HORMONES AND NEUROTRANSMITTERS IN HUMAN DECISION- MAKING

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ABSTRACT

Human brain is an important organ that controls intricate functions including information processing and decision-making. Although making decisions is often thought of as a cognitive activity. Our capacity for making decision is significantly influenced by the interplay between neurotransmitters and hormones. These chemical messengers have an impact on a variety of physiological and psychological processes which in turn affect decision making.

1. INTRODUCTION

Enhancing cognitive capacities, understanding human behavior, and encouraging mental health all depend on our ability to know how hormones and neurotransmitters affect our ability to make decisions. We acquire important insights into the intricate basis of our decisions and behaviors by dissecting the intricacy of these relationships.

In this chapter we are investigating the significance of unraveling the complex interactions between hormones, neurotransmitters in decision-making. There are some important elements that affect our decisions and it can be examined through studying the effect of hormones and neurotransmitters on decision-making.

The role of hormones and neurotransmitters in decision-making is revealed by a careful investigation of their complex actions. Study also reveals that neurotransmitters play an important role in regulation of mood, motivation, reward processing, social bonding, pain perception and memory formation. Studying precise function of each neurotransmitter will help us in better understanding the intricate neurochemical processes in decision-making.We also investigated the complex relationship between brain areas and decision-making. Decision-making processes are influenced by prefrontal cortex, amygdala, striatum, hippocampus, and anterior

cingulate cortex, each in their own special way. Executive functioning, emotional processing, reward processing, habit formation, memory, conflict monitoring are all governed by these brain areas and are crucial for making wise decision. In this way we can maintain a complete grasp of the interactions between hormones, neurotransmitters and structural features of the brain by comprehending the neurological mechanisms that underlie judgment.

We have developed insights into the delicate balance necessary for ideal decision-making by looking at how neurotransmitters interact and affect the results of decision-making. We shed light on the complicated mechanisms behind effective decision-making processes by disclosing complex dynamics of excitatory and inhibitory neurotransmitters.

The chapter also covers the fascinating connection between mental health problems and dietary inadequacies. We look at how a poor diet may interfere with the production and function of hormones and neurotransmitters, resulting in imbalances that have a detrimental effect on mental and cognitive health. In order to mitigate the negative effects on cognitive function and mental health, it is necessary to stress the necessity of eating a balanced diet and to treat nutritional shortages.

Overall, this chapter has explored, how hormones and neurotransmitters play a part in making decisions. Understanding these relationships not only lays the path for advancements in decision-making and mental health treatments but it also provides a solid basis for improving mental and cognitive function. We anticipate that this study will help a greater comprehension of the intricate connections between hormones, neurotransmitters and decision-making, eventually resulting in improved wellbeing and more efficient decision-making techniques.

1.1. COGNITION & DECISION MAKING

Cognitive processes like analysis and judgement have long been focus of research on decision making. Recent studies have nevertheless demonstrated unquestionable role played by hormones and neurotransmitters in determining our actions and behavior. Neurotransmitters help the nervous system's neurons communicate with one another, while hormones serve as chemical messengers that carry signals to and from the brain and throughout the body. Together, they create a sophisticated network that controls our motives, emotions, and cognitive processes, eventually influencing our decisions making.

There are significant ramifications for many different fields when it comes to understanding how hormones and neurotransmitters affect decision-making. It offers important insights into the mechanisms that underlie our decisions in the subject of psychology, understanding why certain people could display particular decision-making tendencies. Furthermore, it provides a better comprehension of mental health

illnesses since hormonal and neurotransmitter imbalances can play a role in ailments including depression, anxiety, and impulsivity.

To know the function of hormones and neurotransmitters in decision-making from a physiological perspective enables us to better understand the links between the brain and body. Endocrine glands secrete hormones that affect our moods as well as our physical health, including immunological response, growth, and metabolism. We can get a complete grasp of human physiology by figuring out the complex interaction between hormones, neurotransmitters and decision-making.

Additionally, research into how hormones and neurotransmitters affect decision-making has real-world applications. It provides opportunities for the creation of interventions meant to enhance decision-making procedures. By concentrating on certain hormones or neurotransmitters, it may be possible to improve overall decision-making abilities, emotional wellbeing, and cognitive abilities. This knowledge might be particularly useful in fields like business, healthcare and education where making wise decisions is crucial.

2. HORMONES AND NEUROTRANSMITTERS

The body's primary chemical messengers, hormones and neurotransmitters play key roles in a variety of physiological and psychological processes. These chemicals significantly affect our cognitive processes, emotions, and behavior. In this chapter details of hormones and neurotransmitters has been given along with their function and how they interact with one another throughout the decision-making process.

Hormones are secreted by endocrine glands and are then released into the blood. From the blood it goes throughout the body and influencing certain tissues and cells. Numerous biological processes, including growth, metabolism, reproduction, and mood control are regulated by hormones.

Hormones like testosterone, estrogen, cortisol, and oxytocin are examples of essential hormones.

On the other hand, neurotransmitters are chemical compounds released by nerve endings and play an important roles in the nervous system to communicate with one another. They travel across synapses after being released by one neuron and binding to receptors on another.

Neurotransmitters, play a critical role in the coordination of numerous cognitive, emotional, and behavioral processes as well as information transmission inside the brain. Serotonin, dopamine, glutamate, GABA, and serotonin are a few well-known neurotransmitters. **(Mehta and *etal* 2014).**

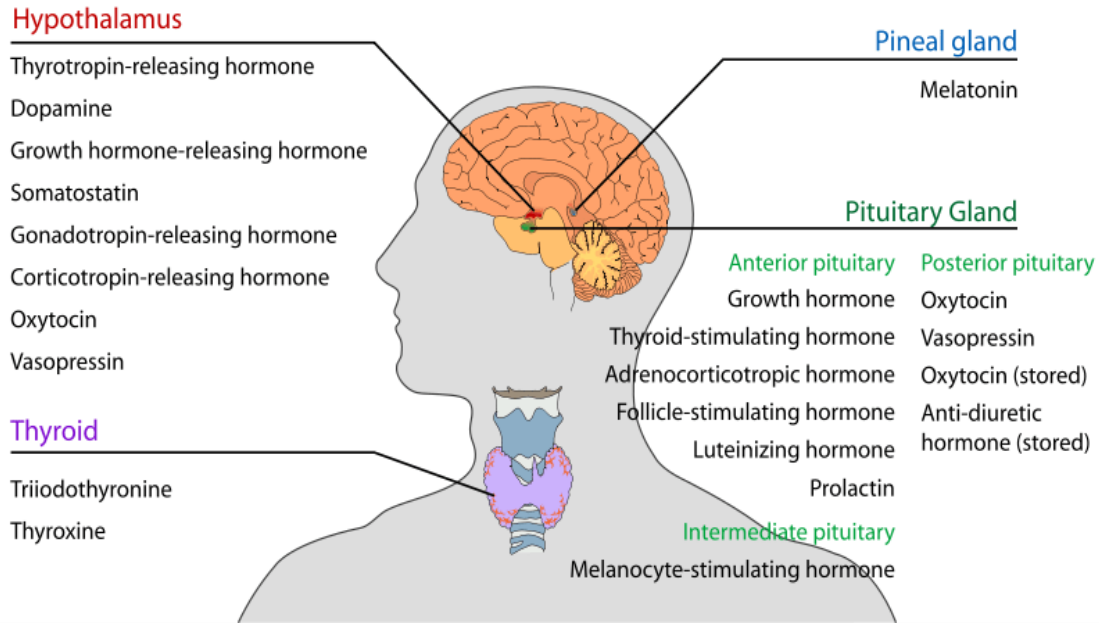

FIGURE 1 ENDOCRINE GLANDS IN THE HUMAN HEAD AND NECK AND THEIR HORMONES (COURTESY-GUYTON& HALL)

