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LIS 880
Assignment #1

Knowledge – Can It Be Defined by Changes to the Brain?

The only source of knowledge is experience.

--Albert Einstein

There have been many attempts to define knowledge, information, and data; but one of the difficulties in defining these terms concurrently is that they are often used to define each other.[1] For example, information is often described as aggregated data; or knowledge is said to be information that resides in the brain's memory. However, many definitions concur that knowledge requires the brain to comprehend and process information. Other terms that have been used to define knowledge include: learning, experience, understanding, values, beliefs, insights, cognizance, and memory. Knowledge is "not made of physical substance, (it) is not able to be touched"; it is intangible.[2] Perhaps, then, we can examine its measureable effects on the brain to understand what it means. Could we say that knowledge only exists after physiological or neurological changes occur in the brain?

In 2000, the Nobel Prize in Physiology or Medicine was awarded to Eric R. Kandel, MD, for his discoveries "concerning signal transduction in the nervous system."[3] He and his colleagues demonstrated that specific biochemical brain changes occur during learning. It was found that memory, or stored knowledge, relies on modifications in the synaptic responses

[1] Anthony Liew, "Journal of Knowledge Management Practice," accessed September 20, 2014, http://www.tlainc.com/articl134.htm.

[2] "Intangible - Definition and More from the Free Merriam-Webster Dictionary," accessed September 28, 2014, http://www.merriam-webster.com/dictionary/intangible.

[3] "Eric R. Kandel," Text, *HHMI.org*, accessed September 21, 2014, https://www.hhmi.org/scientists/eric-r-kandel.

between neurons, and that long-term memory involves the synthesis of new proteins.[4] Eleven years later, Katherine Woollett and Eleanor Maguire published their study *Acquiring 'the Knowledge' of London's Layout Drives Structural Brain Changes* in which they examine the brains of London taxicab drivers over a period of four years as the men learned the complex system of streets known as "the Knowledge."[5] This writing will use relevant material from this study to provide context for typical definitions of data, information, and knowledge.

Data

Data "is." At its purest level, it simply indicates factual existence, but without context. Some definitions will describe data as unprocessed or unorganized information. To further clarify, we look at examples from the London Taxi drivers study. What is the data? The relevant facts (data) exist independently, and if the study had not taken place, the data would not be affected. Therefore, we could say that the data includes (but is not limited to) the facts of the roads, buildings, intersections, and landmarks, as well as the subjects, their brains, ages, education, IQs, and brain scans of the study participants.[6]

Information

Data can exist independently of information, but information and knowledge do not exist without the data. In order to undertake this study, data had to be aggregated, interpreted, and codified to become information. The scientists began by examining the driver trainees before their "the Knowledge" training to acquire the data that would be necessary to measure brain

[4] "Eric Kandel," *Wikipedia, the Free Encyclopedia*, September 16, 2014, accessed September 21, 2014, http://en.wikipedia.org/w/index.php?title=Eric_Kandel&oldid=625857594.

[5] Katherine Woollett and Eleanor A. Maguire, "Acquiring 'the Knowledge' of London's Layout Drives Structural Brain Changes," *Current Biology* 21, no. 24 (December 20, 2011): 2109–2114, accessed September 20, 2014, http://www.cell.com/article/S096098221101267X/abstract.

[6] Ibid.

changes. This data became information as the data was collected and codified. The driver trainees were required to memorize over 25,000 streets, places, hills, and over 20,000 geographical landmarks and places of public interest within a six-mile radius of Charing Cross train station. During this training process, they are studying the "Blue Book," the handbook that has codified the geographic data into information that must be learned by the taxi driver trainees.[7] Thus, we see that the data is organized and codified in maps, a study guide, and documentation of the study as the data accumulates. At the end of the study, the scientists again examined the study participants to obtain relevant data, and to codify it into published results. During the compilation of the study results, Woollett and Maguire acquired the knowledge necessary to understand their findings, and their publication provided information to be examined by other readers, resulting in their own newly acquired knowledge.

