

THE BOSTON GLOBE TUESDAY, DECEMBER 18, 2001

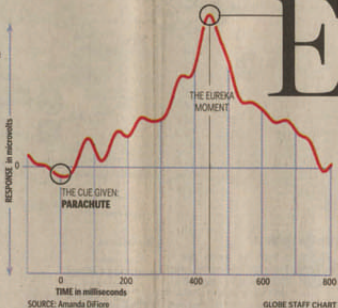
Now I get it

By measuring changes in electrical activity in the brain, researchers believe they have pinpointed the so-called "Eureka moment," the point in time a person understands a concept.

Subjects were shown a sentence, one word at a time, on a computer screen. On its own, the sentence seems nonsensical, but becomes clear when a cue word is presented.

THE SENTENCE GIVEN

The haystack was important because the cloth ripped



SOURCE: Amanda O'Flaherty

Eureka!

The thrill of discovery is the purest, least understood event in science. Now, studies of the brain are revealing the anatomy of a "Eureka moment."

By Gareth Cook
GLOBE STAFF

The story begins in utter confusion. Imagine reading a sentence that doesn't seem to make sense: "The girl spilled her popcorn because the lock broke." The mind starts casting about for answers: Who is the girl? Why would she have popcorn, and why would a lock make her drop it?

Then comes the clue — lion cage. Suddenly — aha! — the sentence snaps into focus. Such a moment of clarity may feel like a fleeting and mysterious experience, but now Tufts University scientists say they can measure it. Using sentences like the one above, they are finding that the "eureka moment" is marked by a distinct electrical pulse in the brain.

Their work suggests that eureka moments can be studied in the laboratory — and that they could be used to improve people's ability to learn and remember.

"The 'aha sentences' are a beautiful analogy to what happens when a scientist creates a new theory," said Sal Soraci, an associate professor at Tufts and one of the scientists involved. "Suddenly you look back and it all makes sense."

The eureka moment has a long and colorful history in human culture. The word eureka — "I have found it" — was supposedly uttered by Archimedes as he was gripped by a sudden realization in his bath. Such instantaneous flashes of insight have shaped history in profound ways, inspiring new scientific theories as well as lively artistic, philosophical and religious movements. Charles Darwin, for example, said the theory of evolution occurred to him in a sudden storm, while reading a book by Thomas Malthus on population.

Scientists working today tell of similar experiences, even if they do not understand its source. Daniel Dennett, a leading theorist on the nature of consciousness, said that when he is stuck on a problem, sometimes he will think about it a little before going out to do chores at his Maine farm.

"Very often, at some point, when I am going around and around the field, all of a sudden I have a breakthrough," said Dennett, who is the director of the center for cognitive studies at Tufts University.

But such eureka moments were long thought to be too ephemeral to study, except anecdotally, after the fact.

Now, work by Soraci and other scientists is revealing the anatomy of the eureka moment. Page C15



PHOTO BY LEONARDO DE SILVA, CORBIS

THE ORIGINAL "EUREKA MOMENT"

In the third century BC, the king of Syracuse suspected that a goldsmith had replaced some gold in his crown with silver. So he asked the great scientist, Archimedes, to find the truth without damaging the crown in any way. Archimedes was baffled, until he got into the bathtub one day and water flowed over the sides. Suddenly, Archimedes knew that he could determine whether the crown was gold by how much water it displaced compared to a gold block of the same weight. Since silver is lighter than gold, a silver crown of the same weight would have to be bulkier — raising the water level more. He jumped out of the bathtub and ran around the town yelling "Eureka!" which means, "I have found it!"

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Researchers can identify the eureka moment

EUREKA MOMENT
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tists indicates that the eureka moment can not only be detected electrically, but may itself hold important secrets, giving new insights into creativity, thinking and memory, and even suggesting better ways to teach. One of the secrets may be the intriguing notion that confusion is key to memory.

