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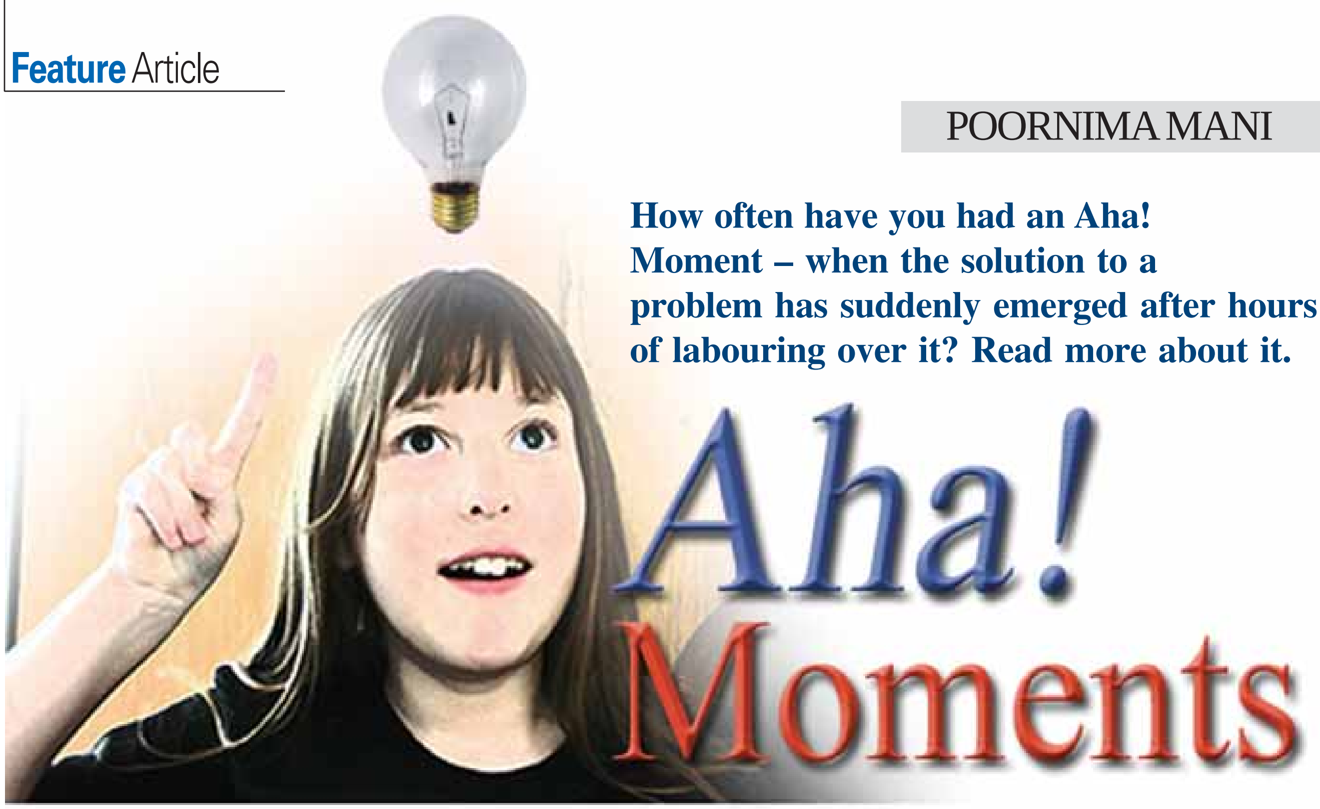


How often have you had an Aha! Moment – when the solution to a problem has suddenly emerged after hours of labouring over it? Read more about it.

Aha! Moments

ONE hot afternoon at home, I was making an Origami (paper folding) frog. Origami books describe complex 3D folds with 2D drawings. However good the illustrations and descriptions maybe, some folds end up being very hard to understand. That afternoon I was stuck on one such difficult fold. After a long struggle trying out different folds, I was about to give up and close the book, when I had this sudden moment of revelation and I knew how to make the fold. Until this day I have no idea how I arrived at the solution. The answer suddenly 'clicked' to me and the frog was done.

