Chapter 3
Why Should We Care About Functional Neuroanatomy?

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Learning Objectives

1. To understand why functional neuroanatomy developed.
2. To understand how functional neuroanatomy developed.
3. To understand the practical and clinical uses of functional neuroanatomy in addressing and prioritizing an individual's problem set, needs, and subsequent interventions.
4. To explain how to use a multicultural approach to functional neuroanatomy to help guide treatment from assessment to intervention.
5. To understand the implications and future directions of functional neuroanatomy.

Overview

The purpose of this chapter is to provide the history and background of functional neuroanatomy and its critical role in working with the biological basis of behavior of individuals in clinical, counseling, and school settings. This chapter will address the importance of examining the client or student from a multicultural perspective. It will identify the areas of growth and implications of clinical practice within the psychological fields. Finally, it will address the future of functional neuroanatomy

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after decades of expansion and research in practice, in an attempt to give the reader a better understanding of where we are with functional neuroanatomy and the biological basis of behavior.

Functional Neuroanatomy and the Biological Basis of Behavior

School, clinical, and counseling psychologists are essentially experts in helping others with emotional regulation and changing behaviors that may be intrusive to their life at school, in the workplace, at home, or in the community. As a psychologist or counselor, people come to us to understand why they or a loved one are engaging in inappropriate behaviors, or why they are not performing up to standards in school or the work place, and what can be done to help them. It is important to understand the underlying biological bases of an individual's behavior in order to create a more personalized and accurate treatment plan or educational plan. As stated in Chap. 2, various parts of the brain are associated with emotion. In this chapter, there will be more focus on the circuitry of the brain and its connection to behavior. One way to think of the circuitry of the brain is to compare it to wires that connect different parts of machinery. While the individual parts of the brain are generally used for specific functions, the neurological circuitry is what connects those different parts. Complications in these circuits can cause clinical implications which school, clinical, and counseling psychologists commonly encounter when working with their clients. Through understanding networking and connections of the various areas of the brain, mental health professionals can better support their clients through evidence-based interventions and psychoeducation. See Tables 3.1 and 3.2 for more specific information about brain lobes, structures, and their functions.

When a student or client is brought to the attention of the practitioner, it is often because they are engaging in some sort of negative behavior. For example, a teacher may come to a school psychologist describing a student who is impulsive and never stays in her seat, or a student who never pays attention and is constantly daydreaming. One may jump to thinking that the child has attention-deficit/hyperactivity disorder (ADHD) and an exhausted parent or teacher may want to move quickly toward medication. Practitioners who understand the biological basis of behavior will know to dig deeper. While prescribing medication may not be within the realm of some psychologists, having this understanding will strengthen the skill of case conceptualization and aid those involved on the decision as to whether medication is necessary, and if this is a child with ADHD or not. Given the brief description of the child, a psychologist may begin to think of frontal lobe circuitry and possible implications in the anterior cingulate, orbitofrontal, dorsolateral, and ventrolateral cortexes. All of these areas are involved with various functions, such as self-regulation of behavior, decision making, planning, monitoring, focusing and sustaining attention, motivation, self-awareness, and self-restraint (Torregrossa, Quinn, & Taylor, 2008). A

