Chapter 1

What Is Neuropsychology?

> Welcome! I'm Dr. Bellone. Please come in and have a seat. Many people are not exactly sure who I am or what this is all about, so I'll give you a quick overview. I'm a neuropsychologist. That's a fancy way of saying that I'm a psychologist with specialty training in brain function and dysfunction. You are here for a neuropsychological evaluation, which takes place in two parts. The first part involves me asking you questions in order to learn important information… questions such as the nature of your cognitive problems, your medical history, and your social background. This will help me get to know you better so that I can tailor my opinions and recommendations to you. The second part involves objectively testing your thinking skills such as memory, attention, and problem solving using paper-pencil and computer-based tests. The purpose of this is to help me understand your cognitive strengths and weaknesses; we are all better at some tasks than others and if I know your unique profile, I can make the most accurate diagnosis and suggest ways to improve your health and quality of life.
>
> The entire evaluation typically takes about three to four hours. When you leave, I will score the tests and compare your performance to other people of a similar age and education level. Then I will write up what I've learned about you in a medical report so that your doctors can use it to provide you with the best possible care. Finally, I like to sit down with people on a separate day, once everything else is completed, so that I can share my findings, provide recommendations, and give you the opportunity to ask any questions that you might have. How does this sound? Do you have any questions so far?

This is how I (John) typically introduce the neuropsychological evaluation to my patients and I thought that it would be fitting to share it with you right up front. Although this is a relatively standard approach, there are multiple flavors or varieties to the basic template, and the specific language used is largely contingent upon the setting, the patient, and the neuropsychologist themself.

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Neuropsychology is a fascinating area of study (we're not biased at all!). It can be loosely defined as the scientific study of how the brain produces behavior and how behavior is altered when something atypical happens to the brain (the "brain-behavior relationship").[1,2] That is, our cognitive abilities, emotional states, personality traits, and overt actions can all be traced back to brain activity that occurs in complex, interconnected networks (Kolb and Whishaw 2015). In other words, these few pounds of jelly between our ears are responsible for *everything* that we do, think, and feel. If something changes the structure and functioning of our brain (e.g., a severe traumatic brain injury), or if the brain did not develop normally to begin with (e.g., megalencephaly; Mirzaa and Poduri 2014), we see alterations in thinking and actions. For example, imagine that a man has a stroke that cuts off blood supply to his left frontal lobe, adjacent to the Sylvian fissure. It is likely that this injury would leave him with significant difficulties in expressing his thoughts verbally. In this case, speech is the behavior that is affected.

Throughout the rest of the chapter, we will cover the purpose of neuropsychology, the types of patients seen, the cognitive skills assessed, and the differences relative to related professions.[3] However, before we get into these weeds, we will briefly discuss past approaches for examining brain-behavior relationships because this rich history laid the foundation for the field of neuropsychology as we know it today.

Roots of Neuropsychology/Historical Context

> One thing that I try to pass on to trainees is not to be too short-sighted. We should all appreciate the giants on whose shoulders we're standing, and the history of our field.
>
> – Lisa Eyler, PhD

People have been interested in the cause of thinking and behavior for thousands of years. The earliest available evidence for this comes from ancient skulls with burr holes (Fig. 1.1). It is thought that these holes were created to release evil spirits or to facilitate the introduction of benevolent spirits, and as a primitive surgical intervention to treat injuries (any volunteers??). The procedure is called "trepanning" or "trepanation" and was widespread, having been developed independently through-

[1] Scientists use the term "behavior" in two different ways. Here we are using it broadly so that it includes not only overt actions but also thought processes and affective states. The other meaning of "behavior" (e.g., "behavioral observations") is narrower and refers specifically to observable actions, not cognition and emotion.

[2] There are slight variations in the definition of "neuropsychology." For example, see The American Academy of Clinical Neuropsychology practice guidelines (Board of Directors 2007) and the National Academy of Neuropsychology's position paper (Barth et al. 2003).

[3] Also, listen to NavNeuro episode 2, *Neuropsychology for Non-Neuropsychologists*, for an overview (www.NavNeuro.com/02).

Fig. 1.1 A skull with a burr hole

out Europe, China, and the Americas, with 5–10% of all discovered Neolithic skulls (circa 6500 BCE and earlier) showing evidence of the practice (Faria 2015).

The earliest known written mention of the brain comes from a document made by an Egyptian physician around 1600 BCE (although it may be a copy of a manuscript dating back to 3000 BCE) called the *Edwin Smith Surgical Papyrus* (Kamp et al. 2012). The document describes 27 battlefield head injury cases, including the nature of the injury, examination, and diagnosis. At the time, the brain was generally not recognized as an important organ, as evidenced by the Egyptian practice of throwing it away when preparing a corpse for embalming; in contrast, the heart was thought to be the center of intelligence. Other ancient civilizations such as the Mesopotamian, Hindu, and Hellenic peoples held similar views about the heart being central to thought and emotion (Faria 2015).[4] Even many esteemed scholars of antiquity did not understand the importance of the brain. For example, Aristotle believed that the brain's purpose was to cool the blood and heart (Aristotle, ca. 350 BCE/ 1912).

Although early prevailing views of the brain's function were based on philosophical and religious beliefs rather than careful scientific examination, there were some who used anatomical study as early as the fifth and sixth centuries BCE to begin understanding the importance of the brain for higher-level abilities (Konstantine and Peter 2015). Anatomical study became more and more common over the next few centuries; for example, Galen dissected the brains of animals in the second century CE. By ~1000 CE, Middle Eastern physicians were regularly performing surgical procedures for brain-related issues (e.g., Al-Zahrawi; Al-Rodhan and Fox 1986) and presenting detailed accounts of brain injuries and treatments (e.g., Ibn Sina; Aciduman et al. 2009). The first European anatomy textbooks began emerging in the

[4] Remnants of this sentiment are evident in various idioms, such as "to know by heart" or "you will always be in my heart."

thirteenth and fourteenth centuries (e.g., *Anathomia Corporis Humani*), and anatomical inquiry blossomed throughout the Renaissance (Nanda et al. 2016).

The study of brain-related problems through anatomy continues today in the field of neuropathology. Modern neuropathology began in the late 1800s with the discoveries of Santiago Ramón y Cajal, Camillo Golgi, and others. A neuropathological examination typically involves dissecting a human brain after the person dies, both visually inspecting the gross anatomy and cutting small pieces in order to examine neurons and glial cells under a microscope. Various staining methods can be applied to the tissue to visualize different components or pathology. For example, in 1906 Alois Alzheimer used these techniques to view the amyloid plaques and neurofibrillary tangles that would become known as hallmarks of Alzheimer's disease. Eventually, in vivo biopsies became common – this is where pathologists study a resected portion of a living person's brain in order to assess for various disease processes such as whether or not a mass of cells is cancerous.

