YOUNG SCIENTISTS journal

The Brain and Its Frontal Lobes

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March 1, 2016 · Biology

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Chun L. The Brain and Its Frontal Lobes: In this article, Lisa (17) explores the brain and its frontal lobes.. Young Scientists Journal. 2016 Mar 1 [last modified: 2016 Mar 31]. Edition 1.

Abstract

Neuroscience is a relatively new field of study that explores the brain and the nervous system, the great controllers of our body. This article focuses on the frontal lobes of the brain, expatiating on its functions and how their dysfunction could give rise to various psychological disorders. It also deals with the history of interpretations about the brain, as well as technological modes through which scientists can now examine the brain — e.g. the MRI and the PET scan.

Introduction

Many are likely familiar with the horrific yet fascinating story of Phineas Gage, the man who continued to live a good eleven years after an iron rod of 3 feet 8 inches and approximately 13 pounds was driven right through his brain. The good news was that he survived; the news that puzzled numerous doctors and scientists of the time was that the incident had turned Gage into, according to his associates, a different man. He lost his cheery character, instead becoming capricious, irritable, and irreverent.

It was quite evident that his character change derived from losing a chunk of his brain when the rod pierced his cheek and came out through his left forehead. Neuroscientists now are able to explain why this affected his personality. At the time, however, this surprising incident of a man living with a hole in his head spurred many scientists to delve deeper into the realm of neuroscience, a study just beginning to unfold.

History

Early brain science was dominated by phrenologists, who believed that functions of the brain were localized. They believed personality could be predicted simply by feeling the bumps and indents of one's skull and associating them with predetermined categories. A major advocate of phrenology was Franz Gall, born in 1758. He came up with twenty-seven different traits — which were later expanded to thirty-two — and assigned them to his map of the brain. To phrenologists, Gage's story seemed to corroborate their theories. The area of the brain below the left eyebrow was supposedly the "Organ of Veneration" and the "Organ of Benevolence."[1] Gage was able to live on because the rod had pierced organs inconsequential to survival, but he became cranky all of a sudden due to damage in his region of kindness.

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Phrenology

Phrenology

Another dominating idea at the time was that the brain acted as a whole. Specific functions did not work in defined areas; they could move to other parts of the brain if the location they were originally in got destroyed. For Jean-Pierre-Marie Flourens of the eighteenth-century, this became evident when he removed bits of live animals' brains and discovered that all functions grew weaker together, instead of only certain functions becoming disabled. Gage also seemed to prove this notion of a "homogeneous brain". He could think rationally and live almost as well as he had before, because the functions of his frontal lobes were taken on by other parts of his brain.

Both these ideas lost popularity as they began to be proven false. In 1861, when Paul Broca examined the brain of a man who lacked the ability to articulate words, he found damage in the front left side of his brain — contradicting phrenologists' belief of where language was controlled. Similarly, when Carl Wernicke studied patients who could not speak coherently — rather than pronounce properly — the impairment of the brain was in a whole other location, revealing that even speech was not localized to one area.[2]

In spite of the debunking of these two beliefs, in truth, neither were completely wrong. Neuroscientists today understand that the brain does have certain localized functions — although in a very different manner than the phrenologists proposed — at the same time that it interacts and works as a one and whole synchronized organ.

Examining the Brain

With recent technological advances, all other unsupported speculations of the how the brain works were irrefutably invalidated. Now machines can be used to probe into the brain and delineate authentic visualizations of what really goes on: the EEG, CT, PET, and MRI scans all procure a clear image of the brain — in its very literal sense.

The electroencephalogram (EEG) is used for a surface-layer reading of the brain's electrical activity, which occurs through signals from the billions of neurons in the brain. Activity is detected through electrodes that are covered with conductive gel attached to the scalp; these read the electrochemical activity of the brain conducted through the meninges (membranes that enclose the brain), the skull, to the scalp. When a person is presented with a stimulus, the EEG displays the galvanized electrical wave on a chart recorder or computer screen. The EEG has proven beneficial in diagnosing and identifying sleep-related disorders such as epilepsy.

Computed tomography (CT) scans — also known as CAT scans — produce structural images from a series of X-ray photographs of the head at different angles. These are analyzed and combined by a computer, which then yields compound pictures of various slices of the brain. CT scans, however, cannot detect activity; they are only able to depict the brain's structural changes, and thus are seen as useful in determining brain damage in certain areas and its effects.

CT Scan

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CT Scan

Positron emission tomography (PET) scans manifest brain activity and its changes under different circumstances by following the consumption of glucose in different areas of the brain. Radioactive markers, such as Oxygen-15, are taken up by active neurons once injected into the body. The gamma rays that active neurons release with use of glucose are tracked as the participant engages in diverse tasks such as solving arithmetic problems or coloring shapes. Since active neurons consume more glucose, the subsequently released gamma rays reveal which areas of the brain become more active when a specific task in undertaken.