2.1. DISTINCTION BETWEEN-

HORMONES AND NEUROTRANSMITTERS

The two main differences between hormones and neurotransmitters are their mechanisms of action and cell targets. Neurotransmitters are locally produced inside the nervous system and act on nearby neurons or certain regions of the brain, whereas hormones are predominantly released into the circulation and operate on distant target cells throughout the body.Hormones influence long-term processes including growth, development, and reproduction by having comparatively slower but more enduring impacts. In contrast, neurotransmitters have quick and fleeting actions that help with real-time signal transmission between neurons and immediate neural activity control. (Dhingra & Parle, 2011).

TABLE 1 DISTINCTION BETWEEN HORMONES AND NEUROTRANSMITTERS

	Hormones	**Neurotransmitters**
Mode of Action	Released into the bloodstream and act on distant target cells	Released locally within the nervous system and act on adjacent neurons or specific areas of the brain

Target Cells	Act on distant target cells throughout the body	Act on adjacent neurons or specific areas of the brain
Effects	Slower and longer-lasting effects, regulating long-term processes such as growth, metabolism, and reproduction	Rapid and transient effects, facilitating real-time transmission of signals between neurons
Transportation	Circulate in the bloodstream to reach target cells	Diffuse across synapses to bind to receptors on neighboring neurons
Time of Action	Relatively slower onset of action	Rapid onset of action
Examples of Molecules	Testosterone, estrogen, cortisol, oxytocin	Serotonin, dopamine, GABA, glutamate
Functions	Regulate bodily functions, including growth, metabolism, and reproduction	Facilitate communication within the nervous system, modulating cognitive functions, emotions and behaviors

The fundamental differences between hormones and neurotransmitters are shown by the tabular data, which also highlights their mechanism of action, target cells, effects, transportation, timing, examples of molecules and roles.

2.2. INTERACTIONS BETWEEN-

HORMONES AND NEUROTRANSMITTERS IN DECISION MAKING

Neurotransmitters and hormones frequently interact to affect our decisions making processes. Cognitive processes, emotions, and behavioral responses all can be influenced by conjugated interactions between these chemical messengers. For instance, stress hormones like cortisol can change neurotransmitter function and alter decision-making processes under stress condition.

The link between serotonin and decision-making is one illustration of how hormones and neurotransmitters interact. A chemical called serotonin affects mood, social behavior, and impulse control. Low serotonin levels have been linked to increased impulsivity and risk-taking, which may provide less than ideal decision-making results.
Additionally, hormonal changes, such as those that take place throughout the menstrual cycle, might have an impact on neurotransmitter levels, which can alter our decision making process. For instance, changes in cognitive function and decision-making processes have been related to variations in estrogen and progesterone levels in women. (Kumar, 2012).

TABLE 2 HORMONES AND NEUROTRANSMITTERS IN DECISION MAKING

Hormones	Neurotransmitters	Interaction
Testosterone	Dopamine	Testosterone enhances dopamine release in the brain, influencing reward and motivation systems which can impact decision-making processes.
Estrogen	Serotonin	Estrogen modulates serotonin levels, affecting mood and impulse control, ultimately influencing decision making.
Cortisol	GABA	Cortisol can inhibit the release of GABA, an inhibitory neurotransmitter, leading to increased excitability in decision-making regions of the brain.
Oxytocin	Glutamate	Oxytocin enhances glutamate release, promoting communication between neurons and potentially influencing decision-making processes related to social bonding and trust.
	Acetylcholine	Oxytocin modulates acetylcholine release, which may influenced attention, memory, and learning processes relevant to decision making.
	Norepinephrine	Oxytocin can influence norepinephrine release, affecting arousal, attention, and emotional responses, which can impact decision making under different contexts.

A few key hormones and the related neurotransmitters are linked with each other and are involved in decision-making, are shown in TABLE 5.2.
To study how these molecules worked simultaneously and affect decision-making processes, it is essential to know the process of interactions between them. Fundamental elements of the complex systems that direct human decision-making

include hormones and neurotransmitters. Their tasks go beyond their separate responsibilities since they interact and have an impact on one another, affecting thought patterns, emotional states, and behavioral reactions. Study of the complex interaction between hormones and neurotransmitters offers important insights to understand decision-making processes and open up possibilities for future research.

3. HORMONES & GOOD MENTAL HEALTH

A person's complete wellbeing depends on his excellent mental health. Hormones are vital in controlling mood, emotions, and decision-making.

3.1. ROLE OF HORMONES ON MOOD REGULATION AND EMOTIONAL WELL-BEING

Various physiological and psychological processes are influenced by hormones. The control of mood and mental health is largely influenced by a number of hormones including:

Serotonin

- Controls happiness, anxiety, and mood.
- Depression and anxiety problems have been related to low serotonin levels.

Estrogen and Progesterone

- Mainly influenced women, while men are also affected to a lesser extent.
- The menstrual cycle's fluctuations in Estrogen and progesterone can have an effect on a person's mood and mental health.
- Hormonal changes have an impact on conditions including premenstrual syndrome (PMS) and postpartum depression.

3.2. HORMONAL IMBALANCES & DECISIONS MAKING

Hormonal abnormalities might sporadically upset the delicate balance required for the best decision-making.

Hormonal imbalances can be caused by a variety of things such as stress, drugs, illnesses, and way of life decisions. These discrepancies may have a big impact on decisions making: (Rao *etal,* 2008).

Cortisol

- Cortisol, sometimes known as the stress hormone, can make it difficult to make decisions.

- Increased stress reactions might cause impulsivity, reduced cognitive function, and a tendency to make risk-averse or unfavorable decisions.

Thyroid Hormones

- Low titer of thyroid hormone causes hypothyroidism which can lead to cognitive problem such as trouble in focusing, remembering things and making decisions.

TABLE 3 HORMONAL INFLUENCES IN DECISION MAKING

HORMONE	INFLUENCE ON DECISION MAKING
Serotonin	Regulates mood, affects decision-making strategies
Estrogen	Influences risk-taking behavior, especially in women
Cortisol	Impairs decision making, bias towards negative choices
Thyroid Hormones	Impacts cognitive functioning, including decision making

Hormonal changes' influenced mental health: Certain mental health illnesses are inevitably accompanied by hormonal changes, which have a major negative influence on judgement and emotional stability:

TABLE 4 HORMONAL FLUCTUATIONS IN MENTAL HEALTH DISORDERS

DISORDER	HORMONAL FLUCTUATIONS	IMPACT ON DECISION MAKING
Bipolar Disorder	Mania and Depression	Heightened impulsivity during manic episodes; difficulties in decision making during depressive episodes
Premenstrual Dysphoric Disorder (PMDD)	Hormonal fluctuations during menstrual cycle	Mood swings, irritability, difficulties in decision making

Bipolar Disorder:

- Mania and depression are experienced in succession.