Because it is obviously not easy or without risks to open up the skull and examine what is going on inside, people have searched for other methods of investigating what is happening up there in a living person. One popular early method, "phrenology," originated in 1796 based on the work of German physician Franz Joseph Gall and was popularized by Johann Spurzheim. The technique involved performing a "skull reading" in which the phrenologist would assess the contours of the outer surface of the skull (especially the indentations and protuberances), and then associate the measurements with cognitive and personality abilities/traits. For example, a phrenologist might conclude that their patient was particularly witty, benevolent, or combative based on feeling the outside of the skull (see Fig. 1.2). Although recognized as pseudoscience by the 1840s (the topography of the skull does not correlate with brain functioning), it helped promote the idea that different regions of the brain relate to different mental abilities, which is often referred to as "localization" or "functional specialization" (see Kolb and Whishaw 2015, for a more thorough discussion). This

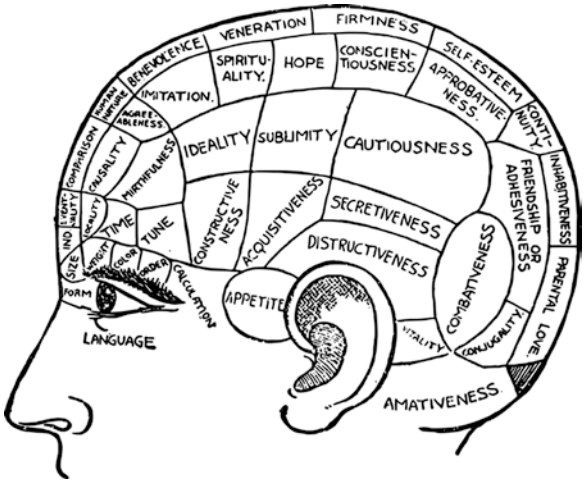

Fig. 1.2 A phrenological map of characteristics and abilities

concept is perhaps most concisely summed up by Norman Geschwind's quote, "every behavior has an anatomy" (Geschwind 1975, p. 3).

During and after the phrenology craze, functional specialization became more widely recognized. Perhaps the most famous example illustrating this principle is that of Phineas Gage. In 1848, Gage was a construction foreman preparing a roadbed for a railroad when an accidental explosion sent a three-and-a-half foot, 13-pound tamping iron through his left jaw and out of his frontal lobe (Harlow 1848). Surprisingly, he survived the injury and ultimately made an incredible recovery, but his physician noted that his personality had been drastically altered. The man people knew to be reserved and considerate was now impulsive and profane; the physician noted that he "was no longer Gage" (Harlow 1868). Although there is debate about whether the degree or persistence of Gage's personality change was exaggerated (Macmillan 2000), it is clear that this case helped people begin to understand that personality and social behavior can be modified by injury to specific brain regions.

Given the growing confidence that it is possible to acquire knowledge pertaining to what is happening in the brain by observing a person's behavior, many physicians began correlating neuroanatomy and neuropathology with clinical observations in a systematic way. This led to what has been referred to as the "golden age of cerebral localization" (Benton 2000, p. 223). For example, Paul Broca performed autopsies on his patients and noticed that people who had difficulty speaking fluently often had damage to a specific part of their brain (Broca 1865). Thus, if a patient presented with an expressive language deficit, the physician could infer that it was likely caused by damage in the left posterior inferior frontal gyrus. Shortly after Broca's discovery,[5] Carl Wernicke observed that a different type of language problem involving poor comprehension and fluent but incoherent speech was linked to damage to the posterior superior temporal gyrus (Wernicke 1874; see Fig. 1.3). A more recent case study of brain-behavior relationships involves a patient called "H.M.," who had both of his medial temporal lobes surgically removed in 1953 as a treatment for intractable epilepsy.[6] Although the procedure partially controlled his seizures, it robbed him of his ability to form memories of new events (Milner et al. 1968). So, within minutes of being presented with information, the material would be completely forgotten (think of the 2000 movie *Memento* or the 2004 movie *50 First Dates*). This case helped clinicians better understand how learning and memory work – i.e., structures in the brain known as the hippocampus and parahippocampal regions play an integral role in memory formation. Many more of these

[5] Another French neurologist (Marc Dax) actually made this discovery ~30 years earlier but it was not publicized until after Broca's famous paper, so the finding is generally associated with Broca instead of Dax (Drouin and Péréon 2019). It is thought that Broca's discovery was independent of Dax's work.

[6] It is meaningful that both medial temporal lobes were removed because we have one in each of our two cerebral hemispheres (right and left) and each can partially compensate for damage to the other.

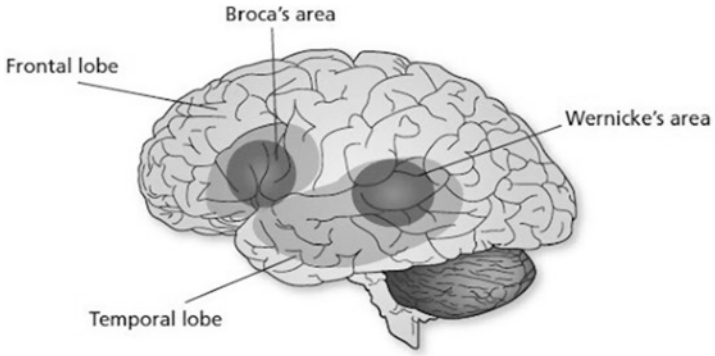

Fig. 1.3 Language areas in the brain

types of cases emerged, with additional major anatomical regions being related to specific behaviors.[7,8]

Early Days of Neuropsychology

Neuropsychology emerged in part from the flurry of localization insights in humans and animals. It is impossible to pinpoint exactly when the field was born, but the term "neuropsychology" was first used in a 1913 address by William Osler, who viewed the field as the study of the impact of brain injury, disease, and/or mental illness on "higher functions" (Bruce 1985).[9] Because there was no easy way to peer inside the brain of a living person at the time, the field initially focused on lesion localization – i.e., estimating the location of brain injury based on an assessment of cognitive abilities. As you would expect, there was much need for this during and after World War I (WWI; 1911–1916) and World War II (WWII; 1939–1945), when soldiers were wounded by bullets, shrapnel, and other weapons. Additionally, there was a need for evaluations of military personnel prior to battlefield engagement. In this vein, in 1917, President of the American Psychological Association Robert Yerkes persuaded the US Army that conducting intelligence testing on military

[7] We encourage readers to check out books by the late Oliver Sacks, a behavioral neurologist who describes interesting brain-behavior relationships in an entertaining way (e.g., *The Man Who Mistook His Wife for a Hat*; and *An Anthropologist on Mars*).

[8] This was only a very brief overview of the history of neuroscience and does not include important theories such as connectionism, equipotentiality, and hierarchical organization. For more thorough accounts, see the following books, both by Stanley Finger: (1) *Origins of Neuroscience: A History of Explorations Into Brain Function*, and (2) *Minds Behind the Brain: A History of the Pioneers and Their Discoveries*.

