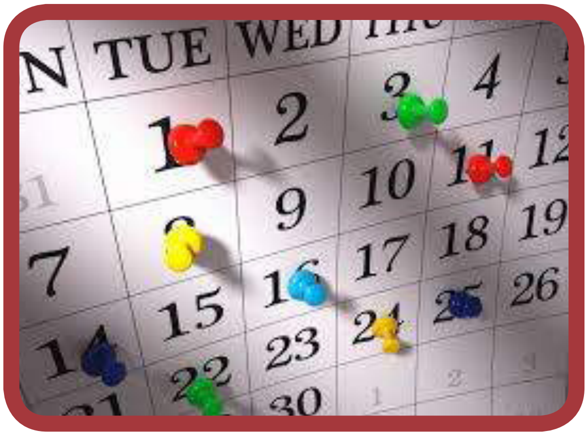
The metabolic or neuromuscular elicited .... ______________________

The style(s) or type(s) of exercise selected .... ______________________

Either the number of minutes in a session or the weeks/months within an intervention .... ______________________

Session Frequency

Session Frequency often refers to how many structured exercise sessions **per week** are performed. However, frequency may also refer to the **daily frequency** of physical activity. **Timing** within a single day (i.e. when exercise or physical activity is performed) may also modify have the brain is affected by interacting with **circadian rhythms (biological clocks)**.



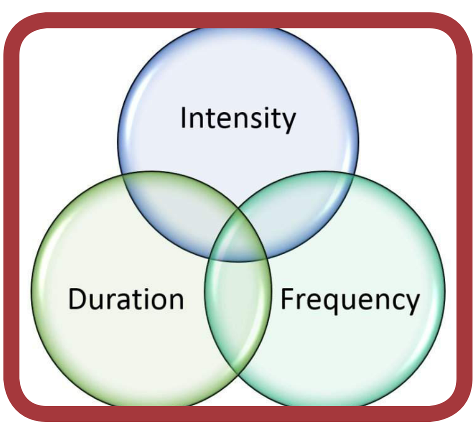
When using a single modality exercise, a person may require a **minimum of 2 days per week** per modality to sustain beneficial cognitive effects, but this is not always the case.

For example, performing cardiovascular exercise twice per week is certainly better than no exercise at all, and walking is certainly better than no physical activity.

However, we want to **encourage clients to reach the minimum required recommendations** for exercise in a stepwise and personalized manner.

Multi-component exercise programs seem to be more beneficial on cognition, and in the prevention of cognitive decline in populations without cognitive impairments. Organizing a multi-modal exercise program can be **time-consuming,** and therefore HWPs should ask the client to perform the exercise in a way that is most convenient for them.

For example, a client may prefer to spend **60 minutes** exercising, with **30 minutes** dedicated to **cardiovascular** exercise and **30 minutes** dedicated to **resistance** training, rather than performing two separate 60-minute sessions of each respective modality on different days.



Depending on the cognitive status of the client, a **greater frequency** of sessions may be more important for cognition than longer, less-frequent sessions.

For example, **3 sessions per week** consisting of **30 minutes** of exercise each may be more beneficial than 90 minutes of exercise 1 day per week. Greater frequency may also contribute to better **mental health** outcomes.

While most clients will desire to adopt an EPAP that range from **2-3 days per week** on average, the HWP should seek opportunities to encourage greater frequency based on the level of **willingness** and motivation of the client.

Contextualizing the potential brain health benefits of doing so may motivate clients to increase their exercise **frequency**, which in turn may contribute to a variety of other physiological and behavioral benefits.

Intensity

Intensity refers to the **metabolic**, cardiovascular, muscular, and/or **neurological effort** elicited in exercise or physical activity interventions. In research, exercise intensity is most commonly a measure of cardiovascular demands, based upon a percentage of VO2 Max, “Zones”, Max Heart Rate, or **Rate of Perceived Exertion (RPE)**. Therefore, a majority of the levels of intensity presented in this section are associated with cardiovascular demands.

Low Intensity

Low-intensity exercise is typically categorized as **40-54% of Max Heart Rate**, Zone 1, or from **1-3 / 10 of the RPE** scale. Low-intensity exercise can be helpful by adding **variability** to an EPAP, especially in the context of “rest-days” throughout the week. In addition, lower intensity modalities may help in the management of elevated cortisol levels and other **inflammatory biomarkers**.

Lower intensities are valuable in the context of managing chronic diseases and **rehabilitation** settings, especially when cognitive demands are greater, such as in the context of motor-learning, **dual-tasking**, and corrective exercise.

Low-intensity exercise can have many benefits. **Lower intensities** are most common in activities such as walking, gardening, **mind-body exercise**, balance training, restorative movement practices, and certain forms of **neuromotor training**.

Lower intensity and mind-body modalities, such as **Tai Chi,** certain forms of **yoga**, and walking, have been found to have a variety of benefits on cognitive and mental health outcomes depending on the frequency and **population**. For example, a recent systematic review* found that **yoga** at a frequency of approximately **2.5 times per week or more** led to significant improvements in **depressive symptoms**.

Brinsley, J., Schuch, F., Lederman, O., Girard, D., Smout, M., Immink, M. A., ... & Rosenbaum, S. (2020). Effects of yoga on depressive symptoms in people with mental disorders: a systematic review and meta-analysis. British Journal of Sports Medicine.

Moderate Intensity

Moderate-intensity exercise is typically categorized as **55-69% of Max Heart Rate**, Zone 2, or from **4-6 / 10 of the RPE** scale. Moderate-intensity exercise is likely the most **common** intensity that is adopted across most exercise modalities. Research continues to demonstrate the benefits of moderate-intensity exercise, especially in the context of cognition and mental health.

Moderate intensities are most **realistic** for a majority of the population to achieve (including those with chronic conditions) and serve as an excellent measure in which to **compare** the subjective experiences of both lower and higher intensities. Moderate intensity exercise may also be viewed as the most "**behaviorally sustainable**" intensity that would contribute to the greatest cognitive and mental benefits over time.

High Intensity

High-intensity exercise is typically categorized as **70% of Max Heart Rate** or greater, Zone 3-4, or from **7-10 / 10 of the RPE scale**. The adoption of higher intensity exercise modalities continues to be **adopted** in the fitness and scientific communities, primarily due to their metabolic benefits. Higher intensity exercise also has its own **unique risks and benefits** in the context of brain health.

It is common that as clients age, they may be **averse** to higher intensities of exercise, likely due to a combination of reasons, such as societal perspective, personal beliefs, fear of injury, or **aversion to effort**. Clients may also present with low-to-moderate intensity exercise **routines** that have gone unchanged for several years. These types of clients likely need **higher intensities** of exercise within their EPAP.

Individuals who primarily adopt higher intensity modalities of exercise should consider incorporating **both low and moderate intensities**. Higher intensities can increase the presence of circulating inflammatory markers such as **IL-6** (while still having beneficial effects on other biomarkers), affect the **HPA axis**, and in some cases modify mental health outcomes.

In terms of cognition, higher intensities of exercise have been found to increase **brain processing speed**, perhaps due to increased neuromuscular output and/or the increased processing speed demands of higher intensity training regimens. Considering that **processing speed declines with normal aging**, it behooves the HWP to incorporate higher intensity training strategically into an EPAP.

Duration of Interventions

The duration of an EPAP intervention (**not to be confused with session duration**) refers to how many weeks, months, or years it may be adhered to or planned for.

A recent systematic review found that regardless of exercise modality and intensity, **52 hours of the exercise** was required to achieve significant improvements in **processing speed, executive functioning, and global cognition in older adults***. 52 hours is an interesting number to arrive upon, and it can be split up in any number of ways, including:

- 5 days per week of 60-minute sessions (**300 minutes per week**) for approximately **3 months**
- 5 days per week of 30-minute sessions (**150 minutes per week**) for approximately **5-6 months**
- 3 days per week of two 60 minute sessions & one 30 minute session (**150 minutes per week**) for approximately **5-6 months**
- 2 days per week of 30-minute sessions (**60 minutes per week**) for approximately **12 months**

**Gomes-Osman, J., Cabral, D. F., Morris, T. P., McInerney, K., Cahalin, L. P., Rundek, T., ... & Pascual-Leone, A. (2018). Exercise for cognitive brain health in aging: A systematic review for an evaluation of dose. Neurology: clinical practice, 8(3), 257-265.*

A common question for HWPs and clients alike include "**how soon until I see results?**" While this is highly individual and depends upon the variables within an EPAP, one may be able to answer this question confidently by referring to the "52 hours research" above. Most interventions that study the effects of exercise on cognition, especially those that integrate more novel interventions (such as exergaming or cognitive-motor training) seem to be for **3 months (12 weeks)**.

Of course, individuals may experience subjective changes in mood and cognition earlier than that, anywhere from **1 month**, to feeling the acute benefits of exercise after a single session.

Modality (Type) of Exercise

More research is beginning to highlight the possible differential effects of various modalities of exercise on brain health. The next module, "**Modalities of Exercise and Cognition**", will focus on detailing the differential effects of multiple exercise modalities on various brain health outcomes.

Varying exercise modalities within an EPAP should be approached with both enthusiasm and caution. Too much variety to an EPAP, or too much **deviation** from what a client has found to be **routine**, can be disruptive and sometimes upsetting to certain clients.

However, **enriching** an EPAP with greater **variety** may allow for greater brain health benefits when compared to a single modality. Below are some examples of **scenarios** in which exercise **modality variability** should be considered:

- A client only performs **aerobic** exercise **twice** per week. **Adding resistance training** to this program would be a logical modification
- A client performs **resistance** training but rarely gets their **heart rate** up. Adding **aerobic** exercise to this program would be indicated.
- A client performs both **aerobic** exercise and **resistance** training on **machines**, mostly while watching television. Adding **skill-based** or **motor** training to this program would add more **cognitive load**.

Within-Modality Variability

Incorporating novelty and variability into a program can be done by introducing new **techniques**, new **modalities** (a different type of aerobic training, martial arts, or dance, for example), and by changing **variables** (such as duration, intensity, and exercise order).

In addition, varying **sub-modalities** (a variation of an existing modality) of exercise would allow a client to experience program **variability** without drastically changing the modality itself. For example:

- A client that engages in **moderate, continuous aerobic** exercise is encouraged to incorporate high-intensity interval training (**HIIT**).
- A client that uses exercise **machines** for resistance training is introduced to **functional** training.
- A client engages in tennis, strength training, and HIIT training. Incorporating **mind-body exercise** may be indicated.

Knowledge Check

52 Hours of Exercise, 150 Min/Week, or Multimodal Program? Match the acute variable to these effects on cognition.

Record your answers here for future reference.

Executive Functions & Processing Speed .... ____________________

Minimum Recommendations .... ____________________

More Effective in Slowing Decline .... ____________________

Moderators that May Impact Cognitive Outcomes of Exercise Interventions

More research continues to shed light as to whether **moderating variables** may influence the significance of the benefits that exercise may have on the brain. A **moderator**, in short, is **another variable that can change the strength of an effect**, or not. For example, one may assume that **mood** is a strong **moderator** of exercise on **brain health**, but this is debated. In fact, we lack a clear understanding as to whether or not physical activity and mood **inter-related**, and if so, to what effect?

While this a more complex topic, it may be helpful to consider some of the **variables** that may **impact** the brain health **outcomes** of exercise interventions, even if we do not completely know to what degree. These include: **Sleep, Mood, Medication(s), Comorbidities, Stress Levels, Enjoyment of Activity, Educational Attainment, Demographics, Socioeconomics, Location** (i.e. Weather), **Socialization**, and **Music**.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Frequency, intensity, type, skill demands, duration, and intervention length are all acute variables that may modify the cognitive, mental, and neurological effects of exercise and physical activity.
- ☐ 52 hours of exercise over a reasonable length of time has been shown to significantly improve processing speed and executive functioning in older adults with and without cognitive impairments, regardless of exercise modality.
- ☐ Chronic exercise (aerobic and/or multimodal exercise) that occurs over several months at a moderate-vigorous intensity of moderate duration has strong evidence for enhancing neuroplasticity, cognition, wellbeing, mental health, and counteracts neurodegeneration.
- ☐ A larger variety of variables, mediators, and moderators may affect the cognitive, mental, and neurological outcomes of exercise and physical activity interventions.

Lesson 3: Open vs Closed Skills

Lesson 3 Objectives

1. Define open skills and closed skills as they relate to exercise and physical activity.
2. Differentiate the benefits and programmatic roles of open versus closed skills.
3. Identify examples of how to modify exercises to be a more open or closed skill.

The Effects of Physical Activity on the Brain

Regular participation in **physical activity** and **exercise** has been correlated with positive changes in **brain structure** and **volume** (such as an increase in **white matter volume** increases in **parietal, hippocampal**, and **basal ganglia volume**) and improvement in a wide **range** of **cognitive functions** in **older adults**.

While participation in **any** physical **activity** has cognitive **benefits** over **little-to-no** physical activity, **certain types** of physical activity may have **selective** and additional **beneficial effects** on **cognition**.

Open versus Closed Skills

Watch the video below to learn more about the definitions, differences, and benefits of both open and closed skills.

VIEW ON VIMEO >

OPEN SKILLS: Open skills are **goal-oriented** movements in which temporal and/or spatial **accuracy** is important for achieving predetermined objectives, mostly **novel** activities.

These open skills are more unpredictable with dynamically changing demands. An environment like this requires the use of more executive functions.

Open Skill
Dynamic Environment
Object manipulation Space parameters not fixed Time parameters not fixed Group Performance High Inter-trial variability Simultaneous oppositional performance Dual/Multi-task

Closed Skill
Static environment
Fixed apparatus/no object manipulation Defined space Defined time Individual performance High Inter-trial consistency Sequential opposition performance

CLOSED SKILLS: Closed skills refer to skills within environments that **do not** constantly **change**, and are relatively **stable** and **predictable**. When a certain level of motor planning is allowed, there is **less** of a **dynamic** nature involved in these tasks.

These include **routines**, **learned** motor **skills**, or **repetitive** movements and sequences. Examples include **aerobic** exercise, golf swings, and **routines** of dance or martial arts.

"Open vs. Closed Skills." IDTS, www.danceteachingstandards.com/blog/blog/open-vs-closed-skills.

Are Leisure Activities Cognitively Demanding?

Leisure activities include a broad range of **physical activities**. They can include **sports**, outdoor activities, **games**, and other activities associated with leisure time.

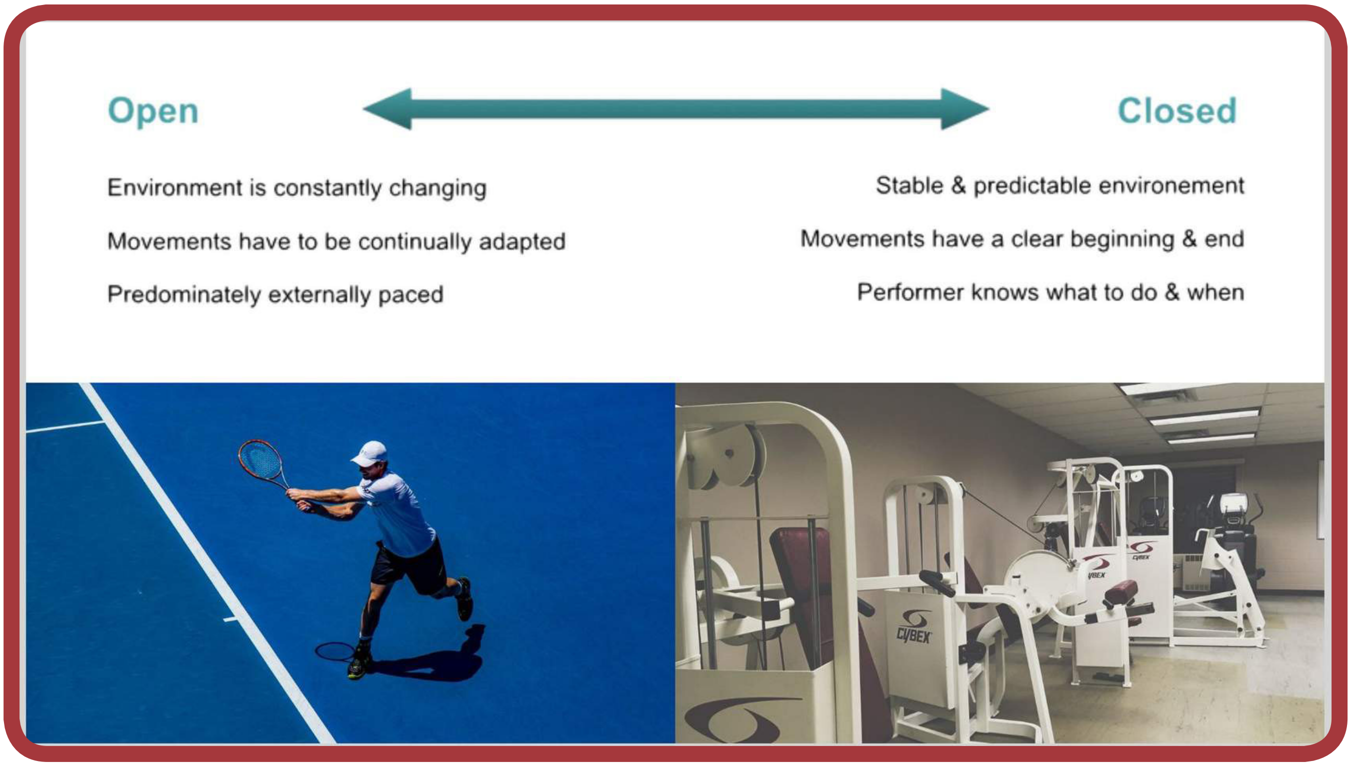
- Due to the **variability** of these activities, it is difficult to identify the specific cognitive effects of the "**leisure time**" category as a whole. However, categorizing activities as **open** or **closed skills** can help to elucidate their potential **cognitive benefits**.

- Leisure activities often include **skill demands** that involve **objects** such as **racquets**, and paddles (tennis, golf, badminton, ping pong, pickleball, etc), **balls** (soccer, football, basketball, etc), **moving persons**, and/or **unpredictability**. These skill demands classify these activities as **open skill** training.

- These leisure activities are not typically high-**frequency**, high-**challenge**, or variable after a certain period of time, as individuals may **adapt** to them. However, this does not mean that they are not beneficial for cognition. In addition, an individual's **enjoyment & social support** within these activities may **support** brain health.

The "Spectrum" of Skill

Open and closed skills are on a spectrum, are not binary classifications. While it is possible to classify an activity as "closed" or "open", it might better serve HWPs to place specific activities on the "**skill spectrum**." Recognizing that both sides of the spectrum offer value, a goal of a BH-EPAP might be to "populate" as many regions of the spectrum as possible for **novelty** and **variability** of activities and their cognitive characteristics.



The Spectrum of Open vs. Closed Skills

Knowledge Check

Do the terms below describe Open or Closed Skills?

Record your answers here for future reference.

Manipulation of objects (rackets, balls, functional training tools, etc) .... ________________

Dynamic and unpredictable .... ________________

Usually associated with group or social constructs .... ________________

Using a machine or fixed apparatus .... ________________

Sport skills in predictable practice settings .... ________________

Usually involves a single individual.................................... ________________

High degrees of variability .... ________________

Changing variables associated with timing & direction .... ________________

Dual-tasking & Cognitive-Physical Training .... ________________

Consistent trials .... ________________

Variables of time and direction are defined .... ________________

Sports, Dance or Martial Arts in performance settings .... ________________

Sequences, routines, & procedures .... ________________

Single, focused task .... ________________

Cognitive Effects of Open vs. Closed Skills

Certain types of physical activity may have selectively beneficial effects on cognition.

Older adults participating in **open** skill activities may improve **executive functions**, such as inhibitory control, **visual attention**, and cognitive flexibility

Older adults participating in **closed** skill activities may improve **selective attention** and **visuospatial** perception.

According to the **Copenhagen City Heart Study**, those who participated in sporting activities, particularly **racquet sports**, had **greater longevity** when compared to gym activities (weights, aerobics), perhaps due to the **social & cognitive components** of open skill activities.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Open skills are **goal-oriented** movements in which temporal and/or spatial **accuracy** is important for achieving predetermined objectives, mostly **novel** activities.
- ☐ Closed skills refer to skills within environments that **do not** constantly **change**, and are relatively **stable** and **predictable**. When a certain level of motor planning is allowed, there is **less** of a **dynamic** nature involved in these tasks.
- ☐ **Physical activity**, whether an open or closed skill, has **benefits** on **cognition** in older adults when **compared** with **little-to-no** physical activity participation.
- ☐ There may be some potential **additional benefits** provided as a result of participation in **open-skill** physical activities for **certain cognitive abilities**.

SECTION 5: Modalities of Exercise and Cognition

Lesson 1: Aerobic Exercise

Introduction to Section 5: Modalities of Exercise and Cognition

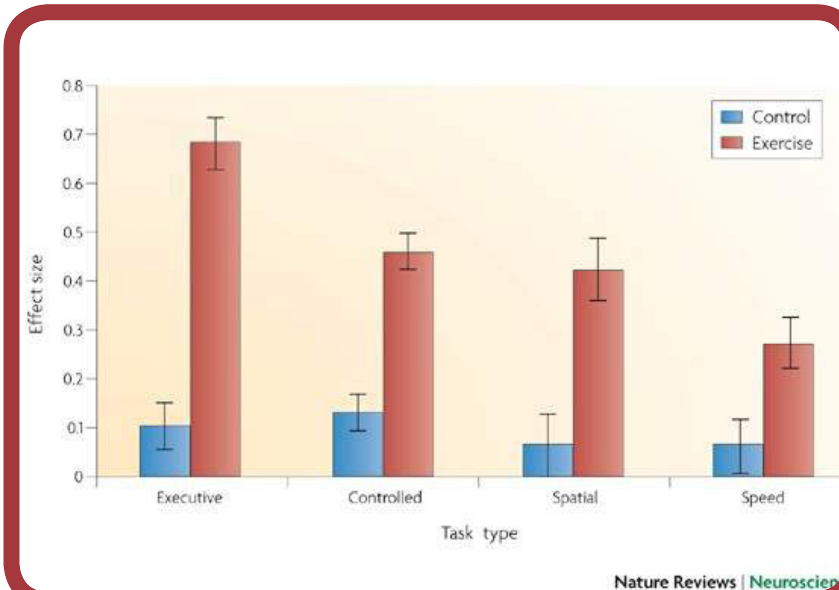
Section 5 is divided into **5 lessons**. This section identifies the effects of certain exercise **modalities** on **cognition** and **brain health**. You are currently in **Lesson 1**, which will give you a comprehensive overview of the effects of **aerobic** exercise and **physical activity** on the brain and cognition. Lesson 2 will focus on the effects of **resistance** and strength training on the brain, while Lesson 3 will focus on the effects of **neuromotor** (motor & coordinative) training. Lesson 4 will define **multimodal** exercise programming and how combining multiple modalities of exercise may affect the brain. Lesson 5 will define **dual-tasking**, detailing how it can be assessed and trained.

By the end of Section 5, you will have an in-depth understanding of how different exercise modalities affect the brain at multiple levels. You will also gain an understanding of how aerobic exercise, resistance training, neuromotor training, multimodal exercise, and dual-tasking can all affect the brain in both shared and unique ways. At the end of Section 5, you will be presented with a quiz that will you need to score at least 70% on in order to progress through the course.

Lesson Objectives

1. Identify the shared and differential effects of various exercise modalities on the brain and cognition.
2. Define the unique mechanisms underlying the effects of each modality on the central nervous system.
3. Relate the benefits of each exercise modality and understand how to combine them in creating a variable BH-EPAP.