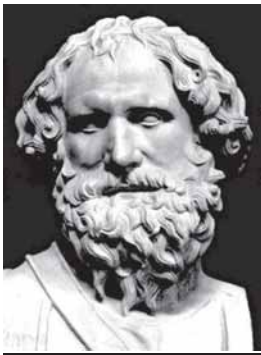
Years later when I had a discussion with my professor of Neuro-engineering, I understood that what I had experienced was an 'Aha!' moment. Mine wasn't a groundbreaking discovery. Nevertheless it was similar to the Aha! moment experienced by Archimedes, who ran out of his bath tub shouting 'Eureka!' (I found it). Many a famous discoveries are attributed to Aha! Moments—Newton's discovery of the gravitational force, Charles Darwin's discovery of evolution and Kekule's Benzene ring.

Now, there are some unique characteristics of an Aha! moment: 1. The solution is sudden, 2. We are never aware of the steps through which the solution occurred to us, 3. The solution usually occurs after a period of fruitless struggle and 4. Not to forget the strong emotional Aha! or Wow! or Oh! feeling that accompanies any Aha! moment.

The following fact makes Aha! moments more special: According to Donald O. Hebb, a prominent neuroscientist, Aha! moments are the predominant mode of adult learning. 'Learning' is an unsolved mystery for neuroscientists. That's right, the great gift that we humans possess, the ability to 'learn' is still not completely understood. Understanding Aha! moments would be a small step towards understanding learning. Not only learning, the greatest wonder of science is that, having explored from quarks to quasars, we have not explored much into our 'exploring instrument', our brain.

Why did Donald Hebb consider Aha! moments the 'most' important form of adult learning? Because a linear learning curve is not sufficient to obtain the kind of vast knowledge we possess, jumps and leaps are certainly necessary. So Aha! moments are not the unique property of scientists but a common occurrence even to the common man.

Aha! moments have been the subject of the neuroscientist's curiosity always. Until now Aha! moments were studied during puzzle solving, wherein the occurrence is frequent. But Aha! moments occur during day-to-day activities also. At University of Houston, we took up a new method that employs visual images to elicit Aha! moments.



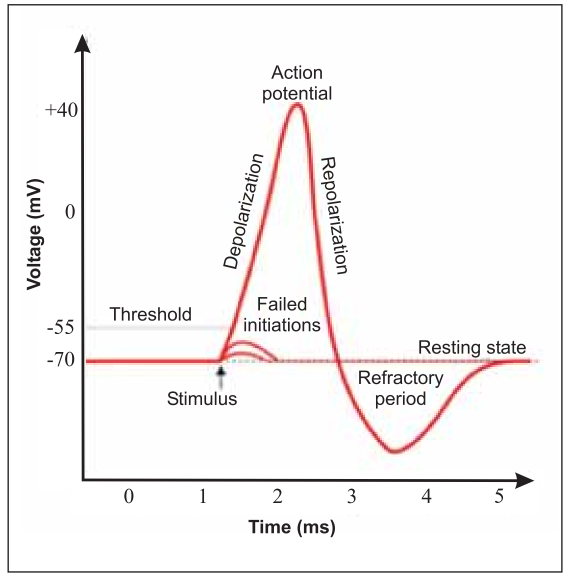
Archimedes, had a 'Eureka!' moment

What studies show is that, the more 'focused' attention you pay, less the chances of an Aha! moment.

For an Aha! moment to occur a proper problem space has to be formed in the brain, the constraints of the problem should lead to a fruitless struggle and only then, all of a sudden the answer might suddenly click.

A two-tone image used in the study, after focused viewing the object suddenly 'pops-out' to the viewer.