Table 3.1 Brain lobes and hemisphere functions, notes, and structures

Brain lobes and hemispheres			
Brain structure	Function	Notes	Damage
Frontal lobe	Responsible for emotional regulation, reasoning, risk taking, expressive language, muscle movement, planning, judgment, decision-making, and attention	Located at the front section of the brain; ultimate control and information processing center; interprets and acts on information processes by sensory areas; often seen as the most understood brain lobe	Executive processing problems, attention concerns, sexual issues/habits, apathy, overall socialization, ability to attend, and frontotemporal dementia
Temporal lobe	Serves as primary auditory cortex; important for hearing, recognizing sounds and language, and memories; it is the auditory center of the brain	Located in the bottom section of the brain; above the ear; the hippocampus is housed in the temporal lobe; long-term memory and conscious memory can be found here	Disturbance of sensation and perception, inability to attend to sights and sounds, and memory loss; speech perception problems, language issues, and emotional problems
Parietal lobe	Tactile/sensory *(senses)* and body processing center; it is responsible for understanding pressure, touch, temperature, and pain; includes academic abilities with sound symbols in reading, math and spatial reasoning	Located in the top and rear of cerebral cortex in the middle section of the brain; behind the frontal lobe; its role is in self-awareness and attention has recently been highlighted in research	Impaired attention, academic dysfunction, tactile and sensory processing issues; socialization issues relating to self-awareness may be affected, and difficulty writing and problems connecting words in speech
Occipital lobe	Is responsible for processing, understanding, and remembering visual perceptions; allows for the interpretation of depth, distance, location, and identity of objects	Located in the rearmost lobe of the cerebral hemisphere, this is the brain's smallest lobe but remains a unique and indispensable part of the brain's sensory system	Problems with sight, visual hallucinations, and illusions. Lesions on the occipital lobe can result in a "hole" in your vision known as a scotoma. Extensive damage can result in total blindness
Left hemisphere	Processes verbal information and language sequentially; interprets actions logically and analytically that are detail-oriented to math/science; hemisphere typically used during traditional learning activities (e.g., verbal lectures)	Typically associated with logic, processing science/math, and written information; controls right side of body (contralateral) including right field vision and motor skills	Problems with language (aphasia), judgment, and motor planning. Trouble reading and writing and changes in speech. Deficits in planning, organization, and memory

(continued)

Table 3.1 (continued)

Brain lobes and hemispheres			
Brain structure	Function	Notes	Damage
Right hemisphere	Processes visual/nonverbal information simultaneously, holistically, and globally; includes nonverbal functions, such as depth perception, tactile/sensory perception, creativity, art, emotional thought, nonverbal memory, and face recall	Typically associated with art awareness, creativity, music awareness, intuitiveness; includes novel and nonverbal abilities, impulsivity, center for imagination, and adventure. Controls left side of body (contralateral) including left field vision and motor skills	Problems with emotional recognition, such as recognizing faces and emotions; semantic processing; and other cognitive processing skills such as attention, memory, and executive functioning has been related to ADHD

Table 3.2 Brain structures, functions, and location/damage notes

Brain structure	Function	Notes
Angular gyrus	Combines sensory inputs; allows visual patterns to be covered to suitable auditory structures; word reading	Part of the language system in the left temporal lobe; damage causes inability to read and speak; problems writing
Amygdala	Processes emotions (aggression) rage, fear; relates to risk and loss abilities.	Almond-shaped mass; deep in the temporal lobes; relates to survival abilities
Auditory cortex	Responsible for hearing and processing sounds	Part of the temporal lobe, on the posterior superior temporal gyrus; Brodmann's areas 41 and 42
Broca's area	Produces speech through control of the motor cortex, in left frontal lobe; allows for ability to sing and comprehend speech	Damage disrupts speaking; located in the inferior frontal gyrus
Cerebral cortex	Allows for learning, thinking, and enabling adaptability; information processing center	Damage disrupts a person's ability to think, manage emotions, and behave appropriately
Corpus callosum	White mass axon fibers which connect both hemispheres for processing and communication of efficient brain functioning	Arched mass of white matter found deep in the longitudinal fissure; damage leads to disconnection of the hemispheres and processing problems
Hippocampus	Involves memory and learning; including visual, spatial (right hemispheric), and verbal (left hemisphere)	Medial region of the temporal lobe; damage impacts specific types of memory
Hypothalamus	Regulates thirst, hunger, body temperature, sexual behavior (hormone release); controls/regulates maintenance reflexes (eating); homeostasis linked to emotion	Located next to the third ventricle; helps govern endocrine system, monitors glands; controls hunger; linked to emotion and rewards

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Table 3.2 (continued)