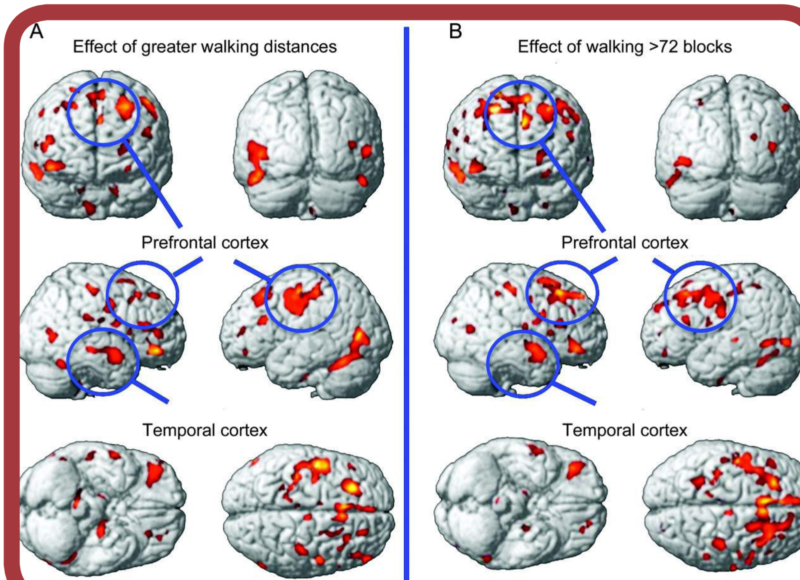
Aerobic Exercise & Cognition



Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. Nature reviews neuroscience, 9(1), 58-65.

Aerobic (or cardiovascular) exercise is the **most studied** modality of exercise in relation to cognition and brain health. Cardiovascular exercise serves as a "**foundation**" for improving cognition and brain health. An EPAP without cardiovascular exercise is less likely to produce **long-term** brain health **benefits** and **significant improvements in** cognition as shown in the image on the left-hand side.

Physical Activity versus Exercise

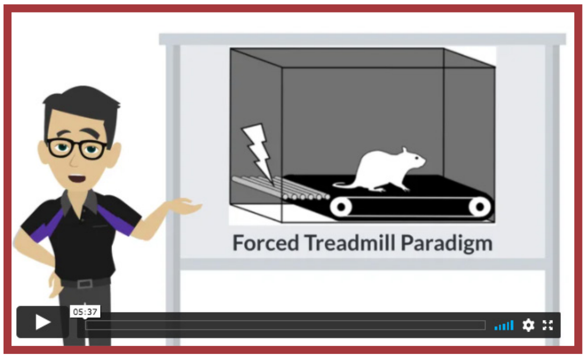


It is important to separate **physical activity** from **exercise** in an EPAP when creating a brain health outcome plan. **Physical activity** is **any form** of movement or **activity** that occurs throughout **daily life**, whereas **exercise** is an intentional, **structured**, and **planned movement**. Clients may argue that **physical activity** is **equivalent** to **aerobic exercise**. However, they may not be reaching the levels of **cardiovascular demands** that trigger the **beneficial mechanisms** underlying **brain health** (such as **intensity**).

It is important to note that **walking** (considered **both exercise & physical activity**, depending on the context) has been found to improve **cerebral blood flow** and is correlated to larger **hippocampal, frontal & occipital volumes**. It is important to encourage clients to **maintain** or **increase** their existing levels of **physical activity** (which is still beneficial for brain health) while finding **opportunities** to **promote exercise**.

Aerobic Exercise & The Brain

Watch the video below to learn more about aerobic exercise and the various effects that it can have on brain function & structure.



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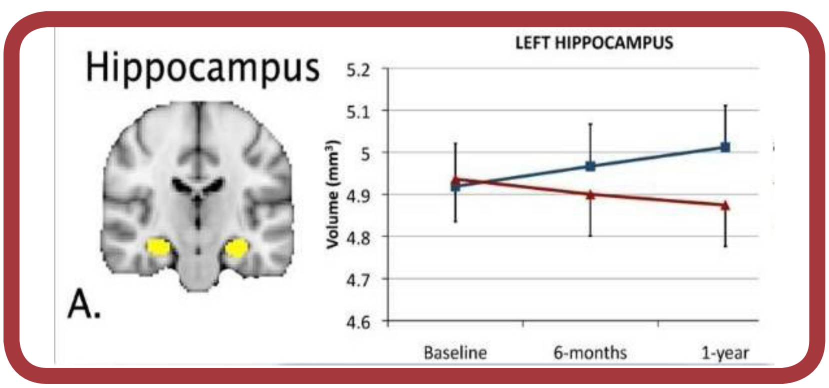
Cardiovascular Exercise & Memory



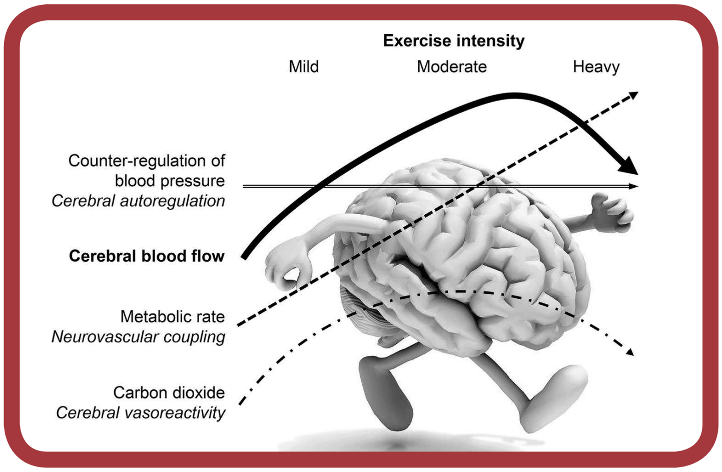
Blue = Aerobic Exercise Group
Red = Stretching Control Group

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., ... & Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. Proceedings of the National Academy of Sciences, 108(7), 3017-3022.

Cardiovascular training has demonstrated an impact on **hippocampus size** and **function**. Given the clear role that the hippocampus plays in memory, it is safe to assume that cardiovascular training can improve **memory**. In addition, cardiovascular training causes **micro-level changes** in brain **metabolism** and **neurotransmitter** regulation. These changes also potentially explain improvements in memory.

What About HIIT Training?

High-Intensity Interval Training (**HIIT**) continues to gain scientific and mainstream adoption. While HIIT training should not be considered "the best" form of exercise for brain health, it is helpful to acknowledge some of the **potential unique benefits** of HIIT training on the brain, such as **increased cerebral blood flow**, although more research is needed.

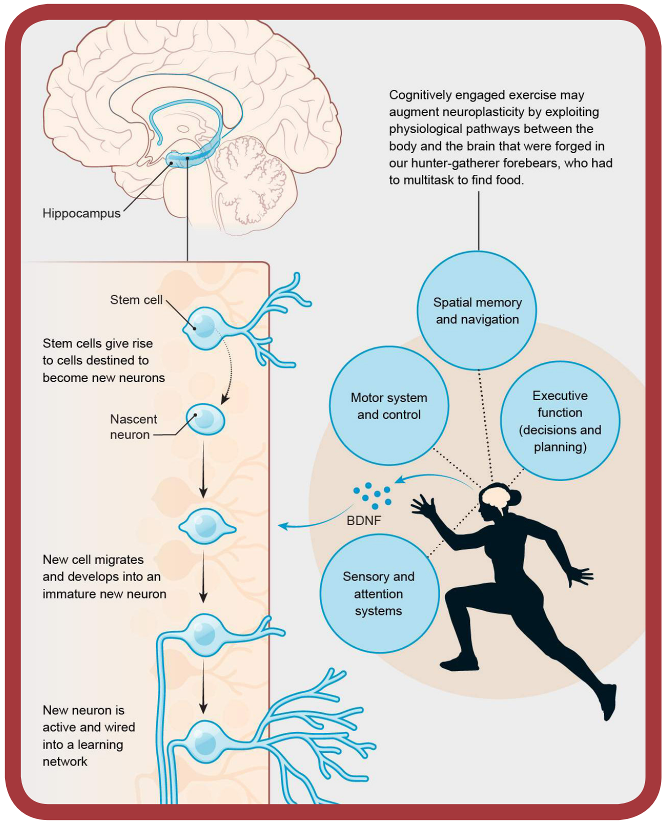


Tan, C. O., Meehan, W. P., Iverson, G. L., & Taylor, J. A. (2014). Cerebrovascular regulation, exercise, and mild traumatic brain injury. Neurology, 83(18), 1665-1672.

- HIIT training may increase the **plasticity** of the motor cortex and **corticospinal excitability** more so than moderate-intensity exercise
- HIIT may oxidize fat and increase **VO2max**, release higher levels of circulating **lactate**, and may increase higher levels of **BDNF** expression when compared to continuous exercise
- HIIT may cause transient changes in the levels of **glutamate** and **GABA** due to lactate production, which may influence **cognition**
- More research is needed to determine if HIIT is superior for certain aspects of brain health, but likely has **differential biochemical effects** that benefit brain health.

Open vs. Closed Skill Aerobic Exercise

Aerobic exercise is often conducted on **cardio machines**, and this **predictable** mode of training makes this a form of **closed skill** training. However, **open skill** aerobic exercise, such as hiking or **sports** activities, may **increase cognitive demands**. Exercise techniques may also include bodyweight, **metabolically-demanding movements** involving **coordination**, and **cognitive demands**, which may **differentially** affect the brain compared to **closed-skill** aerobic activities. Aerobic exercise combined with cognitive demands may affect **neuronal survival and integration**, as shown in the image on the left and as described by the **Adaptive Capacity Model**, which is explained in **Lesson 5**.



Raichlen, D. A., & Alexander, G. E. (2017). Adaptive capacity: an evolutionary neuroscience model linking exercise, cognition, and brain health. Trends in neurosciences, 40(7), 408-421.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Aerobic exercise can facilitate **neurogenesis**, **angiogenesis**, and **synaptogenesis** via the release of **growth factors**, such as **BDNF** and **VEGF**. These **micro-level** changes can lead to increases in **brain function** and **volume**, such as seen in increased **hippocampal** volumes.
- ☐ The **cognitive** effects of **aerobic** exercise may be **global** and/or **selective**, and this is not yet conclusive. Aerobic exercise has been found to benefit **global cognition**, as well as specific types of **memory, executive functioning**, and **attention**, but more research is needed.
- ☐ The **significant** effects of aerobic exercise on **executive functioning** is **debated**, as aerobic exercise does not typically possess characteristics that are likely to **demand executive functions** when compared to **open skills** or more **cognitively demanding** activities.

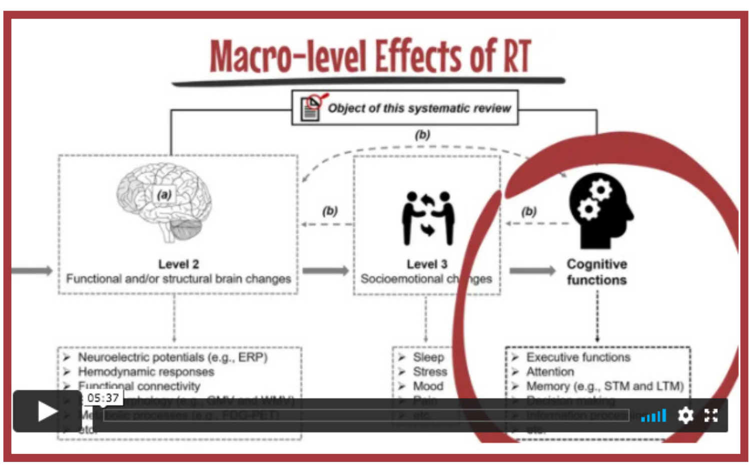
Lesson 2: Resistance Training

Lesson 2 Objectives

1. Identify the multi-level benefits of resistance training on the brain
2. Differentiate open versus closed skill resistance training
3. Identify the acute variables associated with resistance training that can modify the outcomes of a BH-EPAP

Resistance Training

Watch the video below to learn about Resistance Training (RT) and its effects on the brain structure, cognition, and various growth factors.



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Open Skill Resistance Training

Open Skill Resistance Training is associated with **unconventional** movement patterns with an external load, often referred to as "**functional training**". This type of training often includes greater degrees of **motor learning** and movement **variability**. Resistance exercises that are **novel** and **open skill** may differentially affect **cognition** in comparison to more traditional, **closed-skill** RT.

Acute Variables in Resistance Training

Different acute **variables** within a resistance training program may further **modify** the resulting cognitive outcomes. While more research is needed, certain variable modifications might include the following examples.

- Greater movement **intensity**, especially in **interval** formats, or **power** training may be more likely to improve **processing speed**.
- Greater movement **complexity**, such as is found with **coordinative** demands, may be more likely to have higher **attentional** demands and **executive functioning** demands.
- Greater reliance on **choreography** or **sequences** may be more likely to have higher short-term (**working**) and **spatial memory** demands.

When attempting to **progress** to more **complex** resistance training, or add **novel**, loaded movement patterns, it is a sound strategy to plan for **incorporating** novel movements into an EPAP every **12-16 weeks**. Modifying or adding them in a **smaller time frame** may not allow for optimal **adaptation** (i.e. **motor learning**), and not modifying them enough may lead to increased **injury risk**.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] **Resistance training** (RT) is often **missing** in programs for **older adults**, yet is likely very important for **brain health**, in addition to the **management** of **musculoskeletal** conditions.

- [ ] RT has been found to release various **growth factors** via the **contraction** of **skeletal muscle** tissue, including **irisin, IGF-1,** and **BDNF**. RT has been found to positively affect the function and structure of the **frontal lobes** and the **hippocampus**.

- [ ] RT has a **unique set** of **cognitive demands** compared to other forms of exercise, and "**functional training**" that possesses more **open skill** characteristics may further **affect cognitive** outcomes.

- [ ] While RT has been found to affect **executive functioning**, likely due to its effects on the **frontal lobes**, it has also been found to address certain domains in **attention, memory,** and **information processing** with varying degrees of significance, as well as **global cognitive abilities**.

Lesson 3: Motor & Coordinative Training

Lesson 3 Objectives

1. Define neuromotor training, also known as motor & coordinative training.
2. Relate neuromotor training to open-skill activities
3. Identify the unique benefits of neuromotor training on the brain.

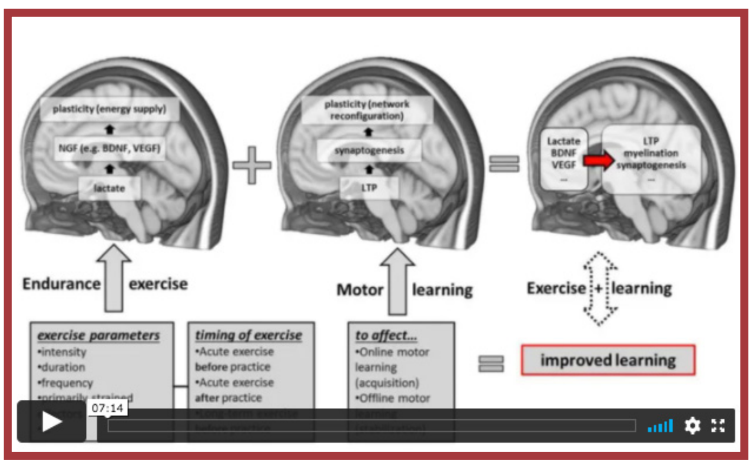
Neuromotor Training

Neuromotor training includes **hand-eye** coordination, **balancing** exercises, **leg arm** coordination, **spatial** orientation, and **reacting** to moving **objects** or **persons**. These different activities involve **different cognitive demands** and are often classified as **open-skill** activities.

Neuromotor training, which we refer to as **motor** or **coordinative training**, includes **goal-oriented motor** tasks, **coordinative** exercise, and **dual-task** training. This can lead to various **cognitive outcomes** depending on the specific **activity** and **variables** that it **possesses**.

Motor & Coordinative Training

Watch the video below to learn about the process of motor learning, and how they underly the modalities of motor and coordinative training, the different types of motor & coordinative exercise, and how it may affect brain health and cognition.



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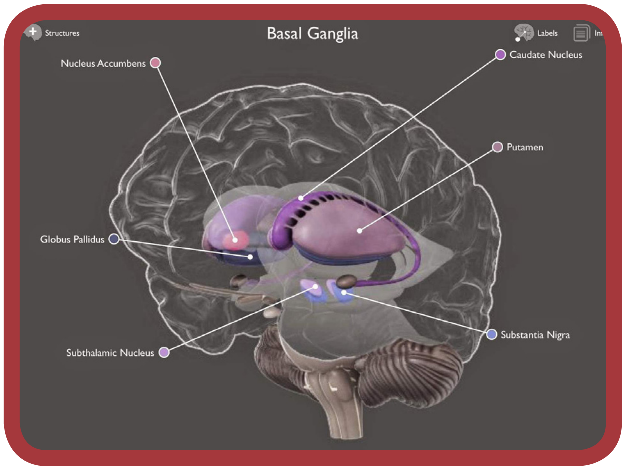
The Basal Ganglia & Motor Fitness

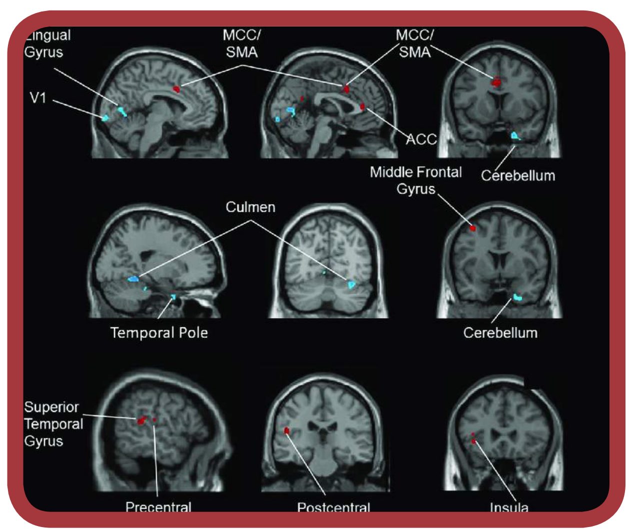


Niemann, C., Godde, B., Staudinger, U. M., & Voelcker-Rehage, C. (2014). Exercise-induced changes in basal ganglia volume and cognition in older adults. Neuroscience, 281, 147-163.

While aerobic exercise is the most studied form of fitness, research has demonstrated that higher **motor fitness & coordinative training** improves over **12 months** increases **volume** in certain areas of the **basal ganglia**, particularly the **caudate** and the **globus pallidus**, more than aerobic exercise and stretching. **Larger basal ganglia volumes** are also related to improved **executive functions**.

Dance Training & the Brain

Research has demonstrated the **dance training** consisting of **multiple forms** of dance in older adults can improve **brain volume** in certain areas of the brain responsible for **executive functions, long-term memory**, and **working memory** better than general sport and exercise training. Areas such as the **cerebellum** (shown in blue in the image on the right) increase in both **gray** and **white matter** in response to dance training. In addition, higher levels of **BDNF** were released after dance training in comparison to general sport & exercise.



Rehfeld, K., Lüders, A., Hökelmann, A., Lessmann, V., Kaufmann, J., Brigadski, T., ... & Müller, N. G. (2018). Dance training is superior to repetitive physical exercise in inducing brain plasticity in the elderly. PloS one, 13(7), e0196636.

Mind-Body Exercise & the Brain

Mind-Body Exercise

Mind-body exercise (referred to as "**MBE**") is a sub-domain of exercise that often includes **slower** and **lower-impact** movements that can be initiated in **sequences** or choreographies of **postures, stretches, movements**, and/or **breathing** patterns.

MBE can include elements of **rhythm, coordination, mindful awareness**, and **focus**. These integrated elements of MBE likely contribute to its **multifaceted benefits** on the **brain** and **body**.

MBE can include **yoga, TaiChi, QiGong, Pilates**, and other modalities that include such mind-body components.

Effects of MBE on the Brain

Areas of the brain responsible for **emotional regulation, executive functions** (higher-level cognitive processes), and **memory** are also positively affected by MBE.

Research demonstrates that forms of MBE can increase **gray matter volume** of **temporal, prefrontal**, and **limbic** brain regions.

In addition, various types of MBE including **yoga** and **TaiChi**, have been shown to improve **executive functioning, attention, memory**, & **language** abilities.

Mental Health Benefits of MBE

MBE also has been shown to have positive effects on **mental health**. For instance, MBE has been hypothesized to modify the activity of **connectivity** of brain regions involved in **mood** regulation and **depression**, such as areas of the **prefrontal cortex**, the **basal ganglia**, the **amygdala**, and regions in the **parietal** lobes.

MBE is also thought to have **anti-inflammatory** effects in the nervous system while regulating the **Autonomic Nervous System**. MBE seems to have a positive effect on the **Default Mode Network**, which is affected by various mental illnesses such as **depression** and **addiction**.

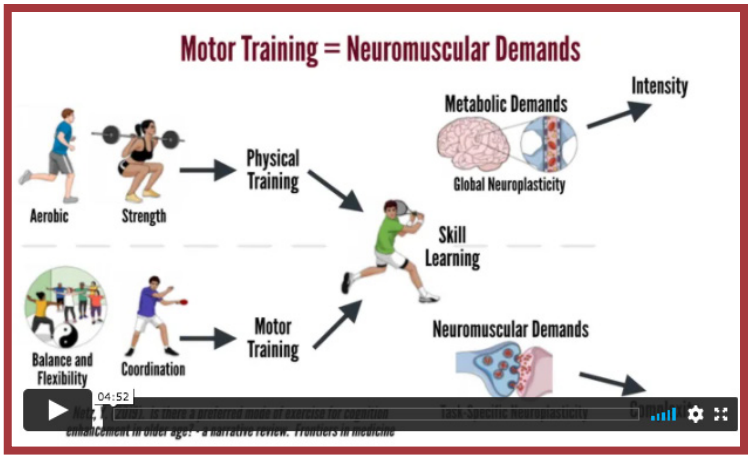
Summary of MBE

While more **research** is needed, the current evidence for MBE is both **convincing** and opportune. Comparative studies to further determine the **unique** benefits of **different** types of **MBE** are needed. In general, MBE could be **recommended** between **2-3 times per week**.

Such findings would **empower** HWPs to **program** and **recommend** MBE for clients and local communities for specific **cognitive** and **psychological** outcomes.

Motor Training vs. Metabolic Training

Watch the video below to learn about the similarities and differences between motor training and more “metabolic”-focused training, such as aerobic exercise and resistance training, and their shared and differential effects on the brain and cognition.



VIEW ON VIMEO >

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] **Motor** and **coordinative** training, which is derived from the “**neuromotor**” category of training, includes more **open skill** activities with components of **motor learning** present, such as **sports, dance, martial arts, mind-body exercise**, and **leisure activities**.

- [ ] Motor and coordinative training has been shown to affect various **domains** of **cognition**, including **executive functions**, and open skills exercises have been found to affect **certain aspects** of **cognition more than closed skills**. Some research has found **coordinative exercise** to **elicit superior cognitive benefits** in **healthy adults**.

- [ ] **Motor** and **coordination training in combination** with **aerobic** stimulus may facilitate improved **motor learning** via **synaptic plasticity**. Motor and coordinative training may increase the **function** and **structure** of the **cerebellum, basal ganglia & prefrontal cortices** more than other forms of exercise.

Lesson 4: Multimodal Exercise

Lesson 4 Objectives

1. Define multimodal training and its value in improving cognition and contributing to brain health goals.
2. Identify the unique cognitive and brain benefits of multimodal exercise programming.
3. Identify programmatic considerations for multimodal exercise programming.

Multimodal (Multi-component) Exercise

Multi-component exercise seems to hold the greatest promise for benefiting the widest range of cognitive abilities, addressing multiple physical adaptations, and ensuring EPAP variability over a period of time without excluding other modalities.

Multidomain, Multimodal, and Multi-component Training Programs are synonymous and refer to exercise sessions or programs with multiple modalities.

Multi-Component Exercise Variables

Multi-component Exercise Structure

A typical multi-component training program will **incorporate** balance, resistance, aerobic, and **neuromotor** training in a **single** session, or individual modalities across **multiple** sessions.

The results of this type of intervention have been demonstrated to yield a **breadth** of **cognitive benefits** and allow an individual to **glean** the **physical benefits** of each of the included modalities.

Volume Considerations

The **effects** of these programs depend on the **volume** of the overall multi-component training program, primarily in the relation to overall **metabolic, neuromuscular, & cognitive** demands.

