

# NEUROSCIENCE

## 7. NEUROPSYCHOLOGY

### 7.1. Background Information

Neuropsychology studies the structure and function of the brain as they relate to specific psychological processes and behaviors. It is seen as a clinical and experimental field of psychology that aims to study, assess, understand and treat behaviors directly related to brain functioning. The term neuropsychology has been applied to lesion studies in humans and animals. It has also been applied to efforts to record electrical activity from individual cells in higher primates. It is scientific in its approach, making use of neuroscience, and shares an information processing view of the mind with cognitive psychology and cognitive science. In practice neuropsychologists tend to work in research settings (universities, laboratories or research institutions), clinical settings (involved in assessing or treating patients with neuropsychological problems), forensic settings or industry (often as consultants where neuropsychological knowledge is applied to product design or in the management of pharmaceutical clinical trials research for drugs that might have a potential impact on CNS functioning).

Neuropsychology is a relatively new discipline within the field of psychology. However, the history of its discovery can be traced all the way back to the Third Dynasty in ancient Egypt, perhaps even earlier. There is much debate in regards to when people started seriously looking at the functions of different organs, but it has been determined that for many centuries, the brain was looked upon as a useless organ and was generally discarded during burial processes and autopsies. As the field of medicine developed in understanding human anatomy and physiology, people often developed different theories as to why the human body functioned the way it did. Many times, functions of the body were observed from a religious point of view and any abnormalities were blamed on bad spirits and the gods. The brain has not always been looked upon as the center for the functioning body as we know it to be now. Rather, the brain has been the center of much discussion for many centuries. It has taken hundreds of years to develop our understanding of the brain and how it directly affects our behaviors, and hundreds of great minds committed to discovering the way our bodies work and function both normally and abnormally.

## **7.2. Contributors to the Field of Neuropsychology**

### **Imhotep**

The study of the brain can be linked all the way back to around 3500 B.C. Imhotep, a highly regarded priest and one of the first physicians recorded in history, can be seen as one of the major pioneers in the history of understanding the brain.

Imhotep took a more scientific, rather than magical, approach to medicine and disease. His writings contain intricate information on different forms of trauma, abnormalities, and remedies of the time to serve as reference to future physicians, as well as a very detailed account of the brain and the rest of the body. Despite this detailed information, Egyptians did not see the brain as the seat of the locus of control, nor as a glorious or noteworthy organ within the body at all. Egyptians preferred to look at the heart as the seat of the soul.

### **Hippocrates**

The Greeks however, looked upon the brain as the seat of the soul. Hippocrates drew a connection between the brain and behaviors of the body saying that the brain exercises the greatest power in the man. Apart from moving the focus from the heart as the seat of the soul to the brain, Hippocrates did not go into much detail about its actual functioning. However, by switching the attention of the medical community to the brain, the doors were opened to a more scientific discovery of the organ responsible for our behaviors. For years to come, scientists were inspired to explore the functions of the body and to find concrete explanations for both normal and abnormal behaviors. Scientific discovery led them to believe that there were natural and organically occurring reasons to explain various functions of the body, and it could all be traced back to the brain. Over the years, science would continue to expand and the mysteries of the world would begin to make sense, or at least be looked at in a different way. Hippocrates introduced man to the concept of the mind which was widely seen as a separate function apart from the actual brain organ.

### **René Descartes**

Philosopher René Descartes expanded upon this idea and is most widely known by his work on the mind-body problem. Often, Descartes ideas were looked upon as overly philosophical and lacking in sufficient scientific background. Descartes focused much of his anatomical experimentation on the brain, paying specific attention to the pineal gland which he argued was the actual seat of the soul. Still deeply rooted in a spiritual outlook towards the scientific world, the body was said

to be mortal, and the soul immortal. The pineal gland was then thought to be the very place at which the mind would interact with the mortal and machine like body. At the time, Descartes was convinced the mind had control over the behaviors of the body, controlling the man, but also that the body could have influence over the mind, which is referred to as dualism. This idea that the mind essentially had control over the body, but man's body could resist or even influence other behaviors was a major turning point in the way many physiologists would look at the brain. The mind-body problem, spurred by René Descartes, continues to this day with many philosophical arguments both for and against his ideas.

### **Thomas Willis**

It was during the mid-17th century that another major contributor to both the field of psychology and neurology emerged. Thomas Willis studied at Oxford University and took a more physiological approach to the brain and behavior. It was Willis who coined the words hemisphere and lobe when referring to the brain. He also is known to be one of the earliest to use the words neurology as well as psychology. Without him, these disciplines would not be as they are to this day. With a more physiological approach to the brain and a rejection to the idea that humans were the only beings capable of rational thought, which was central the Descartes theory, Willis looked at specialized structures of the brain. He hypothesized and experimented within the theory that higher structures within the brain accounted for the more complex functions of the body whereas the lower structures of the brain were responsible for functions similar to animals, consisting mostly of reactions and automatic responses. Throughout his career, he tested this hypothesis out on both animals and human brains. Most of Willis' attention seemed to be focused on localized area of the brain that were designed specifically to carry out certain functions, both voluntary and involuntary. He was particularly interested in looking at both the behaviors as well as the brains of people who suffered from manic disorders and hysteria. This is one of the first times that psychiatry and neurology came together to study the individual.

