The Chemistry of Thought

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This essay outlines some general issues and introduces some specific considerations relevant to the scientific understanding of the mind and brain. It is intended to elevate critical issues with regard to the current state of this understanding, and to define some simple concepts that may help to move this understanding forward. This work is based on a synthesis of ideas derived from neuroscience and psychophysiology, combined with a novel approach to the understanding of the electroencephalogram (EEG). These ideas are presented in a very basic form, and should lead to specific approaches to the measurement and analysis of brain processes as revealed by the EEG. It should also lead to the development and improvement of methods for the diagnosis and treatment of mental conditions using EEG and neurofeedback, in conjunction with various forms of sensory stimulation.

What is needed is a scientific development that accomplishes for the mind what chemistry has done for the physical world. That is, a science that includes simple, terse models for the underpinnings of thought, and that can be used to derive the experiences of thought, both behavioral and introspective. The field that we call Psychology barely approaches this goal. It has a moderate ability to connect with our understanding of the physical brain, but it lacks rigorous and complete models that are based on neurophysiological principles. While we have the beginnings of some of this science, we do not have anything near what has been achieved in the physical sciences. There is little agreement on anything approaching a cohesive model of the substrates of conscious thought. The clinical effectiveness of conventional methods in psychology and psychiatry border on chance, further indicating that this field is still in the stage of being alchemy rather than science. In particular, our ability to apply EEG recordings and methods to the study and development of the mind is in its infancy.

Nonetheless, recent progress using neurofeedback to treat conditions such as ADD, depression, autism, and other disorders, indicates that there is significant promise in this area. We have demonstrated the fundamental possibility of affecting the structure and function of the brain using biofeedback techniques, and even simple methods may be as effective as medication in treating a wide range of conditions. This underscores the remarkable plasticity of the brain, and its ability to learn. We may anticipate further conceptual breakthroughs in the near future that could revolutionize both our understanding and our ability to address the issues of the mind and brain in a constructive manner. It is hoped that this will help to sweep away much of the imprecision, bias, and parochialism that currently dominate theoretical and clinical approaches to the mind.

Whereas we are very good at describing the world around us, we are very poor at describing the world of our thoughts. Tibetan Buddhists are perhaps the masters of this. Nonetheless, we should look to create a vocabulary and set of paradigms that penetrates the layers beneath what we commonly think of as thought. To extend the analogy with the physical world, we have had our "biology of thought" defined. Freud, Jung, James, and others have been our Lamarke, Darwin, Linneaus, and Mendel. What we need now are the Pauling, the Watson and Crick, and the Krebs to take us the next level down. We know what the "organisms" of thought are. They are the ideas, thoughts, impressions, perceptions, opinions, moods, and other major entities that are the realm of psychology. What we know of them we know from behavioral studies, and a first level of introspection. What they are comprised of, we do not know. That is what we are looking for. What are the "organs" and "molecules" of thought? How does the brain produce them? What is their "molecular biology"? From the work of Damasio, Calvin, Crick, Freeman, Edelman,

and others, we have some rudimentary, basic concepts about brain dynamics relative to thought. We know that the brain contains neural subsystems that receive trains of stimulation, and that reverberate in a complex way, in accordance with the laws of nonlinear chaos, to achieve states and state transitions that lead to recognition, memory, and other primitive processes.

What we would like to do is to find a connection with the EEG signal in a way that explains what we know about EEG dynamics in connection with moods, states of mind, and behavior. This connection should also have bearing on the observed effects of light and sound stimulation, which can cause a variety of affective states, depending on the frequency and structure of the stimulation. Our basic model is this: The response of a given cortical sub-circuit to an incoming burst of stimulation (whether from the outside world or from a lower brain center) produces what we will call (for now) a "process burst". This burst is a short (250-300 millisecond) pattern of reverberation that is determined by the resonant properties of the sub-circuit. Although we only see a simple burst of EEG activity, we know that there is a complex pattern of information processing underlying the burst. It is the underlying processing that we wish to understand. It is as if we have a scale, a thermometer, and a barometer, and we wish to begin to develop the science of chemistry. Instead, we have an EEG instrument, some lights, sounds, and the introspective and behavioral reports from our subject.

THE BRAIN TAKES IN EXPERIENCE IN CHUNKS. WE CALL THEM "PROCESS BURSTS". CHUNKS COME IN RAW, COOKED, AND STALE.

The "process burst" takes in the "experience" that feeds it, and it has a life of its own. It is initially "raw", being only aware that something has happened. Shortly later, it "ripens", and contains information regarding the details of the input. Still later, it relaxes, and "chews on" the data, and reaches a stable plateau of "understanding". Still later, it introspects, ponders the information, produces intuitive and deeper interpretation. Finally, it dies away. The "process burst" is like a bubble that starts out small, grows, pauses, grows some more, and finally disappears either by bursting or by collapsing. These bursts occur in parallel. There may be thousands of them at once, in different parts of the brain, processing different types of information, different modalities, different views. They are also coordinated by cross-communication with each other, using combinations of feedback, feed-forward, and collateral connections. This provides the spatio-temporal binding that fuses thousands of responses into the cohesive experiences that we interpret as perception, conscious awareness, and the sense of identity.