Research has begun to observe the **differences** in the **effects** of multi-component **program variations** on cognitive function. For example, research might compare the effects of a **strength training & balance** program vs. an **aerobic & dual-task training** program.

Combinations of Modalities

While there are numerous **combinations** of modalities and various volumes that can be studied, and encouraging research continues to emerge, it may be too **early** to state the **cognitive benefits** of these various combinations, especially due to the high amount of **potential configurations**.

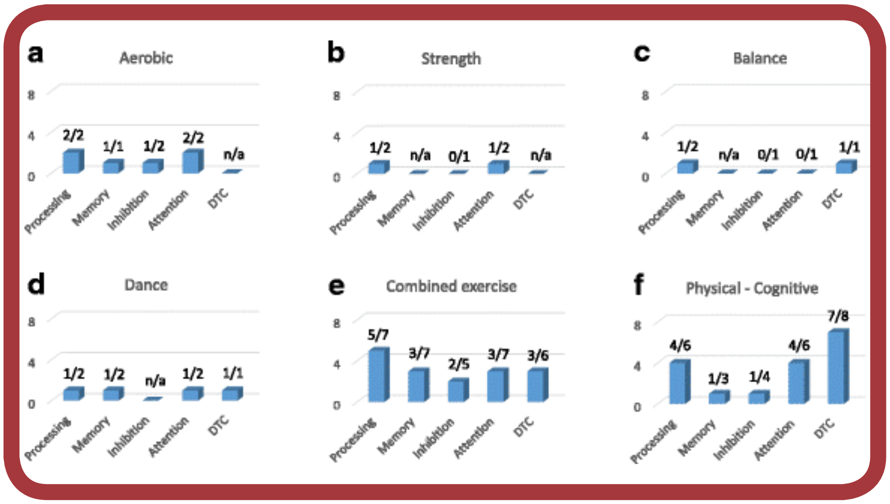
Summary

The multi-modal approach is exciting, as more research may allow health and wellness professionals to further **target** and **precisely** prescribe EPAPs for certain **brain health outcomes**.

In addition, the concept of **precision medicine** (which takes **individual biology** into account) creates fascinating possibilities for the application of **specific** exercise **programs** and the **manipulation** of their acute **variables**.

Multi-Component Training & Brain Health

Multi-modal exercise programs consist of various **beneficial characteristics** and **exercise types**. Multi-modal exercise programs often include both **aerobic** and **resistance** training components, and may or not include **neuromotor** aspects, although it is **recommended** to do so. Current exercise guidelines recommend the **practice** of **multiple exercise regimen**, and therefore **combining modalities** in **single** sessions or **separately** are strategies for meeting the recommended guidelines.



Levin, O., Netz, Y., & Ziv, G. (2017). The beneficial effects of different types of exercise interventions on motor and cognitive functions in older age: a systematic review. European Review of Aging and Physical Activity, 14(1), 1-23.

In a review of different types of exercise on motor and cognitive functions in older adults, **combined exercise** (multimodal exercise) was found to produce **superior cognitive outcomes** across multiple domains, alongside physical-cognitive (dual-task) training. The key points below summarize the potential individual contributions from each modality of exercise that may lead to this outcome.

- Aerobic exercise induces **cardio-metabolic** and respiratory changes in the body, which contributes to metabolically-related adaptations such as **angiogenesis** and increased **cerebral blood flow**. **Growth factors** such as **BDNF** are also released as a result of aerobic exercise.

- Resistance training also affects metabolic and **energetic processes**, both in shared and **unique pathways** in comparison to aerobic exercise. Resistance training also demands **intra-muscular coordination** & **differentially releases various growth factors** (such as **IGF-1 & irisin**)

- Both resistance and aerobic training may include aspects of coordination or **skill-learning**, but these both depend upon the **novelty** and **complexity** of the modality. Additional **neuromotor modalities** would theoretically enhance the **additive benefits** of such a program, such as adding **coordinative exercise**.

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Multimodal exercise programs consist of more than one modality of exercises, such as aerobic exercise, resistance training, and neuromotor training, across multiple sessions and/or within single exercise sessions.
- [ ] Research has demonstrated that a multimodal training program may benefit brain health and slow cognitive decline more than a singular modality of exercise.
- [ ] The nature of multimodal exercise may create more cognitive demands, and the "temporal ordering" of exercise modalities and stimuli may affect cognitive outcomes, although more research is needed.

Lesson 5: Multimodal Exercise

Lesson 5 Objectives

1. Define dual-tasking, dual-task ability, dual-task cost, and their relationship to aging, neurodegeneration, cognition, and functional abilities.
2. Identify how dual-task ability is assessed and calculated, as well as understand examples of dual-task interference.
3. Understand the science behind using combined cognitive and physical, or dual-task, training to enhance cognition.

Dual-Tasking

Watch the video below to learn more about dual-tasking, dual-task assessment, and dual-task training.

VIEW ON VIMEO >

Types of Dual-Task Training

In order to better classify interventions that include dual-tasking, it is helpful to specify what kinds of dual-tasks are included. The **4 types of dual-task training** below are based upon what, if any, technology is utilized, and what **physical** and/or **cognitive** assessment was utilized in the intervention in which it was studied.

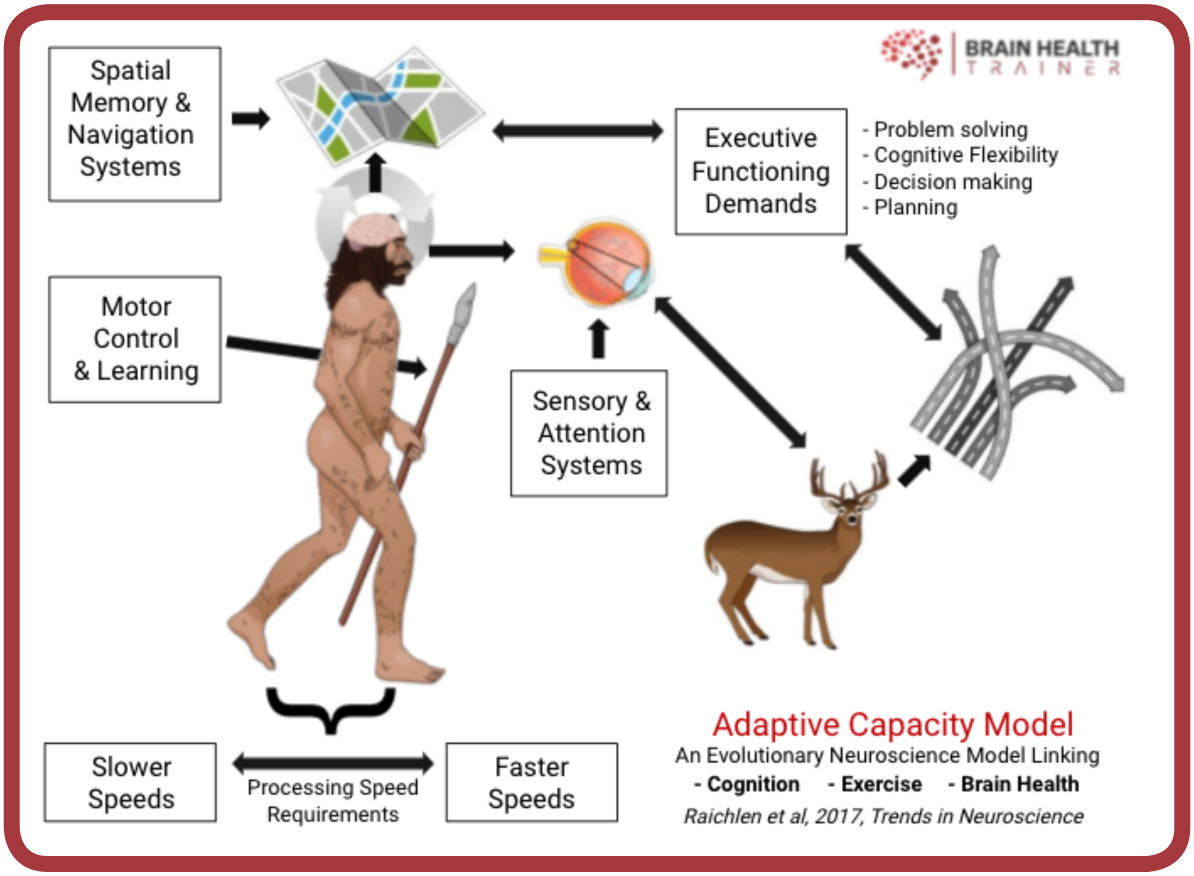
General dual-task training (GDT): Nonspecific training tasks in relation to the assessment. For example, working memory was assessed, but no specific drills include exercises that demand working memory.

Specific dual-task training (SDT): Consists of **specific training tasks** that address cognitive domains, usually **relevant** to the **assessment**. For example, processing speed is assessed, & processing-speed based exercises are provided.

General dual-task exergame (GDT-EX): An **exergame** that employs **nonspecific** training tasks in relation to the assessment. For example, memory could be assessed, but a general exergame was given.

Specific dual-task exergame (SDT-EX): An **exergame** that consists of **specific training tasks** that address cognitive domains, usually relevant to the assessment. For example, executive functioning is assessed, and **digital** executive functioning tasks are given.

The Adaptive Capacity Model



There are various perspectives on the explanatory model on the relationship between exercise, movement and the human brain. Many of these perspectives arise from evolutionary models, and the most relevant model to exercise and the brain is the Adaptive Capacity Model. Dr. David Raichlen and his team describe the Adaptive Capacity Model as an evolutionary neuroscience model that connects exercise, cognition and brain health together.

Looking through the evolutionary lense, let's start by observing the behavior of a hunter-gatherer. This person needs to hunt in order to survive, and they use their sensory systems to pay attention to the environment around them, searching for prey. This includes a heavy reliance on the visual system.

This person also needs to navigate both familiar and novel environments, relying on spatial memory and navigation systems. These spatial maps get sharper and more detailed with experience and practice, and they work directly with the sensory and attention systems in both their development and application.

Finally, a prey appears, and the hunter must begin hunting. Since this human has the capacity to run for longer distances, they must speed up their gait from slower speeds into a faster run. This requires increases in processing speed, which requires faster neural signaling and increases corticospinal excitability.

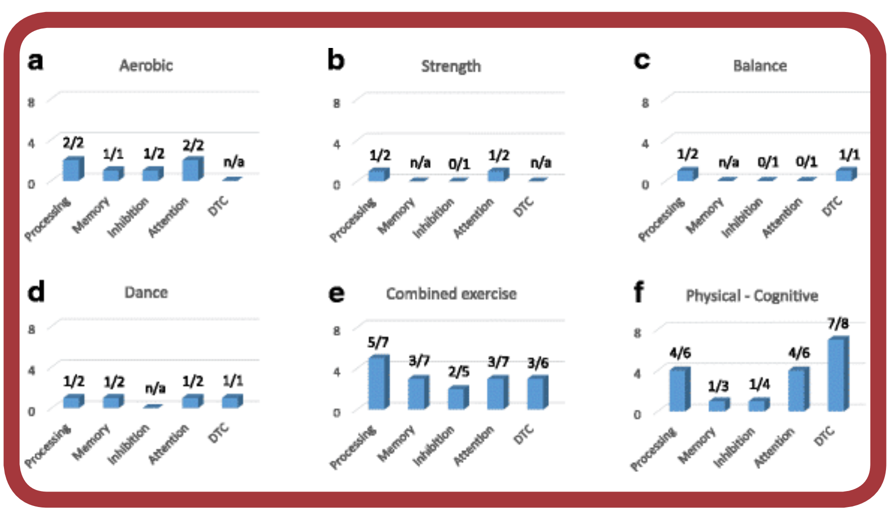
Other evolutionary theories point out that what separates humans from earlier ancestors is the large size of the frontal lobes of the brain, and a capacity for endurance metabolism and bipedalism that allowed these species to outrun their prey. In addition, the integration of tools involves aspects of motor learning and control, which provide further cognitive demands. An example is a spear, that while running requires the use of reaction time, hand-eye coordination, planning, and procedural memory.

However, the prey does not move linearly or in a predictable fashion. It moves in different directions, and unpredictably can pivot its trajectory without notice. This places greater demands on executive functioning abilities; problem-solving, cognitive flexibility (the ability to adapt to unexpected circumstances), decision-making, and planning. However, these executive functions must occur quickly, and therefore require a higher reliance on levels of processing speed.

Not only does the Adaptive Capacity Model demonstrate the relationships between attention, memory, processing speed, and executive functioning, but it justifies why combined exercise and cognitive training is more natural to the human brain and body than originally thought. Considering humans are no longer in this type of environment, this model sheds light on the potential for cognitive and physical training to slow cognitive decline and prevent neurodegenerative disease.

Dual-Task Training Effects on Cognition

Cognitive-motor interventions seem to improve **global cognition** and **executive functioning**, with many studies showing effects on **specific cognitive domains**.



Levin, O., Netz, Y., & Ziv, G. (2017). The beneficial effects of different types of exercise interventions on motor and cognitive functions in older age: a systematic review. European Review of Aging and Physical Activity, 14(1), 1-23.

Training **motor** and **cognitive tasks simultaneously (dual-task training)** seems to improve cognitive functions (**executive functions, processing**, and **attention**), and **dual-task cost** significantly **more** than **sequential** cognitive and physical training or performing them **separately** or alone.

How Much Dual-Training is Needed?

In adults **60 and older**, a dose of cognitive-motor training (**GDT, SDT, and/or Exergaming**) of at least **60 minutes per week** for a **total of 12 hours** (or 720 minutes), regardless of the number of sessions per week (which ranged from **1-3 times per week**, with sessions ranging from **20-90 minutes**) seems to be necessary to positively improve certain cognitive domains

Wollesen, B., Wildbredt, A., van Schooten, K. S., Lim, M. L., & Delbaere, K. (2020). The effects of cognitive-motor training interventions on executive functions in older people: a systematic review and meta-analysis. European Review of Aging and Physical Activity, 17(1), 1-22.

Of the **25 studies** on **dual-tasking** in the systematic review and meta-analysis above, the interventions studied used either **traditional** dual-task interventions, **technology**-enabled interventions (such as **exergames**), or a **combination** of the two.

- The **physical** components included tasks such as **stepping, squatting, balancing, gait, strength training**, and **postural control**.
- The **cognitive** components included **visual tasks, mathematics, working memory tasks, verbal fluency tasks**, and **rhythmic tasks**.

Improving the Effectiveness of Dual-Tasking

In order to improve the **effectiveness** and **individualization** of cognitive-motor interventions, there should be:

- **Cognitive** and **physical** task-**specificity**.
- Consider inter-individual **traits** (age, sex, conditions, genetics)
- Incorporate proper **progression, regression**, and **overload** principles
- Incorporate **variability** in a **periodized** manner

HWPs can **integrate dual-tasking** into an EPAP within **existing** sessions or as an entirely **separate** modality. These cognitive-motor training techniques can also be applied to **resistance, cardiovascular** or **coordinative** exercises for further variable outcomes.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ Dual-task ability requires aspects of divided attention and efficiency of activity in the frontal lobes, which can decline with age and neurological conditions.
- ☐ Dual-task ability can be assessed via questionnaires or tests such as the Timed Up and Go Cognitive, and then compared with single-task conditions, such as the Timed Up and Go.
- ☐ Training motor and cognitive tasks simultaneously (dual-task training) seems to improve cognitive functions significantly more than sequential or separate cognitive and physical training.

Reflection

Take a moment to reflect on all that you have learned in this module. Use the space below to record your thoughts.

Module 3:
Module 3: Becoming a Brain Health Trainer
Handbook

Introduction

Module 3 is the portion of the course where you apply what you have learned to **create** a **Brain Health Exercise and Physical Activity Plan** using data from an intake form. Module 3 contains **2 Sections**, a total of **8 Lessons**, and a **quiz**.

In the Course Introduction and in **Module 1** you learned about the **types of clients** you will be able to serve, the **stages of cognitive decline**, and the **effects of aging** on four **cognitive domains**.

Module 2 explained how **exercise affects** the brain at the **micro, macro**, and **behavioral levels**. You also learned about **different modalities of exercise** and the specific effects they can have on the brain and cognition.

You will use this knowledge to select appropriate exercises and interventions for a BH-EPAP given information about a client's cognitive status, ability level, goals, and preferences. We will also demonstrate how you can work with a client to identify a primary cognitive functioning goal to facilitate medical referrals, elicit motivation and subjectively track progress.

Module 3 Overview

Introduction

Module 3 will provide you with **demonstrations** and **practice activities** to apply the information you have learned thus far. By the end of this module, you will be able to **conduct** a Brain Health Trainer **intake** for a client, select different interventions to **build** a multi-modal **BH-EPAP**, and **modify** the **plan** based on client preferences and lifestyle considerations.

You will need to **recall** what you learned in Module 1 to categorize the client's level of decline, discuss the **four primary domains of cognitive functioning**, and justify the need for a BH-EPAP. To educate and motivate your clients to follow your recommendations, you will need to use terms and concepts related to **macro and micro brain structures**, **behavior (i.e. cognition), neurotransmitters**, and the processes of **neurodegeneration**. Explaining these concepts effectively will build confidence with current and potential clients and make it easier to market your certification.

Additionally, you will need to **apply** what you learned about the general and specific **effects of exercise on the brain** and the **processes** of **cognitive aging**. This is extremely important information when **modifying** the **duration, frequency**, **intensity**, and **variability** of a BH-EPAP. You will also use this information to **justify** the **recommendations** you make in the plan and **build motivation** by focusing on a specific domain of cognitive functioning.

Module 3 Agenda and Objectives

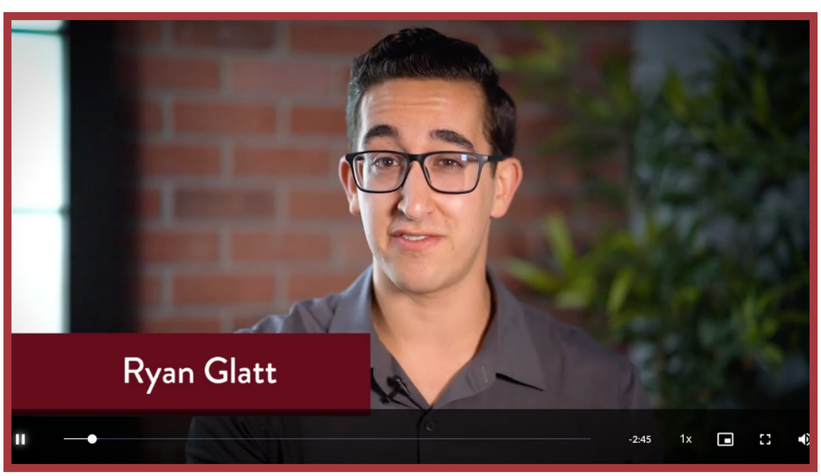
1. **The Intake Process**
This section will cover how to identify clients to work with and demonstrate how to discuss the value of a BH-EPAP.

2. **Creating a BH-EPAP**
This section will demonstrate how to create a Brain Health Exercise and Physical Activity Plan (BH-EPAP).

3. **Updating and Modifying a BH-EPAP**
This section will address strategies for updating, modifying, and enhancing existing BH-EPAPs over time.

Becoming A Brain Health Trainer

In this video, Ryan bridges the gap between the practical knowledge you will learn in Module 3 and the scientific information presented in previous sections of the course



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Knowledge Check

What is the primary goal of a Brain Health Exercise and Physical Activity Program (BH-EPAP)?

Record your answer here for future reference.

- ○ To identify opportunities for modifying an individual's exercise behaviors to be more aligned with brain health goals.
- ○ To prescribe an exercise program that is guaranteed to improve cognition and diagnose neurological conditions.

SECTION 1: THE INTAKE PROCESS

Lesson 1: Identifying Clients

Introduction to Section 1: The Intake Process

Section 1 is divided into **4 lessons**. You are currently in **Lesson 1**, which will give you a brief overview of how to **identify**, market to, and onboard new and existing clients for brain health-oriented services. Lessons 2 will define the Brain Health Trainer **Intake Interview** process. Lesson 4 will present certain client **considerations** in developing BH-EPAPs, and Lesson 5 will identify programming considerations for individuals with **cognitive impairments**.

By the end of Section 1, you will be able to identify strategies for identifying clients, **marketing** your enhanced services, and **performing** an intake interview. In addition, you will develop an understanding of considerations for program design, including the cognitive status, **preferences**, and abilities of clients.

Lesson 1 Objectives

1. List strategies that you can use to market your Brain Health Certification to new and existing clients.
2. Recall the appropriate way to interact with allied health professionals and doctors to generate referrals.
3. Justify the value of a BH-EPAP to a given client.

Marketing your Brain Health Trainer Certificatio

This video will explain ways to market your certification and identify new clients

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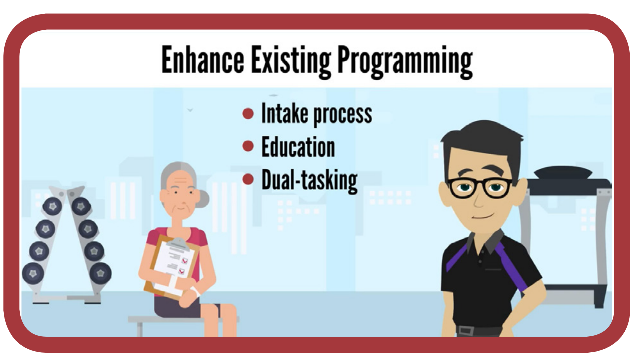
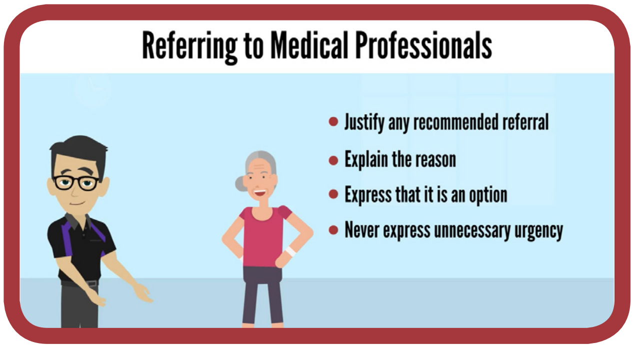
Marketing Tips



The skill sets developed in this course can be utilized to **enhance existing programming**, **attract** new clients, and **retain** existing clients.

Hosting **workshops, presentations, webinars**, and **seminars** in various aspects of the **community** are all ways to **market** your enhanced **services** and spread **information** about brain health.



Referring to and collaborating with **medical** professionals is an essential process to facilitating **assessment** and improvement in a client's **brain health**, & influences BH-EPAPs.

Ways to Generate Interest and Referrals

Using the summary of the guidelines found below, generate some action steps to start developing a plan for generating new leads and discussing the value of a BH-EPAP with existing clients or patients.

Enhance Existing Programming	Market to Existing Clients	Generate Word of Mouth Referrals	Community Awareness	Referrals from Medical Professionals
Add the BHT intake process to existing systems.	Explain the process of cognitive aging & brain health with existing clients.	Identify who generated the referral or where the new client heard of you.	Present on healthy cognitive aging to community centers and senior living communities.	Identify potential referrals in your area, and who is currently in your client's medical team.
Educate Clients & Justify Programming for Brain Health.	Discuss the long-term benefits of exercise on the brain and the process of updating the BH-EPAP over time.	Educate the new client about cognitive aging and the role of multi-modal exercise based on their age group and client type.	Even if this doesn't directly result in new business, your ability to inform others about healthy cognitive aging can support their brain health.	Encourage your clients to speak to their doctor about specialty referrals for brain health, and to ask about memory assessments.
Incorporate elements of a BH-EPAP and Dual-Task Training into your programming.	Ask a client if they are struggling with any aspects of cognition. Use this as a point of motivation and on-going discussion.	Explain the long term benefits of a multi-modal BH-EPAP that is consistently updated with new interventions based on their progress.	Hold a webinar or workshop for new and existing clients that demonstrate dual-task exercise and discuss its value.	Provide medical professionals with non-narrative progress reports and marketing materials when requested.

