Brain Systems 2

[00:00:00.73] We're now going to review some of the brain functions that are less the focus of this course, including autonomic function, which is absolutely target of neural engineering. Individuals who are partially or completely paralyzed rate digestive function, especially bowel and bladder function, even more highly as a priority for treatment than walking.

[00:00:21.37] And all control of autonomic systems is subconscious. However, it's not been as much of a target of neural engineering research to date, not to the extent of skeletal muscle control. That said, it is absolutely investigated and it absolutely is a target for treatment.

[00:00:40.02] However, why would we not engineer respiration or heart rate to help people who need a pacemaker or a respirator to help them function with these very basic things? This is because these functions are located in the brain stem. And engineering in the brain stem is very risky.

[00:01:00.31] Any damage to this region is quite likely to be fatal or to cause an even greater degradation in quality of life than the original injury we were trying to treat. Engineering solutions to these brain stem function deficits is a very difficult and very risky proposition. And therefore, not really much of a target of research.

[00:01:23.53] If a person has received a new neural engineering device, they need to learn how to use that new device. So we need to cover learning and memory, as well as the use of the device itself. Short term memory covers the period from a few seconds to a few minutes, and it involves the manipulation and access of information that's relevant to whatever the person is doing at that moment.

[00:01:48.43] It's partially handled by the prefrontal cortex, especially the superior frontal and middle frontal gyrus. And it's partially handled by the parietal cortex, which especially deals with manipulating sensory information. If you'll recall, the parietal cortex handles touch sensory information, as well as sensory integration of multiple senses.

[00:02:09.82] If that information is then going to be stored for the long term, it's passed to the hippocampus, which is located deep inside of the temporal lobe. And while it's derived from cortical tissue, it isn't normal cortex. Information is processed in the hippocampus to prepare it for long term storage, but the long term storage of most memory does not happen in the hippocampus. Some spatial memory, such as finding a path through a maze, is thought to be stored in the hippocampus itself. Long term storage is thought to occur throughout the temporal lobe, especially in the medial temporal lobe, which is located on the opposite side of the brain stem in this diagram.

[00:02:49.66] Now we're going to talk about emotions. Emotions are a cognitive experience combining a level of intensity with a positive or negative value which motivate behavior, especially social behaviors. The long term equivalent of an emotion is a mood. And both are responses to events in the environment or to internal cognitive mechanisms, or thoughts.

[00:03:12.74] Emotions are also highly linked to reward systems or motivated behavior that is responsive to a positive, rewarding feedback from the environment. Emotions are linked to the limbic system, which consists of several primary cortical structures-- the cingulate, the parahippocampal gyrus, and the entorhinal cortex. The parahippocampal gyrus and entorhinal cortex are not visible in this diagram, but they lie on the medial wall of the temporal lobe.

[00:03:45.43] The limbic system also includes several non-cortical structures, including the hippocampus, the hypothalamus, the amygdala, parts of the thalamus, the fornix, and the mammillary bodies. Although historically the limbic system was sometimes called the limbic lobe, we now recognize that it includes many non-cortical structures, so it's not called a lobe anymore. These regions work together to handle motivation, reward, and emotion.

[00:04:17.36] The amygdala handles fear uniquely. It's separate from all other emotions, because it responds to fearful or threatening stimuli that requires an immediate response. The right amygdala in particular is strongly linked to negative emotions and to emotional memory. The left amygdala is also linked to these negative emotions, but also sometimes to positive emotions. The left amygdala is also linked to fear and negative emotions, but it's also linked to some positive emotions. Both amygdala are also linked to anxiety, PTSD, and reward responses.

[00:04:55.21] Executive functions are processes for managing cognitive resources, planning for and executing steps towards goals, and selecting behaviors. Executive functions include planning, both short and long term, problem solving, language, both understanding and producing language, attention or managing what in the environment receives the most cognitive resources at any given moment, decision-making, risk assessment, personality, manipulating items in short term memory, impulse control, and inhibiting behavior.