[9] For more information about the origins of the term "neuropsychology," including its use by Karl Lashley and Kurt Goldstein, see Finger (1994).

recruits would help them select the best soldiers and assign them to appropriate tasks. Along with Henry Goddard, Lewis Terman, and others, Yerkes developed the Alpha and Beta tests for those who were literate and those who were illiterate, respectively (there was also a modified test for those who failed the Beta version). To create these measures, they capitalized on tests that had been recently developed such as the Binet-Simon test and the Stanford-Binet Intelligence Scales. They started the assessment program in 1918 and tested about 1.7 million recruits, making this the largest cognitive assessment project of the time (Shephard 2015). There is a complex and rich history behind intelligence testing and the evolution of psychology in general, but it is beyond the scope of this book.[10]

A scientifically grounded understanding of intelligence played an important role in the genesis and development of neuropsychology by increasing funding and jobs in psychology, particularly in the area of cognitive assessment (Flanagan and Harrison 2018).[11] Importantly, the newfound popularity of intelligence testing also acted as an incubator for the development of statistical methods and psychometrics (the study of measuring cognitive abilities), which are integral to the theory and practice of neuropsychology.

By the time of WWII, a psychologist named David Wechsler had just created the precursor to his intelligence scales, which are still widely used by neuropsychologists today (Rabin et al. 2016).[12] The war and its aftermath provided no shortage of patients, and many brain-behavior enthusiasts offered their knowledge and skills to help these Veterans. A secondary benefit of this movement was that it advanced our understanding of brain functioning broadly and traumatic brain injuries specifically. One particularly prominent figure in the post-WWII era was Alexander Luria, a Russian neuropsychologist who was integral to the development of assessment practices (Kostyanaya and Rossouw 2013). Among his many accomplishments was the development of various cognitive and sensory tests, as well as contributions to the systematic description of functional neural systems (Luria 1966). His work provided the theoretical basis that led to the development of the Luria-Nebraska Neuropsychological Battery, a popular assessment method in the late twentieth century (Golden et al. 1979). Other prominent pioneers of neuropsychological assessment in the WWII/post-WWII era include Ward Halstead and Ralph Reitan, who collaborated on the Halstead-Reitan battery. This family of tests gained widespread popularity among clinicians and researchers who were looking for a comprehensive, data-driven method for determining the presence of neurocognitive impairment. Importantly, Luria, Halstead, and Reitan were not alone; the drive to continue

[10] If you are interested in learning about other key players, look up the work of Charles Spearman, Raymond Cattell, John Horn, and John Carroll.

[11] There were glimmers of systematic neuropsychological assessment prior to this intelligence testing period; See Benton (2000) for details.

[12] The Wechsler-Bellevue Intelligence Scale came out in 1939. The Wechsler Intelligence Scale for Children (WISC) was published in 1949 and was made up of many of the original measures. The Wechsler Adult Intelligence Scale (WAIS) came out in 1955. As of the time of writing, the WISC is currently in its fifth edition and the WAIS is in its fourth edition.

generating and refining our theories and methods has led to major contributions by countless other men and women.[13]

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Although the principles and underlying science of neuropsychology are centuries old, the field as a coherent discipline is quite young (Grote et al. 2016). For example, the first neuropsychology journal, *Neuropsychologia*, was established in 1963. Our oldest professional society, the International Neuropsychological Society (INS) was founded in 1967. The first two textbooks specific to the field came out in 1976 and 1980.[14] The first formal training programs were established in the 1970s, with specialty board certification developing in 1981 and formal training guidelines being published in 1987 (INS-Division 40 Task Force 1987) and 1998 (i.e., Hannay et al. 1998). Consequently, we believe that the field is both built on a solid foundation of philosophical and scientific inquiry, and is still in its early adolescent phase of development. This makes neuropsychology ripe for the novel ideas and creative thinking that is characteristic of newcomers such as yourself!

Modern-Day Neuropsychology

Purpose of Clinical Evaluations

The practice of neuropsychology today looks very different than it did in the early years. One of the stronger pressures driving the shift in the field was the advent of widely available neuroimaging tools in the 1980s. The ability to noninvasively scan brain tissue with computed tomography (CT), magnetic resonance imaging (MRI), and other techniques reduced the value of neuropsychological testing for the purpose of lesion localization. With this technology, physicians were able to send a patient through a scanner and visualize the size, type, and location of a lesion.

Some neuropsychologists initially feared that neuroimaging would put them out of a job, but we are a resilient bunch! Instead of closing up shop, clinicians and researchers began expanding their roles and areas of expertise. The emphasis of our evaluations shifted from lesion localization to (1) clinical diagnosis, (2) characterizing cognitive strengths and weaknesses, (3) determining appropriate interventions and services, and (4) cognitive training and rehabilitation. Let's talk more about each of these tasks performed by neuropsychologists.

[13] Examples of scientist-clinicians who made outstanding contributions to neuropsychology include Arthur Benton, Elizabeth Warrington, Hans-Lukas Teuber, Brenda Milner, Manfred Meier, and Edith Kaplan.

[14] *Neuropsychological Assessment*, by Lezak et al., was first published in 1976; *Fundamentals of Human Neuropsychology*, by Kolb and Wishaw, was first published in 1980.

1. Most of today's neuropsychologists are expert diagnosticians, meaning that we are trained in identifying and labeling various neurological and psychiatric disorders. For example, an older woman presents to her primary care provider with complaints of forgetfulness and the physician refers her to a neuropsychologist to determine the cause of the problem. It might be that she is showing the first signs of Alzheimer's disease, it may be a different type of neurodegeneration (e.g., Lewy body pathology, frontotemporal lobar degeneration), it could be related to a history of heavy alcohol use, she may have depression, or it might just be normal age-related cognitive decline. By reviewing medical records, completing a thorough clinical interview, and conducting comprehensive cognitive testing, we can often parse out the likely etiology (the underlying cause) of the symptoms. We are able to do this because certain diseases and injuries have signature patterns, or "fingerprints," that stand out in comparison to other conditions. For example, a person with Lewy body dementia typically presents with well-formed visual hallucinations, motor symptoms, sleep disturbances, fluctuating cognitive abilities, and poor visuospatial abilities. This cluster of symptoms and performance on testing is unique relative to the typical Alzheimer's disease presentation (i.e., early-stage impairments in memory for recent events).

2. In addition to determining diagnosis and etiology, a major purpose of neuropsychological testing is to characterize cognitive strengths and weaknesses. Everyone has a unique set of mental aptitudes. For example, some people are adept at visual learning but are below average with regard to verbal abilities; others rapidly process information, but have trouble with reasoning and problem-solving. By administering a variety of tests that tap into different types of skills (see below for a description of cognitive "domains"), we get a picture of our patient's individual profile, from impairments to above-average abilities.

