Our Brain Shape May Matter More Than We Think

The human brain is often regarded as an unfathomable enigma, and while science knows that our brain function is a result of the transmission of signals between connected billions of neurons, it has now found what influences those transmissions is actually the shape of our brain.

For decades, scientists subscribed to the hypothesis that the 86 billion neurons in the brain, connected by trillions of links, must be controlling the brain activities and that we only need to know the patterns of these connections to unveil the mysteries surrounding our brains.

However, a new study published in the journal Nature challenged this theory and proposed a new hypothesis: that the shape of the brain is actually what influences more our brain activities like thinking, feeling, behaving, etc.

The Groundbreaking Study

The study conducted by Monash University, Australia, was based on the hypothesis that the nervous system must be no exception to the dynamics of many natural systems, which are constrained by their underlying structure.

For example, the morphology of the proteins determines which molecules they will interact with; the shape of the river bed shapes the underwater currents; and the shape of the drums, which influences their acoustic properties.

So the scientists conducted an experiment where 255 people were performing tasks like tapping their fingers and took magnetic resonance imaging (MRI) scans of their brains.

After that, they gathered 10,000 different maps of human brain activity from other similar experiments around the world and created a computer model of the link between brain size and brain waves.

They compared this model with the previous existing one that aligns the brain activity with the neuron activities as the key to the function of the brain and found that the new model actually shows a better reconstruction of the brain activity in the MRI scans.

The lead author of the study, James Pang, who is a research fellow at Monash University, compared the waves of the brain to the ripple effect in a pond, with the analogy that the shape and size of the pond would shape the look of the ripples.

"The geometry is pretty important because it guides how the wave would look, which in turn relates to the activity patterns that you see when people perform different tasks," said Pang told NBCNews.

Eigenmodes: A New Aspect of the Study

The authors state that they used the patterns known as "eigenmodes."

Eigenmodes arise from the concept of eigenvalues and eigenvectors in linear algebra, and in the context of a physical system, the eigenvalues correspond to the frequencies at which the system can oscillate, and the eigenvectors describe the spatial distribution or pattern of the oscillation.

For example, if we look at a vibrating string fixed at both ends, the eigenmodes of the string represent the different ways it can vibrate with specific frequencies and patterns.

Eigenmodes are relevant in various areas of science and engineering, including electromagnetics, acoustics, structural mechanics, and quantum mechanics, and are used to understand the behavior and properties of complex systems and to analyze the response of these systems to external stimuli or boundary conditions.

Two of the authors of this study, James Pang and Alex Fornito, explain how exactly they applied the eigenmodes concept in their work in an article for The Conversation.

“We uncovered this close relationship between shape and function by examining the natural patterns of excitation that can be supported by the anatomy of the brain. In these patterns, called “eigenmodes”, different parts of the brain are all excited at the same frequency,” they said.

“Consider the musical notes played by a violin string. The notes arise from preferred vibrational patterns of the string that occur at specific, resonant frequencies. These preferred patterns are the eigenmodes of the string. They are determined by the string’s physical properties, such as its length, density, and tension.

“In a similar way, the brain has its own preferred patterns of excitation, which are determined by its anatomical and physical properties. We set out to identify which specific anatomical properties of the brain most strongly affect these patterns.”

The researchers concluded that the brain shape is more accurate to assess brain activity.

“We attempted to describe each activity map using eigenmodes based on the brain’s connectivity and eigenmodes based on the brain’s shape. We found that eigenmodes of brain shape–not connectivity–offer the most accurate account of these different activation patterns,” Pang and Fornito said.

However, another neuroscientist, David Van Essen, who is a professor at Washington University in St. Louis, thinks that most researchers still believe in the original hypothesis that brain activity is due to the communication of the nerve cells, and especially their axons, which act like a wire in the process of transferring information between the nerve cells.

“The fundamental starting hypothesis is that the wiring of the brain is central to understanding how the brain functions,” Van Essen told NBC.

Van Essen is skeptical about these new findings. He raises the concern that the models are based on the average shape of the brains of participants, whereas in reality, there is a difference in the patterns of the brain’s surface folds.

"It would be an understatement to say this is a controversial theory, and it really needs to be put through its paces to evaluate critically whether it stands the test of time," he said.

Another concern of Van Essen's is the accuracy of the MRI's readings when it comes to the wiring of the brain.

As exciting and informative as it is, it's still inaccurate in fundamental ways and incomplete, and leaves a lot left to be sorted out by future studies," he said regarding MRI technology.

Advantages of This Research

However, the researchers have said that the new research does not diminish the role of the communication between the nerve cells, but it does contribute to the understanding of the key role the brain shape plays in the whole process.

"What the work is showing is that the shape has a stronger influence, but it's not saying that connectivity is not important," Pang explained.

He pointed out that the new hypothesis has a significant advantage in that the shape of the brain is much easier to measure than the brain wiring, thus assessing the curves and the size of the brain can help further this research in various directions, like the role of the brain shape for developing neurological and psychiatric diseases.

Another advantage could be the ability to measure the speed at which the brain waves travel in the various parts of the brain, which can predict how people process information and can help with diseases like depression and schizophrenia, Pang thinks.

However, Pang thinks this research is strong on individual base brain shape too.

"We're pretty confident that the influence is really there," he told NBC.

"Our approach draws on centuries of work in physics and engineering. In these fields, the function of a system is understood with respect to the constraints imposed by its structure, as embodied by the system's eigenmodes," Pang wrote for ScienceAlert.

"This approach has not been traditionally used in neuroscience. Instead, typical brain mapping methods rely on complex statistics to quantify brain activity without any reference to the underlying physical and anatomical basis of those patterns."

They argue that the new approach opens possibilities for studying how brain shape affects function through evolution, development, aging, and brain disease.

"Our discovery also offers immediate practical benefits since eigenmodes of brain shape are much simpler to quantify than those of brain connectivity," the researchers said.