- Extreme energy, impulsivity, and risk-taking behaviors are characteristics of manic episodes, which affect decision-making.
- Low energy, lack of motivation, and trouble making decisions are traits of depressive episodes.

Premenstrual Dysphoric Disorder (PMDD):

- A severe type of PMS that some women experience.
- The menstrual cycle's hormonal variations can cause mood swings, impatience, and difficulty in making decisions.

Hormones have a substantial effect on emotional health and mood management. The hormone serotonin, sometimes known as the "feel-good" hormone, is essential for controlling mood, anxiety, and happiness. Depression and anxiety problems have been linked to low serotonin levels. Progesterone and estrogen largely influenced women, also assist in controlling mood. Premenstrual syndrome (PMS) and postpartum depression are two illnesses that can result from fluctuations in these hormones during the menstrual cycle**.** (Muthusamy and colleagues, 2018).

Hormonal abnormalities might sporadically upset the delicate balance required for the best decision-making. The stress hormone cortisol has a significant effect on decisions makings. Increased cortisol levels, which are frequently linked to long-term stress, can make people more impulsive, less cognitively capable and more likely to make risk-averse or unfavorable decisions.

Decision-making can be impacted by thyroid hormone imbalances, particularly hypothyroidism, which can result in cognitive problems such as trouble focusing, remembering things, and processing the information.It is important to know, how hormonal changes relate to mental health illnesses.

Hormonal changes have a significant impact on decision-making in bipolar disorder, which entails alternating bouts of mania and despair. Individuals who are experiencing manic episodes have increased energy, impulsivity, and risk-taking behaviors, which might affect their decision-making. Making choices is made even more challenging by depressive episodes, which are typified by low energy and motivation. Premenstrual dysphoric disorder (PMDD) is a condition heavily influenced by hormonal fluctuations.

Hormonal changes associated with the menstrual cycle might affect one's mood, irritability, and ability to make choices. It is crucial to recognize and treat these hormonal changes if mental health diseases are to be properly managed.In conclusion, hormones play a major role in mood regulation, emotional well-being, and decision-making. Hormonal imbalances can impair decision-making, and hormonal changes might exacerbate mental health issues. Individuals and healthcare

professionals can more effectively support and manage mental health by studying the function of hormones in that condition.

To increase our comprehension of the complex interaction between hormones and decision-making, more study and awareness in this area are required, which will ultimately lead to better mental health.

4. NEUROTRANSMITTERS: TYPES AND FUNCTIONS

Chemicals called neurotransmitters serve as messengers in the nervous system, promoting communication between neurons. They are essential for signal and information transmission across synapses, the connectors between neurons. The presynaptic neuron releases these chemical messengers into the synaptic gap, where they attach to receptors on the postsynaptic neuron and affect its activity. The roles and consequences of numerous physiological systems, such as cognition, emotions, and behavior, are different for each neurotransmitter. Serotonin, dopamine, oxytocin, endorphins, glutamate, and GABA are a few neurotransmitters. The complex interactions and delicate balance of these neurotransmitters affect human decision-making and add to the nervous system's sophisticated operations. (Purves *etal,* 2018).

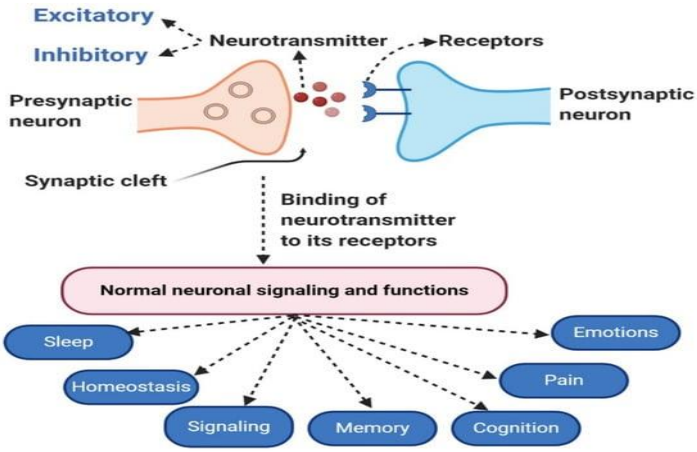

FIGURE 2 THE DIAGRAM SHOWS THE BASIC MECHANISM OF NEUROTRANSMISSION. *(MOLECULES 2023, 28(1),* 210)

- **Acetylcholine**

    a) Acetylcholine, which is necessary for motor control and is involved in signal transmission between motor neurons and muscles, controls muscular movement.
    b) Cognitive processes: Acetylcholine is essential for the development of attention, learning, and memory. It participates in the information encoding, consolidation, and retrieval processes.

c) Autonomic nervous system: The parasympathetic nervous system, which regulates functions linked to digestion, rest, and hormone synthesis uses acetylcholine for signal transmission.

- **Dopamine**

a) Dopamine plays a crucial role in pleasure, reinforcement learning, and motivation. It takes part in the brain's reward system, which encourages activity based on positive results and reinforces activities linked to survival.
b) Movement, coordination, and fine motor abilities are regulated by dopamine. It is especially important for the basal ganglia, a portion of the brain that organizes and executes motor motions. Dopamine impacts perception of pleasure and reward as well as mood and emotions. Unbalanced dopamine levels have been related to addiction, bipolar disorder, and depression among other mental health conditions.

- **Serotonin**

a) Serotonin is widely recognized for its role in regulating mood. It enhances sentiments of well-being, happiness and enjoyment through supporting emotion management. Unbalanced serotonin levels have been linked to mood disorders as anxiety and depression.
b) Sleep and appetite: Serotonin controls hunger and fullness as well as the sleep-wake cycle. It helps with portion control and heightens sensations of fullness. Serotonin also aids in the establishment of healthy sleep habits.
c) Serotonin has an impact on social conduct, including animosity, cooperation, and social bonding. It improves prosocial behaviors, empathy, and trust.

- **Norepinephrine**

a) Norepinephrine is essential for sustaining arousal, alertness, and vigilance. It also helps with arousal and attention. It aids in improving concentration and focus, as well as cognitive performance and stimulus response.
b) Norepinephrine serves as a neurotransmitter and a stress hormone in the body. It plays a role in the body's "fight or flight" response, which raises heart rate, blood pressure, and glucose release to get the body ready for action in stressful conditions.
c) Norepinephrine regulates mood and is important in controlling mood disorders including anxiety and sadness. It is connected to sensations of vigor, drive, and all-around wellbeing.

- **GABA (Gamma-Aminobutyric Acid):**

a) GABA is the main inhibitory neurotransmitter in the central nervous system, which also promotes relaxation. By blocking or diminishing the action of other neurotransmitters, encouraging relaxation,

lowering anxiety, and preventing overstimulation, it aids in the regulation of neural excitability.

b) Stress and anxiety reduction: GABA contains anxiolytic properties that assist to relax the mind and reduce emotions of anxiety. By blocking the effects of excitatory neurotransmitters, it aids to maintain the ratio of excitatory to inhibitory signals.

c) Promotion of sleep: GABA has a role in controlling sleep. It facilitates deep sleep phases, induces sleep, and controls the sleep-wake cycle. GABA level imbalances have been linked to sleep problems including insomnia. (Sadava *etal,* 2017).