3. It is important to know a person's diagnosis, etiology, and strengths and limitations so that we can (a) link their abilities to real-world functioning, (b) estimate their risk for poor outcomes in response to certain medical procedures,[15] (c) select the most appropriate interventions, (d) set goals, (e) direct services, and (f) help them plan for the future. For example, a parent brings their young son to you (a neuropsychologist) because they suspect that he has dyslexia – a type of learning disability in reading. Based on your evaluation, you confirm that he has a reading disability and you also diagnose him with attention-deficit/hyperactivity disorder (ADHD). You carefully construct a list of personalized recommendations based on these disorders and the child's unique situation. Your recommendations include (a) behavior modification for hyperactivity, (b) a referral to a psychiatrist to assess the appropriateness of a stimulant medication, (c) a request for an individualized education program (IEP) to track the boy's educational progress and recommend special accommodations (e.g., 50% extra

[15] For example, surgery to resect seizure-producing tissue in someone with epilepsy or deep brain stimulation (DBS) surgery for a patient with Parkinson's disease.

time on tests), and (d) a referral to a tutor who is experienced in educating children with reading disabilities. Based on the severity of the impairment and the cognitive profile, you help the parent understand how the boy is likely to progress through the next few years of school and which services might be needed down the line (e.g., help with social skills and/or employment accommodations).

4. A more recent application of our services – one that is progressing rapidly – is providing cognitive training in order to restore or (more commonly) compensate for cognitive deficits. With regard to the latter, we can use the person's cognitive strengths to help them work around their limitations. For example, there are different types of memory and most people with typical memory disorders have trouble with explicit or declarative memory, where they cannot learn and retain facts and knowledge in their daily lives. Cognitive training for such a person will likely involve capitalizing on intact "implicit" or "procedural" memory.[16] Our patient with an explicit memory disorder may be forgetting novel information such as her plan to call her sister. To take advantage of her implicit memory, we might suggest that she write herself a note the day before she wants to call her sister and stick it to the coffee maker. She knows that she will be making her coffee the next morning (it's an ingrained habit), so even if she forgets to call her sister, she will be reminded of it when she encounters the note. This technique is called "linking" because it involves identifying a behavior that we know will take place (making coffee) and creating a link (the note) between that behavior and the desired behavior (the phone call). This is just one of many examples of cognitive training techniques that have been shown time and time again to improve people's everyday functioning and quality of life (e.g., Greenaway et al. 2013; Huckans et al. 2013; Twamley et al. 2012, 2014).

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In addition to clinical diagnosis, characterizing strengths and weaknesses, recommending interventions, planning for the future, and conducting cognitive training, neuropsychologists still occasionally perform "lesion localization" evaluations, albeit in a limited set of contexts. For example, presurgical evaluations of epilepsy patients often involve attempting to identify which brain hemisphere (right or left) is more dominant for language and verbal memory so that the surgeon will have an idea about whether removing parts of the brain will leave the patient aphasic (without language) and/or amnestic (without memory; consider the case of H.M., above). Although neuroimaging techniques such as CT and MRI are useful in these circumstances, neuropsychological testing provides unique clinical information that cannot be collected via brain scanning.

[16] Implicit memory involves learning habits such as riding a bike, playing golf, or tying your shoes.

Neuroimaging and Neuropsychology

As two classes of tools, neuroimaging and cognitive testing are far from mutually exclusive; in fact, they are complementary. To use an automotive analogy, imagine that you are buying a new car. Structural neuroimaging is similar to examining the car's engine to ensure that everything is intact and in the right place, while cognitive testing is comparable to taking it out for a test drive to ensure that it is working properly. Both of these steps are critical, as you want to know what is under the hood and what happens when you put your foot on the brake pedal.

> One of the origins of neuropsychology was in localizing brain injury. Today, we have neuroimaging techniques that are far better at doing that. But what no imaging technique can do is tell you about what's most important about the brain and that is its output. Output has to do with cognition and behaviors and emotions, and this is where neuropsychology and psychology should be focused.
>
> – Igor Grant, MD

The story behind neuroimaging and cognitive testing goes deeper. It turns out that the search for structure-function relationships (i.e., the localization theory) that was all the rage back in the nineteenth and twentieth centuries is incomplete and has been challenged in recent years.[17] Many studies have shown that cognitive abilities are much more distributed than we had originally thought (Bressler and Menon 2010). In other words, cognitive functions arise from activity in *neural networks,* which span large swaths of interconnected brain tissue, rather than arising from a single discrete region. Consequently, because no part of the brain works in isolation, we should not make statements such as, "memory is in the hippocampus" or "emotion is in the amygdala." Instead, we can make statements such as, "memory is subserved in part by hippocampal circuits" and "emotion regulation is partially mediated by prefrontal-subcortical networks." This may sound overly pedantic and esoteric, but the subtle difference in the above wording is incredibly important, as the network-based phrasing is far more accurate than the localization-based terminology with respect to the organization and function of the brain (see Kolb and Whishaw 2015, for more detail).

Neuropsychology Training

You may be wondering where the "psychology" part of "neuropsychology" comes in, especially because the field has many similarities to neuroscience (the scientific study of the brain and nervous system) and neurology (described below). The distinction between psychology, neuropsychology, and neuroscience/neurology mostly has to do with the knowledge we have, patients we see, and the tools we use. We will briefly cover the first of the three (knowledge) here and the second

[17] There were some scientists that challenged it in the past (see Finger 1994), but the push-back did not gain significant traction until recently.

Fig. 1.4 Neuropsychology's location in a simple, non-exhaustive taxonomy of psychological disciplines

(patients) in the following subsection. You can learn all about the tools (i.e., specific tests) by reading the excellent texts by Lezak et al. (2012), and Sherman, Tan, & Hrabok, 2020.

Neuropsychologists are trained as psychologists. This means that we attend graduate school and obtain a doctorate in psychology (either PhD or PsyD; see Ch. 5).[18] We study human development and behavior across different areas of psychology (e.g., social, personality, behavioral, cognitive, clinical). We receive training in psychological therapy ("psychotherapy") and other interventions.[19,20] However, our specialized cognitive assessment skills and in-depth knowledge of brain-behavior relationships are what make us a truly unique discipline relative to the dozens of subspecialties in psychology (see Fig. 1.4).[21]

Similar to many fields within psychology and medicine, neuropsychology has both research and clinical arms. The purpose of the research portion is to generate new knowledge and test interventions through scientific investigation, while *clinical* neuropsychology applies that knowledge to working directly with patients (i.e., "bench to bedside"). Moreover, science and practice support and reinforce each other, where research provides the knowledge base upon which clinical decisions are made, and applied work leads to better research questions (see Fig. 1.5). Many

[18] Note that this is how it is done in North America. Also, there are some exceptions that we will discuss in Part II.