In 1979, Soraci and a group of other scientists found a way to start lifting the veil when they discovered what they called "the aha effect."

They gave subjects sentences and asked them to remember as many of the sentences as they could. In some cases, the sentences made sense. In others, they didn't make sense until a key word was given. (For example: "The home was small because the sun came out: Igloo.") The team found that the subjects were much more likely to remember information delivered in the form of aha sentences — sentences where the subjects experienced a period of confusion before suddenly being given a key.

A more recent paper showed the same effect with images. If an image is shown far out of focus, and slowly brought into focus, people have an aha moment when the blob becomes recognizable. Re-

Coming into focus

Researchers studying the "aha effect" say confusion is an essential component for a strong memory. In one test, subjects are shown a series of images in which a blurry image is slowly brought into focus. Because the subjects repeatedly guess at what the image is, they are more likely to remember the image than are people shown a clear image that is gradually blurred.



GLOBE STAFF GRAPHIC

gardless of their intelligence, people remembered these images much better than if the image started clear and was then moved out of focus, according to the paper by Soraci and collaborators in the July issue of the American Journal of Mental Retardation.

Soraci said that he now believes confusion is an essential part of remembering things. As the object comes into focus, he said, the brain generates a stream of guesses (Is it a doughnut? A peace symbol?) until the truth emerges (a clock). These wrong guesses may lay the foundation for a strong memory, he said. Other experiments conducted by Solaci, in which people have to generate words in response to clues, have

shown the same effect.

The work "reinforces the importance of letting people struggle with concepts a little bit first," said Dorothy Leonard, who has been following the research and is a professor of business administration at Harvard Business School. Harvard's MBA program has long used case studies where students are presented with a wealth of information, sometimes confusing and contradictory, without being told the lesson ahead of time. Solaci said educators should strive to design lessons that will give students aha moments. A lesson on evolution, for example, might start with some of the same clues Darwin saw — striking similarities between man and ape,

finches exquisitely attuned to their environments — before explaining his theory.

Harvard's Leonard said that the research was of particular interest to her as she designed new educational programs for executives. "The pressure is to provide answers, to provide frameworks, to provide lists," Leonard said. "But, if [Soraci's] research is correct, they will not remember them as long if you don't design in time to be confused and struggling."

Meanwhile, scientists say that another rapidly growing field of research is making them rethink the aha moment in other ways. One of the hallmarks of a eureka-type realization is its suddenness, but these moments may not be so

sudden after all.

James L. O'Keefe, a university professor of neuroscience at George Mason University, said every year brings more evidence of the many ways the brain works away on problems even when we are not consciously aware of it.

The classic example, O'Keefe said, is motor learning, where someone improves a golf stroke or tennis serve by practicing, but is not conscious of the lessons being learned. More recent work suggests the same is true with higher learning. For example, the basic task of recognizing an object — which seems sudden to the conscious mind — actually occurs gradually, said Moshe Bar, an assistant professor at Harvard Medi-

cal School who published the research in the journal *Neuron*.

Research like this hints that a eureka moment is not so much a quick mental leap as it is the final stage of a long, partly unconscious battle to understand.

In the most recent research on aha moments, scientists have measured a distinct pattern of brain activity that comes with the sudden insight, according to Amanda DeFlore, the lead scientist on the experiment, which has not been published. About 400 milliseconds after the key word is read, revealing the meaning of the sentence, electrodes on the scalp pick up a pulse, called an N400.

The N400 is well known to other researchers but, with aha moments, the pulse seems to be coming from a more-forward part of the brain, said DeFlore, who is an engineering psychologist at the Volpe National Transportation Systems Center in Cambridge and is finishing her dissertation, under Soraci, at Tufts University.

The next step, DeFlore said, would be to use more sophisticated brain-scanning equipment to discern where in the brain, precisely, the aha pulse originates. Eureka moments remain deeply mysterious, she said, but with this information, perhaps everything would start falling into place.