A single action potential plotted from an intracellular recording from a neuron. Note the time span and amplitude of the action potential. (right)



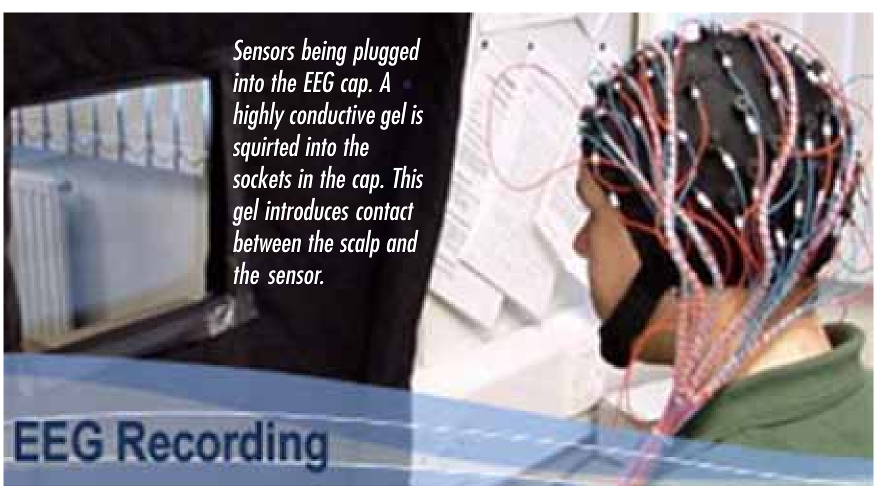
The great gift that we humans possess, the ability to 'learn' is still not completely understood.

A black and white image with no gray shades looks like a collection of splotches; only after a period of focused viewing the object in the image suddenly 'pops-out' to the viewer. The moment when the object in the image 'pops-out' to the viewer is the Aha! moment. That is, without integrating the splotches part by part and finding the solution, all of a sudden, a hitherto nonsensical image becomes meaningful.

For the study, we make our test subjects (people taking our test) look at our test images (we made 300 black and white images of common objects). While they try to decipher the objects in the images, we record their 'brain waves', the electroencephalogram or EEG.

Before going any further, the EEG must be explained. The brain is made of millions of nerve cells called 'neurons'. Neurons talk to each other. Their language is in the form of electrical and chemical signals. The electrical signals are called 'action potentials'. Action potentials are generated inside each neuron and this action potential triggers the release of neurotransmitters (chemical) from that neuron, which forms the chemical signal. The generation of action potentials by a neuron is informally called 'firing'. The chemicals released from one neuron, when received by neighboring neurons trigger an action potential in them.

The bewildering aspect is that all action potentials are always the same. An action potential is always 40 microvolt high and a few millisecond long. Pick any neuron in any region of the nervous system and the action potential you will plot will be identical to that from any other neuron. So our neurons speak in a single alphabet language! How can a single alphabet code lead to all the complexities of our brain? Our dreams, imaginations, mathematics, language, art, and simple activities like movements, speaking, eating and breathing are all the result of this single alphabet code!



Sensors being plugged into the EEG cap. A highly conductive gel is squirted into the sockets in the cap. This gel introduces contact between the scalp and the sensor.

Although the study of action potentials and the brain language is tempting, it is not always possible to study the brain using action potentials, because we will have to cut open the skull and place sensors on the live brain without damaging it. So what most studies do is listen to the neurons from the outside. Even the simplest job lifting a finger or even deciding to lift a finger requires the functioning of thousands of neurons. The combined activity of neurons can be measured as tiny electrical signals on the scalp. We place sensors called electrodes on the scalp. These sensors have very powerful amplifiers.

The analog signals from the sensors are digitized and stored in a computer. Any activity that can lead to firing of neurons is called a stimulus. Stimuli can be external or internal. A sound tone, a visual image, a touch or smell are external stimuli. Some examples of internal stimuli are the thought that makes you lift a finger or rub your nose. But apart from the response to stimuli, the brain has a constant background rhythm called the 'spontaneous' EEG. All responses to stimuli are believed to be superimposed on the spontaneous rhythm.

During the recording of the EEG there is a lot of noise addition. Head movements, eye movements and blinks, swallowing and talking also lead to electrical signals generated by the muscle cells. These signals called

EEG provides very good temporal resolution but not good spatial resolution.

the Electromyograph also get recorded along with the EEG. Any analysis using EEG should first clean the EEG signals from the electromyographs, and separate the responses to stimuli from the spontaneous rhythms.