[19] In fact, clinical neuropsychologists use psychotherapy skills throughout their careers. Some maintain a psychotherapy practice in addition to assessment; however, even if they do not see patients for therapy, those skills still come in handy during neuropsychological evaluations.

[20] Master's-level practitioners can also engage in therapy, with appropriate credentials and license; however, they are not considered "psychologists," which is a protected term in most states/provinces.

[21] The American Psychological Association currently recognizes 54 distinct disciplines under the umbrella of psychology.

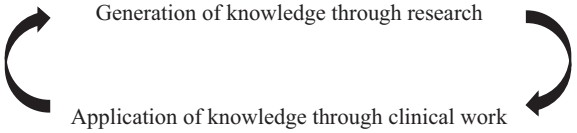

Fig. 1.5 The bidirectional relationship between science and clinical practice

neuropsychologists engage in both research and clinical work, although some focus their entire careers on one or the other.

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Although the field of neuropsychology has expanded rapidly since its inception, there are still fewer neuropsychologists than is typical in many other professions, so it is considered a niche specialty. Specifically, the best current estimate of the number of neuropsychologists in the US is at least 5765 (C. Morrison, PhD, ABPP-CN, March 2, 2020 personal communication). Of these, 1159 are board-certified through the American Board of Professional Psychology (Armstrong et al. 2019), with approximately 60–80 additional professionals becoming board certified each year (K. Fuchs, PhD, ABPP-CN, August 2, 2020, personal communication).

Clinical Populations Served

Because neuropsychologists specialize in assessing cognitive abilities, any disease, injury, developmental abnormality, or other factor that could affect cognition falls under our purview. One important distinction is that most neuropsychologists consider themselves to be either pediatric (child) neuropsychologists or adult/geriatric neuropsychologists. Similar to physicians, we draw an imaginary line in the sand between age 17 and 18 and most of us spend our time working with one group or the other.[22] There are some lifespan neuropsychologists out there – people who work with both children and adults – but these practitioners are in the minority.

Examples of common childhood disorders/problems that bring youngsters into a neuropsychologist's office include neurodevelopmental disorders such as ADHD, learning disabilities, intellectual disability, autism spectrum disorder, traumatic brain injury, toxic exposure (e.g., fetal alcohol spectrum disorder), cancer, chromosomal and genetic syndromes (e.g., neurofibromatosis, Fragile X, Klinefelter), cerebral palsy, and seizure disorders. Young to middle-aged adults are most often evaluated because of neurodevelopmental disorders, traumatic brain injuries, multiple sclerosis, cancer, infections (e.g., meningitis), substance use disorders, and psychiatric issues (e.g., mood, psychotic, and/or trauma-related symptoms). Older adults often find themselves in a neuropsychologist's office due to concerns about neurodegenerative conditions (e.g., Alzheimer's disease, Lewy body pathology,

[22] Some pediatric neuropsychologists see patients into their early 20s.

frontotemporal lobar degeneration), stroke/cerebrovascular disease, traumatic brain injuries, epilepsy, psychiatric symptoms, delirium (drastic fluctuations in awareness and attention), and hydrocephalus (a buildup of cerebrospinal fluid in the brain). Frequently, patients come in for an evaluation without a clear understanding of the underlying cause of their difficulties and part of our job is to help rule in or out certain problems.

Cognitive Domains Measured

Neuropsychologists are experts at assessing behavior. We use observation, interview questions, inventories, rating scales (e.g., self, parent, teacher), and cognitive tests to measure behavior, both subjectively and objectively. The subjective pieces (e.g., asking the person about changes in cognition or mood) are very useful.[23] However, what really sets us apart is our ability to *objectively* assess cognitive functioning. An individual's subjective sense of their abilities does not always line up with how they actually perform on testing (Jessen et al. 2014, 2020), which is why it is necessary to assess cognition at both levels. In other words, how do you know if your patient, who complains of forgetfulness, actually has a problem with memory? You test their memory! As such, much of what we collect are quantitative data, although qualitative information (e.g., flat affect, tangential speech, unusual behavior) is also highly valued.

Below, we cover the specific areas, or cognitive domains, that modern neuropsychologists typically evaluate (see Table 1.1).[24] This is Neuropsychology 101, so we recommend reading this section closely. As you peruse each description, it is important to note that cognitive abilities are interrelated, and tests often tap into multiple domains (this is called "task impurity"). For example, in order to complete Part B of the Trail Making Test, a popular measure where the patient rapidly draws connecting lines between numbers and letters, they must demonstrate focused attention, visual scanning, motor sequencing, and rapid information processing, among other skills. A breakdown in any one of these abilities will lead to poor performance.

Six Core Cognitive Abilities

Attention We are constantly bombarded with a wealth of information from our senses, but our brains cannot process everything that we encounter at any given point in time. As conceptualized by neuropsychologists, attention is a cognitive

[23] For more information about qualitative aspects of neuropsychology, see the book, The Boston Process Approach to Neuropsychological Assessment, by Ashendorf and colleagues (2013).

[24] This is not meant to be an exhaustive list. The purpose is to give you a general framework about the primary domains assessed in neuropsychology. For a much more comprehensive review of the thousands of cognitive tests, read Sherman et al., 2020, Lezak et al. (2012), and Carlson and Geisinger (2017).

Table 1.1 A simple taxonomy of neuropsychological domains

Core	Supplemental
Attention	Performance validity
Processing speed	Academic achievement
Language	Sensorimotor
Visuospatial/visuoconstruction	Psychological functioning
Learning/memory	Intelligence
Executive functioning	

"spotlight" or "gatekeeper" that determines which information is processed and which information is ignored (for a fun demonstration of this phenomenon, Google *The Monkey Business Illusion*). With this in mind, attention is often broken down into several subcategories. The first is sustained attention – the ability to focus on a single stream of information for at least a moderate amount of time. When it goes awry, a person will be distractible any time a conversation, lecture, book, or other stimulus requires them to concentrate for more than a few minutes at a time. The second category is selective attention – the ability to *intentionally* block out irrelevant information and process relevant material. People with poor selective attention are pulled toward salient aspects of objects in their environment (e.g., a flashing billboard on the side of the highway) at the expense of more relevant stimuli (e.g., the cars around them traveling at 65+ MPH). Finally, there is divided attention – the ability to rapidly and efficiently shift attention between two different stimuli. Divided attention is frequently mislabeled as "multitasking." In reality, human beings are not capable of multitasking – that is, our brains cannot concurrently process two separate and complex streams of information. Instead, we rapidly switch back and forth from one stream to the other (Shallice et al. 2008). Highway driving is the perfect example; we do not simultaneously attend to the task of operating our vehicle *and* talking on the phone or sending text messages – we switch back and forth from one task to the other. That means that while we are attending to our phone, we are not attending to the cars around us, and we do so at our own (and others') peril.