Brain structure	Function	Notes
Medulla	Responsible for controlling autonomic functions such as breathing, heart rate, and blood pressure	Major relay point for information going to and from the brain and spinal cord; located directly above the spinal cord in the lower part of the brainstem
Midbrain	Serves as relay station for auditory and visual information including eye movement; smallest region of the brain	Controls eye movement and body movement; degeneration of this area is associated with Parkinson's disease
Motor cortex	Allows for processing of body movements; controls body parts; sends messages out to body, controls body movement	Premotor, primary, and supplemental motor areas responsible for movement from initiation to execution
Pituitary gland	Regulates hormone release related to growth, blood pressure, and reproduction; small bean-shaped gland	Located at the base of the brain; controlled by hypothalamus
Pons	Responsible for autonomic functions such as breathing and sleep cycles; integration of motor impulses, and postural and kinesthetic information	Portion of the brain stem, located above the medulla oblongata and below the midbrain; damage relates to nerve palsies, vertigo, facial paralysis, and gaze palsy
Prefrontal cortex	Plays a critical role in executive functioning, including working memory, planning complex behavior, decision-making, and moderating social behavior	Behind forehead and controls motor cortex; damage results in short-term memory, impulse control, and long-term planning
Reticular formation	Helps control behavioral arousal and consciousness	Network of interconnected nuclei located throughout the brainstem; damage can cause coma or death
Sensory cortex	Responsible for receiving and interpreting sensory information from the body	Behind and parallel to motor cortex. Modulates speech and clarity; includes touch, proprioception, and temperature
Spinal cord	Connects the brain to the body; long thin tubular structure made up of nervous tissue	Pathway to neural fibers; damage can lead to paralysis and/or death
Thalamus	Acts as a switchboard between sensory neurons and higher brain regions to relay sensory information	Deals with sight, hearing, touch, taste. Transmits replies from higher brain to cerebellum and medulla
Limbic system	Regulates autonomous and endocrine function, and consolidates memories. Set of brain structures that deal with emotion and memory; links emotion (fear and anger), basic motives (food and sex)	Located on both sides of the thalamus beneath the medial temporal lobe. Supports emotion, behavior, long-term memory, and olfactory functioning. Damage can cause hormonal imbalance and emotional dysfunction
Wernicke's area	Assists in the processing of speech. Responsible for auditory coding and understanding	Damage disrupts language comprehension

Adapted from D'Amato et al. (2005), Das et al. (1994), Hale and Fiorello (2004), Hynd and Willis (1988), Goodwin (1989), and Lezak et al. (2012)

disconnection or miscommunication between these areas with the rest of the brain may look like inattention or hyperactivity (Torregrossa et al., 2008). However, these areas are also involved with functions, such as judgment of another's feelings, self-regulation of behavior, emotional processing, anticipation, use of feedback, response inhibition, and emotional regulation. If the child looks like she is never paying attention, maybe she is hypervigilant. If she has poor concentration, it may not be due to ADHD, but instead she may have experienced a traumatic event which has negatively impacted her ability to sustain attention. Understanding the biological and physical differences of these complications is significant for identifying and implementing appropriate supports.

With the current increase in awareness of how toxic stress and adverse events during childhood can impact brain development, we look at the communication between the limbic system and the prefrontal cortex; however, several areas of the brain are activated when responding to stressful situations. Two major parts of the limbic system are the amygdala and hippocampus. Together these areas create and store memories and produce emotional responses. Research in neuroimaging has shown that the amygdala and hippocampus are altered in children who experience toxic stress and adverse events (De Bellis & Zisk, 2014; Souza-Queiroz et al., 2016). This type of alteration leads to a disruption in communication between the limbic system and the prefrontal cortex, which can then lead to the fight, flight, or freeze reaction instead of processing through appropriate decision making and problem solving (De Bellis & Zisk, 2014). Thus, experiencing neglect or chronic stressors during childhood increases the risk of significant problems with cognitive, affective, behavioral, physiological, relational, and self-attributional functioning (Kinniburgh et al., 2005; Perry & Hambrick, 2008). Psychoeducation can help individuals to understand their emotional and behavioral responses and work toward healthy emotional regulation. It can also aid parents and educators to promote and create predictable, consistent, and nurturing environments that lead to healthy brain development.

During childhood and adolescence, healthy environments that are stimulating and allow for opportunities of creativity and critical thinking can lead to positive neural growth (Cozolino, 2013; De Bellis & Zisk, 2014). Cozolino (2013) explains how social experiences affect brain function and development and argues as to why this is closely related to how humans learn throughout their lifetime. With his book, *The Social Neuroscience of Education*, Cozolino (2013) explains the brain-body connection and highlights the benefits of centering education on building secure and healthy attachments and how it impacts learning. Many of the behavioral aspects in his book, which are focused on teachers and the field of education, can be generalized and applied to other fields. For example, teacher burnout is explained as a hit to self-esteem and emotional well-being which leads to lowered job satisfaction and poor performance. In other words, when humans feel a decreased sense of self-worth, an emotional response to environmental factors, their behavior reflects that (i.e., career change or poor job performance). As Albert Bandura (1997) once stated, "The work we do determines whether a substantial part of our lives is repetitively boring, burdensome, and distressing, or lastingly challenging and self-fulfilling" (p. 422).