[00:05:34.36] Executive function is almost exclusively associated with cortex, especially the prefrontal cortex. The human prefrontal cortex is marked in yellow on this diagram at the top. And it constitutes the entire frontal cortex with the exception of the motor cortex, premotor cortex, and supplemental motor area.

[00:05:56.10] You can compare the relative volume of the human prefrontal cortex in yellow to the monkey prefrontal cortex, which is all three of the colored regions on the lower diagram. Human executive resources are significantly greater than any other species that we know of. And that's a function of the greatly expanded area of cortex associated with those executive functions. Particularly relevant for neural engineering is the role of executive functions in learning new skills, especially for its role in planning and decision-making.

[00:06:31.21] We're going to conclude this portion of the lecture by reviewing blood and cerebrospinal fluid. Blood is not so much a target for neural engineering as a reason that neural engineering might be necessary for a rehabilitation. The brain is supplied with blood by a network of major and minor blood vessels that extend all throughout the brain and supply neurons and glia with a constant supply of blood.

[00:06:53.66] An interruption in this blood supply is very dangerous because it can lead to unconsciousness within seconds and permanent damage within minutes. Most of the time, blood loss is only partial due to something like a stroke or an aneurysm. So even permanent damage is restricted to just the area that lost blood, to just the area that was served by the blood vessel that was blocked.

[00:07:16.30] So rehabilitation is targeted to recovering the lost functions that were associated with the impacted area of the brain via trying to reassign them to other regions as much as possible. Due to the brain's plasticity, we can recover a lot of function or learn to live with the function that we have left. But it's obviously optimal to just avoid the injury entirely or to try to recover the damaged tissue before it's permanently lost.

[00:07:45.35] The blood-brain barrier is a physical barrier that surrounds all of the blood vessels serving the brain that's composed of endothelial cells and astrocytes, a type of glia. And the blood-brain barrier only allows certain substances to reach the neurons via either diffusion through the blood-brain barrier membranes or through specific transporters that physically move the desired molecules through to the brain. Allowed molecules include water, amino acids, oxygen, neurotransmitter precursors, which are the materials needed for the brain cells to build their neurotransmitters, some but not all hormones, ethanol, which is drinking alcohol, caffeine, and psychoactive drugs.

[00:08:31.22] And blocked are most pathogens, antibodies, antibiotics, and most other pharmaceuticals. The exceptions are there are few pathogens that are known to regularly cross the blood-brain barrier. And these include toxoplasma gondii, which is generally found in cats and can also be found in humans, especially cat owners; Borrelia or Lyme disease; and group B streptococcus, which causes meningitis especially in children. The blood-brain barrier may be physically opened to allow drugs into the brain for the purposes of treatment, Either by administering other drugs or through ultrasound, which causes the blood-brain barrier's cells to release their grip and pull away from each other.

[00:09:18.32] Cerebrospinal fluid circulates throughout the brain, where its primary job is to clear away waste products. You have about 125 to 150 milliliters of cerebrospinal fluid at any time. And it's derived from blood, primarily in the lateral and third ventricles.

[00:09:34.88] The lateral ventricle, which here is marked by its subportions, the interior horn, body, atrium, and posterior horn, is the largest ventricle. And the inside of it is coated with the choroid plexus, which is sort of fluffy, lacy material that extracts cerebrospinal fluid from blood.

[00:09:53.15] The cerebrospinal fluid clears away the waste and it flows from the lateral ventricle through the interventricular foramen to the third ventricle. There is no second ventricle. And from the third ventricle, it flows through the cerebral aqueduct to the fourth ventricle, and then out to subarachnoid space which is under the meninges surrounding the brain. And then it drains to blood. And it takes away all of the waste products that neurons and glia generate on a continual basis in order to keep the brain functioning properly.