Processing Speed Now that we have established what it means to attend to stimuli, we will consider the rate at which we do so. People vary greatly in their information processing speed – the rapidity with which they analyze and respond to environmental stimuli to which they have attended. Processing speed is tightly correlated with age such that the older we are (after our mid-twenties or so), the slower we process information (Eckert 2011). This is a big part of the reason why elite Formula One drivers and National Football League quarterbacks tend to be in their 20s and 30s.

Language We all have a sense as to what language is – on a basic level, it is a system of communicating with other members of the same species. However, when neuropsychologists consider language, we organize it into components that are tied to brain networks – receptive language (the ability to understand), expressive language

(the ability to communicate our thoughts to others), and "naming" (word retrieval and expression) are a few of the most commonly assessed skills. Although attention is the most basic cognitive ability (everything else depends on it), language is not far behind. It is very difficult to accurately assess other areas of cognitive functioning such as mood, memory, and problem solving when the person across from you cannot comprehend you and/or express themselves to you.

Visuospatial/Visuoconstructional Abilities These skills are a bit less intuitive than the last three. What we are describing here are cognitive abilities that allow us to understand spatial relationships. Because we do not localize sounds well and our senses of smell and touch are relatively rudimentary (compared to other animals), our spatial skills are primarily visual (hence, "*visuo*spatial"). So, what exactly do we mean by spatial relationships? Think about tasks performed by engineers or architects: envisioning the position of an object in three-dimensional space, rotating it, creating a mental map of its interior, and then manipulating that map. These are the core aspects of visuospatial skills. Then, when we say "visuoconstructional skills," we mean visuospatial + a motor task (e.g., building a Millennium Falcon™ out of LEGOs®). When these skills go awry in a typical person, we observe that they have trouble navigating their environment. They are at risk of becoming lost and confused when driving to the store, when walking around their neighborhood, or even when ambulating around their home. Interestingly, in the world of modern technology, visuospatial skills are far less essential than they were throughout human history. We have GPS built into our cars and cell phones, so we do not always need to use our own mental maps to navigate the world as our predecessors, the hunter-gatherers, did. If you are visuospatially challenged as I (Ryan) am, you will be very thankful for this fact.[25]

Learning/Memory After we attend to information, our brains process and *encode* it into short-term memory storage. From there, it is *consolidated,* or transformed, from short-term to long-term memory. Later (days, weeks, months, years), it is *retrieved* when our brains activate the particular circuit that corresponds to that memory. For example, at some point in your early education, you probably learned many facts that you may or may not be using in your daily life (e.g., $12 \times 7 = 84$; the second President of the United States was John Adams). Each time you learned one of these tidbits, the structure of your brain was being slightly altered – neurons were expanding and branching out ("dendritic arborization") and releasing neurotransmitters at synapses, thereby forming new connections with other neurons and allowing your brain to accommodate the new information. Now, if I were to ask you, "How many quarts are in one gallon?" and you were to answer, "four," this happened because executive control processes in your brain searched your memory store, rapidly located the corresponding memory circuit, and pulled it into your

[25] If you are interested in learning more about visuospatial skills, check out the book, *Mind in Motion* by Barbara Tversky.

conscious awareness. Of course, this complex set of memory processes can go awry at each and every stage. You may not encode information that you attended to, you may initially encode it but fail to consolidate it, and you may have it fully stored in long-term memory but be unable to retrieve it in a particular circumstance. Neuropsychologists test and parse out memory failures at each of these stages because memory is integral for everyday functioning and because different disease processes/injuries impact memory in unique ways.

Executive Functioning We started with the most basic and foundational cognitive construct (attention) and we have been working our way up the hierarchy of complexity. We have now reached the zenith – the highest level of thinking – which we call "executive functioning." This is a heterogeneous *family* of abilities. We often explain it to patients as "the CEO of your mind" – it is the boss who solves problems, makes decisions, shifts attention between multiple projects, shows restraint where necessary, and displays mental flexibility and dexterity in making sense of the world. Executive functions rely on the functioning of all of the lower-level systems discussed earlier. They are also very susceptible to becoming impaired when someone sustains a brain injury, leading to fascinating (and tragic) cases of "dysexecutive" behavior such as frank disinhibition, where a person loses all sense of self-awareness (their "filter") and becomes prone to cursing, making sexually inappropriate advances, urinating in public, etc.

Supplemental Domains

Performance Validity This is not a "cognitive domain," per se, but it is an essential consideration in each and every neuropsychological evaluation. What we mean by "performance validity" is the extent to which a patient's cognitive scores represent their true abilities. This is imperative because we cannot make accurate judgments about a person's cognitive strengths and weaknesses if their low scores (interpreted as weaknesses) result from something other than true deficits. There are myriad reasons why this may be the case: a person may be severely underslept, they may be acutely confused, they may be highly medicated, they may be in acute pain and/or highly distressed, or they may be intentionally performing poorly in order to appear impaired and receive some type of secondary gain (e.g., workers' compensation benefits). Because of the importance of this issue, neuropsychologists have a plethora of techniques to detect performance *invalidity*, including behavioral observations and specialized tests.

Academic Achievement Here we are referring to scholastic performance, especially with regard to core abilities such as reading, writing, and math. We think of these skills as cognitive "aftermarket add-ons," (think of a standard Volkswagen Jetta with tinted windows and a turbocharged engine) because our brains did not evolve the abilities to perform algebra or write out sentences onto paper. Instead,

these skills have become important to our functioning due to cultural and industrial advances. In the world of neuropsychological evaluations, academic achievement is particularly important in the assessment of learning disorders. Some children have great difficulty developing and fine-tuning the building blocks necessary for successful performance in school (e.g., phonological awareness, orthographic processing), likely because their brains are less adept at adding the tinted windows and turbocharged engine of reading and writing. Fortunately, there are tests that can detect early problems in academic achievement and, once a child's particular set of strengths and weaknesses is identified, the neuropsychologist can then recommend personalized interventions to bring the child closer to grade level in a particular skill. This is incredibly important because the slow development of basic academic skills can constrain a person throughout the rest of their educational and occupational lives.[26]

Sensorimotor Like everything we do, think, and experience, sensorimotor skills are controlled by the brain. However, they are typically conceptualized as distinct from cognitive abilities and are generally the wheelhouse of other experts such as ophthalmologists, audiologists, physical therapists, kinesiologists, and neurologists. Still, because sensory impairments can masquerade as cognitive deficits (e.g., hearing loss can be mistaken for memory loss) and because motor impairments are present in a number of diseases that impact the brain and cognition (e.g., Parkinson's disease, Tourette's disorder), it is often important for neuropsychologists to briefly assess basic sensation and movement. We do this by asking patients to complete tests of basic visual acuity (e.g., "read the letters on this page from top to bottom"), olfaction (e.g., "what does this scratch and sniff smell like?"), rapid movements (e.g., "tap your index finger as quickly as you can for 10 seconds"), fine-motor control (e.g., "rotate and place each of these pegs into the small holes as quickly as you can"), and strength (e.g., "squeeze this device as hard as you can"). With regard to sensation, deficits such as hearing loss and visual field deficits can be identified and accommodated for in the neuropsychological evaluation so that cognition, rather than vision or hearing, is measured. Neuropsychologists might also provide recommendations for patients to receive specialist assessments for vision or hearing loss if it appears that they have untreated problems in these areas. In terms of motoric abilities, bilateral or asymmetric weaknesses can provide information about possible brain pathology and can help us determine what someone can and cannot do (e.g., go back to work, drive a car), as well as what types of recommendations might assist them in their daily lives.