- **Glutamate:**
  a) Serves as the brain's main excitatory neurotransmitter.
  b) Plays a critical role in synaptic plasticity, memory formation, and learning.
  c) Helps neurons to communicate with one another, allowing information to be sent and neuronal connections to be strengthened.
  d) Glutamate activity imbalances have been linked to a number of neurological conditions, including epilepsy, Alzheimer's disease, and schizophrenia.
- **Endorphins:**
  a) Serve as natural mood lifters and pain relievers.
  b) Releases endorphins, a feel-good chemical, in reaction to stress, physical activity, and enjoyable activities.
  c) By attaching to opioid receptors in the brain and spinal cord, which lessens the signaling of pain, substances can help modify pain perception.
  d) Endorphins also play a role in controlling immunological, stress, and hunger responses.
- **Oxytocin:**
  a) Regularly referred to as the "love hormone" or the "cuddle hormone."
  b) Has a significant impact on attachment, trust, and social bonding.
  c) Released during happy social interactions, such as giving birth, nursing, and private times.
  d) Encourages pair bonding in love relationships as well as attachment and bonding between mothers and their babies.
  e) Additionally, oxytocin controls how we respond to stress, empathize with others, and digest our emotions.
- **Histamine:**
  a) Involved in controlling a number of physiological processes, such as arousal, alertness, and allergic reactions.
  b) Acts as a neurotransmitter in the brain, influencing mental processes including memory, learning, and attention.
  c) Contributes to the sleep-wake cycle by encouraging attentiveness and wakefulness.

d) Histamine has a role in the immune system's role in inflammation and allergic responses, which result in symptoms including itchiness, sneezing, and swelling.

- **Adenosine:**
  a) Acts as a neuromodulator and neurotransmitter in the brain.
  b) Regulates sleep-wake cycles and promotes sleep.
  c) Inhibits arousal and promotes relaxation by binding to adenosine receptors.
  d) Also influences cognitive functions, including attention, learning, and memory.
  e) Adenosine levels increase during periods of increased brain activity and decrease during sleep.
- **Glycine:**
  a) Inhibits neuronal activity, which helps to govern movement and trigger reflexes.
  b) Functions as an inhibitory neurotransmitter in the brainstem and spinal cord.
  c) Contributes to the processing of sensory data and aids in controlling muscular tone.
  d) Glycine has been investigated as a possible therapeutic target for the treatment of chronic pain since it is also implicated in the regulation of pain perception.
- **Substance P:**
  a) Contributes to the transmission of pain signals by acting as a neurotransmitter and neuromodulator.
  b) Has a part in how pain is perceived and transferred from the peripheral nervous system to the brain.
  c) Controls inflammatory, emotional, and stress responses.
  d) Regions of the brain and the spinal cord that are involved in the processing of pain, such as the dorsal horn, are particularly rich in substance P.
- **Cortisol:**
  a) Cortisol, although largely recognized as a hormone, can also function in the brain as a neurotransmitter.
  b) Controls how the body reacts to stress and contributes to homeostasis.
  c) Influences mood and motivation through having an impact on cognition, memory, and emotion.
  d) Chronic stress can have a severe impact on mental health, causing illnesses like anxiety and depression owing to prolonged or excessive cortisol release.
- **Epinephrine (Adrenaline):**
  a) Serves as a neurotransmitter and stress hormone.
  b) Increases blood pressure, heart rate, and blood flow to the muscles.
  c) Elicits the "fight or flight" response from the body when under stress.

d) Increases energy, attention, and alertness.
e) Releases stored energy for quick use.

- **Noradrenaline (Norepinephrine):**
  a) Arousal, concentration, and mood control are all important functions of this hormone. It also affects the body's stress response and alertness.
  b) Raises blood pressure and heart rate.
  c) Improves memory encoding and retrieval.
  d) Controls the rhythms of wakefulness and sleep.
- **Anandamide:**
  a) Belongs to the group of neurotransmitters known as endocannabinoids.
  b) Plays a part in the control and perception of pain.
  c) Contributes to the control of emotions and mood.
  d) Impacts eating habits and appetite.
  e) Involved in learning, memory, and neuroprotection.
- **Nitric Oxide:**
  a) Acts as a neurotransmitter and signaling molecule.
  b) Controls blood flow and vasodilation of blood vessels.
  c) Involved in memory, learning, and synaptic plasticity.
  d) Controls the release of neurotransmitters and neural transmission.
  e) Plays a part in inflammatory reactions and immunological reactions.

TABLE 5 SOME OTHER NEUROTRANSMITTERS AND FUNCTIONS (SIEGEL *ETAL*, 2011).

NEUROTRANSMITTER	FUNCTION
Neuropeptides	Modulation of pain, mood, and behavior
Dynorphins	Regulation of pain perception, reward systems
Somatostatin	Modulation of neurotransmitter release
Substance P	Pain perception, inflammation
Corticotropin-Releasing Hormone (CRH)	Regulation of stress response
Melatonin	Regulation of sleep-wake cycle
Vasopressin	Water retention, social behavior
Calcitonin Gene-Related Peptide (CGRP)	Regulation of pain perception, vasodilation
Neuropeptide Y	Appetite regulation, stress response
Prostaglandins	Inflammatory responses, pain perception
Cholecystokinin	Regulation of appetite, anxiety modulation
Thyrotropin-Releasing Hormone (TRH)	Regulation of thyroid function, mood, and energy
Substance K	Pain perception, inflammatory responses

VIP (Vasoactive Intestinal Peptide)	Neurotransmission, vasodilation, immune regulation
Neurotensin	Modulation of dopamine transmission, pain perception
Met-encephalin	Modulation of pain perception and mood
Substance F	Involved in pain transmission
Vasopressin	Regulates water retention, social behavior
Cholecystokinin	Regulates appetite and anxiety modulation
Galanin	Modulates pain perception, feeding behavior
Prolactin	Regulates lactation, reproductive behavior
Neurokinin A	Involved in pain transmission and inflammation
Melanin-Concentrating Hormone (MCH)	Regulation of feeding behavior, sleep
Somatostatin	Modulates neurotransmitter release
Thyrotropin-Releasing Hormone (TRH)	Regulation of thyroid function, mood, and energy

5. PARTS OF THE BRAIN INVOLVED IN DECISION MAKING

To analyze alternatives, consider probable outcomes, and select the best course of action, decision-making is a complicated cognitive job that requires the cooperation of several brain areas.

While decision-making is a complex process, multiple important brain areas are involved in various parts of it.

- **Prefrontal Cortex:**

a) Decision-making is one of the higher-order cognitive processes in which prefrontal cortex (PFC) is involved.
b) The dorsolateral prefrontal cortex (DLPFC) is involved in working memory, decision-making, and reasoning.
c) The ventromedial prefrontal cortex (VMPFC) is linked to emotions, value-based judgement, and weighing the pros and cons of various scenarios.
d) To help in decision-making, the orbitofrontal cortex (OFC) combines sensory data, emotions, and rewards.
e) The anterior cingulate cortex (ACC) regulate cognitive control during decision-making and is involved in conflict monitoring, mistake detection, and error correction. (Glimcher, 2003).