Magnetic resonance imaging (MRI) scans are based on hydrogen atoms' response to radio waves within strong magnetic fields, in order to obtain images of soft tissue. The reasoning behind this, is that hydrogen atoms' density in varying types of brain tissue differs; and thus the tiny magnetic fields hydrogen atoms produce can be measured to generate images through a computer. An advantage of using MRI scans is that they produce images with high resolution without exposing participants to radiation. MRI scans have exhibited differences in neural areas of people with disorders, such as enlarged ventricles (fluid-filled cavities in the brain) in some patients diagnosed with schizophrenia.[3][4]

Frontal Lobes

The frontal lobes account for about one-third of the brain's mass.[5] Due to their comparatively greater size in humans than other primates — as well as the fact that they are the brain's most recently developed area — they are frequently regarded as the place that facilitates the most complex cognitive activities such as making plans and judgments. They also participate in restraining impulses and regulating alertness as well as personality, as manifest in Gage's surprising case.[6]

The prefrontal cortex lies at the front of the frontal lobes, which are situated right behind the skull of one's forehead. While the frontal cortex is involved in setting goals and formulating plans to achieve them — using the correct cognitive skills in the correct order — the prefrontal cortex analyzes the potential success or failure of one's actions in respect to the objective.

An important note on these regional functions is that they do not work on their own. Connected to the rest of the brain as they are, dysfunction of the frontal lobes may affect the overall interplay of different areas of the brain. Take, for example, the amygdala: an almond-shaped piece of the brain's limbic system that is linked with emotion. When one's amygdala is activated, the neocortex of the frontal lobes becomes responsible for assuaging the firing amygdala and forming reasonable responses; this prevents a person from acting irrationally at an emotional stimulus such as an insult. Damage to the neocortex, then, creates a situation in which one acts upon impulses rather than considering the societal context they're in.[7]

With the frontal lobes acting as the control center of decisions and organization of stimuli to prepare for future plans, damage to them often leads to dysexecutive syndrome. Afflicted patients continuously return to routine undertakings, appearing distracted when assigned original exercises to execute, with a tendency to perseverate on old strategies.[8]

They do not struggle in repeating previously learned or well-structured tasks; instead they become stumped when initiating activities in novel situations or when working with abstract concepts. For instance, asked to copy a square of alternating six red and white stripes according to a given formula of nine red-and-white blocks, they can hardly come to an insight unless provided with a grid. This grid then serves as an external structure that guides them so they need not contrive their own strategy to solve the problem.

Incompetence in devising plans has partly to do with impairment in working memory. Working memory is the ability to actively process incoming sensory information in the short-term memory together with already stored information from the long-term memory. Damage to the frontal lobes enfeebles the working memory; thus, integrating past memories with the current situation to plan ahead is rendered difficult.[6]

The frontal lobes do not impede memory as a whole. On tests on factual memory, the scores of patients with frontal lobe dysfunctions were not lower than average; they straggled, however, on tests of frequency or temporal order of information, as well as those with successive trials — this revealed their susceptibility to interference (information collected later pushing out previous ones from memory). Such patients moreover were inept in perceiving their own memory capabilities.[8]

Problems that May Arise

In the early 20th century, psychiatric disorders were often treated through frontal lobotomy — in which the frontal lobes were entirely removed or disconnected from the rest of the brain — until it became clear the patient's general condition worsened after undergoing lobotomy. Evidently, neuropsychologists of the time knew about the frontal lobes' influence on personality. This change in personality, however, was more of a change in behavior and lack of inhibition on impulses that brought forth what others viewed as rash and illogical actions.

Attention Deficit Disorder is a largely widespread case associated with such sporadic uncontrolled behavior. The frontal lobes process sensory inputs and subsequently guide performance, hence playing a major role in the maintenance of attention. Impairment in the frontal lobes' exchange of perception and sensation potentially gives rise to deficiency in attention.[9] MRI scans of patients with Obsessive-Compulsive Disorder may display heightened activity in the frontal area's anterior cingulate cortex, which monitors and reviews one's actions, when performing obsessive behaviors such as washing or organizing.

Depression may also in part be due to frontal lobe abnormality. The left frontal lobe is active when one feels positive, and less active when depressed. MRI scans of one group of severely depressed patients revealed that they have 7 percent smaller frontal lobes than normal. Otherwise, persistent firing of a frontal area that works with attention may cause one to incessantly focus on a negative problem, or ruminate, which may lead to the negative emotions of depression.[4]

Inevitably, impairment of the frontal lobes' executive function yields lack of concern for the future, impetuosity, difficulty in retrieving memory, reduced initiative, trouble in dealing with abstract terms etc. In other words, a person with frontal damage becomes inflexible, straining to shift according to changing demands or break out of an established habit. Their motivation may also be affected; as the links between the prefrontal cortex and the limbic system are activated upon rewarding behaviors, frontal damage may result in diminished overt behavior.[5] It is yet to be confirmed, however, the absolute extent to which difference in frontal structure generates difference in behavior.

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