Sample Presentation

As you plan on delivering presentations, in-person or virtually, below you will find a pre built presentation for you to utilize.

All of the slides have images that provide visuals for your brain health education and follow the order of how information is presented in this course.

Note that the format of this presentation is in PDF format. We cannot provide this in any other formats, due to potential compatibility issues with a variety of presentation programs. We recommend that you copy or "screenshot/screen capture" slides that are desired, and insert them into your own presentation within your software of choice.

Do not forget to add in your introduction and contact information in their respective areas, and please cite *Ryan Glatt - Brain Health Trainer Course* as your source.

Brain Health Education Presentation Template

Click the button to the right to download the PDF Brain Health Education Presentation Template

PRESENTATION

Lesson 2: Intake Interview

Lesson Objectives

1. List the steps of the Brain Health Trainer Intake Interview.
2. Collect identifying information and Health History Information.
3. Gather baseline data on a client's existing exercise behaviors.
4. Collaborate with a client to identify a primary cognitive functioning goal for their BH-EPAP.

The Brain Health Trainer Short Form Intake Interview

The Brain Health Trainer Short Form is a fillable PDF document that you can download and should use every time you **create** or **modify** a Brain Health Exercise and Physical Exercise Plan.

This form will enable you to gather all of the minimum, relevant data needed to **formulate** or **update** a BH-EPAP.

You will use this form to complete the **practice activities** throughout the rest of Module 3.

Guidelines For Setting Up An Intake Interview

Whether you applying the Brain Health Trainer Intake Interview for an existing client or as a consultation, the guidelines below will help set you up for success.

1. Set a **30-60 minute** time block to **meet** with the client. The intake interview can take place in **person** or **remotely**.

2. **Prepare** the client for the **intake** by describing what the goal of this process is before the day of the **interview** and **advising** them on any important **information** about their appointment or **logistics**.

3. To begin the **interview**, make sure your client is in a **comfortable**, quiet environment and is **focused** on the interview and not another workout, exercise, or activity.

4. Complete the **intake interview** with the client using the **Brain Health Trainer Short From PDF**.

5. OPTIONAL: Conduct a **physical assessment** with tests that have direct (or indirect) relationships with brain health, or get the results or score from your client from similar **assessments**. These may include **Dual-task**, cardiorespiratory, **balance**, strength, and/or anthropometrics. This may be within the same **session** as the intake interview or a **separate** one.

Goals of the BHT Short Form Intake

This **information allows** you to have **more focused conversations** with a client, **develop** an **exercise and physical activity plan (EPAP)**, and prevent future issues with plan adherence, injury, or medical contradictions. There are several general areas that are assessed during the intake.

1. **Age** and **concerns** related to **cognition**, which may aid in understanding **client type** & referral opportunity.

2. Information related to **medical** professionals and diagnosed **health conditions**.

3. Important client **considerations** related to safety, lifestyle, **preferences**, and motivation.

4. **Existing exercise behaviors** including duration, **frequency**, intensity, variability, and **enjoyment**.

BHT Short Form Intake

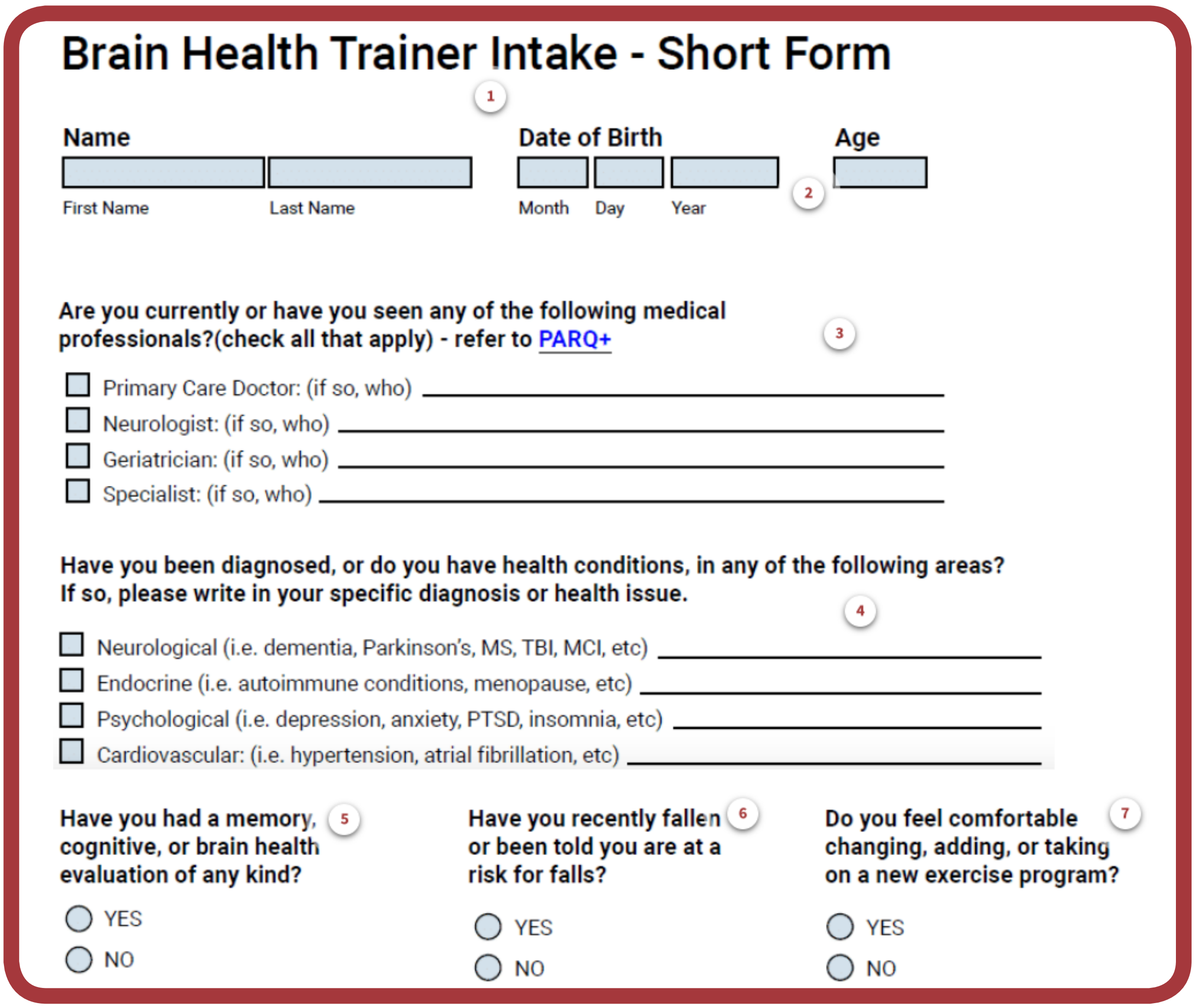
Click the button to the right to download the PDF BHT Short Form Intake.

INTAKE FORM

Identifying Information, Medical Professionals, and Health History

The ability to **refer** individuals to **medical** professionals for brain health assessments is a **critical skill** that separates **Brain Health Trainers** from other health professionals.

Less than 50% of those with subjective cognitive decline (**SCD**) consult a doctor, and it is likely that a **majority** of these individuals include **existing clients**. While client types change over time, a majority of the "**common clientele**" (i.e. Worried Well & SCD) likely maintain **higher levels** of physical and cognitive function but may experience cognitive aging at varying rates.



Brain Health Trainer Intake - Short Form

1

Name — First Name ____ Last Name ____

Date of Birth — Month ____ Day ____ Year ____

2

Age ____

Are you currently or have you seen any of the following medical professionals?(check all that apply) - refer to PARQ+

3

- ☐ Primary Care Doctor: (if so, who) ____
- ☐ Neurologist: (if so, who) ____
- ☐ Geriatrician: (if so, who) ____
- ☐ Specialist: (if so, who) ____

Have you been diagnosed, or do you have health conditions, in any of the following areas? If so, please write in your specific diagnosis or health issue.

4

- ☐ Neurological (i.e. dementia, Parkinson's, MS, TBI, MCI, etc) ____
- ☐ Endocrine (i.e. autoimmune conditions, menopause, etc) ____
- ☐ Psychological (i.e. depression, anxiety, PTSD, insomnia, etc) ____
- ☐ Cardiovascular: (i.e. hypertension, atrial fibrillation, etc) ____

Have you had a memory, cognitive, or brain health evaluation of any kind? 5

○ YES
○ NO

Have you recently fallen or been told you are at a risk for falls? 6

○ YES
○ NO

Do you feel comfortable changing, adding, or taking on a new exercise program? 7

○ YES
○ NO

1. Using This Form: This **1 page intake form** was created to ensure that you are able to gather all of the information needed to create a **BH-EPAP** efficiently.

2. Age: If **65 years** of age or older, clients should have a **memory/cognitive evaluation**. Age can also be helpful for **normative data** within **assessments**.

3. Medical Professionals: An understanding of **existing medical** professionals will provide opportunities for **collaboration, referral, & clearance**.

4. Medical Referrals: Consider **referrals** if your client is willing and able to consult **specialists**. Stay within your **scope of practice**, as only medical professionals can **diagnose** health **conditions** associated with **brain health**.

5. Memory Evaluation: Identifies whether or not an individual has had a **memory or cognitive evaluation**. This can be a brief evaluation with their doctor (such as a **MOCA, MMSE** or equivalent), or a more extensive **neuropsychological** assessment.

6. Fall Risk: A **history** or current **risk** of falls provides opportunities for **programming** and **prevention** (including referrals to **specialists**). Risk and history of falls have been **correlated** with **cognitive** decline.

7. Readiness for Change: Its important to assess a client's **readiness for change** their exercise program. Consider a client's safety, comfort, and **convenience** during the intake and when creating a BH-EPAP.

All clients should be **aware** of the factors that can **prevent** cognitive decline, and what elements **contribute** to brain health. In general, anyone that is **65 years** of age or older should have a **memory assessment** completed by a **medical** professional.

Referring to medical professionals at earlier ages for **cardiovascular, sleep**, or **mental health-related** conditions is important for addressing other factors that can affect brain health.

Knowledge Check

Which of the selections below are referred to as Acute Variables?

Record your answer here for future reference.

- ○ Duration, Frequency, Intensity, Variability
- ○ Safety, Fall Risk, Medications, Health History
- ○ Attention, Executive Functioning, Memory, Processing Speed

Exercise Modalities and Acute Variables

This is the most important information collected during the intake interview process. It directly informs the goals and programming for an individualized Brain Health Exercise and Physical Activity Plan.

1 **Which of the following types of exercise are you currently participating in? (check all that apply)**

- ☐ Aerobic or Cardiovascular Exercise (walking, jogging, running, cardio machines, etc)
- ☐ Resistance or Strength Training (weight machines, free weight, functional training, etc)
- ☐ Skill-Based Exercise (dance, tennis, Tai Chi, other sports, martial arts, etc)
- ☐ Leisure Time Activities (hiking, cycling, leisurely walks, leisure sports, etc)

How many days per week on avg. are you exercising? 2

How many minutes on avg. do you exercise per day? 3

Do you enjoy your current exercise program? 4
- ○ YES
- ○ NO

How intense is your exercise program? (1 - not intense, 10- very intense) 5

1. Exercise Modalities - An understanding of the current exercise modalities reveals which exercise modalities are being engaged in. This helps to identify **preferences, opportunities for recommending specific modalities**, and **potential health risks** in the absence of certain modalities.

2. Days Per Week - Days per week reflects the frequency of exercise. Individuals should seek to incorporate exercise **at least 2-3 times per week** on the lower end, and **5+ times per week** on the higher end, with **3-5 times per week on average**.

3. Minutes per Session - Minutes per session refers to the average duration of an exercise session. While this likely will vary, session minutes should equal at least **150 minutes per week**, depending on intensity.

4. Enjoyment - Enjoyment refers to the **affective appraisal** of the individuals exercise and physical activity. Greater levels of enjoyment may be associated with improved mood and cognitive outcomes. **Greater enjoyment** will often result in **longer-term adherence**.

5. Intensity - Intensity refers to **metabolic**, neuromuscular, and/or **cognitive load** of the exercise or physical activity in question. There is no “best” intensity of exercise, as all intensities have been found to benefit brain health in a variety of ways.

The Primary Cognitive Functioning Goal

It is helpful in the context of a Brain Health Trainer Exercise and Physical Activity Plan to identify a primary Cognitive Functioning Goal or CFG.

It is very important to note that you should not express that a BH-EPAP will have a direct and predictable effect on a single domain or aspect of cognition. As you learned in Module 2, this is due to the complexity and interconnected nature of the brain, its structures, and functional networks.

1 **Which of the following are you experiencing issues with? (check all that apply)** 2

- ☐ Memory problems (forgetting names/faces/numbers, misplacing items, forgetting events, etc)
- ☐ Attention problems (focusing, fatigue, distractability, ignoring sights/sounds, paying attention, etc) 3
- ☐ Speed Processing Issues (slowing of movement/thought, tip-of-tongue moments, retrieving information, etc)
- ☐ Executive Function Issues (planning, organization, impulse control, task switching, emotional, etc)

1. Client's Primary CFG - This section of the intake process is intended to **identify** a primary domain of cognitive functioning (or "**Cognitive Functioning Goal" - CFG**) to **motivate** the client and track **progress**.

2. Subjective Experience - Ask the client if they are **experiencing** any of the following **issues**. If so, then get them to **elaborate** and be **specific** about the **cognitive issues** they may be experiencing.

3. Improvements in Cognition - This aspect of the BHT-SF is not meant to exist as an "assessment", but rather as a **general subjective baseline**. Cognitive **impairment**, health history, & **lifestyle factors** can affect changes in these domains.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ The Brain Health Trainer Short Form Intake (BHT-SF) Interview can allow you to appraise a current or prospective client's exercise behaviors, medical history, and team, brain health gaols, and other factors related to BH-EPAP design.
- ☐ In discussing the BHT-SF with current and prospective clients, it is important to keep your scope of practice in mind and refer to allied medical professionals whenever possible.
- ☐ When looking to make exercise programming recommendations, seek to select the activities and modifications that the client will most likely adhere to in both the short term and the long term.

Lesson 3: Client Considerations

Lesson 3 Objectives

1. List important client considerations to keep in mind when creating a BH-EPAP.
2. Identify how social interaction, activity preferences, environment, and finances can inform the creation and modification of a BH-E AP.
3. Identify how perceived stress, motivation, and mental health can inform the creation and modification of a BH-E AP.

Client Considerations

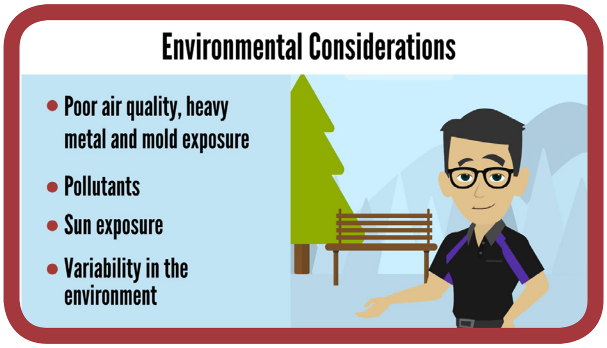
When designing or modifying BH-EPAPs, there are various considerations to keep in mind when personalizing programs for clients. Watch the video below to learn about how considerations such as preferences, social interaction, finances, and environment can modify the details of a BH-EPAP.

VIEW ON VIMEO >

Social, Financial & Environmental Considerations

Social interaction is an important component of **brain health**, and certain **exercise types** may possess more or less social contact, which is dependent upon a client's **preferences**.

Financial considerations are important for **long-term** BH-EPAP **sustainability** and can include a variety of training options, such as **group, private**, and **technology-enabled** training and exercise.



Environmental considerations are important for managing **risks** (such as **visual**, dermal, or respiratory conditions) and **maximizing** BH-EPAP **bene its** (such as **enjoyment**, healthy **sun** exposure, and variability).

Program Safety and Fitness Level Constraints

When creating a Brain Health Exercise and Physical Activity Plan, there are specific limitations related to exercise volumes, fitness levels, and program safety.

Exercise Volumes

Intensity X Frequency X Duration
=
Overall Load

When participating in exercise and physical activity plans (EPAP), HWP's must consider the **biomechanical, physiological**, and **cognitive stress** that any given EPAP may impose. The overall load and other factors may affect the **risk, enjoyment**, and **sustainability** of certain exercise modalities and physical activities. levels, and program safety.

Stress, Motivation & Mental Health

When designing or modifying BH-EPAPs, there are various psychological considerations to keep in mind when personalizing programs for clients. Watch the video below to learn about how considerations such as perceived stress, motivation, and mental health issues can modify the details of a BH-EPAP.

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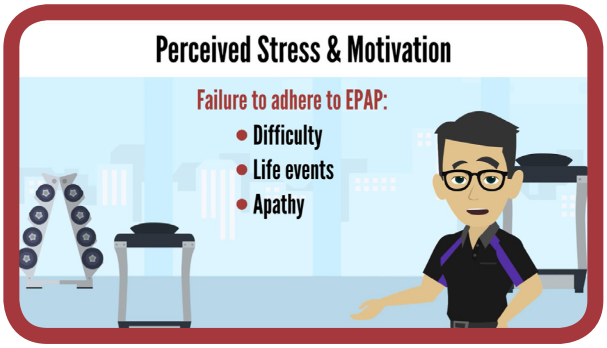
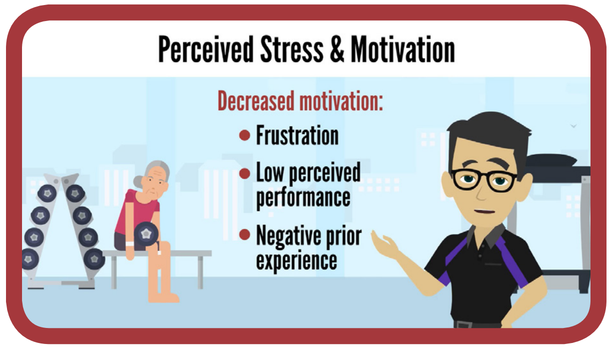
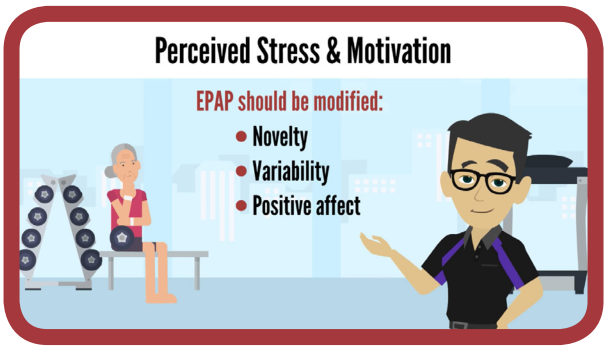
Consideration for Stress, Motivation & Mental Health



Managing perceived **stress** and **motivation** surrounding BH-EPAPs is important to consider to ensure long-term **sustainability**, enjoyment, and **participation** in various exercise and physical activity types.

Mental health issues, especially in those with cognitive impairments, can play a role in the **motivation** to participate in a BH-EPAP, and programs should be designed with **mood** and relative levels of executive **functioning** in mind.





The **motivation** to adhere to a BH-EPAP should be **assessed**, with programs being designed based on the client's **preferences** and **abilities**, recognizing that these may **change** over time.

Note: Keep in mind the generalized guidance for "mental health" is geared towards older adults with cognitive impairments, rather than generalizing towards all older adults or mental health conditions. Exercise programming for mental health conditions is not addressed within the scope of this course, and seeking guidance from mental health & medical professionals is recommended in such cases.

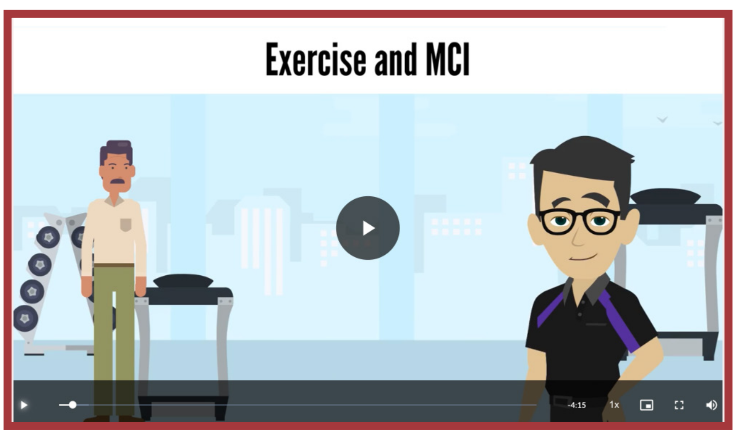
Lesson 4: Cognitive Impairments

Lesson 4 Objectives

1. Identify the effects of cognitive impairments on the development of a BH-EPAP
2. Understand the effects of various exercise programs for those with MCI and dementia.
3. Identify specific considerations for developing and modifying a BH-EPAP for those with MCI and dementia.

Considerations for Cognitive Impairments

Working with clients with cognitive impairments can present additional considerations in designing and modifying a BH-EPAP. This section will focus on **generalized considerations** for individuals with mild cognitive impairment (MCI) and dementia. Watch the video below to learn more about some of the summarized **effects of exercise** on **cognitive outcomes** in these client types.



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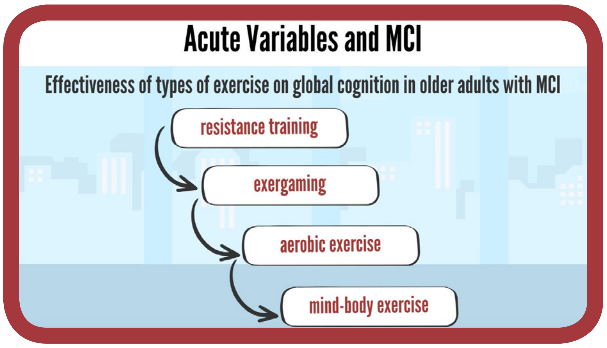
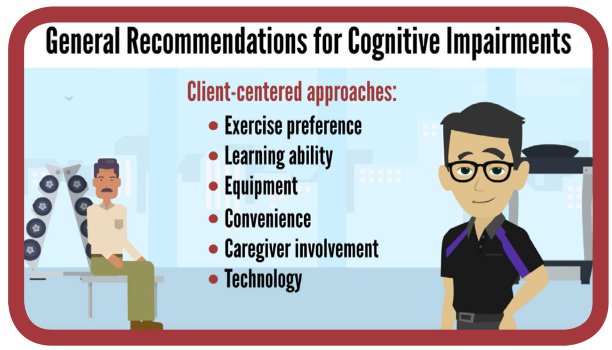
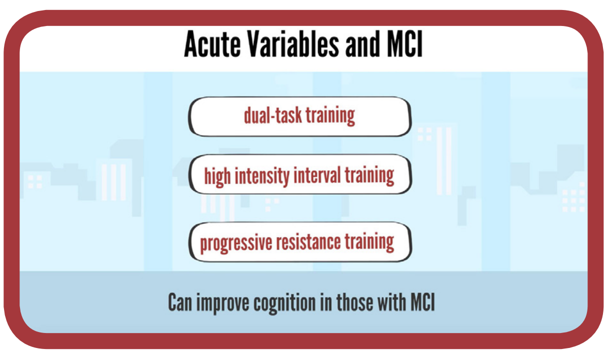
Effects of Exercise in MCI & Dementia



The research on the **cognitive** effects of **exercise** in individuals with mild cognitive impairment (**MCI**) and **dementia** may seem **limited** and **contradicting**. However, much research suggests that **various** exercise **modalities** and acute variables may **improve cognition** in those with **cognitive impairments.**

In designing **programs** for individuals with **cognitive impairments**, there is a wide range of individual **considerations**; including preference, **cognitive ability**, utilization of **technology**, program **complexity**, and enjoyment.