Functional neuroanatomy has provided researchers and clinicians with a greater understanding of how the brain is connected to behavior. With this understanding, health service psychologists can evaluate more comprehensively and create and implement additional sound and sustainable interventions and supports for those with whom they work. This information is invaluable when considering how to psychologically approach situations, no matter the complexity. Functional neuroanatomy has provided psychological practitioners with the knowledge base to provide support at individual, family, small group, and system-wide levels, while, at the same time, it has increased awareness and reliability in differential diagnosis.

History of Functional Neuroanatomy

The American Psychological Association (APA) promotes psychology programs to include history of psychology in the curriculum. It is important to study the history of functional neuroanatomy in order understand where we have been, how we have gotten to where we are currently, and where we are going in the future of the field of psychology. Having a deeper understanding of how the field has developed also allows for a more in-depth understanding and sound practice of one's theoretical orientation. The American Psychological Association (APA) also requires graduate programs to include history in the curriculum of the program (APA, 2006). The study of neuroanatomy dates back to pre-World War II with psychologists, such as Broca and Wernicke, who studied localization of brain functions (Hebben, Milberg, & Kaufman, 2010). After the war, major contributions were made to the field of clinical neuropsychology due to the large number of soldiers experiencing symptoms of post-traumatic stress disorder (PTSD), then viewed as "shell shock" or "soldier's heart," and traumatic brain injuries (Substance Abuse and Mental Health Services Administration, 2014). Researchers and clinicians thus began working toward a deeper understanding of the brain and its connection to emotional, behavioral, and physical responses.

Some of the most notable clinicians and researchers include, but are not limited to, Ward Halstead, Ralph Reitan, Alexander Luria, and Edith Kaplan. Halstead and Reitan created the assessment *Halstead-Reitan Neuropsychological Test Battery* (HRNTB), which has been updated several times and is still used in adult clinical neuropsychology today (Horton & Reynolds, 2015). The original core subtests of the HRNTB were created by Halstead and then updated by Reitan, who was his mentee. The development of both the original battery and the updated subtests were significant milestones in the field of neuropsychology. Reitan's contributions to the HRNTB allowed for assessment and treatment of individuals who suffered from brain damage and established that performances were related to the brain rather than related to behavior. Because of his research and practice, the role of clinical neuropsychologists in the healthcare system was recognized and welcomed for the first time. Horton and Reynolds (2015) argue, "every clinical neuropsychologist working today owes a debt to Reitan's contributions."

Alexander Luria (1902–1977) is another neuropsychologist who is well known for his significant contributions to contemporary neuropsychology through his findings on the function and organization of the brain (Hazin & Tarcísio da Rocha Falcão, 2014). Luria has contributed to the field in various ways, including the theory of extracortical organization of higher mental functions (Kotik-Friedgut, 2006). This theory laid the foundation for consideration of cross-cultural differences of brain development and structure. Thus, it is now well accepted today that social, cultural, and historical factors all play a vital role in neural development and must be considered throughout the evaluation process. Luria established that an evaluation should include both qualitative and quantitative measures.

Additionally, psychologist Edith Kaplan has contributed to the field of neuropsychology in many domains, most notable through her focus on apraxia, aphasia, and developmental issues (Oscar-Berman & Fein, 2013). Kaplan also developed a predoctoral and postdoctoral clinical neuropsychological internship-training program during her time as the director of Clinical Neuropsychological Services at the Boston VA Medical Center (1976–1987). Along with Luria, Kaplan added to the assessment domain by emphasizing the importance of qualitative data collection and analysis alongside of quantitative data. Kaplan and colleagues developed the Boston Process Approach (later called the Boston Hypothesis Testing Approach) which laid emphasis on the importance of *how* an individual arrives at an answer and initiated the concept of "testing the limits" (Miller, 2013).