- **Basal Ganglia:**

  a) The striatum and other basal ganglia are essential for selecting suitable behaviors depending on outcomes and learning from rewards and punishments.
  b) The processing of rewards and reinforcement learning are mediated by the ventral striatum and nucleus acumens, which have an impact on the motivational and value-based components of decision making.
  c) The putamen and caudate nucleus are related to the development of habits and automatic behavior. (Fellows & Farah, 2007).

- **Hippocampus:**

  a) The hippocampus integrates contextual information and spatial navigation, contributing to the appraisal and selection of choices.
  b) It plays a role in memory formation and retrieval, which is crucial for decision-making based on prior experiences**.** (Bartra *etal,* 2013).

- **Amygdala:**

  a) The amygdala is crucial in processing emotions and how emotions affect our decisions.
  b) It gives emotional value to stimuli and aids in assessing the benefits and hazards of future choices.

- **Insula:**

  a) Interceptive awareness, which entails perceiving and interpreting internal body states, is controlled by the insula.
  b) It aids in decision-making by assessing emotional and physical conditions including hunger, pain, and discomfort.

- **Ventral Striatum:**

  a) In the basal ganglia, the ventral striatum plays a role in motivational elements of decision-making and anticipation of rewards.
  b) It reacts to favorable results, such as financial incentives and pleasant social feedback.

- **Posterior Parietal Cortex:**

  a) Attention, spatial awareness, and sensory integration are all regulated by the posterior parietal cortex.

b) It aids in describing choices, assessing prospective consequences, and directing decision-making based on sensory information at hand.

- **Medial Prefrontal Cortex:**

a) The medial prefrontal cortex has a role in moral judgement and social cognition.
b) It contributes to the analysis of social cues, taking into account other people's viewpoints, and reaching ethical conclusions.

These brain areas collaborate in intricate networks throughout the process of decision-making, which is extremely interrelated. There may be various degrees of activity and communication across these areas while making decisions that entail emotions, risks, rewards, or social factor. **(Bechara *etal,* 1994).**

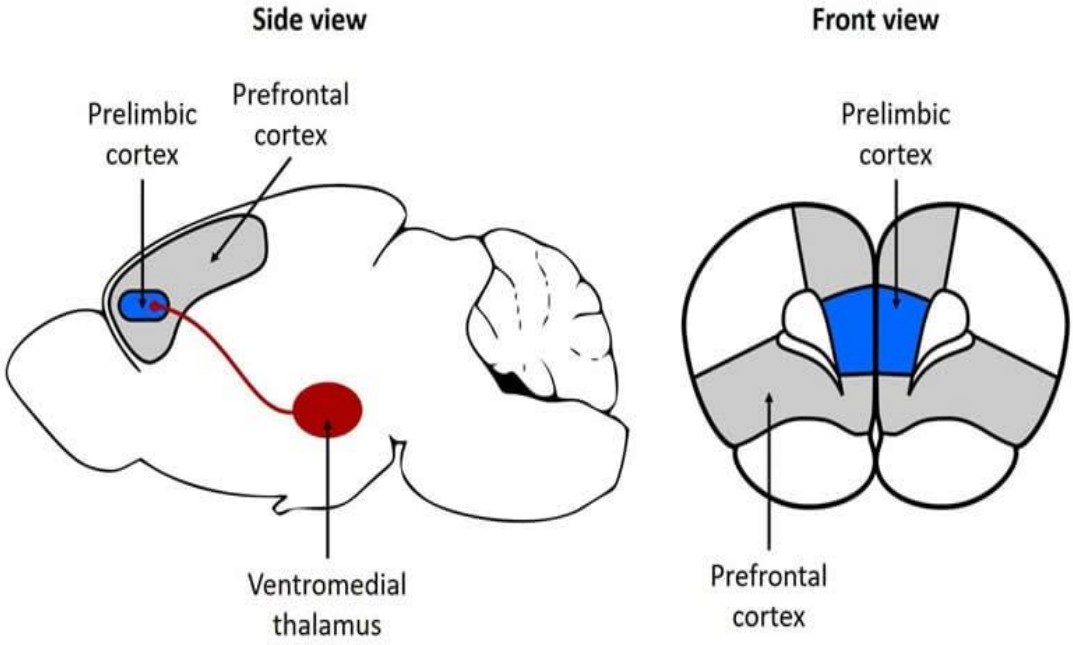

FIGURE 3 NEURONS FROM THE VENTROMEDIAL THALAMUS (RED AREA) EXTEND INTO THE PRELIMBIC CORTEX (BLUE AREA) WHICH IS A REGION WITHIN THE PREFRONTAL CORTEX (GREY AREA). IMAGE COURTESY- OKINAWA INSTITUTE OF SCIENCE AND TECHNOLOGY GRADUATE UNIVERSITY (OIST).

6. THE ROLE OF PRINCIPAL NEUROTRANSMITTERS IN DECISION MAKING

A complicated cognitive process, decision-making entails considering potential outcomes, assessing choices, and selecting a course of action. Neurotransmitters play

a critical part in decision-making, which is impacted by a variety of factors, including past experiences, emotions, and environmental cues.

Chemical messengers called neurotransmitters let neurons in the brain communicate with one another. Serotonin, dopamine, and oxytocin are three major neurotransmitters that are involved in decision-making processes.

Understanding the role these neurotransmitters play in decision-making may provide light on the brain processes that underlie our decisions and behaviors.

6.1. ROLE OF SEROTONIN, DOPAMINE, OXYTOCIN AND OTHER NEUROTRANSMITTERS IN DECISION MAKING PROCESSES: (SINGH & SINGH, 2015).

- **Serotonin**: Serotonin is a mood, emotion and social behavior regulator. By altering risk appraisal, impulsivity, and reward processing, it has an impact on decision-making. Recent studies reveals that higher levels of serotonin encourage more cautious decision-making, whereas lower levels are linked to increased risk-taking behavior. Serotonin also affects process of long-term and short-term goals, influencing our capacity to postpone gratification and make decisions that are in line with our long-term wellbeing.
- **Dopamine**: Dopamine is a key player in the motivation and processing of rewards. It stimulates actions that result in rewards and reinforces successful outcomes. Dopamine aids in decision-making by making it easier to assess potential rewards and risk factors. It assists us in valuing various possibilities and selecting activities that will maximize benefits. Impulsive decision-making, addiction, and reward-seeking behaviors have all been connected to imbalances in dopamine function.
- **Oxytocin**: Known as the "love hormone," oxytocin is linked to social connection, trust, and empathy. It affects decision-making by encouraging teamwork and prosocial actions. Oxytocin improves social cognition, resulting in a greater comprehension of the thoughts and feelings of others. This may have an impact on choices including social relationships, collaboration, and trust.
- **Other Neurotransmitters:** Several neurotransmitters, including dopamine, oxytocin, and serotonin, are involved in decision-making. For instance, endorphins can affect how one perceives risk and are implicated in the regulation of pain. The principal excitatory neurotransmitter glutamate is crucial for synaptic plasticity and learning, two processes that are fundamental to decision-making. When making decisions, the primary inhibitory neurotransmitter GABA helps control neuronal activity and maintain a balance between excitement and inhibition.

6.2. NEUROTRANSMITTER INTERACTIONS AND THEIR IMPACT ON DECISION-MAKING OUTCOMES

Neurotransmitters interact with one another rather than functioning alone, generating intricate networks that affect how decisions are made.