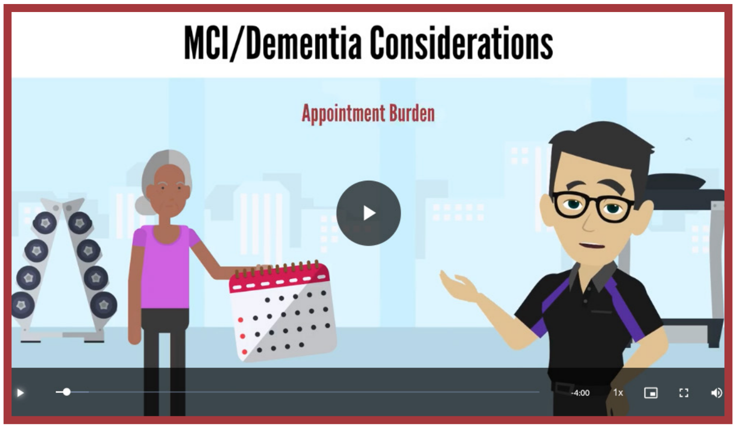




Combined **cognitive-motor** interventions may **improve cognition** and **mood** in those with **cognitive impairments**, either in **equivalence** or in **superiority** to single modality interventions, but **more research** is needed.

Considerations for Cognitive Impairments

This section will focus on additional occupational and psychological considerations for individuals with mild cognitive impairment (MCI) and dementia. Watch the video below to learn more about some of the factors to consider when designing BH-EPAPs for these client types.



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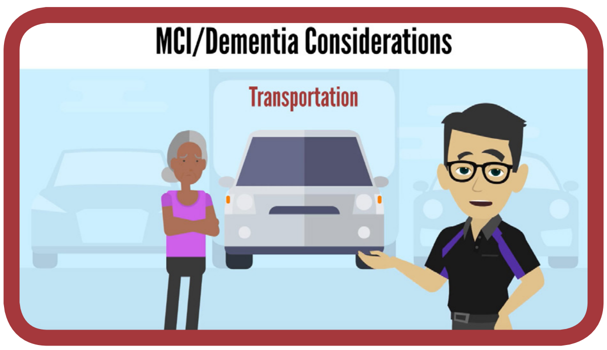
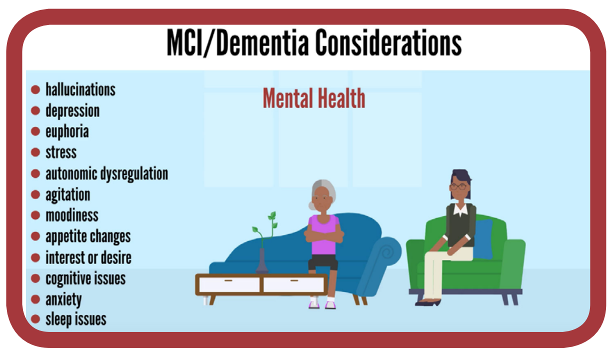
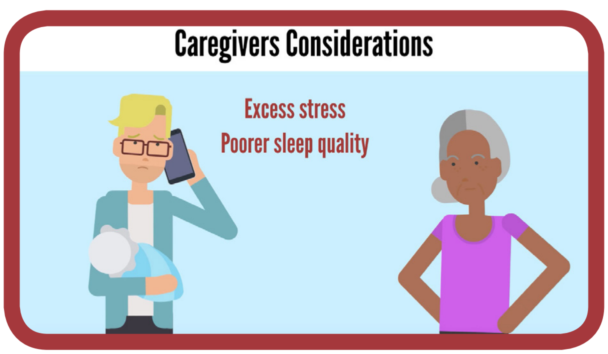
Transportation, Mental Health & Caregiving Tips



Transportation is an important consideration when designing BH-EPAPs for clients with cognitive **impairments**. Transportation is closely associated with **appointment burden**, access, location, and **finances**.

Mental health in individuals with **cognitive impairments** can play a role in determining the **adherence**, enjoyment, and ease of **access** in BH-EPAPs.





Caregivers should be **considered** when designing BH-EPAPs, including their **levels** of **stress** and their own **risk factors** for **cognitive decline**. Caregivers can be trained to **participate** in and **assist** in **delivering** BH-EPAPs.

Programming Guidelines Based on Client Types

Ceiling effects on cognition exist for those who are healthier and **younger**, and those with **more cognitive impairments** are likely **less lexible** in **responding** to **cognitive changes**. As individuals become more cognitively **impaired**, the likelihood of **improving domain-speci ic cognition** becomes **less likely**, as **global cognitive changes** in those with more **cognitive impairments** are more **likely**.

For individuals with Subjective Cognitive Decline (**SCD**), BH-EPAPs should focus on **moderate** to **high intensities**, **moderate** to **high complexity**, and **multiple** modalities of exercise as tolerated. **Various frequencies** and **durations** are acceptable.

For individuals with Mild Cognitive Impairment (**MCI**), BH-EPAPs should focus on **moderate** to **high intensities**, **moderate complexity, shorter duration, greater frequency**, and only as many modalities as the individual would likely be **successful** with (airing on the side of **simplicity** versus complexity).

For individuals with **Dementia**, BH-EPAPs should focus on **moderate intensities, lower complexity, shorter duration, greater frequency**, and **less** modality **variability** with a primary focus on **enjoyment, tolerability**, and **socialization**.

SECTION 2: CREATING A BH-EPAP

Lesson 1: Exercise Counseling Decision Tree

Introduction to Section 2: Creating A BH-EPAP

Section 2 is divided into **4 lessons** and a **quiz**. You are currently in **Lesson 1**, which will give you a brief overview of the **exercise counseling decision tree**, which is a framework to assist in assessing a client's current exercise program, and making **step-wise recommendations** with sound behavior change strategies. Lesson 2 identifies how to manipulate **acute variables** based on a client's current plan and goals, while Lesson 3 will focus on a similar process with different **modalities** of exercise. Lesson 4 will identify **strategies for modifying** brain health exercise and physical activity plans.

By the end of Section 2, you will be able to analyze a client's current exercise and physical activity program, make a systematic and step-wise modification to the acute variables and exercise modalities within that program and modify their BH-EPAP overtime to ensure variability, enjoyment, and progressive overload.

Lesson 1 Objectives

1. Use the Exercise Counseling Decision Tree to analyze a client's existing exercise routine.
2. Analyze the duration, frequency, and intensity of a client's existing exercise routine and select which variable to focus on for this iteration of their BH-EPAP.
3. Analyze a client's existing exercise routine and assess modalities of physical activity, variability, and presence of dual task training.

Exercise Guidelines

Before going through this section, please review the **Physical Activity Guidelines for Americans, 2nd Edition**, to better understand the **minimum** recommendations for exercise, as well as general **guidelines** for specific modalities of exercise.

Click the square next to each recommendation after you read it to complete the checklist and continue forward.

- [ ] For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate-vigorous intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week.
- [ ] Additional health benefits are gained by engaging in physical activity beyond the equivalent of 300 minutes (5 hours) of moderate-intensity physical activity a week.
- [ ] Adults should also do muscle-strengthening activities of moderate or greater intensity and that involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

Exercise Counseling Decision Tree

This decision tree is a flowchart that will help you to **analyze a client's current exercise routine** and activity habits based on the acute variables of exercise defined in this course. This process of **appraisal, analysis**, and **recommendation** is called "**exercise counseling**."

It is important to remember that a **BH-EPAP** should be **updated roughly every three months**, and you can use the Exercise Counseling Decision Tree each time you assess a new client or an existing plan.

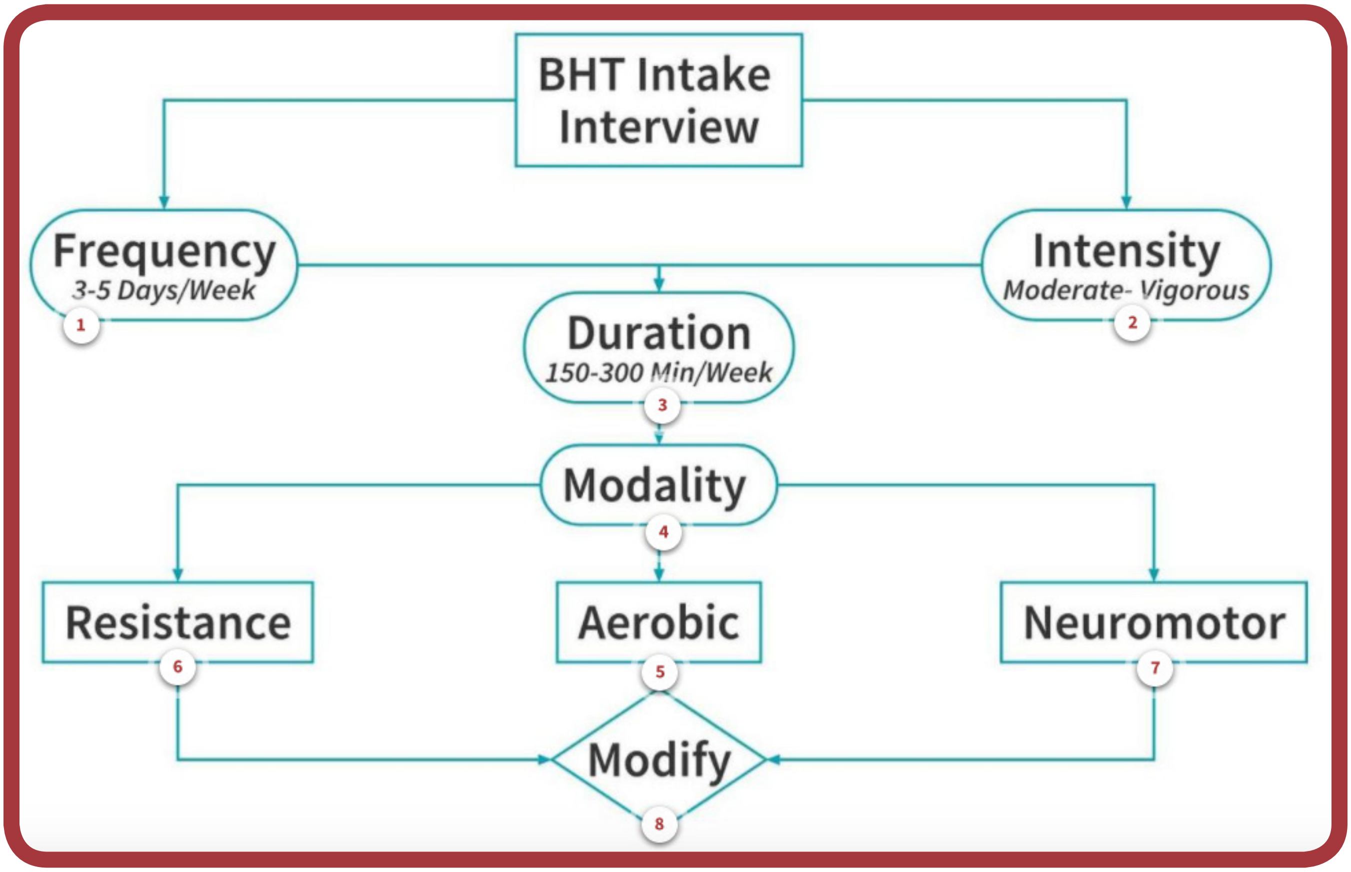
Exercise Counseling Decision Tree

Click the button to the right to download the Exercise Counseling Decision Tree.

DECISION TREE

Exercise Counseling Decision Tree Components

This resource is intended to provide you with easy-to-follow logic to **ensure** that the **duration, intensity, frequency**, and **variability** of any exercise program meets the **minimum exercise recommendations** to support brain health.



1. Frequency - **Days per week** reflects frequency of exercise. Individuals should seek to incorporate exercise at least **2-3 times per week** on the **lower** end, and **5+ times** per week on the **higher** end, with **3-5x/week** on **average**.

2. Intensity - Intensity refers to **metabolic**, **neuromuscular**, and/or **cognitive load** of the exercise or physical activity in question. All **intensities** have been found to **bene it** brain health in **various** ways.

3. Duration - **Minutes per session** refers to the duration of an exercise session, which may vary. **60 minutes** is often recommended, but there is **value** in **shorter bouts** of exercise, such as those found in **7 - 30 minute** sessions.

4. Modality - Understanding which **exercise modalities** are being engaged in helps to identify **preferences**, opportunities for **recommending** specific modalities, and identifying potential **health risks** in the absence of certain modalities.

5. Aerobic - There should be **150 minutes** of **aerobic** exercise present in a client's EPAP. Aerobic exercise includes a **variety** of **activities** that include **open** or **closed** skills that involve increased levels of cardiovascular demands.

6. Resistance - Participation in **resistance training** should occur at least **2 days** per week. increasing to **3 days** per week may be better for **cognitive improvements** if deemed safe & preferable.

7. Neuromotor - Neuromotor, **motor**, coordinative, or **skill-based** exercise should be recommended at least **2 days per week**. **3 days per week** may yield additional benefits but may require a **trade-off** with other modalities of exercise.

8. Modify - **Modifying** BH-EPAPs over time requires a consideration of **progress**, preferences, **problem-solving** & enjoyment.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ The Exercise Counseling Decision Tree will help you analyze a client's existing exercise routine or the current version of their BH-EPAP. You should use it each time you complete the intake interview with a new client or when updating an existing plan.
- ☐ Analyze the frequency, duration, and intensity of exercise first to identify any deficits as related to the minimum standards for exercise.
- ☐ Identify opportunities to add new modalities of exercise, variability, and cognitive-physical or dual-task training. In discussion with the client, refer to their primary CFG and activities they used to enjoy as a way to increase their motivation for change.

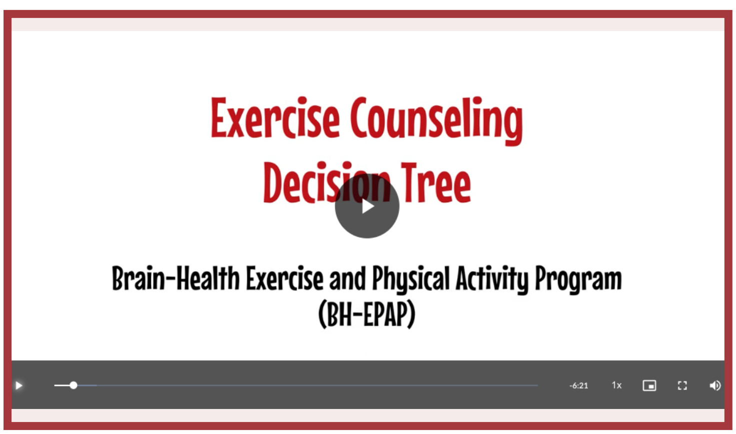
Lesson 2: Acute Variables

Lesson 2 Objectives

1. Identify the importance of modifying the various acute variables within a BH-EPAP.
2. Understand the trade-offs among multiple acute variables.
3. Understand the potential impacts certain acute variables can have on the outcomes resulting from a BH-EPAP.

Programming Acute Variables

Watch the video below to learn about BH-EPAP programming considerations for the acute variables of Frequency, Intensity & Duration as outlined by the Exercise Counseling Decision Tree.



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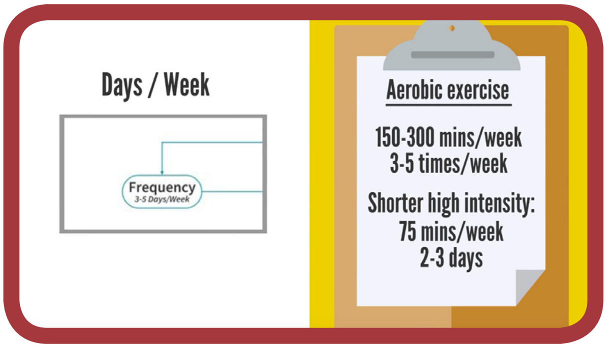
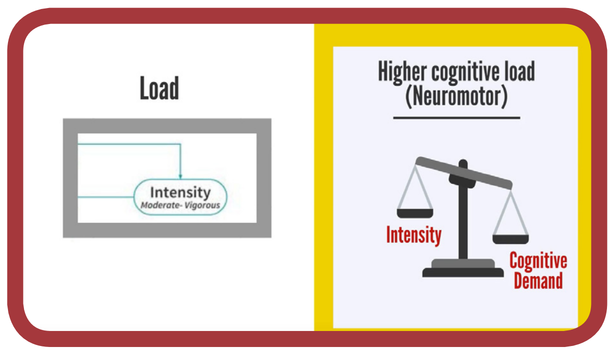
Acute Variable Programming



Frequency within a BH-EPAP is dependent on intensity and duration of exercise, with **3-5x/week** being the most average frequency of exercise sessions. **Multi-modal exercise** can allow individuals to maintain moderate frequency while increasing EPAP variability.

Aerobic, Resistance, and **Neuromotor Training** can generally be programmed anywhere from **2-3x/week** on average, for **each** of the **three modalities** which can be modified depending upon the client's goals and preferences.

All exercise **intensities** can offer brain health benefits via both shared and differential **neurobiological pathways**. BH-EPAPs should seek to have at least **moderate** intensities on **average**, including both **low** and **high-intensity exercise** sessions.



Duration of exercise weekly should equal at least **150 min/week**, with session durations ranging from **20-60 minutes**. Duration is often dependent upon intensity and modality, and **multi-modal** programming may be utilized to integrate **multiple modalities** into **single** sessions.

Assessing Intensity

The **intensity** of exercise may be measured by **perceived** exertion or **physiological** exertion. Perceived exertion may be measured by an **RPE** (Rate of Perceived Exertion) scale, such as the **Borg Scale**, or more simply, a scale of **1 - 10 (low to high intensity)**. Physiological exertion can be measured by workload, volume, force output, and other measures such as **heart rate**.

Using **RPE scales** can be a good way to gauge this intensity, and not adding more than **1-2 points** on the **10 point RPE** scale every **4-12 weeks** is a sound programming strategy.

RPE SCALE	RATE OF PRECEIVED EXERTION
10	**MAX EFFORT ACTIVITY** Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time
9	**VERY HARD ACTIVITY** Very difficult to maintain exercise intensity. Can barely breathe and speak only a few words
7-8	**VIGOROUS ACTIVITY** Borderline uncomfortable. Short of breath, can speak a sentence
4-6	**MODERATE ACTIVITY** Breathing heavily, can hold a short conversation. Still somewhat comfortable, but becoming noticeably more challenging
2-3	**LIGHT ACTIVITY** Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	**VERY LIGHT ACTIVITY** Hardly any exertion, but more than sleeping, watching TV, etc

Programming Intensity

If individuals are performing at least **150 minutes** in the “vigorous” or “high intensity” categories of the IPAQ, it behooves the HWP to **investigate** if this is a **truly vigorous activity**, or if the **client merely perceives** it as vigorous activity. Higher amounts of vigorous activity may yield health benefits, but it is worth noting that too much or **sustained periods of high-intensity exercise may yield deleterious effects**.

Some of these **deleterious effects can involve cognition**, such as **negative** cognitive effects caused by high levels of **cortisol**, excessive neural **fatigue**, musculoskeletal **injury risk**, and more. HWPs should **refer to medical professionals** to assess related **biomarkers** and should continue to monitor a client’s EPAP for such issues.

Modifying the intensity of EPAPs is beneficial for **metabolic** health and **longevity**, and well-modified EPAPs can be **adaptive** with levels of **luctuating stress** the client may **experience** throughout life.

Monitoring Intensity

If there is any concern about the **validity** of the **self-reported** intensities or **duration** of activities, the **HWP may use heart rate monitors**, wearables, activity journaling, or supervision to **con irm these variables**.

An HWP may also obtain **graded exercise testing**, fitness tests, and cardiovascular health measures to further understand the role of **relative intensities** and **exercise volumes**. These may be valuable additions, as observation, speculation, and **self-reporting** may not yield high enough **accuracy** to be proficient. This is especially true in cases of greater **medical** consideration, or when the accuracy of exercise program design is based on this **baseline** information.

Programming Frequency

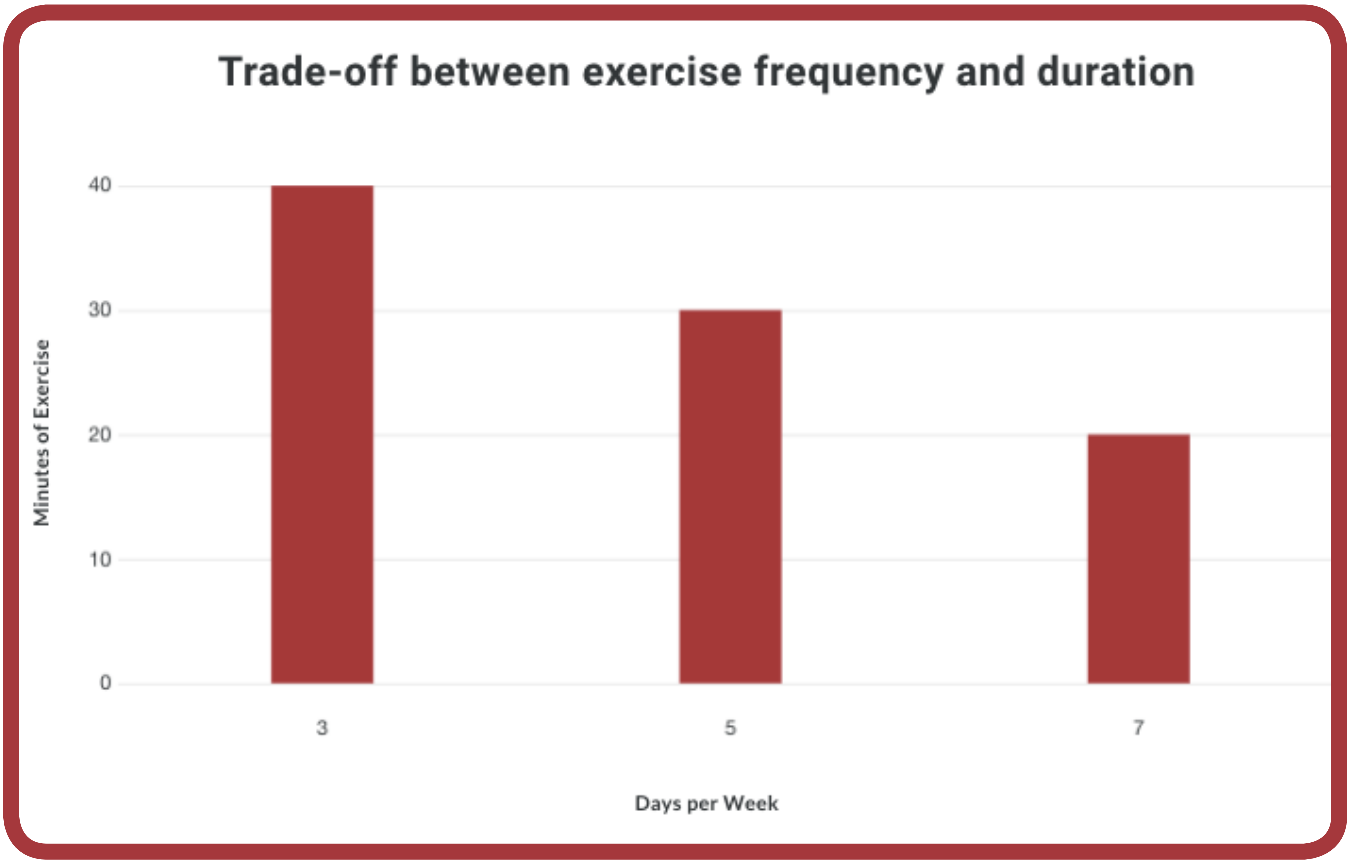
Clients who participate in a **single modality** at a **high frequency** (such as playing tennis every day), are likely to experience **high skill improvement** in that modality, as well as a higher risk of injury. The **frequency of an EPAP depends** on the client's **time commitment**, the client's **tolerance** to overall load, and the **duration** of each exercise session.

Programming Duration

The average exercise **duration** is typically around **60 minutes**. However, individuals with limited experience or exercise tolerance **may need to start at lower durations**, such as at **10 minutes** or **20 minutes**. Durations longer than 60 minutes are likely for physical activities, such as sports, or multi-modal exercise sessions that are less frequent.

