

SCIENCE OF EMOTIONS AND THOUGHT

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The beneficial effects of positive thinking have been extolled by numerous proverbs, such as “Watch your thoughts, they become words. Watch your words, they become actions. Watch your actions, they become habits. Watch your habits, they become character. Watch your character, for it becomes your destiny.” We have often been told to have an optimistic outlook throughout our lives, and the notion of the power of thought has been ingrained in our minds ever since we were young. The function of the brain plays a key role in how thoughts are generated and habits are formed. Numerous scientists have tried to make sense of how consciousness is created by brain activity, and some have even explored how thoughts and the absence of thoughts (meditation) affect activity in the brain. Furthermore, repeated conscious acts can turn into habits due to the brain’s ability to slightly alter its physical structure.

The complex nature of consciousness and the power of thought in the physical world has raised questions in both the scientific and nonscientific worlds. A controversial documentary-style film, *What the bleep do we know?*, aimed at connecting the quantum mechanics to thought processes and bravely stated that our collective consciousness can directly change reality. In other words, our internal thoughts, whether positive or negative, have the power to alter actual events in the world outside, whether we physically intend to or not. While there is much controversy behind whether such a theory is factually correct, many researchers have tried to discover the physical mechanism of how such a phenomenon would occur. Though the film was targeted at the general audience, it discusses concepts such as “an alternate universe” and “the mystery of the direction of time”, raising many questions, without perhaps providing complete answers to all of them. Understanding the structure and function of the brain is essential in order to investigate the physical means by which thoughts may be able to affect our lives.

Research shows that electrical activity is present in the human brain before birth until after death. The electrical activity can be measured through the scalp using electrodes in a procedure known as encephalography (Tufts). A device called a polygraph displays the continuous changes in voltage over time. While EEG is normally used to

diagnose brain diseases and sleep disorders, it is also a crude indicator of the relative mental state of the patient, which can be noted by observing the amplitude and frequency distribution of the EEG. For example, while alpha waves are associated with a relaxed, but awake state, beta waves are associated with an alert and more active mental state (Tufts).

Since raw EEG data only provides general, non-specific information about one’s mental state it is difficult to study “moment-by-moment human cognitive activity [such as] reading, listening to music, or watching T.V.” (Tufts) using raw EEG data. However, event-related potentials (ERPs) can be obtained by selecting the part of the EEG during the exact time interval a specific activity is taking place or a stimulus is invoked and using signal processing techniques to eliminate non-event activity. Examples of various activities include listening to a specific musical note and viewing a picture or word. By zoning into a particular activity, the ERP differentiates itself from the background EEG, because it has a “more consistent morphological structure” (Tufts). However, since the amplitude of an ERP (1 -10 microvolts) is much smaller than the background EEG (10-100 microvolts) that comprises all brain activity, ERPs are hard to spot in the raw EEG data.

When an object is seen, for example, the information captured by the retina of the eye “is scattered and distributed throughout the network” (McFadden 2002) of neurons in the brain. While each neuron contains a modest piece of information, perhaps the alignment or color of a line comprising the image, there is no one single neuron that contains enough information to decode the entire image. How an entire image or object is perceived from separate areas of



Figure 1.
Electroencephalography (EEG) is a commonly used technique in study of the human brain.

the brain is known as the binding problem. According to neural identity theorists, the image is “some kind of emergent property of the entire network”(McFadden 2002). John Joe McFadden, a researcher from the School of Biomedical and Life Sciences in the University of Surrey, theorizes that in order to produce an entire image, all the miniscule details in each neuron are bound together in an electromagnetic field produced by the brain. An electromagnetic field, composed of an electric field and a magnetic field, is produced by moving charges. Theories of consciousness have stated that an extremely weak electromagnetic field is generated by the brain. McFadden speculates that such a field would influence the brain’s function via electromagnetic field sensitive voltage-gated ion channels located in the neuronal membranes (McFadden 2002).