Nearly all domains of the psychology field have changed and developed over the last several decades, including evaluation procedures and assessment tools. Much of the development in these areas is due to the research that has been dedicated to functional neuroanatomy. Because of the work of the previously mentioned individuals, and so many more, functional neuroanatomy has played a significant role in the progress of the fields of adult clinical neuropsychology, pediatric neuropsychology, and school neuropsychology. Miller (2013) addresses the work of Rourke (1982) who researched the history of clinical neuropsychology and described three stages in which the field went through: (1) the single test approach, (2) the test battery/lesion specification stage, and (3) the functional profile stage. The single test approach is described as a stage wherein researchers were utilizing a single measure to determine if a patient had brain damage (Miller, 2013). Psychologists were concerned, at the time, with overall brain functioning versus assessment of diverse domains of functioning. The test battery/lesion specification stage was a time in history when clinicians moved away from the single test approach and began to utilize several test batteries to measure a number of cognitive processes in order to discover neuropsychological dysfunction in patients (Miller, 2013). Much of the credit for the progress made during this stage is given to the previously mentioned psychologists, Ward Halstead, Ralph Reitan, Alexander Luria, and Edith Kaplan. Finally, the functional profile stage is noted as the time when neuroimaging techniques began to tie into assessment procedures for cognitive functioning. The developments made during this stage lead to a more comprehensive approach to neuropsychological assessment.

The study of functional neuroanatomy has evolved over time from a very narrow view of functioning and assessment, to a greater understanding of the brain-body connection and how it relates to emotion and behavior. Today, rather than approaching an evaluation to determine whether there is a presence of brain dysfunction or not, comprehensive assessments are often conducted to look more so at patterns of strengths and weaknesses.

Functional Neuroanatomy and Multicultural Issues

As our world becomes increasingly more diverse, practitioners, researchers, and scholars must all address the broadening of our growing multicultural society and continue to be informed of all of the diverse populations and cultures that make up the world's population. In the United States alone, our population is expected to grow more slowly in future decades than it did in the previous century. However, the total population of over 330 million at the time of publication of this textbook is projected to reach the 400 million threshold in 2051 and 417 million in 2060. In addition, around the time the 2020 Census was conducted, more than half of the nation's children were part of a minority race or ethnic group. This proportion is expected to continue to grow so that by 2060, just 36 percent of all children (people under age 18) will be single-race non-Hispanic White, compared with 52 percent today the U.S. population as a whole is expected to follow a similar trend, becoming majority-minority in 2044. The minority population is projected to rise to 56 percent of the total in 2060, compared with 38 percent in 2014 (United States Census Bureau, 2015). When examining functional neuroanatomy in practice, clinicians must understand the importance of the various multicultural factors and variables of the client in front of them. As the populations become more majority-minority in the next few decades, the biological basis of behavior as seen from the multicultural perspective will also diversify. Human beings are not a homogenous species and the diverse cultures that make up society are factors that can affect the utility of functional neuroanatomy from assessment to intervention.

Pediatric clinical neuropsychology is a subspecialty within the field of clinical neuropsychology that is concerned with the study and understanding of brain-behavior relationships in children and adolescents with known or suspected brain neurodevelopmental disorder, disease, injury, learning disability, or other acquired or congenital disorder affecting brain function and development. As a subspecialty, it has more access to the use of functional neuroanatomy in as many pediatric clinical neuropsychologists work in hospitals, clinics, or specialized practices that have access to equipment, such as a functional MRI (fMRI) and brain scanning technology. However, school and counseling psychologists can also vastly benefit from the use of functional neuroanatomy, but currently do not have the access to the same technology.

What remains a constant is that all of these subspecialties within the field of psychology work with the regular population of individuals from every socioeconomic, ethnic, sociocultural of all genders, beliefs, and walks of life. Therefore, psychologists must take a strong stance on looking at the diverse multicultural components that make up an individual and impact their presentation from a functional neuroanatomy sense. For example, the brain of an individual who experienced early childhood trauma in the form of abuse or neglect may look and present vastly different in an fMRI versus the brain of a regular functioning individual. Therefore, sociocultural components and factors must be taken into effect when examining and assessing individuals with the assistance of functional neuroanatomy.

So, what does a brain scan discover in an individual who reportedly experiences any kind of trauma? First, it is essential to provide a general overview of what a brain scan is in practice. For the purposes of clinical practice, brain scans that identify functional neuroanatomy come from brain scan technology that covers a diverse group of methods for imaging the brain. In psychiatric clinical practice, brain scans are mostly used to rule out visible brain lesions that may be causing psychiatric symptoms. In the schools and counseling psychology, brain scan technology can be used on a consult basis with the professionals who conduct the studies. In research, psychologists use brain scan technology to learn about the pathologies of the brain in mental illness. A common method is magnetic resonance imaging (MRI) which allows clinicians to look at the changes in the volume and structure of different areas of the brain, and integrity of the pathways connecting them.