Frequency-Duration Trade-offs

There is typically a **trade-off** between exercise **frequency** and exercise **duration**. In attempting to create EPAPs that meet the minimum recommended amount of physical activity, there are various configurations that a client can adhere to.



Frequency-Duration Configuration

Below are various frequency and duration trade-off configurations to achieve 150 minutes per week of moderate-to-vigorous intensity aerobic exercise.

- **3 days**/week of **40-60** min sessions of aerobic exercise
- **5 days**/week of **30 min** sessions of aerobic exercise
- **7 days**/week of **20 min** sessions of aerobic exercise

Key Takeaways

Check off each key point if you feel that you understand it.

- [ ] Frequency within a BH-EPAP is dependent on intensity and duration of exercise, with 3-5x/week being the most average

- [ ] Aerobic, Resistance, and Neuromotor Training can generally be programmed anywhere from 2-3x/week on average, for each of the three modalities which can be modified depending upon the client's goals and preferences.

- [ ] BH-EPAPs should seek to have at least moderate intensities on average, including both low and high-intensity exercise sessions.

- [ ] Duration of exercise weekly should equal at least 150 min/week, with session durations ranging from 20-60 minutes.

Lesson 3: Modalities of Exercise

Lesson 3 Objectives

1. Prioritize certain modifications within a BH-EPAP based on a client's existing EPAP.
2. Identify the BH-EPAP template for designing weekly programs
3. Identify how modalities such as resistance training can have variability by identifying open vs. closed skill activities.
4. Differentiate between physical activity and exercise in a BH-EPAP.

Modality

The **modality** of exercise or physical activity may be modified to accommodate a client's **preference**, at least initially. If the client has participated in an EPAP that is highly **repetitive, novel** modalities or **variations** of the same modality may be integrated into an EPAP. This generally should occur **quarterly**, but there are also long-term benefits of **participating** in certain modalities over several **months** and **years**.

Brain Health Exercise & Physical Activity Plan (BH-EPAP)

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Type							
Intensity							
Duration							

The BH-EPAP template can be utilized to assess and recommend the modality (type) of exercise, as well as their intensity, duration, and frequency.

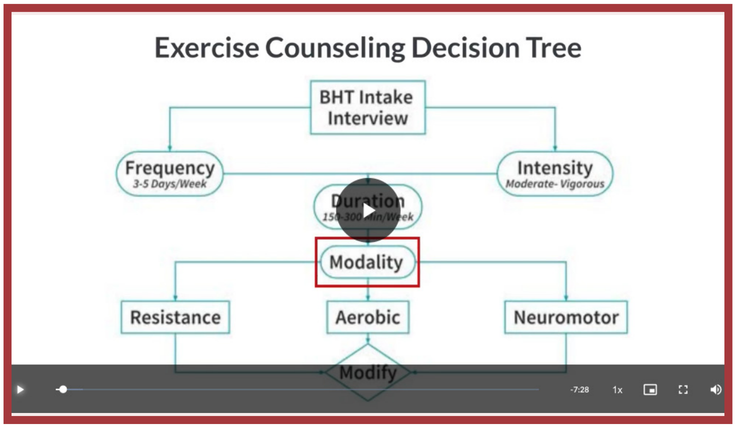
BH-EPAP Template

Click the button to the right to download the BH-EPAP template

TEMPLATE

Programming Exercise Modalities

Watch the video below to learn about BH-EPAP programming considerations for the various modalities of exercise, including aerobic, resistance and neuromotor training.



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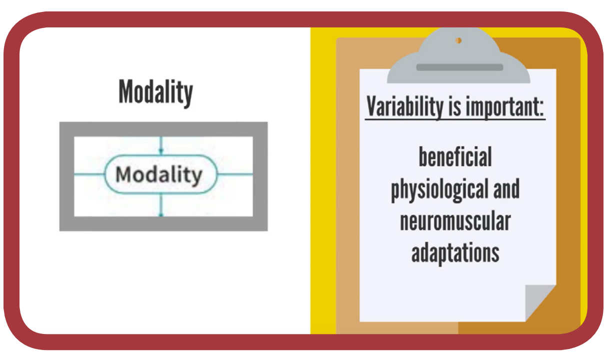
Tips for Programming Exercise Modalities

Participation in **multiple** and **variable** modalities of exercise may be most optimal for brain health, with various modalities **offering** both shared and **unique bene its** to the brain.

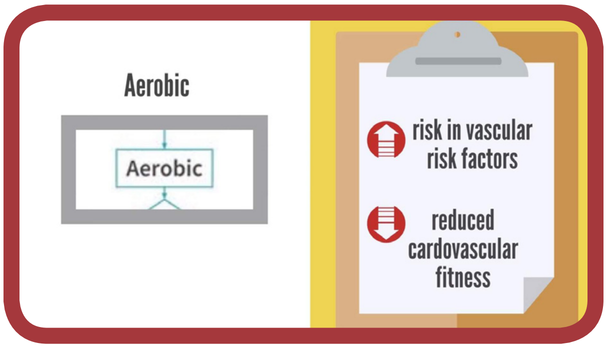


If individuals **do not participate** in one or more of the **primary modalities** of exercise, there exist potential **health risks** for both the **brain** and body.

Enjoyment, preference, **variability**, experience, **cognitive load**, and **cardiometabolic** demands are also **considerations** when **recommending** additional variable modalities of exercise.

Risk of Omitting Exercise Modalities

While meeting the **minimum** recommended **exercise guidelines** is the initial goal of a BH-EPAP (as outlined by the Physical Activity Guidelines for Americans, 2nd Edition), incorporating **additional** exercise **modalities** is thought to lead to a variety of **bene icial** brain health **outcomes** at the micro, macro, and behavioral levels. Therefore, there may be certain health **risks** if **speci ic** modalities are **not included** in a BH-EPAP.

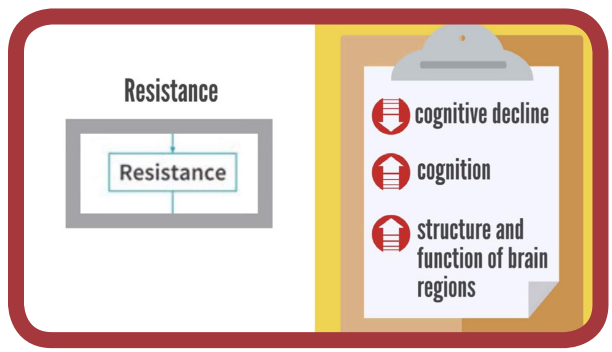


Some of the potential risks of not including Aerobic Exercise in a BH-EPAP.

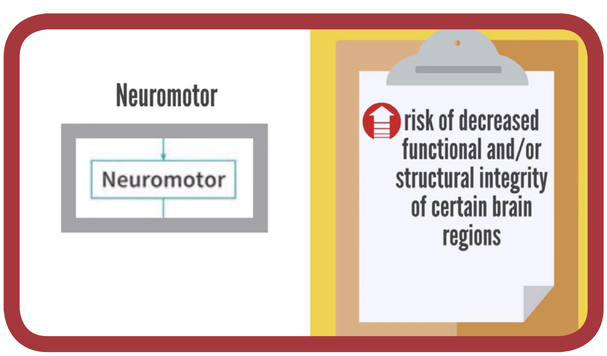
If clients do not participate in **aerobic** exercise, there may be an increased risk of **vascular risk factors** (cardiovascular disease, hypertension, stroke, vascular dementia, etc) and reduced **cardiovascular itness**, which has been correlated with greater **cognitive decline, risk of dementia**, and **reduced brain volumes** (hippocampus, gray matter)

The Risk of Omitting Resistance Training

If clients do not participate in **resistance** training, they may have an increased likelihood of **falls, osteoporosis, frailty, metabolic, musculoskeletal injury**, and/or **endocrine** issues. Resistance training has been found to slow cognitive decline and improve cognition (especially in functional & structural changes in the **frontal lobe**), even in those with **cognitive impairments**.



Some of the potential benefits of including Resistance Training in a BH-EPAP



Some of the potential benefits of including Resistance Training in a BH-EPAP

The Risk of Omitting Neuromotor Training

If a client does not participate in **neuromotor** training (or **open skill**, coordinative, or motor activities), their exercise program may lack sufficient **cognitive, coordinative**, and/or **rhythmic** demands. This may increase the risk of decreased **functional** and/or **structural integrity** of certain brain regions involved in motor **learning**, coordination, **novelty**, and skillful movement (such as the **cerebellum, basal ganglia**, & **PFC**)

How to Select Improvements to Focus On

Some people have several major **gaps** in their current routine or may not engage in exercise or physical activity at all. In other cases, even highly **motivated** clients can be just as **resistant** to making certain **changes**. You will need to collaborate with your client to focus on one or at most two changes during each **iteration** of the BH-EPAP. The **goal** associated with a BH-EPAP can change as you **update** the plan based on your client's **progress**.

Here are some tips for how to discuss which improvements to focus on within a BH-EPAP with a client.

1. It is important to remind the client that **healthy cognitive aging** and preventing dementia is a **life-long process**. This requires substantial **behavior** and **lifestyle modi ication** over **time**.

2. The first **priority** is always to make sure that your client is meeting the **minimum** recommendations for exercise. Make **compromises** with the client by modifying the **frequency, duration**, or **intensity** of the activities they are **already engaged in.**

3. The next priority should be to focus on the **type** and **variability** of the client's physical activity. The brain can benefit from **multiple modalities** of exercise. However, if **minimum** exercise recommendations are **not being met**, variability of exercise and **dual-task** training **alone** may not produce significant benefits.

4. When **discussing** variability and modalities of exercise with clients, it can be helpful to **link changes in behavior** to their **primary cognitive functioning goal.** This can create a point of **motivation** for change and can facilitate future **conversations** about the **bene its** of **including** multiple modalities of exercise.

5. Ask clients to tell you about the **activities** that they used to **enjoy in previous years.** In many cases, these activities can be **built back** into their **lifestyle** with appropriate **modi ications** of duration and intensity.

Programming for Aerobic Exercise

In order to meet at least the **minimum requirements** outlined by *The Physical Activity Guidelines for Americans, 2nd Edition*, HWPs should ensure that there are at least **150 minutes** of **aerobic exercise** present in a client's EPAP.

What's the Best Heart Rate Zone?

There is no "best heart rate zone" for achieving brain health, but some studies speculate that **65-75%** of a client's **Maximum Heart Rate** (MaxHR) is optimal to achieve brain health-specific benefits, such as the **release** of **optimal** levels of **BDNF**. If using the **RPE** Scale this may translate as a **6-8/10**.

Clients may be physically **active**, but may not be engaging in exercise that is **intense** enough. For example, engaging in **30 minutes** of dance at an **RPE** of **4/10** is considered physical activity but the **intensity** may need to **increase** to improve brain-health outcomes.

Tips for Programming Aerobic Exercise

Musculoskeletal Factors

Consider **musculoskeletal** factors, such as pain, **arthritis**, osteopenia, and other conditions that may influence **choices** of physical **activity**. For example, a client with **knee pain** may not be willing or able to begin **running** outside, but they may be able to ride a **recumbent bike**.

Fitness Assessments

Utilize **itness assessments** for threshold-specific programming, with tests for **cardiovascular endurance** (i.e. Rockport Walk Test), **muscular endurance** (i.e. 30 Second Sit to Stand), and **functional mobility** (i.e. Timed Up and Go).

Modifying Frequency

Start by adding **1-2 days** of exercise more than what the client is **already exercising** at. If the client is not currently exercising on a **weekly** basis, then introduce exercise at **1-2 days per week** for the first **4-12 weeks**. If the client is exercising **2-3 days per week**, increasing to **4-5 days per week** may be appropriate.

Modifying Intensity

If the client is exercising at a **low intensity on average**, increasing to **moderate intensity** is warranted. Increasing from a low average intensity **immediately** to a **vigorous** average intensity may not be appropriate, as this requires more steadily **periodized** cardiorespiratory **progression** over time.

Modifying Acute Variables

A client that is **uncomfortable** with increasing their **duration** or **intensity** of exercise may be more comfortable increasing the **frequency** of exercise. Conversely, a client that cannot or does not want to increase their **frequency** of exercise, may consider **greater duration** or **higher intensities** of exercise.

Programming Steady State vs. Intervals

Below are various tips for modifying the types of aerobic exercise, either interval or steady-state training, as well as several acute variables.

- If a client **struggles** with **steady-state** cardiovascular exercise or **longer** session durations, consider using **interval** training. This allows the client to **alternate** session types according to their **comfort** levels. For example, the client can exercise at lower intensities during longer duration sessions and exercise at higher intensities in shorter duration sessions.

- If a client struggles with **interval** training or higher intensities, consider more **moderate** intensity, steady-state sessions of aerobic exercise. This allows the client to stay within a level of **intensity** that is comfortable for them and creates a feeling of **perceived comfort**.

- EPAPs should include **both** higher and lower **intensities**, as well as **interval** and **steady-state** training. This may be done weekly by including both modalities every week on **different days**, for instance, **2 days interval** training, **3 days steady-state** training.

Programming Resistance Training

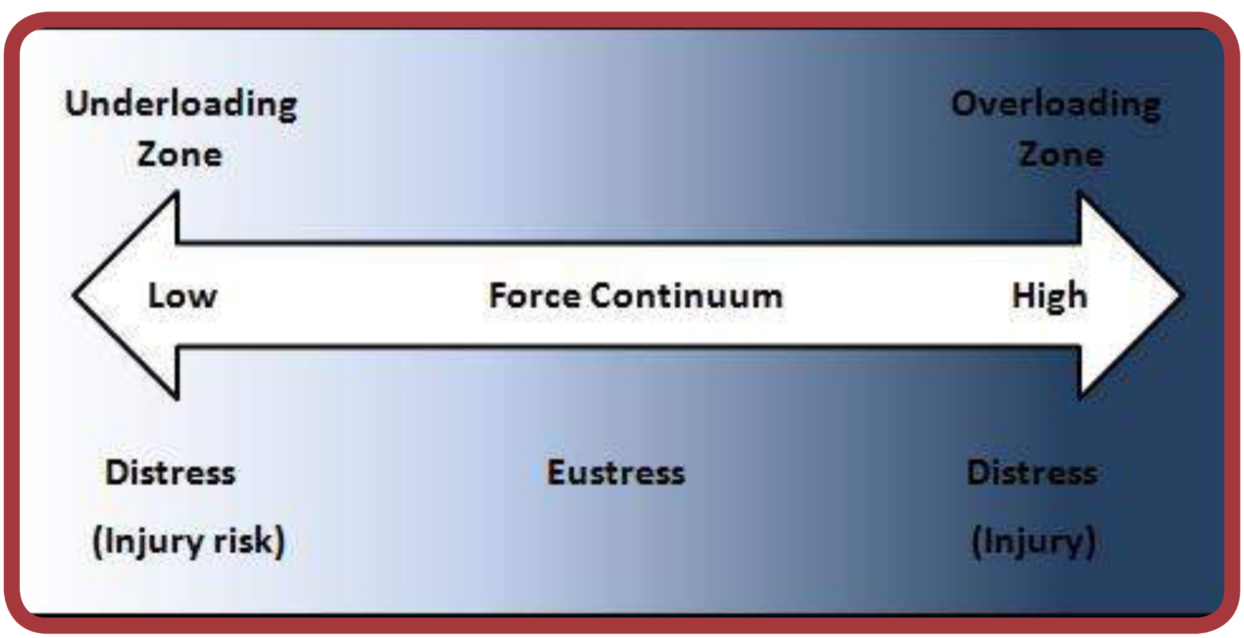
In order for clients to receive the benefits of **resistance** training (RT), HWPs should encourage participation in resistance training at least **2 days per week**. Once the client has demonstrated **readiness**, comfort, and **pro iciency**, increasing the frequency to **3 days per week** may be better to **improve cognition**.

Assessment & management of **injury risk** should occur **prior** to and **during** RT programs, with **supervision** provided at the **initial stages** & during the introduction of **novel techniques**. Including a variety of **skill-demands** in the form of both **open-skill** (i.e. functional training) and **closed-skill** (i.e. traditional or machine-based training) is recommended.

Modifying Training Volume

While the HWP should not be afraid to increase the **volume** of training, they should be **cautious** of injury risk and subjective levels of **comfort** during and post-exercise training, especially resistance training.

The HWP should be sensitive to other **mechanical** or **psychological stressors** the client is undergoing, and anticipate changes in volume as needed.



Programming Motor & Coordination Training

To plan on **integrating Motor** and **Coordination** training into a client's EPAP, HWPs should consider a client's **access, enjoyment**, and **experience** of activities. For example, an HWP should not recommend tennis if a client **cannot access** that type of activity, does not **enjoy** tennis, or has no **desire** to pursue such modalities.

Before integrating Motor & Coordination training, the HWP should consider if a client wants to **pursue** the modality on its own (**dedicated days** to Tai Chi, for example), or **integrate** coordinative exercises into **existing workout** sessions. This can **save time** and provide convenience.

Updating Motor and Coordinating Training

The **challenge**, type, **skill** demands, or context of Motor & Coordination training should be modified about **every 12 weeks**. However, constantly **progressive challenges** (within levels of **enjoyment**) may occur throughout an entire training program.

A **goal-speci ic** Motor and **Coordinative** exercise **modality** should be recommended at least **2 days per week**. Three days per week may yield additional benefits but may require a trade-off with other modalities of exercise or physical activities.

Programming Multicomponent Training

Because recommendations for **cardiovascular, resistance**, and **motor** and coordination training all average around **2-3 days per week per modality**, the HWP may have **difficulty** facilitating **adherence** with an EPAP that requires **7 days per week** of structured exercise. This is **especially** challenging if the client is currently exercising at a **low frequency**.

There is an **opportunity**, therefore, to **combine** at least **two modalities** of exercise together in a **single session**. While multi-component training often refers to **multiple modalities** of exercise **participated** in within a **single week** or month, this approach considers **multiple modalities** within a **single session**.

Multicomponent Training Variability

The **combined** modalities of a multicomponent training program may be **modified** for **novelty** and can be completely changed every **12-24 weeks.** If this is done, whatever modality that was part of a multicomponent session **should not be "entirely removed"**, but **modified** by **combining** it with other modalities or by **manipulating** its acute **variables**.

Including Multiple Modalities

All **three primary modalities** of exercise should be **combined** in most EPAPs to achieve **maximum** cognitive and physical **benefits**. This is best accomplished by incorporating both intra-modal and extra-modal programming, with single-modality sessions being utilized to achieve more selective cognitive benefits, and multi-modal sessions being used to achieve more generalized or global cognitive benefits.

Intra-session multi-component

Intra-session multi-component training involves **multiple modalities** of exercise **within one exercise session**. Therefore, a **single session** of **60 minutes** might include **2-3 modalities**, with **20-30 minutes** spent per modality, following either a **sequential** or **alternating** exercise **order**. This allows multiple variables to be manipulated in order to maintain novelty and **variability**.

Extra-session multi-component

Extra-session multi-component training involves **alternating different modalities** on **different days** of the week. For example, one may participate in **aerobic** training **3 times** per week and **resistance** training **2 times** per week. This is still considered a **multi-component** training program, as compared to a **singular** modality program, such as **12 weeks** of only aerobic training.

Sample BH-EPAPs

Below we have included two sample BH-EPAPs based upon a client's level of experience and motivation. The "Beginner" BH-EPAP is applicable to low-motivation or novice clients, while the "Advanced" BH-EPAP is for more experienced and motivated clients. Each BH-EPAP possesses multimodal characteristics and at least 150 minutes per week with a variety of intensities.

SAMPLE BH-EPAP PROGRAM - BEGINNER

	Monday	Wednesday	Friday	Saturday
Type	Bike & Weights	Dance (Zumba)	Bike & Weights	Walking
Time	30 min ea (60 min total)	60 min	30 min ea (60 min total)	60 min
Intensity	6-8/10	4-7/10	6-8/10	2-5/10

SAMPLE EXERCISE BH-EPAP - ADVANCED

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Multi-component *(AT +RT + Balance)*	**Tai Chi** (group)	**Multi-component** *(AT +RT + Balance)*	**Dance** (skill-based)	**Multi-component** *(AT +RT + Balance)*	**Tai Chi** (home)	**Dance** (skill-based)
- 60 min (20 min/type) *- Moderate intensity*	*-30 min* *-Low Intensity*	*- 60 min (20 min/type)* *- Moderate intensity*	*- 60 min* *-Low to Moderate Intensity*	*- 60 min (20 min/type)* *- Moderate intensity*	*-30 min* *-Low Intensity*	*- 60 min* *-Low to Moderate Intensity*

AT = Aerobic Training

RT = Resistance Training

Congitive Domain Modality Chart

The chart below provides a **summary** of the potentially **selective cognitive** benefits of a variety of types and modalities of exercise. Understand that this chart is incomplete, **inconclusive**, and debatable, but rather exists to provide a **generalized understanding** of how different modalities of exercise may yield differential cognitive outcomes. The understanding of how different types of exercise affect cognition is limited by **research methodology** (what **assessments** are used), **power** (how many subjects were enrolled), and **statistical significance** (level of significance)

Modality	Executive Functions	Processing Speed	Memory	Attention
Aerobic Training (AT) & Closed Skill Training ***	X		X*	X
Resistance Training (RT)	X*	X		
Open Skill Training	X			X*
High-Intensity Interval Training		X*	X	
Mind-Body Exercise (Tai Chi, Yoga, Dance)	X		X	
Coordinative / Motor Training (MT)	X	X	X	
Balance & Gait Training	X			X
Multicomponent Training (AT + RT + MT)	X	X	X	X
Dual-Tasking Training **	X		X	X

X = General Effects … X* = Specific Effects

An effect in one or more cognitive domains for each exercise modality does not indicate how significant the improvement may be.

** Depends on the type of cognitive and physical activities performed

*** Depends on the intensity of training, but typically moderate-intensity cardiovascular exercise seems to yield the best results

Lesson 4: Modifying BH-EPAPs

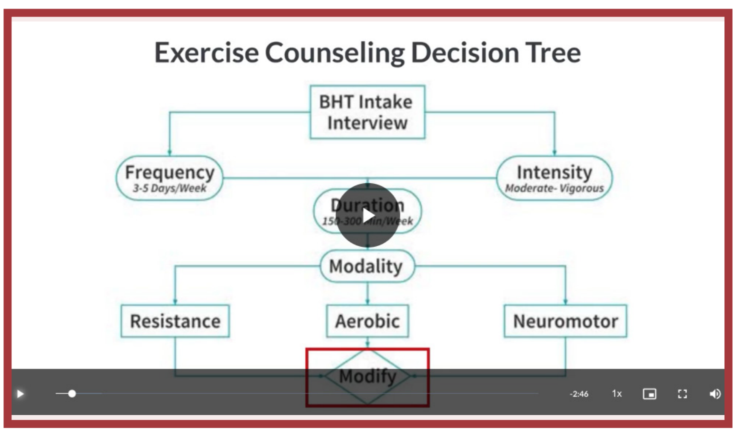
Lesson 4 Objectives

1. Identify reasons for modifying acute variables within a BH-EPAP.
2. Understand the importance of modifying a BH-EPAP to accommodate a client's level of skill and preferences.
3. Identify opportunities to modify a BH-EPAP to better adhere to the minimum guidelines for exercise and BH-EPAP variability over time.

Modifying BH-EPAPs

After BH-EPAPs has been created, it is likely they will require modification in the short, medium, and long-term. Modifications could be anything from increasing an acute variable, such as intensity, frequency, or duration, or adding a new modality of exercise.

Modifications can also occur to provide increased enjoyment, preference, or convenience. As the client's health, environment, and psychology may change, so must their BH-EPAP. Watch the video below to learn more about BH-EPAP modification.