The amplitude, phase, or frequency of the brain’s electromagnetic field is not always directly correlated with consciousness. Take, for example, MEG (magnetoencephalography) or EEG (electroencephalography) rhythms measured at the scalp. Magnetoencephalography measures the magnetic fields generated by neuronal activity of the brain (MIT), while electroencephalography measures the brain’s electrical activity. Consciousness comprises only a small percent of the EEG or MEG signals obtained from the scalp. Even though regular EEG signals have high amplitudes, they “contain very little information; they have nothing to say”(McFadden 2002). Yet, the main reason the brain’s electromagnetic field is able to penetrate brain tissue, and thus be detected on the scalp using electroencephalography is due to the fact that neurons fire in synchrony and thus amplify field effects (McFadden 2002). It seems as if our brain isn’t as

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enclosed from the outside world as had been previously thought. Thus, another question arises: if the brain’s electromagnetic field can penetrate the brain tissue, can external electromagnetic fields, such as those produced by electronics, enter and disrupt our brains? According to McFadden, “static and low frequency electric fields do not significantly penetrate the head... [while those with] high frequencies (MHz or GHz range) are unlikely to interact with low brain frequency waves”(McFadden 2002). Furthermore, radio and T.V. signals comprise of artificially generated electromagnetic fields that only contain the

specific encoded/ transmitted information, and thus do not play a role in consciousness. Low frequency magnetic fields do however interact with the brain’s electromagnetic field, leading to cognitive effects, such as changes in alpha, beta and delta activity in certain regions of the brain.

In McFadden’s conscious electromagnetic (cemi) field theory, “consciousness is the component of the brain’s electromagnetic field that is downloaded to motor neurons and is thereby capable of communicating its state to the outside world”(McFadden 2002). McFadden proposes three levels of awareness, in which consciousness is the third and final level. At the first level, information contained within particles of matter, such as electrons, protons, atoms, or molecules, is “always discrete, limited, static, and independent of context”(McFadden 2002). The information content, which can be characterized as a quantum wave function, does not change regardless of the location or surroundings. The second level of awareness includes the complex information encoded in fields which have unlimited capacity. However, while such fields may hold much information, such as that of faces, shapes, numbers, or words, the majority of this information is not transferred to neurons, and thus is not carried out by actions.

Unlike the first two levels of awareness, the third level of awareness, consciousness is able “to handle irreducibly complex concepts such as face, self, identity, words, meaning, shape, tool, or numbers, as holistic units”(McFadden 2002) and has the ability to affect our actions. Thus, consciousness has been secured by natural selection from generation to generation, while the majority of the information stored in fields has “no phenotype... [and is therefore]... invisible to natural selection, so evolution will not have contributed to their structure or dynamics”(McFadden 2002). The information from the brain’s electromagnetic field that is transmitted to motor neurons is used “either directly to drive actions such as speech or indirectly to lay down memories that may later be reported through motor actions such as speech”(McFadden 2002). It is these thoughts that comprise the final level of awareness, consciousness, that propagate outside the mind via spoken words and actions. What can neuroscience gain, then, from studying the brain activity of individuals who are trying to do exactly the opposite: reducing their thoughts? The goal of meditation is to be absent of thoughts, and as one study describes it, “the development of new states of consciousness”(Fell, Axmacher, and Haupt 2010); can this be detected on an EEG?

A recent study conducted at the University

of Bonn on meditation-related states of consciousness found that as people progress in the practice of meditation, changes in the brain activity occur in a similar fashion. Instead of focusing on a particular type of meditation, the study defined meditation from a general perspective of “various practices aiming to alter the state of consciousness”(Fell, Axmacher, and Haupt 2010) and observed general effects in EEG experiments. Due to differing expenditures of time and energy during meditation practice, results showed great variability between individuals, but the general pattern remained the same. Beginner meditators usually had a harder time focusing their easily perturbed attention. The neurophysiological changes observed at this stage were not distinct to meditation alone and could be seen in

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certain non-meditators as well. An increase in internal attention generated alpha oscillations, and the first basic changes seen in the EEG of meditators were the “slowing of the alpha rhythm (8-12 Hz) in combination with an increase in the alpha power”(Fell, Axmacher, and Haupt 2010). According to EEG biofeedback research, “alpha activity is the brain rhythm that can be most easily controlled. Subjects can be trained to either produce or suppress alpha activity”(Fell, Axmacher, and Haupt 2010).

