2c | Localization of Function

In this section of the module, we're going to focus on localization of function. In the proceeding section, I gave a brief overview of some of the basic structures in the brain. We also talked about some of the key cognitive functions or processes that were thought to be supported by these brain structures. So how is it that neuroscientists know what brain regions support what cognitive functions? The anwer to this question lies in studies of localization of function as a means of mapping basic cognitve processes to the brain.

The original idea of localization of function traces back to an Austrian anatomist named Franz Gall. He believed in something called faculty psychology. He believed that certain human abilities and traits, such as human nature, conscientousness, constructiveness, were associated with specific regions of the brain. He also believed that each of these abilities and traits were autonomous and independent. That is, that your ability in one domain would not impact or could not be impacted by an ability or trait in another domain. Gall's student, Johan Spurzheim took this one step further. He argued that the strengths and weaknesses of specific traits and abilities were precisely correlated to the relative sizes of the different brain regions that were thought to support them. And thus was born the study of phrenology.

So for example, if you look at the following figure with a phrenology head, just above the nose you can see a location labelled punctuality. Someone who is highly punctual would have a slightly larger region of the brain just above the nose, whereas somebody is not very punctual would have a slightly smaller region there. This could be measured with a trained phrenologist using their own hands or it could be measured using a phrenology machine like the one found in the following picture from 1905. It didn't take long however for this idea to become discredited.

The major problem with phrenology was not the assumption of a localization of function. We know for example that many functions or many cognitive processes are indeed localized to some degree in the brain. The problem with phrenology more had to do with the assumption that these processes completely autonomous and independent. We now know that cognitive processes do not operate in a vacuum. On the contrary they operate highly interactively. In addition, researchers have shown that the size of a portion of the brain does not directly correspond to its relative power.

These criticisms aside, Gall's work was extremely influential as he forged the way for future scientists to more precisely map out the relationship between structure and function in the brain.

I'm now going to talk about two different lines of research, one involving patients with specific brain damage and another involving brain stimulation, that were highly influential in determining what specific regions of the brain were responsible for specific cognitive functions.

So first, we're going to talk about patients with specific damage to specific regions of the brain and how it affects cognitive behaviour. To do this, I want to introduce a concept that cognitive psychologists often use to try to isolate specific components of the mind and brain. This is the double dissociations. I'm going to talk about this first in abstract terms and then we'll go through a real example from the literature.

So, imagine you have a patient with damage to area X. Now X can be any region in the brain. And you find out that this patient is impaired for cognition A, but not B. Then you have another patient that comes in that has damage to area Y. Now this area Y is different than area X and they have impairment for cognition B, but not A. So to reiterate, you have two patients, each with different types of brain damage, one has brain damage to area X, one has brain damage to area Y, and the impairments that they show are mere images of each other. The patient with damage to area X is impaired for cognition A, but not B, and the patient with damage to area Y is impaired for cognition B, but not A, so they are complete mirror images of each other. This is what is referred to as a double dissociation, where brain damage and behaviour are completely dissociated from each other and show opposite mirror image patterns. This double dissociation logic is often used in cognitive psychology and cognitive neuroscience.

One very famous example of this, and this is one that you've probably covered in your introductory psychology class, is that of Broca's Aphasia and Wernicke's Aphasia. Here, if a patient has damage to the area known as Broca's Area, in the left frontal lobe which is highlighted here in the following figure, this patient will have a major deficit in expressive language, or speech production. If a patient, on the other hand, experiences damage to an area in the auditory association cortex, specifically Wernicke's Area, they will show deficits in the comprehension of language, but intact speech production. So to reiterate, a lesion to Broca's area impairs speech production, but not comprehension and a lesion to Wernicke's area impairs comprehension, but not production. This is a nice, simple example of a double dissociation. Now you may want to take a little bit of time here just to make sure you go through this logic and have a really good grasp of it, because we are going to see other examples of double dissociations throughout the remaining modules of this course.

Since the time of Paul Broca and Carl Wernicke cognitive psychologists began to establish connections between lesions in other parts of the brain and specific cognitive functions. For example, researchers found that select regions to specific portions of the primary motor cortex would result in the loss of a specific motor control of a select body part. A summary of the mapping between specific locations within the primary motor cortex and the control of specific body areas can be found in the following figure.

For example, damage to the very top or dorsal portion of the primary motor cortex would affect one's control of their feet, whereas damage to the ventro or lower portion of the primary motor cortex would affect the patient's control of their mouth. In addition to the primary motor cortex, neuropsychologists have also clearly mapped out the basic subdivisions of the somatic sensory cortex.

A summary of this topographic representation is highlighted in the following figure. As you can see from this figure, like the motor cortex, the somatic sensory cortex is organized in such a fashion that each part of it receives information from a specific part of the body. As I noted previously, a lot of the research that helped define the relationship between certain structures of the brain and their function was done with patients that had brain damage. So for example, you'd find a patient with a selected lesion in one part of the brain and then through a series of tests find out what capacity or what ability has been compromised.

Wilder Penfield, who is a famous Canadian researcher and neurosurgeon and the founder of the Montreal Neurological Institute, is perhaps most responsible for what we know about the localization of function in the human cortex. What he did was, is he developed a ground breaking procedure called the "Montreal Procedure" for localizing the source of epileptic seizures in patients. Before operating on his patients who were only under local anaesthetic and were thus conscious and could communicate with them, he probed the exposed brain tissue guided by the responses of the patient. And what he would do is he would search for the scar tissue that caused the epilepsy. For example, if a patient often experienced a certain sensation, such as a taste or a smell, Penfield would gently stimulate the exposed cortex until the patient reported experiencing that same sensation, thus localizing the source of the seizures. A byproduct of this procedure was that Penfield clearly mapped out the specific functions performed by various regions of the brain based on participant's responses to the cortical stimulation. Using this technique he created maps of both the sensory and motor cortices of the brain in more detail than anyone before him, and these maps are still used today.

There's a short web clip on the *History by the Minute* website that features Wilder Penfield's work. This clip is worth looking at because it'll give you an idea about how his procedure worked.