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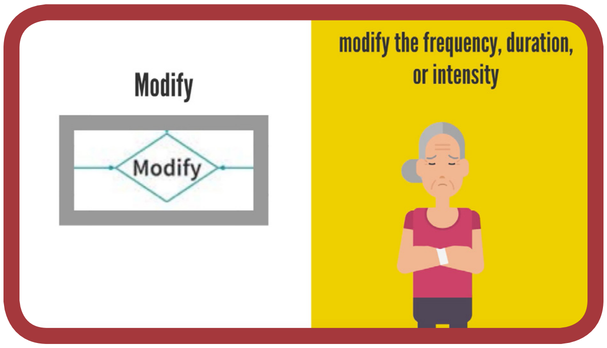
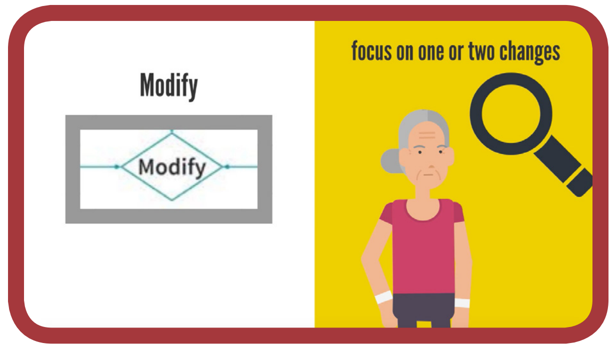
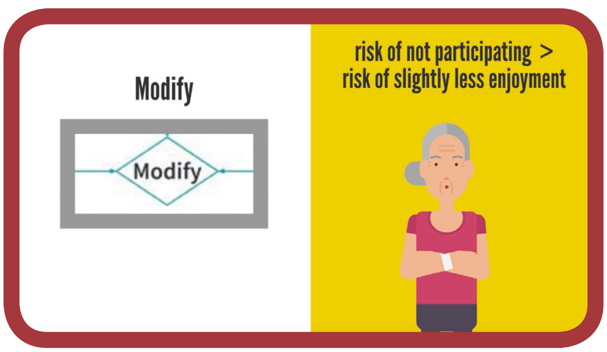
Modifying Acute Variables



Modificatio of BH-EPAPs is necessary to ensure **satisfaction**, progressive **overload**, and **lifelong brain health**.

Focusing on **one or two changes** within a BH-EPAP at a time is most **behaviorally sound,** with **modification** occurring approximately every **3 months**.

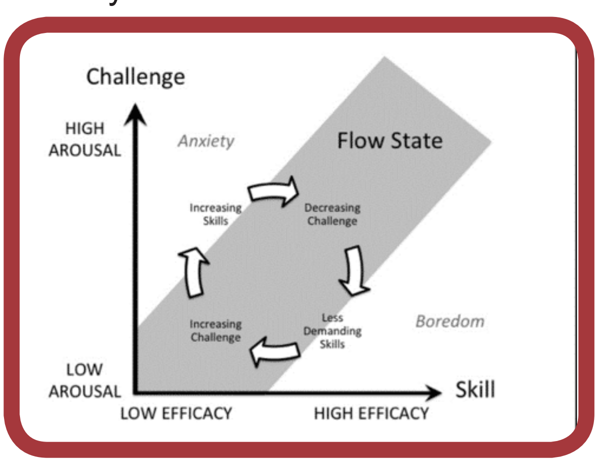




Managing the total **cognitive, neuromuscular**, and **metabolic load** of an EPAP, including the **novelty** of modality, is important for mitigating **risk** and ensuring **enjoyment**.

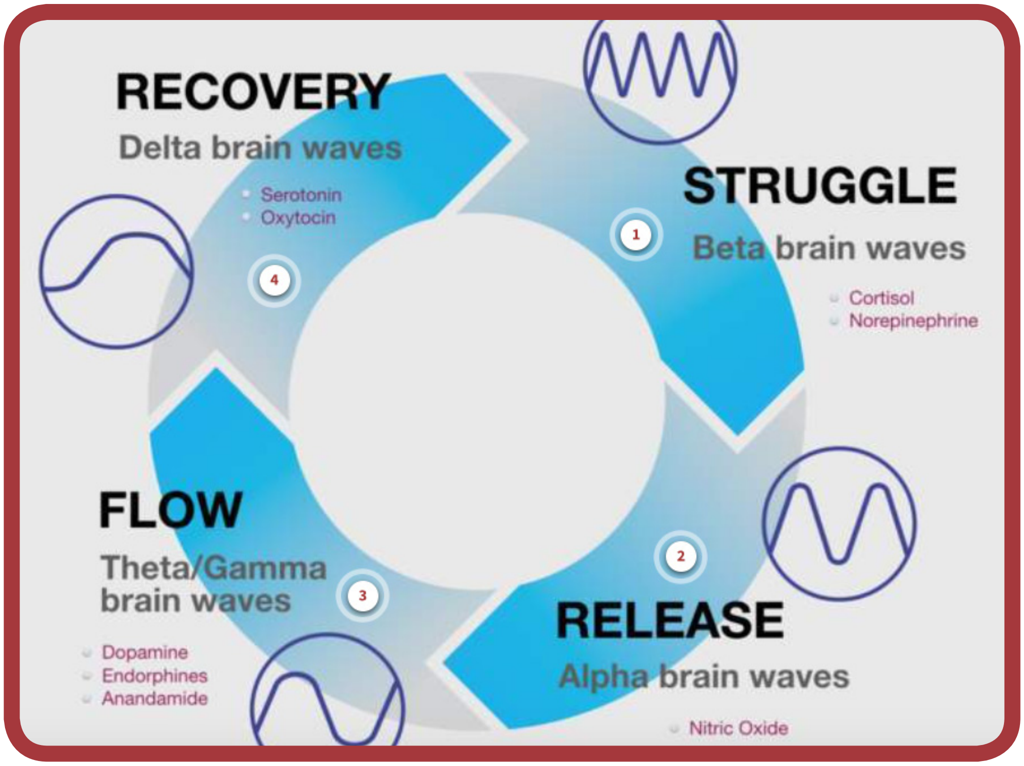
Modifying Skill Demands

A client's **skill level** can often be reflective of their **experience** in any modality of exercise or physical activity. Clients who have limited experience in a modality are likely to have lower levels of skill, and the inverse is true for clients with more experience in a specific modality.



Flow States & the Brain

The level of challenge that activity presents should be slightly higher than the client's skill level in order to maintain a "flow state", in which both positive affect and various micro-level (such as changes in certain neurotransmitters) and macro-level changes (such as changes in brain activity) occur.



1. Struggle - When novel activity or challenge is encountered, the "struggle" phase occurs, releasing cortisol & norepinephrine alongside beta brainwaves (which are fast), all of which is associated with alertness & attention.

2. Release - After higher-level cognitive functions are employed, the "release" phase relieves stress through the release of Nitrous Oxide and increase in alpha waves (relaxation, daydreaming), which may explain such states after intense bouts.

3. Flow - When skills & challenge balance, a "flow" state occurs, with neurochemicals associated with reward & pleasure (dopamine, endorphins) are released alongside theta/gamma waves, which are fast involved in processing, learning & memory.

4. Recovery - After engaging in flow, the "recovery" stage occurs, which releases inhibitory neurotransmitters (serotonin, oxytocin) and increases delta brain waves (slow-waves present in deep sleep) to promote recovery & memory consolidation.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ The Exercise Counseling Decision Tree will help you analyze a client's existing exercise routine or the current version of their BH-EPAP. You should use it each time you complete the intake interview with a new client or when updating an existing plan.

- ☐ Analyze the frequency, duration, and intensity of exercise first to identify any deficits as related to the minimum standards for exercise.

- ☐ Identify opportunities to add new modalities of exercise, variability, and cognitive-physical or dual-task training. In discussion with the client, refer to their primary CFG and activities they used to enjoy as a way to increase their motivation for change.

Reflection

Take a moment to reflect on all that you have learned in this module. Use the space below to record your thoughts.

Module 4:
Cognitive-Physical Exercise Library
Handbook

Introduction

In **Module 2**, you learned about the **value of cognitively-enhanced exercise, dual-tasking**, and **motor & coordinative training**. While programming for aerobic, resistance and skill-based exercise is more common, cognitive-motor dual-task techniques are less commonly known.

Module 4, will **demonstrate** how to apply cognitive tasks to existing exercise techniques, modify them according to an individual's physical and/or cognitive performance on the **combined cognitive-physical task**, and specify what cognitive task category might need to be emphasized for a client.

The **exercise techniques** shown in this module serve as **creative examples** of how to begin **integrating cognitive demands** into traditional **training sessions**. While the videos demonstrate individual training, applications and **ideas** for **group** and **virtual training** are given.

Module 4 Overview

Module 4 Agenda and Objectives

1. Understand how these techniques are applied and modi ied with a client with unique cognitive functioning goals.

2. Use the NASA Task Load Index tool to modify physical, cognitive, and temporal demands.

3. Plan adaptations and variations to cognitive-physical tasks based on changing goals and conditions and adapt various tools and equipment.

Module 4 Introduction Video

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Introducing Cognitive Load to Movements

Before applying a cognitive task to a movement, several suggestions have been provided below to prevent injury, frustration, and effective cognitive-physical task integration.

1. Ensure that the movement has been learned and is within at least the associative or autonomous phases of motor learning.

2. Make sure to select and rehearse cognitive demands before they are given. While some improvisation is normal, complete improvisation is not recommended.

3. Try to select cognitive tasks that relevant to a client's goal (CFG), but not at the cost of frustration, failure, or embarrassment.

2. Select tasks that clients can experience both challenge and success. Be cautious not to select tasks that are too difficult or too easy.

3. Be cautious of adding external load or physical progression to dual-tasks before they have been adapted to, as this may lead to potential injury.

NASA Task Load Index

Click the button to the right to download the NASA Task Load Index PDF.

DOWNLOAD

Print out the NASA Task Load Index to have on hand during the viewing of the videos within the exercise library. Not all scales will be used all of the time. The Cognitive Load and the Physical Load scales will be used mostly in between sets, and the other scales may be used after the entire sets are complete.

NASA Task Load Index

By adding cognitive tasks to movements, there arises a need to measure the amount of work being performed relative to an individual. The NASA Task Load Index (TLX) is a tool developed by NASA's Human Performance Group to measure workload within a task. This on-the-job tool is important for gaining feedback from clients in order to progress, regress or create buy-in for an exercise.

Similar to how RPE scales are used to measure physical intensity, the NASA TLX can also measure cognitive (or mental) demand, effort, temporal (or speed) demands, frustration, and perceived performance. The NASA TLX contains six seven-point scales. Each scale is based on a question that evaluates the workload based on high, medium, or low estimates.

NASA TLX's 7 Scales

While not all scales of the NASA TLX need to be utilized, it is helpful to know what each scale represents. The scale categories are presented as questions that can be used to ask the client. For example, "**on a scale of 1-10, with 1 being the least mentally demanding, and 10 being the most mentally demanding, how mentally demanding was this task?**"

While the original NASA TLX has increments of 21, a **scale of 1-10** is recommended in order to simplify the tool's utility and maintain familiarity with the 1-10 RPE scale. Numbers are utilized for greater specificity, but "**low, moderate, and high**" demands can be used to simplify feedback.

1. **Mental Demand**
   How mentally demanding was the task?

2. **Physical Demand**
   How physically demanding was the task?

3. **Temporal Demand**
   How hurried or rushed was the pace of the task?

4. **Performance**
   How successful were you in accomplishing what you were asked to do?

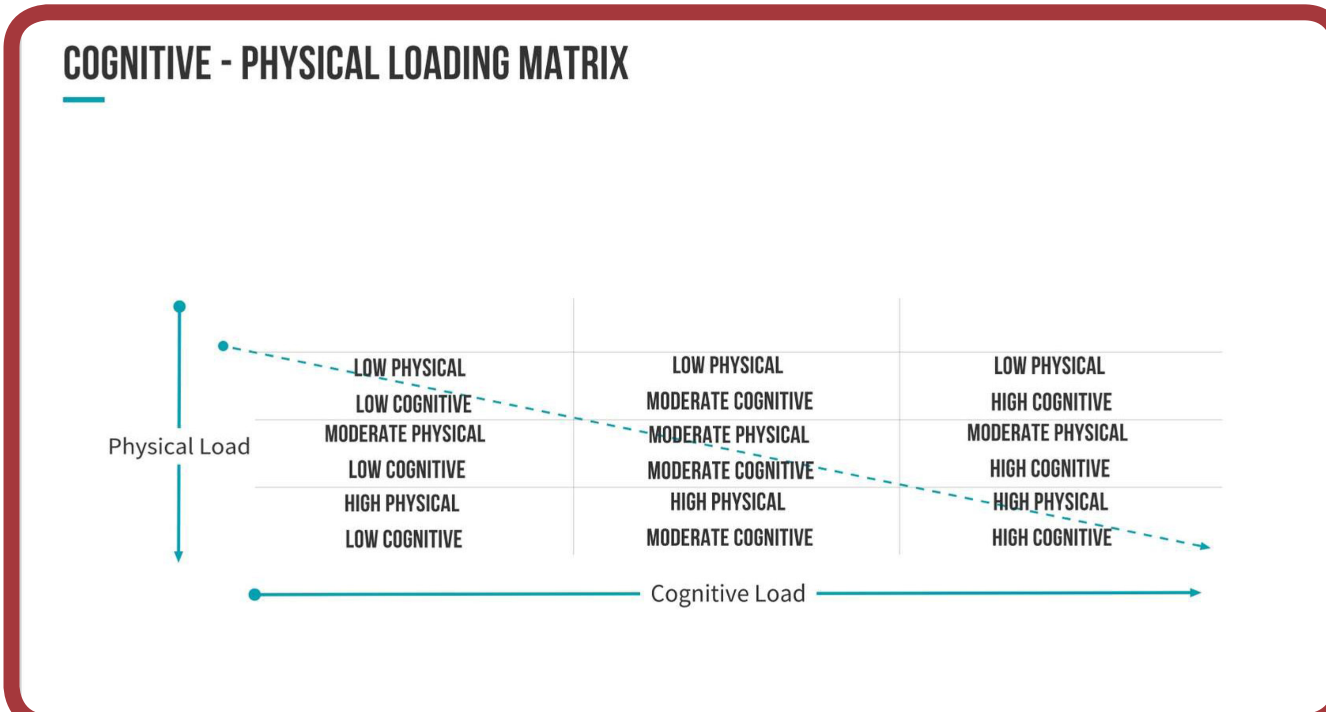
5. **Effort**
   How hard did you have to work to accomplish your level of performance?

6. **Frustration**
   How insecure, discouraged, irritated, stressed, and annoyed were you?

There is no “scoring” the NASA TLX. Rather, the scales are used during or after tasks and activities. The NASA TLX can be used to gain feedback on specific techniques, individual sessions, or BH-EPAPs as a whole. Scores can be recorded (written or digitally), or they can be used to modify exercises or programs “in the moment”.

Managing Cognitive & Physical Demands

While cognitive and physical demands can be measured, cognitive demands arise as another variable to manage in relation to physical demands. Physical and cognitive demands can be progressed or regressed independently or simultaneously. The “matrix” below demonstrates how this may be done with low, moderate, or high cognitive and/or physical demands.



The left-to-right diagonal dotted arrow demonstrates a pathway of increasing cognitive and physical demands simultaneously.

Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ When adding cognitive load, keep safety the #1 priority. Incorporation of cognitive load that is too great or in combination with movements that are not well-learned, can lead to potential injury risk.

- ☐ Cognitive load should be introduced when incorporating more neuromotor activities are warranted and when clients have specific cognitive functioning goals. Cognitive load can be added when more variability is needed, or when physical progressions have plateaued.

- ☐ Cognitive and physical demands can be increased separately or sequentially, depending upon the goals and abilities of the client. General progression and regression principles apply to techniques that increase cognitive demands.

Lesson 1: Tools & Equipment

Section Objectives

1. Identify tools that can be utilized with combined cognitive-physical dual-task techniques.
2. Identify the characteristics of certain tasks as they pertain to one or more of the four primary domains of cognition.
3. Understand the Cognitive Domain Volume Knobs, and how they may be used to classify the domain-specific cognitive demands of tasks.

Identifying Tools & Equipment

Before exploring the opportunities for incorporating cognitive load into exercise, it is important to identify the "toolbox" that an individual may utilize to introduce a novel, variable, and appropriate exercise techniques.

Below are several categories of these tools and explanations as to how they may affect exercise programming.

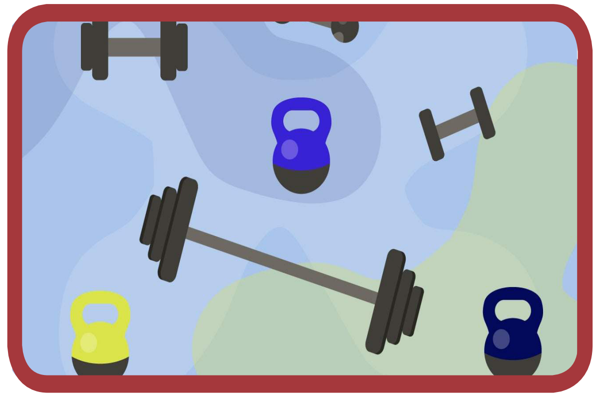
Speed, Agility & Quickness Tools

Speed, agility, and quickness (SAQ) tools can provide an excellent format for adding **coordinative**, aerobic, **motor**, and additional cognitive demands. SAQ tools often include cones, hurdles, floor dots, poles, and ladders. **Various layouts** using one or more of these pieces of equipment allows the potential for variability, **novelty**, and **open-skill** training.

Tools for External Load

Tools that provide external load, such as bands, free weights, cable machines, and functional training tools introduce opportunities to create more **load** and tension, but also provide a unique opportunity for **motor learning**.

Introducing **loaded movement training**, such as that found with kettlebells, clubs, or introducing more conventional external loads, such as dumbbells, barbells, and machines, loaded tools provide contextual **novelty**, as well as unique **cognitive** benefits. Resistance training may provide selective or differential cognitive adaptations when compared to aerobic training.



In addition, **limb** and **fine motor coordination**, as well as the eliciting of **postural control**, may add more cognitive load. The HWP should exercise caution, as having too much cognitive load with higher external loads may put clients at a higher risk for injury.

Linear vs. Triplanar Applications

Direction of movement is also an important factor, and we may delineate this by either the planes of motion (sagittal, frontal, transverse), or by unidirectional or **multidirectional**. While the effects of moving in different planes of motion have not been directly studied, it is interesting to think about the potential effects on cognition.

For example, aerobic training and resistance training are typically conducted in a **unidirectional** fashion, at least in a majority of the research. On the other hand, motor, coordinative, dance, martial arts, mind-body exercise, or sports interventions are typically occurring in **multidirectional** formats. While these associations are by no means exclusive, a variety of directions seem to be coinciding with multimodal EPAPs, which may potentially be better for brain health as much as musculoskeletal health.

Dynamic Tools & Balance Tools

Balance tools and “**dynamic**” tools add elements of unpredictability to exercise and physical activity. Similar to how SAQ equipment may add elements of simulated environmental **enrichment**, balance and dynamic tools also add these elements.

Examples of these include **unstable** surfaces, loaded implements with shifting mass, such as **dynamic resistance** and sandbags, or equipment that mimics irregular terrain. These tools and environments add greater sensory input, typically through **proprioception**, and may add more cognitive load via motor planning and reflexive demands.

Sports Tools

Sports tools are implements derived from sports, such as balls, bats, and racquets. These implements are excellent for providing **motor learning** and **visuospatial** demands. While these tools may be used to participate in the sports and activities they were meant for (each of which provides its own **unique set of cognitive and physical demands**), they may also be utilized to enrich exercise and physical activity sessions.

Although sports are typically conducted in the context of competition or leisure, one approach may be to use these tools within **open-skill activities** in the context of brain health, specifically in **applying cognitive demands**. Since in this application, being “skilled” is not required, there is no concern about “how good” somebody is at the sport movement in order to experience it.

Rather **skill acquisition** is the goal, and therefore the cognitive phase of motor learning, which is typically associated with the practice, frustration, and error. It is important to contextualize expectations with clients, relate the use of these tools and techniques to their **CFGs**, and facilitate the enjoyment of the process.

Technological Tools

While the use of technology is not demonstrated or discussed in the context of this course, it is a major evolving component of the presence of brain health in the wellness, fitness, and medical industries. However, from assessment to training, **technology** provides a variety of potential benefits to exercise and physical activity. One example is the evolving technology surrounding **dual-tasking** and cognitive-physical training.

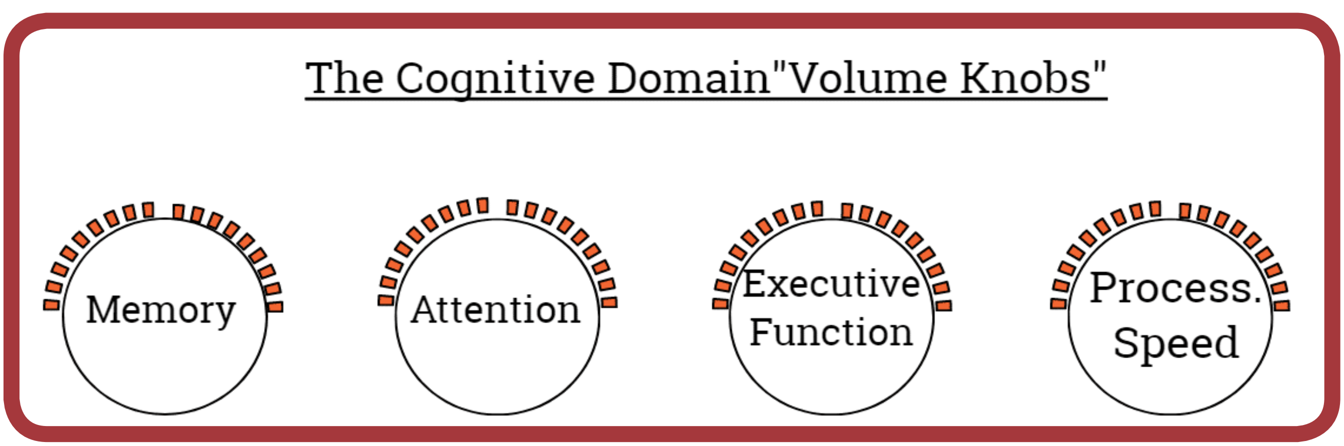
The implementation of technology can often provide **turnkey cognitive stimulation**, reporting, and performance tracking capabilities, and variable stimuli. Technology may be in the form of applications, or a combination of **hardware** and **software** with various levels of portability and specificity towards certain populations.

While no specific technology solves all of the **needs** an HWP has in terms of the **assessment, training**, and enhancement of brain health, the future is extremely promising for bringing **multiple modalities** into the hands of the modern HWP. In general, there are pros and cons to the spectrum of low tech to high tech tools, and a **combination** of these modalities is most likely ideal.

Assessing Cognitive Demands

While we use the **NASA TLX** to assess cognitive and physical **demands**, there is also a need to identify the demands of certain cognitive domains. This concept is based upon a **theoretical** construct that the neural circuits active during specific tasks will be most active if those tasks are given.

Identifying one or more of the **4 Cognitive Functioning Goals** may serve as a method for adjusting the domain-specific cognitive load. All cognitive domains will be active during most tasks at varying levels, but it is helpful to identify which of these four cognitive domains are primarily engaged during these tasks. In order to do this, we created a visual metaphor called **The Cognitive Domain "Volume Knobs**."



The **Cognitive Domain Volume Knobs** are helpful to keep in mind as cognitive-physical techniques are taught. It may even be helpful to print out and keep handy as you go through each cognitive-physical activity within this course or with your clients.

Cognitive Domain Volume Knobs
Click the button to the right to download a picture of the Cognitive Domain Volume Knobs

DOWNLOAD

Each **Volume Knob** relates to one of the four cognitive domains. Since different tasks may require different cognitive abilities more than others, we have defined these abilities and have provided examples below:

Domain-Specific Tasks Characteristics

Certain tasks possess certain characteristics that may pertain to one or more of the four primary cognitive domains.

Memory

Tasks that include **routines**, procedures, steps, complex **instructions**, rules, and choreography are likely to include **memory** processes. Requiring the **visual recall** of locations, the **verbal recall** of lists or numbers, and any movement skill in the **cognitive phase of motor learning** is likely to employ more memory-related resources.