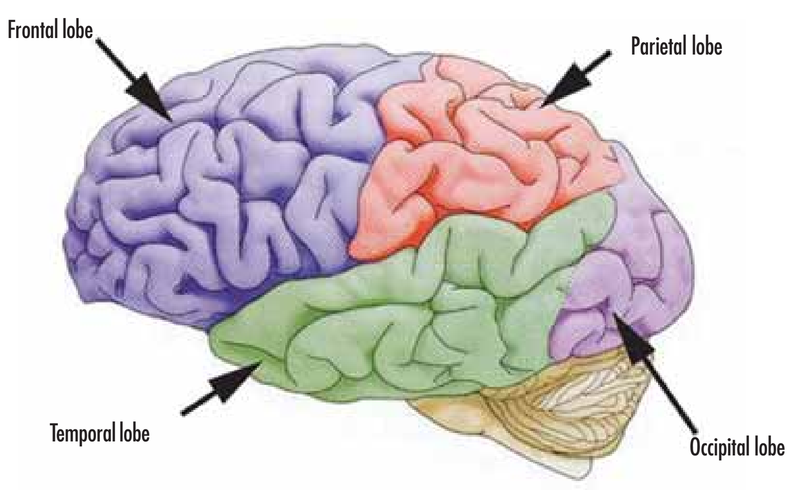
One special aspect of EEG is its sensitivity in time. EEG can capture brain activity almost as soon as it occurs, that is within a few milliseconds, which is quick enough to study the brain. This is not the case with other brain imaging techniques like the MRI or PET scans which can measure responses only a few minutes after they occur. But the problem with EEG is that, it is the sum of activity that happens within the skull, so it is hard to tell if the activity measured in any one sensor is purely due to the activity of the brain directly below it. In technical terms, EEG provides very good temporal resolution but not good spatial resolution.

Going back to the Aha! moment study, we record the EEG of our subjects while they stare at the black and white images and struggle to identify the object in it. The EEG during which the subjects stare at the image fruitlessly would be compared to the EEG when they have an Aha! This would tell us what happens in the brain when someone has an Aha! moment.

One more thing to know about the brain is that, there are specific areas in the brain that perform specific functions.

The brain lobes

For example, the occipital lobe (the portion right above your neck on the posterior side), is responsible for low level visual processing; it is called the visual cortex. The portion right behind and above your ears processes auditory data, it is called the auditory cortex. The parietal cortex (the area between the occipital cortex and your ears) and the frontal cortex (the area behind your forehead) are together responsible for attention. Attention in neuroscience is compared to a spotlight.



Every instant, any region of the brain is flooded with information from the senses, the internal organs and even other regions of the brain. Either consciously or not, it is not possible for us to pay attention to each and every bit of information. The only possibility is that the brain ignores what it thinks as 'unnecessary' and throws light on what it considers important; this is the 'attentional spot-light'.

Now, the parieto-frontal network (that is the parietal and frontal lobes together) is known for focused attention processing. What studies show is that, the more 'focused' attention you pay, less the chances of an Aha! moment. Lesser-focused attention (attention to parts) should lead to processing of the problem as a whole and thus lead to an Aha! moment. In relation to our study this would suggest that if the image is processed as a whole (either consciously or unconsciously), instead of looking at individual splotches and trying to integrate them, there are greater chances of an Aha! moment.

We have proof from studies that Aha! moments do lead to jumps in the learning curve. Donald Hebb's theory that Aha! moments are an important mode of adult learning implies that we have to rethink our teaching methodology. For an Aha! moment to occur a proper problem space has to be formed in the brain, the constraints of the problem should lead to a fruitless struggle and only then, all of a sudden the answer *might* suddenly click.

If things take a good turn, its good news for kids and students, no more mugging up textbooks and no more finger crunching exams, education will be challenging with problem solving and Aha! moments.

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