As an individual advances by repetitive meditation practices, the individual is able to remain in the meditative state for a longer time span, passively observing any thoughts that come up, rather than allowing those thoughts to incite a train of more thoughts. An increase in theta activity (3-8 Hz) has also been observed in meditators. Although theta activity is also generated by drowsiness and sleepiness, “subjects showed ongoing theta activity even after meditation when they had already opened their eyes and were alert”(Fell, Axmacher, and Haupt 2010, 221). Finally, the most advanced stage of meditation elicits peak experiences that simply cannot be described by words alone, but results in “permanent changes of individual properties and alterations of states of consciousness lasting outside meditation practice”(Fell, Axmacher, and Haupt 2010). Individuals who had been practicing meditation for many years exhibited the largest increases of gamma band amplitudes, typically in the 40 Hz range and above.

While meditation focuses on the suppression of

thoughts entirely, research is also being conducted on the effects of positive and negative stimuli as measured through the EEG. Words with different connotations are processed differently in the brain, and electrophysiological methods, such as event-related potentials (ERPs), can determine “separate processing of different features of a stimulus, such as the positive or negative connotation of a word, when these features are processed at different times”(Watson et al. 2007). During the study, less positive amplitude was observed for negative compared to positive word stimuli (Watson et al. 2007). The majority of the individuals attributed “positive traits or outcomes to internal, stable, and global personal characteristics whereas negative traits or outcomes are identified as unrelated to personal characteristics”(Watson et al. 2007). It has also been found that negative words significantly reduced activation in the left and right insula and temporal, occipital, and inferior parietal regions (Watson et al. 2007).

Information, whether it is about one’s internal state or external environment, is passed from one neuron to another by nerve impulses. Neurons consist of a cell body, an axon that propagates signals away from the body, and numerous dendrites that transmit information to other neurons. The signal is propagated electrically by the means of an action potential along the axon and chemically via neurotransmitters across a gap between two neurons, called a synapse. In McFadden’s theory, neurons located along areas of comparable electrical potential will be insensitive to the weak electromagnetic field, and those neurons that span varying electrical potentials will be most sensitive to the field (McFadden 2002). It is important to note that an action potential only occurs if a certain electrical threshold is reached. In vitro experiments have shown that the opening of a single ion channel can produce an action potential. Thus, a few quanta of energy can determine whether or not an action potential is generated. When only a small number of neurons fire, a weak field that is not associated with any conscious state, is generated. In-phase field fluctuations generate a stronger field that leads to synchronous neuronal firing if the action is to be reinforced (positive impact). Negative impacts, on the other hand, veto the action. This effect is very similar to the constructive interference observed when two or more waves reinforce each other, producing greater amplitudes than each component wave.

Synaptic plasticity allows our brains to constantly rearrange neural pathways as repeated experiences reinforce certain connections between synapses and the lack of such repeated experiences weakens the neural association. At the age of two to three years old, the number of synapses per neuron in the human brain

increases from approximately 2,500 to 15,000 (Hoiland) When communication between a synaptic cleft decreases below a certain level, that synapse ceases to exist and neurons can die through apoptosis in a processes known as synaptic pruning. Thus, if one always thinks negatively and cries often, connections between neurons responsible for those actions will strengthen, while the neurons related to satisfaction or pleasure would deteriorate over time. Depending on the intensity and the duration, the individual may spiral into a deeper depression.

Long-term potentiation (LTP) and long-term depression (LTD) are the names given to the processes in which the synapses between two neurons are strengthened or weakened, respectively. While a single high frequency stimulus can prompt the induction phase in LTP, which lasts for about an hour, a series of such stimuli are needed to maintain the association



Figure 2. A neuron transmits information between the body and the brain through synapses.

for a longer time period (from days to weeks) and synthesize proteins that assist new synapses to form. The opposite of long-term potentiation, long-term depression (LTD) affects presynaptic neurons that are active at low frequencies (1 to 5 Hz), by returning synapses that have previously undergone LTP back to normal and enabling them to store new information. Thus, new experiences and repetitive thoughts or actions are constantly “rewiring” the brain, minutely changing its structure so that we can adapt to new changes throughout our lives. When you encounter an obstacle, the way you overcome it is more important than the mere fact that you have overcome it. Your brain will behave differently if the process was grudgingly painful rather than smooth and effortless. Depending on the frequency and intensity, your thoughts and experiences truly have the power to change you. Thus, it is not your destination that matters, but rather

your attitude and how you cope with the difficulties of getting there.

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