Attention

Tasks that require an individual to **attend** to sensory **stimuli**, either in the presence or absence of other stimuli, typically define tasks of **attention**. Listening for **audible cues**, attending or searching for visual cues, and **allocating** attention internally or **externally** are included.

Executive Function

Tasks that require organizing, **planning**, directing, reasoning, problem-solving, **working memory**, or **impulse control** are likely to employ executive functions. Tasks that are **open skill**, **novel**, or in the cognitive phase of motor learning are also likely to employ **executive functions**.

Processing Speed

Tasks with higher **temporal** or **speed demands** are likely to require more resources associated with processing speed. The speed at which any task is executed could be measured in **time**, and therefore **processing speed** may be assessed within any task. Tasks that include how fast movements are executed based on **visual, auditory**, or sensory cues are associated with processing speed.

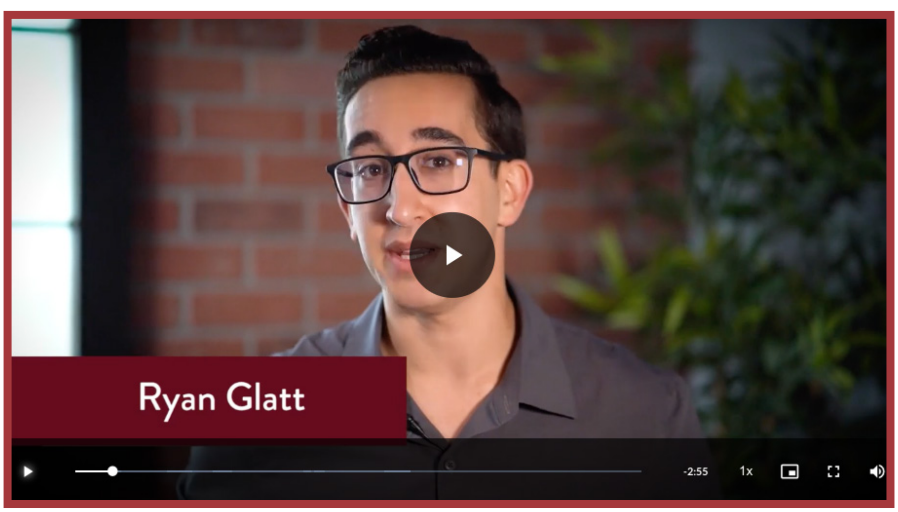
Key Takeaways

Check off each key point if you feel that you understand it.

- ☐ A variety of tools, equipment, and technologies are helpful for keeping EPAPs variable, novel, enjoyable, skill-based, and beneficial to brain health.
- ☐ The NASA Task Load Index (TLX) can be used to assess multiple domains of experience, such as cognitive load and temporal (speed) demands.
- ☐ The Cognitive Domain Volume Knobs can be used to identify how much a task subjectively demands of the four primary cognitive abilities.

Lesson 2: Squat Variations

Watch the first of the exercise library videos, the Squat Variations video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.



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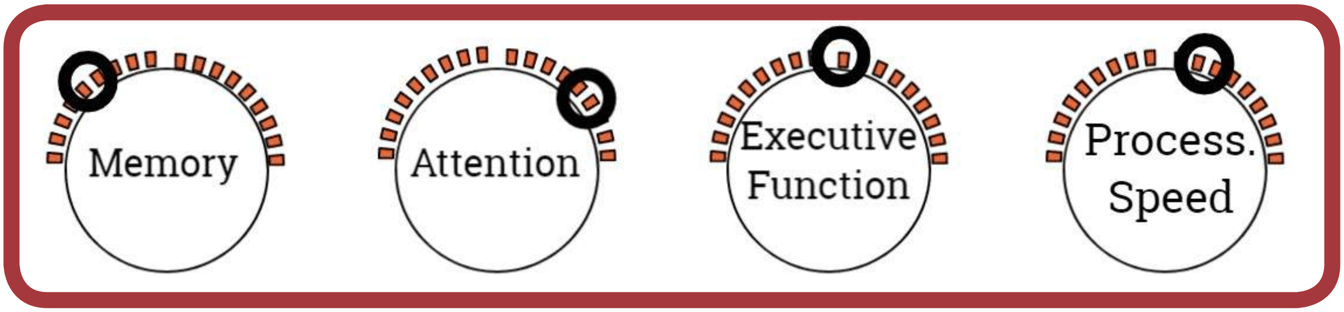
Squat Variations Guidelines

This exercise began with a familiar one; **the squat**. It is important that the client can demonstrate approximately **80% efficiency** of the movement before incorporating a cognitive task, and if this is not the case then regressions (such as range of motion, adding a chair, or placing a stability ball on the wall) should be utilized.

The time-stamps below identify at what points variations (both cognitive and physical) are implemented in the video above. This serves as a guide when referring back to these videos for review.

Attention Variations

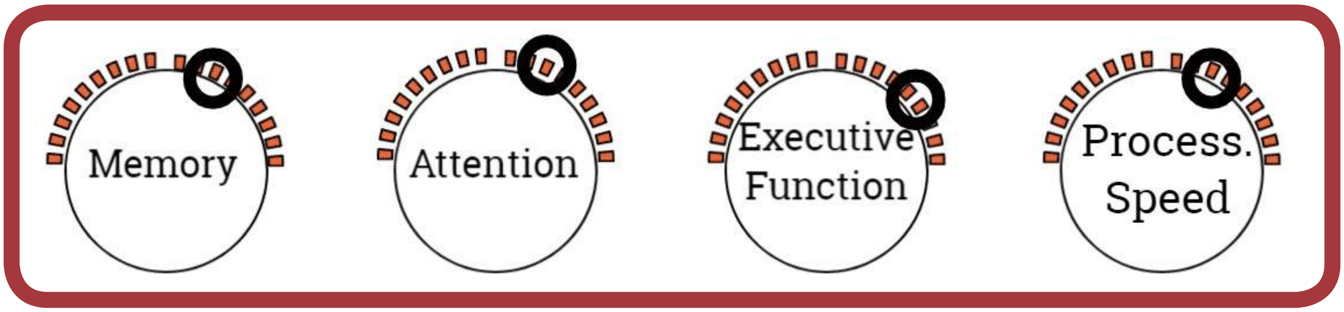
- **1:20** - Sustained Attention variation with one ball
- **2:55** - Attention Switching variation with two balls



Cognitive Domains Volume Knob Levels for Attention Techniques during Squat Variations

Executive Functioning Variations

- **6:30** - Serial 3’s Subtraction Task with external load
- **7:40** - Serial 7’s Subtraction Task with external load



Cognitive Domains Volume Knob Levels for Executive Function Techniques during Squat Variations

Memory Variations

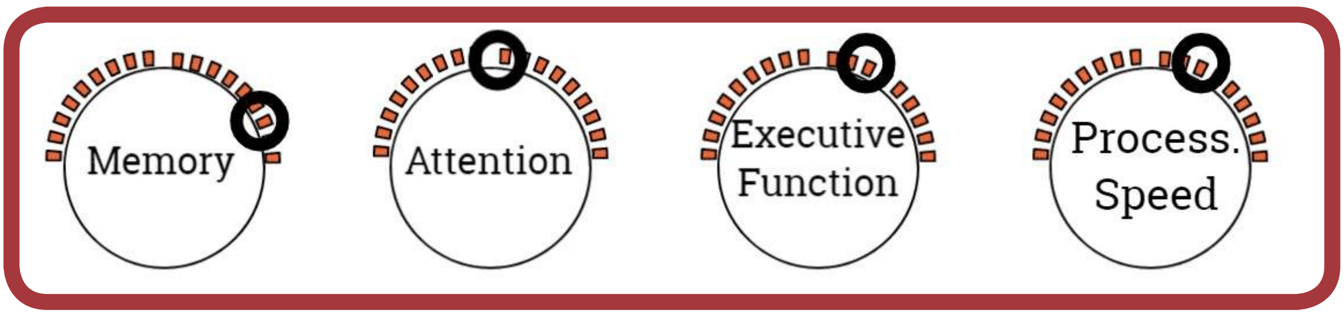
- **9:35 -** Word Lists during continuous squat

The first list that was given consisted of 5 items associated with the grocery store. The immediate recall of this list is associated with **short-term verbal recall**.

The second list consisted of 5 household items. This list served as a “distractor” or an active task that created more time between the first list.

Repeating the first list after the second list is addressing **delayed recall**. The amount of time between stimuli can be modified to be greater between each successful stimuli, which is similar to **spaced retrieval** techniques.

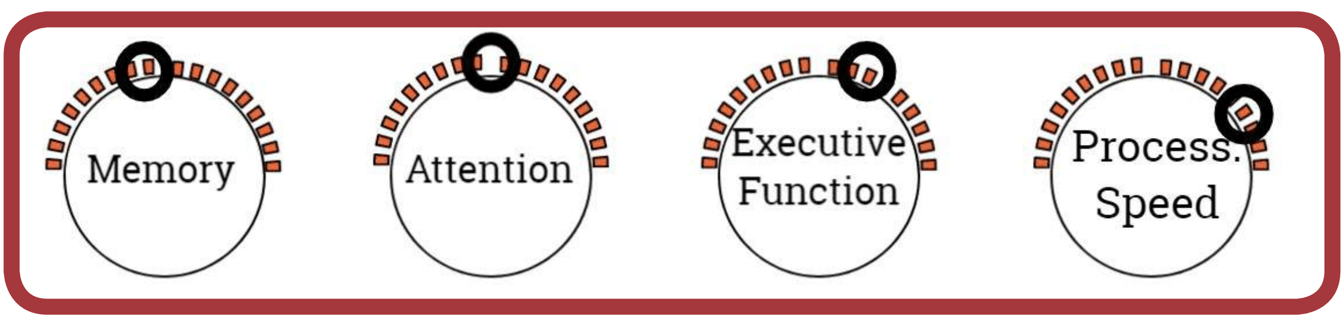
Changes in word length, abstraction, and list length also are potential modifications.



Cognitive Domains Volume Knob Levels for Memory Techniques during Squat Variations

Processing Speed Variations

- **12:45** - Visual Cues: Odds/Evens Response Task
- **14:00** - Audible Cues: Odds/Evens Response Task



Cognitive Domains Volume Knob Levels for Processing Speed Techniques during Squat Variations

Modifications

- **Foot Placement:** Split Stance, Single Leg, Wider/Narrow
- **Load**: Dumbbells (Unilateral or Bilateral)
- **Tools**: Balls, Balloons, Stability Ball, Chair
- **Duration**: Longer Set, Time Under Tension
- **Cueing**: Auditory, Visual, Speed of Stimuli Delivery, Angular Variations of Ball Toss

Group Modifications

- Have partners give each other lists to memorize.
- Have partners alternate lists or numbers.
- Have partners toss a ball with asynchronous squatting.
- Use a “hot potato” variation in a circle or small group.

Lesson 3: Catch and Toss Variations

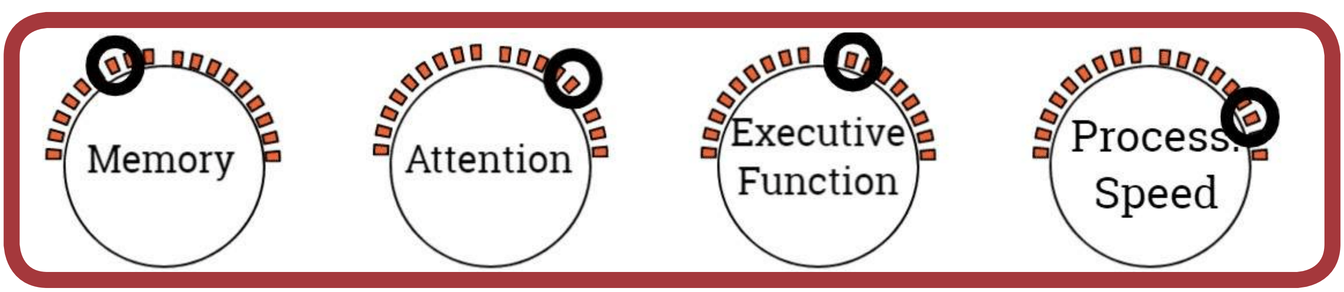
Catch & Toss Variations Video

Watch the second of the exercise library videos, the Catch & Toss Variations video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.

VIEW ON VIMEO >

The time-stamps below identify at what points variations (both cognitive and physical) are implemented in the video above. This serves as a guide when for referring back to these videos for review.

- **0:40** - Left / Right Catch, Add Marching
- **1:15** - Audible Left / Right Catching Cue
- **1:40** - Balance Variations: Tandem Stance and Single Leg (2:00)
- **2:50** - Fast Feet (cardiovascular load), Hands Behind Back (response time demand)



Cognitive Domains Volume Knob Levels for Processing Speed Techniques during Catch and Toss Variations

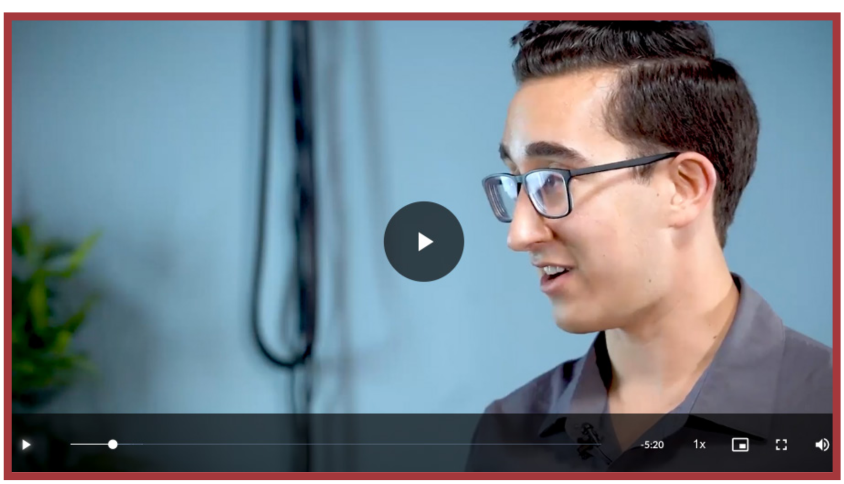
Group Modifications

- Have partners toss a ball back and forth.
- Have one partner be "the trainer" and the other partner be "the client."
- Use a ballon to incorporate multiple people in one drill.
- Use a "hot potato" variation in a circle or small group.

Lesson 4: Utilizing Obstacles

Utilizing Obstacles Video

Watch the third of the exercise library videos, the Utilizing Obstacles video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.



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This Obstacle-based task demonstrates how cognitive domain-specific demands can be combined and emphasized in a task that challenges both dynamic balance and motor planning.

Due to the complexity of the combinations introduced, you are encouraged to use a blank copy of the “Cognitive Domain Volume Knobs” to identify how each variation changes the emphasis on certain cognitive domains.

The time-stamps below identify at what points variations (both cognitive and physical) are implemented in the video above. This serves as a guide when referring back to these videos for review.

- **0:50 -** Assigning Numbers, Audible Call-outs **(Attention Demand)**
- **1:15 -** Assigning Number Series **(Working Memory Demand)**
- **1:40 -** Answering Key, Switching Numbers & Colors **(Executive Functioning Demand)**
- **2:30 -** Series of Colors **(Working Memory Demand)**
- **3:45 -** Faster Cue Delivery **(Processing Speed Demand)**

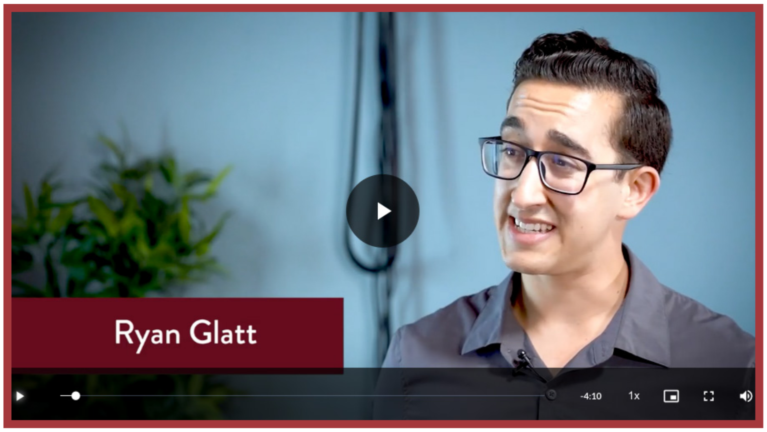
Group Modifications

- Have partners call out directions, numbers or cues.
- Have partners “mirror” or “oppose” each other’s movements.
- Have partners “alternate” a span of cues.
- Create longer obstacle courses that require teamwork.

Lesson 5: Movement Flows

Movement Flows Video

Watch the fourth of the exercise library videos, the Movement Flows video, below. Make sure to review the modifications in the rest of this lesson, and revisit the video as needed for understanding.



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Movement flows are focused on procedural sequences and choreography. These place an emphasis on coordination, **working memory**, and **short-term recall**. If the choreography is repeated on another day entirely, it is likely focused on **long-term recall**.

If the sequence of movements is executed by following along with an instructor (a norm in group exercise classes), then the focus is more on **visual attention**. When flows are executed without pausing or practice, there is a greater demand placed on **processing speed**.

When individuals must apply movement sequences in different combinations, with another person, or in dynamic environments (such as in dance or martial arts), there are greater demands placed on **executive functioning**.

Group Modifications

- Have partners "mirror" or "oppose" each other.
- Have one partner teach their own choreography.
- Have partners execute movements with the same timing.
- Have partners call-out different directions or associated cues.

Lesson 6: Stepping Variations

Stepping Variations Video

Watch the fifth of the exercise library videos, the Stepping Variations video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.

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- **0:50** - Tossing Ball with Paced Lateral Hurdle Steps (**Divided Attention**)
- **3:35** - Stepping Sequences with chunks of Left/Right cues (**Memory**). Starting the next chunk of cues before the previous chunk has been completed will place greater demands on **working memory**. Associating Left/Right directions with numbers, letters, or objects may place greater demands on **executive functioning**.

Variations

- Using one hurdle instead of two, or varying the step height (box, dots, cone, agility ladder, tape on the ground, etc)
- Changes angles or speed of ball toss for greater variability and unpredictability
- Holding a conversation during tasks that are well-performed to add cognitive load and gauge intensity (via the Talk Test)
- Using verbal cues (like “Hot Potato) for faster processing speed demands

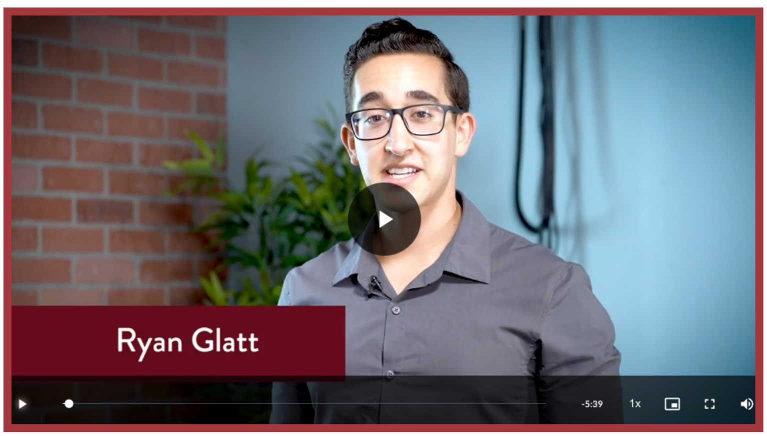
Group Modifications

- Have partners toss a ball back and forth during stepping.
- Have one partner be “the trainer” and the other partner be “the client.”
- Assign different stepping-obstacle pairings to different clients.
- Synchronize the timing & accuracy of stepping.

Lesson 7: Balance Variations

Balance Variations Video: Part 1

Watch the sixth of the exercise library videos, the Balance Variations: Part 1 video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.



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- **1:45** - Visual Cues using Hands (can use cards, printed numbers, etc.) - **Visual Attention**
- **2:10** - Verbal Cues (saying # out loud) one at a time - **Audible Attention**
- **4:20** - Using both Verbal and Visual cues - “Match vs. Mismatch”: Instructions given as to which cue (verbal or visual) should be attended to, providing contextual interference when each cue is delivered (**Executive Functioning demands**)

Balance Variations Video: Part 2

Watch the seventh of the exercise library videos, the Balance Variations: Part 2 video, below. Make sure to review the timestamped techniques in the rest of this lesson, and revisit the video as needed for understanding.

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The variation above demonstrates how to add a **processing speed** demand to any task. The time it takes to execute a task can be a measure of **response times** (a concept related to processing speed in relation to the execution of movement).

- **0:30 -** Processing Speed (via measurement of response times)
- **0:40 -** Equations (presenting a number and having the client add them up with the numbers available). Actual equations may be presented, with the client answering them with similar layouts. This places greater demands on **executive functioning.**

Variations

- Planning - is the number given possible or not? The ability to determine this may place greater demands on planning, a sub-domain of executive functioning.
- Practice effects - improvements in short amounts of time are a function of practice, which we may relate back to the phases of motor learning.
- Creating a list of equations, increasing equation difficulty, and adding more numbers on the ground can allow for greater variety.
- Recording the time to completion of various tasks and recording them can provide measures of performance and serve as motivating factors for the client

Group Modifications

- Have partners face each other in an unstable position.
- Have one partner be “the trainer” and the other partner be “the client.”
- Have partners take turns reaching to the next target in the sequence.
- Have clients mirror each other or synchronize their reaching.

Reflection

Take a moment to reflect on all that you have learned in this module. Use the space below to record your thoughts.

ACH	Acetlycholine
AD	Alzheimer's Disease
ADD	Attention Deficit Disorder
ADHD	Attention Deficit Hyperactivity Disorder
ANS	Autonomic Nervous System
AT	Aerobic Training
BDNF	Brain Derived Neurtrophic Factor
BH-EPAP	Brain Health Exercise & Physical Activity Plan
BHT	Brain Health Trainer
BHT-SF	Brain Health Trainer Short Form
CAQ	Cognitive Assessment Questionaire
CBF	Cerebral Blood Flow
CEN	Central Executive Network
CFG	Cognitive Functioning Goal
CRH	Corticotrophin Releasing Hormone
CRP	C-reactive Protein
CT	Coordinative Training
CT	Coordinative Training
DA	Dopamine
dlPFC	dorsolateral Prefrontal Cortex
DMN	Default Mode Network
EF	Executive Functioning/Functions
EPAP	Exercise & Physical Activity Plan
ERA	Expectations Regarding Aging
ESQ	Executive Skills Questionaire
FC	Functional Connectivity
GABA	Gamma aminobutyric acid
GDNF	Glial-derived Neurotrophic Factor
GDT	General dual-task training
GDT-EX	General dual-task exergame
HIIT	High Intensity Interval Training
HPA	Hypothalamic - Pituitary - Adrenal
HWP	Health & Wellness Professional
IADL	Independent Activities Daily Living
IGF-1	Insulin Growth Factor-1
IL-6	Interleukin-6
IPAQ	Physical Activity Questionaire
LC	Locus Coeruleus
LTB	Long Term Potentiation
MAP	Mental and Physical
MB	Mind Body
MCI	Mild Cognitive Impairment
MDD	Major Depressive Disorder
MS	Multiple Sclerosis
MSK	Muskuloskelatal
MT	Motor Training
MTL	Medial Temporal Lobes
NA	Noradrenaline
NE	Noradrenaline
NE	Norepinephrine
NGF	Nerve Growth Factor
PD	Parkinson's Disease
PFC	Prefrontal Cortex
PTSD	Post-traumatic Stress Disorder
Q-LES-Q-SF	Quality of Life Enjoyment & Satisfaction Short Form
RPE	Rate of perceived exertion
RT	Resistance Training
SAID	Specific Adaptations to Imposed Demand
SAQ	Speed Agility & Quickness
SCD	Subjective Cognitive Decline
SCI	Subjective Cognitive Impairment
SDT	Specific dual-task training
SDT-EX	Specific dual-task exergame
TBI	Traumatic Brain Injury
TLX	Task Load Index
TUG	Timed Up and Go
VEGF	Vascular Endothelial Growth Factor
WM	Working Memory

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