Knowledge

All information, such as thoughts, feelings, and sensations, received by the brain, result in neurological changes. When a neuron receives a signal (information), it passes this signal to another neuron by releasing chemical neurotransmitters into the space between neurons, called the synapse. Neurotransmitters attach to surrounding cells, causing chemical changes that allow the adjacent neurons to receive signals and to continue to transmit the information and encode it into knowledge. Different parts of the brain have different functions such as: executive functioning in the two frontal lobes, the parietal and temporal lobes process sensory information, and the cerebral cortex, often referred to as the "gray matter" where complex information processing also takes place. The cerebral cortex covers the surface of much of the brain, and is characterized by the folds occurring throughout. The hippocampus is located deep inside the

[7] "The Knowledge Taxi - London Knowledge," accessed September 21, 2014, http://www.theknowledgetaxi.co.uk/.

brain, serving as a memory indexer, and as an area of long-term storage that provides and retrieves memories to other parts of the brain as needed.[8]

Learning is the process by which information becomes knowledge. According to its Google definition, learning is "the acquisition of knowledge or skills through experience, study, or by being taught." It is what we know, in context with our experiences and beliefs, resulting in understanding, and only resides in the brain. It is this transition, where information becomes knowledge, that this London Taxi drivers study provides proof that learning, or information processing, results in physiological brain changes. The training process typically takes between two to four years to learn "the Knowledge" and to pass the required examinations. It is appropriately named, as during the training period, the driver must create understanding and familiarity within their brains by memorizing the equivalent of a Google map of thousands of streets and landmarks.. The information provided to them: the study materials, their practice routes and repetitions, their experiences, all combine to create "the Knowledge." In addition, the scientists who followed the trainees, monitored their progress, and measured their brain changes that occurred as the drivers completed training, also built a framework for new knowledge that resulted from the results of their experiment.

This landmark study found that the drivers who completed training and passed their tests had developed a larger hippocampus during this period. This increase in size suggests that this area of neurogenesis was a result of "acquiring the detailed spatial representation of London's layout."[9] In non-technical language, the accumulation of the knowledge required in order to pass the examinations necessary to become a London taxi cab driver is so intensive that it produces an

[8] "Brain Basics: Know Your Brain: National Institute of Neurological Disorders and Stroke (NINDS)," Text, accessed September 28, 2014, http://www.ninds.nih.gov/disorders/brain_basics/know_your_brain.htm.

[9] Woollett and Maguire, "Acquiring 'the Knowledge' of London's Layout Drives Structural Brain Changes."

easily measureable change in the size of the hippocampus. It is the measurable change in the brain, under a controlled and scientific study, that quantifies the effects of changing tangible information into intangible knowledge. We still cannot explicitly quantify the knowledge, however, but we *can* quantify how the process creates physical change.

Conclusion

As a result of their study, Woollett and Maguire concluded that the new knowledge obtained and processed by the drivers and the resulting increase in the size of the hippocampus indicate that learning creates changes in the structures of the brain.[10] This concurs with Kandel's findings that learning, or processing information into knowledge, produces measurable biochemical changes in the brain. Theodore Berger, neuroscientist at the University of Southern California, is currently researching a neural prosthesis to replace severe memory loss, and defines memory as:

> "…a series of electrical pulses over time that are generated by a given number of neurons. That's important because you can reduce it to this and put it back into a framework. Not only can you understand it in terms of the biological events that happened; that means that you can poke it, you can deal with it, you can put an electrode in there, and you can record something that matches your definition of a memory. You can find the 2,147 neurons that are part of this memory. And what do they generate? They generate this series of pulses."[11]

Dr. Cohen's definition of memory appears to define the abstract concept of memory as a purely biological process. In light of this and other scientific research not included here, if we say that information does not become knowledge until it is encoded in the brain, then we could also say that information becomes knowledge only when there are physical and neurological changes in the brain, even at the cellular level.

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[10] Ibid.

[11] Jon Cohen, "Brain Implants Could Help Alzheimer's and Others with Severe Memory Damage," *MIT Technology Review*, last modified April 23, 2013, accessed September 28, 2014, http://www.technologyreview.com/featuredstory/513681/memory-implants/.

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