Neurotransmitter interactions can affect how information is processed, how we feel emotionally, and how we make decisions.

For instance,

- Serotonin and dopamine interact one with the other. Serotonin reduces the production of dopamine, which affects how rewards are processed and risk-taking behavior. Oxytocin can influence how dopamine affects decision-making.
- The equilibrium between excitatory and inhibitory neurotransmitters, such as glutamate and GABA, is critical for maintaining optimum brain function during decision-making. It may increase the relevance of social rewards and affect choices involving trust and cooperation.
- Cognitive impairments and decision-making challenges might result from disturbances in this equilibrium.

The complicated interactions between these neurotransmitters emphasize the difficulty of decision-making and the significance of taking into account of numerous neurotransmitter systems while attempting to comprehend our decisions and behavior's. (Ramaswamy & Narayanan, 2016).

6.3. THE BALANCE BETWEEN EXCITATORY AND INHIBITORY NEUROTRANSMITTERS IN DECISION MAKING

Keeping the equilibrium between excitatory and inhibitory neurotransmitters is crucial for decision-making. While inhibitory neurotransmitters, such as GABA, control and reduce neuronal activity, excitatory neurotransmitters such as glutamate, encourage brain activity and information processing. This equilibrium makes sure that the brain can successfully receive and integrate information, resulting in well-informed judgements.

Making decisions may be impacted when the ratio of excitatory to inhibitory neurotransmitters is off. For instance, increased arousal, impulsivity and risk-taking behavior might result from an excess of excitatory neurotransmitters or a lack in inhibitory neurotransmitters. On the other side, too many inhibitory neurotransmitters or too few excitatory neurotransmitters can cause a decline in motivation, difficulty to make decisions, and incapacity to act.

Neurotransmitter system anomalies may also be influenced by a variety of factors, such as physiological conditions, environmental factors, and genetic predispositions. As an example, certain genetic variations may affect the function of neurotransmitter receptors, which may change how choices are formed. Drug abuse, neurological diseases, and prolonged stress may potentially alter neurotransmitter levels and disturb the delicate equilibrium required for the finest decision-making.

To know, how neurotransmitters affect judgement is very important. It may provide light on how therapy methods to improve judgement in various scenarios were developed. For example, targeting serotonin receptors may benefit individuals who make impulsive judgements, whereas controlling dopamine activity may help those who exhibit addicted tendencies. Additionally, treatments that boost oxytocin release or GABAergic inhibition may aid in improving decision-making in patients.

The importance of neurotransmitters like serotonin, dopamine, oxytocin, and others for decision-making should also be mentioned. They affect several aspects of decision-making, such as motivation, social behavior, processing rewards, and risk assessment. Decision-making outcomes are influenced by the interactions between these neurotransmitters as well as the equilibrium between excitatory and inhibitory neurotransmitters. Understanding the complex function that neurotransmitters play in decision-making will help better understand how people behave and open the path for tailored therapies that will enhance our capacity for making decisions. Further investigation in this area may reveal more complex mechanisms and therapy approaches to improve decision-making in both healthy people and people who have problems in making decisions.

7. NUTRITIONAL DEFICIENCIES AND MENTAL HEALTH PROBLEMS

Maintaining total health, including mental well-being, depends heavily on nutrition. The efficient functioning of the brain and the control of neurotransmitters, which are critical for mood, cognition, and behavior, depend on an adequate intake of essential nutrients. On the other hand, nutritional deficiencies can have a significant impact on mental health and contribute to the onset or aggravation of mental health issues. The association between dietary deficits and mental health issues is examined in this chapter, emphasizing the value of a balanced diet for mental health.

TABLE 6 NUTRIENTS AND THEIR IMPACT ON MENTAL HEALTH

Nutrient	Deficiency Symptoms	Associated Mental Health Problems
Omega-3 Fatty Acids	Fatigue, mood swings, poor memory and concentration	Depression, anxiety, bipolar disorder, ADHD
B Vitamins	Fatigue, irritability, poor cognition	Depression, anxiety, cognitive decline

Vitamin D	Fatigue, low mood, sleep disturbances	Depression, seasonal affective disorder
Iron	Fatigue, weakness, poor concentration	Depression, cognitive impairment
Zinc	Poor appetite, irritability, memory issues	Depression, anxiety, ADHD
Magnesium	Fatigue, irritability, poor sleep	Anxiety, depression, insomnia

Mental health issues and nutritional deficiencies:

- **Omega-3 Fatty Acids:** EPA and DHA in particular are essential for the health of the brain. An increased risk of depression, anxiety disorders, bipolar disorder, and attention-deficit hyperactivity disorder (ADHD) has been associated with deficiencies in certain important fatty acids. Maintaining mental health requires consuming foods high in omega-3s, such as fatty fish, walnuts, and flaxseeds.
- **B Vitamins:** vitamin B, such as folate, B6, and B12, are essential for the production of neurotransmitters and the control of mood. The risk of developing depression, anxiety disorders, and cognitive decline is increased by vitamin deficiencies in these substances, which can cause weariness, irritation, and impaired cognition. Maintaining adequate amounts of Vitamin B may be accomplished by eating things like leafy greens, lentils, and fortified cereals.
- **Vitamin D.** Seasonal affective disorder (SAD) and depression have both been linked to vitamin D insufficiency. The body produces vitamin D when exposed to sunshine, but insufficient exposure to sunlight, particularly in areas with little sunlight, can result in insufficiency. Deficiencies can be avoided by taking supplements and eating foods high in vitamin D, such as eggs, fatty fish, and dairy products with added vitamin D.
- **Iron:** The body, particularly the brain, needs iron to transfer oxygen and produce energy. Fatigue, weakness, and poor focus are symptoms of iron deficiency, which has also been connected to depression and cognitive decline. Fortified cereals, lean meats, beans, and other iron-rich foods must be consumed regularly to prevent deficits.
- **Zinc:** Zinc has a role in the regulation and production of neurotransmitters. Zinc deficiency can increase the risk of depression, anxiety disorders, and ADHD by causing poor appetite, irritability and memory problems. Consuming foods high in zinc, such as oysters, red meat, and legumes, can aid in maintaining health.

- **Magnesium:** The body uses magnesium for hundreds of biochemical processes, including the control of neurotransmitters and the stress response. Magnesium deficiency has been linked to anxiety, melancholy, and insomnia as well as tiredness, irritability, and poor sleep. For optimum mental health, eating foods high content of magnesium, such as dark chocolate, almonds, and leafy greens, is crucial.

Nutritional deficiencies can have a considerable negative influence on mental health, causing onset or worsening of a number of mental health issues.

Release of neurotransmitters, control of mood and proper brain function all depend on getting enough of the key nutrients. Omega-3 fatty acid deficiencies, B vitamin deficiencies, vitamin D deficiency, iron, zinc, and magnesium deficiency, as well as a higher risk of bipolar illness, ADHD, cognitive decline, and sleep difficulties have all been connected to these conditions.

Adopting a balanced diet with a range of nutrient-rich foods is crucial to addressing nutritional deficits and promoting mental health.

Lean meats, beans, fortified grains, oysters, red meat, dark chocolate, nuts, leafy greens, legumes, fortified cereals, fatty fish, walnuts, flaxseeds, leafy greens, and legumes can all be included in one's regular diet.