Then there is functional MRI (fMRI) which examines blood flow in different areas and regions of the brain as a measure of their dynamic function, mostly in response to a task or event, such as thinking about a traumatic event or viewing of a short video that produces stress and raises cortical levels in the brain. Practitioners use brain circuitry to look at how people can be proactive by teaching clients to learn fear and safety, for example. Researchers who want to use functional neuroanatomy through a multicultural lens may also want to add variables in the research that address socioeconomic status, cultural norms, and any array of methodology that addresses the diversity of the subjects. At the current stage of the technology and research, psychiatrists, psychologists, and neuroscientists only use these methods for researching the brain changes in mental illness, and not for making diagnoses. In order to make broader conclusions about the data, practitioners and researchers must combine data from people with a mental illness to determine how, on average, different areas of their brain may differ in volume or function from others. This is further confounded when adding varying degrees of what makes up a groups' multicultural profile and the makeup and constellation of that group can be very complex. To summarize, brain imaging has been a very useful tool in understanding the aberrations in structure and function of a brain with PTSD, but it does not diagnose the condition.

Why Functional Neuroanatomy Is Critical to Professional Psychological Practice

Functional Neuroanatomy is not only critical to the professional practice of psychology, but it has become essential for professionals to utilize it to optimize their assessment, treatment, progress monitoring, and interventions for the client or patient. The 1990s was declared the "Decade of the Brain" in the United States and is now nearly three decades old (Goldstein, 1994). Although there have been great strides taken since then to explore and understand the brain better, there is still a lot of work to be done. Perhaps, the biggest push is in the area of brain scan technology. Although this chapter does not discuss the various technologies that exist, it will address why technology plays a role in why functional neuroanatomy is critical to professional psychological practice. See Chap. 5, (Noggle & Davis, 2021) for comprehensive coverage on neuroimaging.

Using technology to determine the functional neuroanatomy and clinical treatment planning for individuals go hand-in-hand. The data collected from brain scans is only as good as the technology that creates the images needed to examine the brain. However, it is important to note that technology, such as the MRI can only detect changes in blood flow without using a radioactive tracer. When a particular site in the brain is more active, blood flows to that area (Schooler et al., 2018). This blood brings oxygen to the brain cells that are working harder and, subsequently, thought to be working more efficiently. By tracking variations in blood flow, functional MRI can detect activity in the brain as it happens (Filippi, 2015).

So how is this critical to professional psychological practice? The bottom line is that if a client is seen for a severe condition of depression, anxiety, or even psychosis, brain technology can now utilize real-time data in the form of images to detect whether different parts of the brain are being utilized or maybe even neglected as the absence of active blood flow also predicts potential hypotheses for the practitioner.

Scientists have started to discover which areas of the brain are involved in different mental health conditions, such as depression, anxiety, and post-traumatic stress disorder (PTSD; Akiki et al., 2017); more clear data has been collected as to which areas of the brain are involved. For example, PTSD appears to be heavily involved with activity in the amygdala, which is, subsequently, involved in processing fear as well as lowered activity in parts of the frontal lobes (Zotev et al., 2018). This is essential to psychological practice because, with this data and analysis, we can now proceed to better confirmation of diagnoses and, subsequently, better and more accurate treatment plans.

Some technologies, like Positron Emission Tomography (PET) imaging and functional MRI (fMRI), measure the activity of the brain either at rest or while a person performs specific tasks (Filippi, 2015). Other technologies, such as the already discussed MRI, measure the brain's structure and the corresponding size and shape of its various components. All of these technologies play a massive role in how strong a hypothesis can be made leading to better outcomes due to stronger decisions on diagnoses and treatment.

Given the scientific and technological advantages we have to guide treatment based on functional neuroanatomy, we must remember that there is variation in brain activity among people with the same diagnosis. Ultimately, brain scans can be useful and supplemental to better outcomes through confirmation of diagnosis and treatment based on empirical data. However, caution should be taken in considering this a perfect science at this time.