Psychological Functioning Most people think of social/emotional functioning as completely distinct from cognitive functioning. The former refers to someone's self-confidence, their mood, their propensity to seek out other people, their compassion,

[26] If you want to learn more about learning disorders, we recommend the book, *Diagnosing learning disorders: From science to practice, 3rd ed.,* (2019) by Pennington, McGrath, & Peterson. Also, see www.NavNeuro.com/61.

their level of shyness, etc., while the latter refers to their thinking skills. In reality, emotions and cognition are very closely connected in the brain. When someone is depressed, for example, their attention and memory systems function differently and less effectively. Another common psychological state with a major impact on cognition is anxiety. Think back to a time when you experienced performance anxiety – maybe it was immediately before you delivered a presentation in front of your classmates or before you performed in a play or musical. In the grips of crippling anxiety, were you at your very best? Do people dance, sing, take tests, play sports, or give speeches at the highest level when they are paralyzed by anxiety? Of course not. Consequently, when neuropsychologists are evaluating cognition, we also measure psychological functioning. It is not uncommon for someone to think that their memory is being stolen away by an untreatable degenerative condition such as Alzheimer's disease when, in reality, their attention and memory have been constrained by depression. The latter is treatable, and with the alleviation of psychological symptoms, cognitive skills can improve greatly. Therefore, neuropsychologists play an important role in the identification and treatment of psychological distress in people with subjective cognitive decline.

Intelligence There is a long, rich history of research on intellectual abilities in humans. However, we will not go into detail on this topic here for several reasons. First, "intellectual abilities" overlap greatly with "cognitive abilities," and everything that can be objectively measured and labeled as "intelligence" can also be called "cognition." As you may have noticed, we prefer "cognition" because we believe that it is less biased and more useful. Second, and relatedly, the term "intelligence" is often misused and misunderstood. Most people think of it as a synonym for "smart" and use it very loosely; we think that this usage is unhelpful. When we formally measure intelligence, we are only capturing a narrow range of abilities (sometimes called Mental Abilities as Measured by Intelligence Tests, or MAMBIT; Stanovich 2009) and we are missing important real-world skills such as emotional intelligence, musical intelligence, existential intelligence, and bodily-kinesthetic intelligence (Gardner 1983, 1993). Third, "intelligence" has sometimes been used to demean, judge, and ostracize whole groups of people in tragic ways (e.g., the eugenics movement), while "cognition" has not been guilty of such travesties. With all of this said, the past 100+ years of research on intelligence have produced helpful insights into human thinking and we think that this research evidence has utility (Flanagan and Harrison 2018). We simply prefer to include this research under the umbrella of cognitive abilities rather than that of intellectual abilities.

How Is Neuropsychology Different from Related Fields?

Contemporary neuropsychology can easily be confused with related clinical fields such as neurology and psychiatry. There are many similarities between neuropsychology and these other professions, and we generally work with the same patients

in a collaborative fashion in order to arrive at a diagnosis and manage or treat the problem. Furthermore, we all have similar roots, splitting off from the parent fields (namely, neuroscience and philosophy) at different junctures. As noted above, one helpful framework is to think of the distinction as being due to different areas of knowledge, patient groups, and clinical tools. We will describe some of the main similarities and differences between neuropsychology and related fields here (also, see Table 1.2).

Neurology

Neurologists are medical doctors who have extensive training in biology and physiology, with a particular focus on the central nervous system – the brain and spinal cord. They treat many of the same patients as neuropsychologists – patients with

Table 1.2 Comparing and contrasting allied health professions to neuropsychology

Discipline	Similarities	Differences
Neurology	Serves patients with neurological conditions	Attended medical school rather than graduate school
		Prescribes medications and medical procedures
		Conducts neurological examinations
		Less training in mental illness, cognitive and psychological assessment, statistics, and research methods
Psychiatry	Serves patients with psychiatric conditions	Attended medical school rather than graduate school
		Prescribes medications and medical procedures
		Less training in cognitive and psychological assessment, statistics, and research methods
Occupational therapy	Serves patients with cognitive and emotional symptoms	Assesses and treats functional (rather than neuropsychiatric[a]) issues
		Primarily master's-level training
Speech-language pathology	Serves patients with language disorders	Primarily focused on language abilities
		Conducts extensive interventions for speech and communication
		Primarily master's-level training
Psychometry	Serves patients with neuropsychiatric conditions	Does not interpret tests, make diagnoses, or provide feedback to patients
	Administers and scores neuropsychological tests	Works under a psychologist's license
		Primarily bachelor's or master's-level training

[a]The term "neuropsychiatric" helps resolve the false neurology-psychiatry dichotomy by creating a larger umbrella within which traditional "neurological" (e.g., brain tumor) and traditional "psychiatric" (e.g., anxiety) disorders exist

brain diseases such as Alzheimer's disease, stroke, multiple sclerosis, movement disorders, and epilepsy – but they use different tools. They focus on neuroimaging such as CT scans and MRIs, as well as electroencephalography (EEG), blood tests, and lumbar punctures (spinal taps). They also test reflexes and cranial nerve functioning and they write prescriptions for medications. By contrast, neuropsychologists are psychologists by training, not physicians. That means that we attend graduate school rather than medical school and we specialize in human thinking, emotion, and behavior. With few exceptions, we do not prescribe medications and we do not typically order or directly interpret brain scans and other medical procedures. Instead, we develop extensive knowledge and skills in mental illnesses (psychopathology) as well as in the assessment of cognition and personality traits, and we receive training in psychotherapy and cognitive interventions. Finally, in contrast to medical school, we receive training in statistics and research methods during graduate school, and this greatly enhances our abilities as researchers. In a nutshell, compared to neurologists, neuropsychologists assess and treat problems with personality, mood, and cognitive skills, whereas neurologists handle physical examinations, neuroimaging, and medications.