### **Franz Joseph Gall**

With new theories developing on localization of functioning, neuroanatomist and physiologist Franz Joseph Gall made some major progress in the way both neurology and psychology understood the brain. Gall concentrated his career on developing his theories that personality was directly related to features and structures within the brain. However, Gall's major contribution within the field of

neuroscience is his invention of phrenology. This new discipline looked at the brain as an organ of the mind, where the shape of the skull could ultimately determine one's intelligence and personality. This theory was not unlike many circulating at the time, as many scientists were taking into account physical features of the face and body as well as head size and structure to explain personality as well as levels of intelligence, only Gall looked primarily at the brain. There was much debate over the validity of Gall's claims however, because he was often found to be very wrong in his observations.

### **Jean-Baptiste Bouillaud**

Towards the late 19th century, the belief that the size of one's skull could determine their level of intelligence was discarded as science and medicine moved forward. A physician by the name of Jean-Baptiste Bouillaud expanded upon the ideas of Gall and took a closer look at the idea of distinct cortical regions of the brain each having their own independent function. Bouillaud was specifically interested in speech and wrote many publications on the anterior region of the brain being responsible for carrying out the act of someone's speech, a discovery that had stemmed from the research of Gall. He was also one of the first to use larger samples for research although it took many years for that method to be accepted. By looking at over a hundred different case studies, Bouillaud came to discover that it was through different areas of the brain that speech is completed and understood. By observing people with brain damage, his theory was made more concrete. Bouillaud, along with many other pioneers of the time made great advances within the field of neurology, especially when it came to localization of function.

### **Paul Broca**

Inspired by the advances being made in the area of localized function within the brain, Paul Broca committed much of his study to the phenomena of how speech is understood and produced. Through his study, it was discovered and expanded upon that we articulate via the left hemisphere. Broca's observations and methods are widely considered to be where neuropsychology really takes form as a recognizable and respected discipline. Armed with the understanding that specific, independent areas of the brain are responsible for articulation and understanding of speech, the brain's abilities were finally being acknowledged as the complex and highly intricate organ that it is. Broca was essentially the first to fully break away from the ideas of phrenology and delve deeper into a more scientific and psychological view of the brain.

## **Karl Spencer Lashley**

Lashley's theory of the engram was the driving force for much of his research. An engram was believed to be a part of the brain where a specific memory was stored. He continued to use the training/ablation method that Franz had taught him. He would train a rat to learn a maze and then use systematic lesions and removed sections of cortical tissue to see if the rat forgot what it had learned. Through his research with the rats, he learned that forgetting was dependent on the amount of tissue removed and not where it was removed from. He called this mass action and he believed that it was a general rule that governed how brain tissue would respond, independent of the type of learning. But we know now that mass action was true for these rats, because learning to run a maze is known as complex learning and it requires multiple cortical areas, so cutting into individual parts alone will not erase the memory from the rats' brains, but taking large sections removes multiple cortical areas at one time and so they can forget. Lashley also discovered that a portion of a functional area could carry out the role of the entire area, even when the rest of the area has been removed. He called this phenomenon equipotentiality. We know now that he was seeing evidence of plasticity in the brain. The brain has the spectacular ability for certain areas to take over the functions of other areas if those areas should fail or be removed.

### **7.3. Approaches**

Experimental neuropsychology is an approach which uses methods from experimental psychology to uncover the relationship between the nervous system and cognitive function. The majority of work involves studying healthy humans in a laboratory setting, although a minority of researchers may conduct animal experiments. Human work in this area often takes advantage of specific features of our nervous system (for example that visual information presented to a specific visual field is preferentially processed by the cortical hemisphere on the opposite side) to make links between neuroanatomy and psychological function.

Clinical neuropsychology is the application of neuropsychological knowledge to the assessment, management, and rehabilitation of people who have suffered illness or injury, particularly to the brain, which has caused neurocognitive problems. In particular they bring a psychological viewpoint to treatment, to understand how such illness and injury may affect and be affected by psychological factors. They also can offer an opinion as to whether a person is

demonstrating difficulties due to brain pathology or as a consequence of an emotional or another potentially reversible cause or both. For example, a test might show that both patients X and Y are unable to name items that they have been previously exposed to within the past 20 minutes indicating possible dementia. If patient Y can name some of them with further prompting (e.g. given a categorical clue such as being told that the item they could not name is a fruit), this allows a more specific diagnosis than simply dementia. The Y appears to have the vascular type which is due to brain pathology but is usually at least somewhat reversible. Clinical neuropsychologists often work in hospital settings in an interdisciplinary medical team, while others work in private practice and may provide expert input into medico-legal proceedings.