CHUNKS OF REALITY CAN BE HOMEMADE OR CAN COME OUT OF A BOX.

Amidst the cacophony of signals recorded in the EEG, we can see these bursts coming and going. The key to the brain's function is in processing these bursts in trains, one after another. The intrinsic EEG is built of these bursts as produced by lower brain centers creating rhythms via the reticular formation, ascending brain tracts, and thalamus, as well as intracortical reverberatory activity. The EEG waves produced by light and sound stimulation are of course temporally and causally related to the incoming trains of stimulation. In fact, these bursts are in this case what we call "evoked potentials", and that have been studied for many years, albeit with limited insight and few conceptual breakthroughs. The common ground in both is that process bursts are produced at a certain rate. When a neural sub-circuit in mid-burst is hit with another incoming stimulus, the burst that is in progress is interrupted, and the sub-circuit now begins processing, using the state that was produced by the preceding burst. This is why the rate at which the bursts are produced is important. We can think of the next stimulus as "opening" or "cracking" the existing burst. It "probes" the neural sub-circuit by stimulating it when it is in the state produced by the previous burst. This state can be the state of being in a "raw" burst, a "cooked" burst, a "stale" burst or, if long enough, no burst. These bursts are the "chunks" of experience that the brain uses to create reality. By

using these bursts as stepping stones on a vast pool of possible thoughts, the brain navigates its way on the sea of mind, and thus goes where it will go, based on the progress from one stone to the next.

YOU FEED ON THE CHUNKS OF REALITY THAT YOU CREATE.

If bursts are produced at a certain rate, then the progress of brain states will take a certain path. For example, if the bursts are processed at the "alpha" rate, 10 per second, then successive bursts are produced while the sub-circuits are in a relaxed state, hence each burst finds itself built upon a relaxed sub-circuit. The relaxed state of the brain is thus created and reinforced. This also explains why 10 Hz stimulation is relaxing. It in essence "puts" the brain from stone to stone, as though the brain were a marionette on strings, and were being walked along by guidance. Now if the bursts are produced at a very slow rate, say 5 per second, then each new burst is built upon a sub-circuit that is in a deeper, introspective state. This can lead to an intuitive state of mind, but it can also lead to a distracted, understimulated one. This is why kids with ADD typically show a lot of theta waves. Their brains are processing bursts at a slow rate, and the resulting brain state is in accordance with that. If the bursts are produced at a rapid rate, say 15 per second, each stimulus finds the neural substrate in a stimulated, alert state. It is aware of its input, but has not had a lot of time to ponder it, relax, or find the deeper meaning. Kids with ADD typically have a low level of beta, so they do not have enough of this going on.

L/S STIMULATION PRIMES THE PUMP, GIVING YOU A TASTE OF ANOTHER REALITY

What happens with photic stimulation is that you give the brain practice with creating and "opening up" the bursts at a given rate. It is like training wheels, or pushing a child along on his bicycle. The brain gets to experience it. It is spoon feeding the cortex with the experience of processing information in a certain way, without the brain having to produce the rhythms on its own. This also explains why external stimulation can produce a temporary effect, but generally little or learning. The cortex gets to experience the state produced by the burst processing, but it has not learned how to keep that state going. It has not learned to produce the rhythm on its own. Light/sound stimulation can be fun, invigorating, deepening, tiring, or even agitating. What it is doing is force-feeding your cortex with bursts, and then forcing you to process the trains at a given rate. You get to practice processing information at a certain pace, but you have not learned to pace yourself using internal mechanisms. This is why auditory or visual stimulation cannot replace EEG neurofeedback. EEG neurofeedback rewards the brain for producing (or not producing) a given rhythm. It rewards the brain for producing (or inhibiting) the driving stimulation at the desired rate. This is in addition to allowing the brain to learn the experience of processing the bursts at the given rate.

Ultimately, these bursts are taken in a very long sequence. After thousands and thousands of such stepping stones, the brain learns to find its steady-state points. These points may be locations of alertness, focus, distractedness, agitation, depression, joy, whatever. The brain tends to recover and find its equilibrium, which is presumably some state of rest or relaxation. But processing information and "lifting" itself out of the equilibrium point, the brain uses energy to reach a more excited state. This is what the bursts do. They "push" the brain into a higher state. Where that state is, and what its attributes are, depend on the trajectories of the processing of each burst. It is hoped that these considerations may motivate methods that combine auditory and visual stimulation with EEG, to produce useful and objectively designed protocols for training the individual.