In certain circumstances, significant deficiencies may not be sufficiently addressed by dietary changes alone. In such cases, supplementation may be required under the supervision of a healthcare expert. Regular blood testing to check nutritional levels can help identify deficits and direct the right actions.

It is important to remember that dietary deficits can exacerbate mental health issues, they are not the only contributing factor.

The intricate interaction of many elements that affect mental health includes heredity, environment, lifestyle, and social influences. However, correcting dietary inadequacies can be a crucial part of an all-encompassing strategy for promoting mental well-being.

7.1. NUTRIENT DEFICIENCIES, HORMONES, NEUROTRANSMITTERS AND MENTAL HEALTH

The complicated hormone and neurotransmitter balance that is necessary for the human body to function at its best is maintained by proper nutrition. This delicate equilibrium can be upset by nutritional deficiencies, which can result in abnormalities in hormone levels and neurotransmitter activity. The repercussions of these imbalances on many physiological functions, such as judgement and mental health, can be extensive. This chapter examines the connection between nutritional

shortages and hormonal and neurotransmitter imbalances, the effects of poor nutrition on cognition and mental health, and the significance of a balanced diet for healthy hormone and neurotransmitter function.

7.2. RELATIONSHIP BETWEEN NUTRIENT DEFICIENCIES AND HORMONES/NEUROTRANSMITTERS

The body uses nutrients as building blocks to produce and control hormones and neurotransmitters. Unbalances can result from deficiencies in particular nutrients that affect the synthesis, release, or action of hormones and neurotransmitters. (Anderson, 2008). For example:

a) **Thyroid hormones:** Iodine is necessary for the synthesis of thyroid hormones (T3 and T4). Iodine shortage can cause hypothyroidism, which can impair cognitive function and cause tiredness, sadness, and other symptoms.

b) **Insulin:** Chromium, magnesium, and B-vitamin levels must be appropriate for insulin, which controls blood sugar levels. Insulin resistance and poor glucose management can result from a lack of these nutrients.

c) **Sex hormones:** For the production and operation of sex hormones like estrogen, progesterone, and testosterone, nutrients like zinc, vitamin D, and B vitamins are crucial. These vitamin deficiencies can affect a person's ability to reproduce and regulate their mood.**(Venkaiah K, etal 2002)**

- **NEUROTRANSMITTERS:**

a) **Serotonin:** Tryptophan, an amino acid that is derived from food, is necessary for the production of serotonin. Reduced serotonin synthesis due to low tryptophan levels may contribute to the feelings of anxiety and sadness.

b) Tyrosine, a cofactor needed for the production of dopamine, as well as iron, vitamin C, and B vitamins. Dopamine imbalances brought on by insufficient quantities of these nutrients can have an impact on motivation, reward processing, and mood regulation.

c) **GABA:** Magnesium and vitamin B6 levels must be sufficient for GABA to be produced. These vitamin deficiencies might hinder the production of GABA, which may contribute to anxiety and sleep issues. **(Rayman, 2012).**

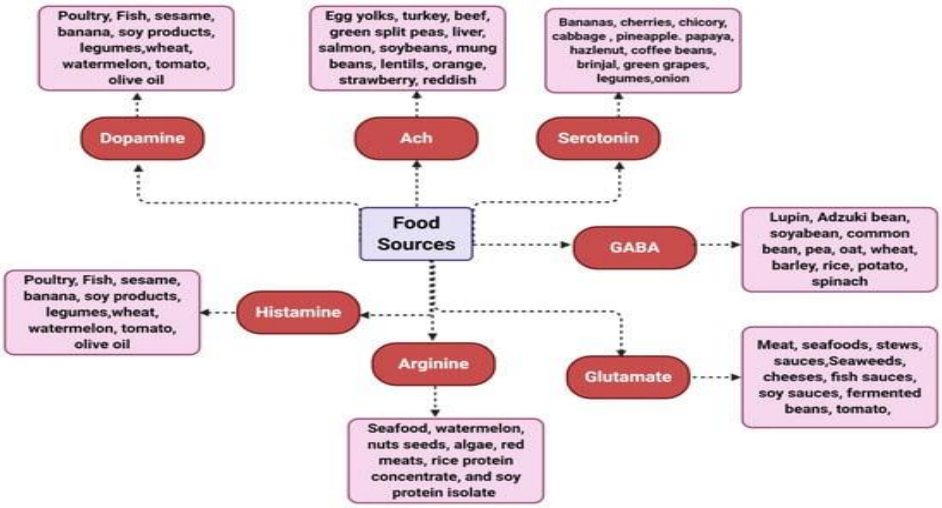

FIGURE 4 FIVE MAJOR NEUROTRANSMITTERS AND THEIR RELATED FOOD SOURCES (*MOLECULES* 2023, *28*(1), 210.)

7.3. ROLE OF POOR NUTRITION IN DECISION-MAKING ABILITIES

Due to its effects on hormones and neurotransmitters, poor nutrition can have a substantial negative influence on ability to make decisions and mental health. These chemical messenger imbalances can result in:

- **Cognitive impairments**: Memory, concentration, and thinking can all be hampered by nutritional deficits. Making decisions and addressing problems may be hampered by the poor diet.
- **Mood disorders:** Mood disorders including sadness and anxiety are linked to neurotransmitter imbalances, especially those in serotonin, dopamine, and GABA. The production and operation of these neurotransmitters can be interfered by inadequate diet, which can lead to the onset or worsening of various diseases. (Deshmukh & Jain, 2014).
- **Impulsivity and addictive behaviors**: Poor nutrition-induced dopamine imbalances might affect reward-seeking behaviors, raising the risk of impulsivity and addictive tendencies.
- **Increased stress response**: An exacerbated stress response can result from nutrient deficits that interfere with the control of stress hormones like cortisol and adrenaline. Under pressure, this might make it harder to make decisions.
- **Reduced resilience**: Maintaining the brain's resilience and capacity to deal with challenges requires optimal diet. Poor nutrition can impair the brain's capacity for change and recovery after stress, which has an effect on mental health and judgement. **(Sathyanarayana Rao and etal. 2008).**

7.4. BALANCED DIET FOR OPTIMAL HORMONE AND NEUROTRANSMITTER FUNCTIONING

For the best hormone and neurotransmitter functioning, we must maintain a balanced diet that offers all the necessary nutrients. Here are some crucial things to remember:

- **Macronutrients:** It's important to consume enough carbohydrates, proteins, and lipids. Proteins offer the building blocks for neurotransmitters and hormones, whereas carbohydrates give the energy for their production. Neurotransmitter function and brain health are supported by healthy fats like omega-3 fatty acids.
- **Micronutrients:** Important vitamins and minerals are necessary for the synthesis, release, and action of hormones and neurotransmitters. For instance, vitamin B, vitamin C, and magnesium contribute to the synthesis of neurotransmitters, while zinc, selenium, and vitamin D help to regulate hormone functioning. (Grosso et al 2014).
- **Antioxidants:** Consuming a diet high content in these nutrients like fruits, vegetables, and whole grains helps to prevent oxidative stress on the brain and neurotransmitters, supporting their optimal performance.
- **Omega-3 fatty acids**: Found in foods like fish, flaxseed, and walnuts and are essential for maintaining healthy brain function, producing neurotransmitters, and controlling mood.
- **Hydration:** Hormone balance, healthy brain function, and the production of neurotransmitters all depend on adequate water.
- **Balanced meals**: For the best functioning of hormones and neurotransmitters, balanced meals are required. It includes a diversity of macronutrients. Meals should include complex carbohydrates, good fats, and protein which help to maintain blood sugar levels constant and provide long-lasting energy. (Murphy et al., 2014)
- Nutrient shortages may lead to hormonal and neurotransmitter imbalances, which can have a negative impact on thinking and making decisions. Inadequate nutrition may have a detrimental effect on cognitive function, impulsivity, mood problems, and stress resistance. To maximize the action of hormones and neurotransmitters, it is vital to maintain a diet that is well-balanced and rich in the nutrients that are needed.
- A diet rich in macronutrients, micronutrients, antioxidants, and proper hydration supports the synthesis, release, and functioning of these crucial chemical messengers. Prioritizing a balanced diet has the potential to enhance decision-making abilities and promote better mental health. (Gómez-Pinilla, 2008)

8. CONCLUSION

The complex interactions between dietary deficit, hormones and neurotransmitters, as well as their effects on cognition and mental health, have been covered in this chapter.

We have emphasized the importance of nutrition in preserving the appropriate synthesis, release, and activity of hormones and neurotransmitters and the requirement for a balanced diet to support these processes.

The impact of nutritional deficits on hormone imbalances and neurotransmitter disturbance is one of the major topics covered.

We've studied, how food inadequacies can affect synthesis and function of some hormones including insulin, sex hormones, and thyroid hormones. Similarly, the low quantity of important nutrients can have an impact on neurotransmitters including serotonin, dopamine, and GABA.

There are significant ramifications to comprehending how hormones and neurotransmitters influence decision-making.

Understanding how dietary inadequacies affect these chemical messengers can help us better understand the causes of cognitive decline, mood disorders, impulsivity, and stress-related behaviors.

This information creates opportunities for interventions and tactics meant to strengthen mental health and decision-making skills.

To further comprehend the precise processes by which foods affect hormone and neurotransmitter activity, additional study is crucial.

It will be beneficial to investigate how various nutrients interact and how it affects decision makings. Studying the effectiveness of nutritional therapies, such as dietary changes or targeted supplements to enhancing decision-making skills might also pave the road for real-world applications.

For the maintenance of ideal hormone and neurotransmitter functioning, a balanced diet with enough nutrients is essential.

Deficits in some nutrients can upset the delicate balance, which can have a negative impact on mental and decisional health. We can enable people to make educated decisions to support their cognitive ability and general well-being by emphasizing diet and comprehending the impact of hormones and neurotransmitters.

The creation of focused therapies and techniques to improve decision-making processes and encourage improved mental health outcomes offers promise for future study in this area.

9. REFERENCES

- Anderson, R. A. (2008). Chromium and polyphenols from cinnamon improve insulin sensitivity. Proceedings of the Nutrition Society, 67(1), 48-53.
- Gasmi et al (2023). Neurotransmitters Regulation and Food Intake: The Role of Dietary Sources in Neurotransmission. Molecules 28(1) 210 https://doi.org/10.3390/molecules28010210
- Bartra, O., McGuire, J. T., & Kable, J. W. (2013). The valuation system: A coordinate-based meta-analysis of BOLD MRI experiments examining neural correlates of subjective value. Neuroimage, 76, 412-427. DOI: 10.1016/j.neuroimage.2013.02.063
- Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. Cognition, 50(1-3), 7-15.DOI: 10.1016/0010-0277(94)90018-3.
- Venkaiah K, Damayanti K, Nayak MU, Vijayaraghavan K. Diet and nutritional status of rural adolescents in India. Eur J Clin Nutr. 2002 Nov; 56(11):1119-25. doi: 10.1038/sj.ejcn.1601457. PMID: 12428178
- Deshmukh, V. D., & Jain, R. (2014). An update on antianxiety activity of Clitoria ternatea Linn. Journal of Ayurveda and Integrative Medicine, 5(2), 102-105.
- Dhingra, D., & Parle, M. (2011). Role of serotonin in stress-induced memory deficits: A study in the rat. Current Neuropharmacology, 9(4), 523-532.
- Fellows, L. K., & Farah, M. J. (2007). The role of ventromedial prefrontal cortex in decision making: Judgment under uncertainty or judgment per se? Cerebral Cortex, 17(11), 2669-2674.
- Glimcher, P. W. (2003). Decisions, uncertainty, and the brain: The science of neuro-economics. MIT Press.

- Guyton and Hall: Textbook of Medical Physiology, Fourteenth Edition.
- Gómez-Pinilla, F. (2008). Brain foods: the effects of nutrients on brain function. Nature Reviews Neuroscience, 9 (7), 568-578.
- Grosso G, Galvano F, Marventano S, Malaguarnera M, Bucolo C, Drago F, Caraci F (2014) :Omega-3 fatty acids and depression: scientific evidence and biological mechanisms. Oxid Med Cell Longev. doi: 10.1155/2014/313570.
- Kumar, A., & Khanna, V. K. (2012). Role of dopamine receptors in ADHD: A review. International Journal of Pharmaceutical Sciences Review and Research, 12(2), 50-57.
- Franco R, Reyes-Resina I, Navarro G. (2021): Dopamine in Health and Disease: Much More Than a Neurotransmitter. Biomedicines 9 (2):109. doi: 10.3390/biomedicines 9020109.
- Muthusamy, S., Ravichandran, V., & Muthuramalingam, A. (2018). Role of hormones in mental health: A review. International Journal of Health Sciences and Research, 8(2), 224-230.
- Murphy T, Dias GP, Thuret S. (2014) Effects of diet on brain plasticity in animal and human studies: mind the gap. Neural Plasticity. doi: 10.1155/2014/563160.
- Rayman, M. P. (2012). Selenium and human health. The Lancet, 379(9822), 1256-1268.
- Ramaswamy, S., & Narayanan, N. S. (2016). Neural mechanisms underlying decision-making: Insights from Parkinson's disease. Indian Journal of Medical Research, 143(6), 659-665. doi: 10.4103/0971-5916.192060
- Rao, T. S. S., Asha, M. R., Ramesh, B. N., & Jagannatha Rao, K. S. (2008). Understanding nutrition, depression and mental illnesses. Indian Journal of Psychiatry, 50(2), 77-82.
- Sathyanarayana Rao, T. S., Asha, M. R., Ramesh, B. N., & Jagannatha Rao, K. S. (2008). Understanding nutrition, depression and mental illnesses. Indian Journal of Psychiatry, 50(2), 77-82.

- Singh, A., & Singh, S. (2015). Serotonin and decision-making: An update on potential therapeutic interventions. Indian Journal of Pharmacology, 47(4), 387-393. doi: 10.4103/0253-7613.161269
- Siegel, G. J., Albers, R. W., Brady, S. T., & Price, D. L. (Eds.). (2011). Basic neurochemistry: Principles of molecular, cellular, and medical neurobiology (8th ed.). Academic Press.
- Sadava, D., Hillis, D. M., Heller, H. C., & Berenbaum, M. R. (2017). Life: The science of biology (11th ed.). W. H. Freeman.