Cognitive neuropsychology is a relatively new development and has emerged as a distillation of the complementary approaches of both experimental and clinical neuropsychology. It seeks to understand the mind and brain by studying people who have suffered brain injury or neurological illness. One model of neuropsychological functioning is known as functional localization. This is based on the principle that if a specific cognitive problem can be found after an injury to a specific area of the brain, it is possible that this part of the brain is in some way involved. However, there may be reason to believe that the link between mental functions and neural regions is not so simple. An alternative model of the link between mind and brain, such as parallel processing, may have more explanatory power for the workings and dysfunction of the human brain. Yet another approach investigates how the pattern of errors produced by brain-damaged individuals can constrain our understanding of mental representations and processes without reference to the underlying neural structure. A more recent but related approach is cognitive neuropsychiatry which seeks to understand the normal function of mind and brain by studying psychiatric or mental illness.

Connectionism is the use of artificial neural networks to model specific cognitive processes using what are considered to be simplified but plausible models of how neurons operate. Once trained to perform a specific cognitive task these networks are often damaged or lesioned to simulate brain injury or impairment in an attempt to understand and compare the results to the effects of brain injury in humans. Functional neuroimaging uses specific neuroimaging technologies to take readings from the brain, usually when a person is doing a particular task, in an attempt to understand how the activation of particular brain areas is related to the task. In particular, the growth of methodologies to employ cognitive testing within established functional magnetic resonance imaging (fMRI) techniques to study brain behavior relations is having a notable influence on neuropsychological

research. In practice these approaches are not mutually exclusive and most neuropsychologists select the best approach or approaches for the task to be completed.

#### **7.4. Methods and Tools**

These tasks have been designed so the performance on the task can be linked to specific neurocognitive processes. These tests are typically standardized, meaning that they have been administered to a specific group of individuals before being used in individual clinical cases. The data resulting from standardization are known as normative data. After these data have been collected and analyzed, they are used as the comparative standard against which individual performances can be compared. Examples of neuropsychological tests include: the Wechsler Adult Memory Scale (WMS), the Wechsler Adult Intelligence Scale (WAIS), and the Wechsler Intelligence Scale for Children (WISC). Other tests include the Halstead-Reitan Neuropsychological Battery, the Boston Naming Test, the Wisconsin Card Sorting Test, the Benton Visual Retention Test, and the Controlled Oral Word Association. (The Woodcock Johnson and the Nelson-Denny are not neuropsychological tests per se. They are psycho-educational batteries of tests used to measure an individual's intra-disciplinary strengths and weakness in specific academic areas (writing, reading and arithmetic).

The use of brain scans to investigate the structure or function of the brain is common, either as simply a way of better assessing brain injury with high resolution pictures, or by examining the relative activations of different brain areas. Such technologies may include fMRI (functional magnetic resonance imaging) and positron emission tomography (PET), which yields data related to functioning, as well as MRI (magnetic resonance imaging) and computed axial tomography (CAT or CT), which yields structural data. The use of electrophysiological measures designed to measure the activation of the brain by measuring the electrical or magnetic field produced by the nervous system. This may include electroencephalography (EEG) or magneto-encephalography (MEG). The use of designed experimental tasks, often controlled by (AACN and NAN Joint Position Paper) computer and typically measuring reaction time and accuracy on a particular tasks thought to be related to a specific neurocognitive process. An example of this is the Cambridge Neuropsychological Test Automated Battery (CANTAB) or CNS Vital Signs (CNSVS).

## 7.5. From Then to Now

Armed with the new understanding that the brain has independent structures responsible for both voluntary and involuntary functions, the next steps made were in developing this new discipline called neuropsychology. The bridging of the two disciplines meant studying and applying research to the functions and dysfunctions of the brain and how it affects the body as well as personality. This led to defining mental disorders and cognitive impairments that were characterized by different models of treatment. Over the years, different treatment plans and tests have been developed with the intention to help those with dysfunctions of the mind cope in daily living. Neuropsychology is a constantly evolving field that relies heavily on research and the ability for the neuropsychologist to be multidirectional and experimental in nature. It is essential for them to know and understand intricate behaviors such as emotion in context of brain physiology as well as the ability to assess what treatment would suit an individual the best. Often, abnormalities of the brain may overlap with one another in terms of diagnoses, which leads to an ambivalence in the ability to diagnose what the underlying issue, thus a neuropsychologist must work hard and diligently to assure accuracy and competency. The discipline is extremely difficult, but is one that is very rewarding. Although only a few contributors were mentioned in this condensed version of the history of neuropsychology, they are some of the most well-known pioneers in the development of the discipline. Each person expanded upon the ideas of their forefathers, and the field of neuropsychology has benefited greatly from the inquisitive minds that dared to think there might be more to the mysterious organ called the brain than previously imagined.