> As a neurologist, I routinely benefit from the ability to access the knowledge and skills of our neuropsychology team. A particularly memorable patient had recovered from a traumatic brain injury but was struggling to reintegrate to his work environment. His consultation with a neuropsychologist revealed difficulty with processing parallel input streams and led to concrete behavioral adaptations that radically improved his performance. I was so happy that they were there for him and for me!
>
> – Sean Evans, MD

> Early diagnosis of neurodegenerative diseases represents a complex clinical puzzle for cognitive neurologists to solve. Trying to solve these clinical puzzles requires exceptional tools. An adept neuropsychologist, with in-depth testing and insightful interpretation, can be a key piece to helping us understand which large scale brain network is likely involved. This knowledge helps improve early diagnosis and understand how these diseases evolve.
>
> – Ryan Townley, MD

Psychiatry

Similar to neurologists, psychiatrists are also medical doctors, but they specialize in treating psychopathology rather than traditional brain-related problems. This is actually a false dichotomy because mental illnesses occur in the brain just as a tumor or a stroke occurs in the brain; however, this is how medicine has been conceptualized for years and this terminology is still in use today.[27]

Psychiatrists are experts in the use of psychotropic medications such as antidepressants, antipsychotics, mood stabilizers, and anti-anxiety medications; these are

[27] In fact, neurology and psychiatry are combined into one board in the US, The American Board of Psychiatry and Neurology. Also, the American Neuropsychiatric Association reflects influence from both of these fields: https://www.anpaonline.org/

all used specifically to treat the symptoms of mental illnesses. Psychiatrists understand important aspects of these medications such as correct dosage, potential side effects, and complex interactions between different agents. They spend a significant amount of time identifying the optimal medication regimen for each individual patient, and this is a complicated task because everyone's biology is unique. Psychiatrists also occasionally perform psychotherapy and other interventions, but their bread and butter is a brief medication consultation with their patients. So, while psychiatrists and neuropsychologists often work with the same patients – people with depression, anxiety, bipolar disorder, schizophrenia, and other mental illnesses – the psychiatrist's primary tools are medications, while the neuropsychologist's primary tools are cognitive tests.

Occupational Therapy

Contrary to what is suggested by their title, occupational therapists (OTs) are not strictly focused on helping people go back to work. They do address vocational issues, but they do it within the broader context of assessing and improving a patient's functional abilities – i.e., how well the patient performs the tasks that are needed to take care of themselves and fulfill their daily obligations. As an example, an OT might assess whether or not a patient can prepare a meal, write a check, drive their car, or manage their medications; next, the OT generates a plan to strengthen these abilities if necessary. This is incredibly important because a patient's functional problems can be a safety hazard, potentially leading to a car accident, malnutrition, a fall, or a house fire. Improving activities of daily living also helps people remain independent and in their homes for longer and enhances their overall quality of life.

Neuropsychologists and OTs often work together in caring for a patient. The neuropsychologist measures the patient's cognitive abilities, while the OT measures and works to improve the patient's functional skills. For many people with neurological illnesses, the changes in their brain typically first impact their thinking skills and later cause a decline in their ability to carry out everyday activities.

Speech-Language Pathology

Speech-language pathologists (SLPs) work with patients who have deficits in language and communication, one of the cognitive domains described above. For example, if a stroke causes significant language impairment (aphasia), an SLP can assess the extent and type of impairment and then treat the problem. They also commonly work with children with neurodevelopmental disorders and with individuals with difficulty swallowing. Neuropsychologists and SLPs often work together in rehabilitation hospitals; in these settings, the neuropsychologist typically assesses

the nature and extent of the language problem, as well as the impact on other areas of cognitive functioning. The SLP then uses the findings from the neuropsychological evaluation to create a personalized treatment regimen where they help the patient improve the language deficits.

Psychometry

Psychometrists are trained in administering and scoring various cognitive and psychological tests. Many neuropsychologists work with a psychometrist – the neuropsychologist performs the medical records review and gathers background information from the patient, and then the psychometrist administers and scores the tests. Later, the neuropsychologist writes the report, consults with allied health professionals as necessary, and provides the patient with feedback about the results. Because they are not involved in diagnosis or interpretation, psychometrists typically have a bachelor's or master's degree (as opposed to a doctorate), and they can pursue certification in psychometry as well.[28] Psychometrists are very skilled in terms of developing rapport with patients, observing and recording behavior, handling difficult clinical situations (e.g., when a patient has visual impairments, narcolepsy, or psychotic symptoms), and administering and scoring dozens of complex neuropsychological tests. Neuropsychologists have great respect and appreciation for their psychometrist colleagues, and psychometrists help improve the efficiency of neuropsychologists. If you want to learn more, visit the National Association of Psychometrists' website, https://www.napnet.org/.

Conclusion

We have come a long way in understanding the causes of behavior, as well as how to identify and manage maladaptive neurocognitive abnormalities. It took thousands of years before the brain was widely recognized as the seat of thoughts, emotions, and actions, and several hundred more years before specific brain networks were linked to specific behavioral outputs in a systematic and objective manner. A major goal for this chapter has been to describe how the discipline of neuropsychology emerged from this cacophony of intellectual discoveries and insights.

And yet there is much still to be learned. For example, we have only recently begun to realize that the localization model is only partially true – that is, that the connections among brain regions and parallel processes are at least as important as the specialized regions of interest (e.g., your vision would be impaired if the connections

[28] Requirements vary by state.

to and from your occipital lobe were disrupted).[29] Over time, new advancements in neuromonitoring will allow us greater temporal and spatial resolution as we examine the structure and function of the human brain. We will better understand the genetic underpinnings of diseases and developmental issues. Precision medicine will help us tailor interventions to each individual. Technological advances will allow clinicians to share data, to optimize the efficiency of the modern neuropsychological evaluation, and to study patients outside of the clinic – for example, by receiving data from wearables or other "smart" devices. Indeed, some neuropsychologists believe that we are in the midst of a revolution in the field, something that Dr. Robert Bilder terms "Neuropsychology 3.0" (Bilder 2011).[30,31]

Given the relative youth of the field and the rapidity of technological and scientific progress, the answer to the question "What is neuropsychology?" will likely be a bit different by the time you become a neuropsychologist. We currently stand on the shoulders of giants, but many more such titans of science and clinical practice are needed to accomplish the tasks that will lead neuropsychology into the future. We're counting on you!

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[29] The full web of connections between all brain cells is called the "connectome." The Human Connectome Project launched in 2009 as a large-scale attempt to comprehensively map all of the brain's connections. As of the time of writing this book, the project is still on-going. We recommend Sebastian Seung's book, *Connectome: How the brain's wiring makes us who we are* (2012) on this topic.

[30] See Bilder and Reise (2019) for a more in-depth discussion of technology that could revolutionize the field of neuropsychology. See NavNeuro episodes 33, 35, and 37 for discussions with Dr. Bilder.

[31] If you are looking for a book on innovation in our field, check out, *The role of technology in clinical neuropsychology* (2019) by Kane & Parsons.

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