Functional Neuroanatomy and Its Relationship to the Future

Research has indicated very specific reviews and critiques of cross-linguistic brain imaging studies of conditions, such as developmental dyslexia (Lallier et al., 2017). Inquiries arise as to the predictions that should be tested in future brain imaging studies of typical and atypical reading in order to refine the current neurobiological understanding of developmental dyslexia. This is only one example of where functional neuroanatomy can go in the future in terms of identifying, understanding, and treating complex mental health and disabling conditions. Watson, Kirkcaldie, and Paxinos (2010) posed that the future of functional neuroanatomy needs to be considered with caution so that the future generation of scientists that we are training are more optimistic and open-minded by realizing the limitation of the scientific tools in the past, present, and future. They emphasized that they become more motivated to look forward for proper application of the future technologies in discovering the etiologies and treatments of the Central Nervous System (CNS) disorders. Ultimately, we need to increase the amount of research in the areas of functional neuroanatomy to obtain larger sample sizes of individuals with specific mental illnesses and their symptomatology. Watson et al. posed that we must not rely on the scientific tools alone, but, in addition, on stronger clinical judgment based on the best diagnostic and treatment measures we can obtain.

A number of functional neuroanatomy studies have been conducted on Tourette syndrome (Stern et al., 2000), anxiety (Etkin, 2009), and bipolar disorder (Strakowski et al., 2005; Cerullo et al., 2009). The future of functional neuroanatomical studies look to include other psychiatric disorders and a host of research on emotional regulation, working memory, and specific learning disabilities.

Conclusions

As mentioned, the study and practice of functional neuroanatomy is not perfect and we have many more opportunities to improve the accessibility of what researchers and practitioners are looking to find. Most notably, functional neuroanatomy could use a tremendous boost in funding for researchers to build lasting outcomes that are specific to the field. Also, the number of individuals who have a diagnosed mental illness and who are willing to be a part of research must be willing to participate in larger participant pools for research fidelity and validity.

With all the improvements and changes in technology, it remains to be seen, but the future of functional neuroanatomy will likely follow suit with much exciting research and trials conducted with larger numbers of participants. As long as there are practitioners and researchers interested and looking to advance the research in cooperation and collaboration of better outcomes for more diverse and multicultural populations, there will be a better and more substantial set of research agendas willing to advance the field of functional neuroanatomy.

Discussion Questions

1. Why is it important to understand the history of neuroanatomy? When might knowledge of historical events and developments in the field come into play?
2. What are the practical and clinical uses of functional neuroanatomy in addressing and prioritizing an individual's problem set, needs, and subsequent interventions?
3. Thinking of Luria's theory of extra-cortical organization of higher mental functions, how might one's culture impact the development of cognitive functioning? Why is it important to consider cultural, social, and historical accounts when assessing children and adults?
4. How have Halstead/Reitan and Luria historically influenced the area of understanding functional neuroanatomy?
5. What are the implications and future directions of functional neuroanatomy?
6. How does using a multicultural approach to functional neuroanatomy help guide treatment from assessment to intervention?

EPPP Sample Questions

1. One of the major parts of the brain that stores memories is the:

   (a) Anterior cingulate
   (b) Hippocampus
   (c) Parietal lobe
   (d) Cerebellum

2. Two main functions of the prefrontal cortex are:
   (a) Language and movement
   (b) Vision and memory
   (c) Planning and decision making
   (d) Speech and balance
3. The Boston Process Approach was developed by:
   (a) Luria
   (b) Kaplan
   (c) Halstead
   (d) Reitan
4. The principle of extracortical organization of higher mental functions paved the way for:
   (a) Examining "shell shock" after World War II
   (b) Consideration of cross-cultural differences of brain structure and function
   (c) The creation of the *Halstead-Reitan Neuropsychological Test Battery* (HRNTB)
   (d) The concept of "testing the limits"
5. Early childhood toxic stress may cause an adolescent to have a "fight, flight, or freeze" response to an adverse stimuli. When looking at an fMRI of this adolescent in comparison to a same aged youth who did not experience early childhood toxic stress, you may notice:
   (a) More activity in the occipital lobe of the child who experienced toxic stress
   (b) Less activity around the amygdala of the child who experienced toxic stress
   (c) Less activity in the frontal lobe of the child who experienced toxic stress
   (d) Less blood flow near the hippocampus of the child who experienced toxic stress

   Answers: B, C, B, B, C

Proactive Readings

Transcending the Past

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Goldstein, M. (1994). Decade of the brain. An agenda for the nineties. *Western Journal of Medicine*, *161*(3), 239.

Excelling in the Present

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