Learning and Memory Series

106

7 EMOTIONAL TRIGGERS FOR LEARNING

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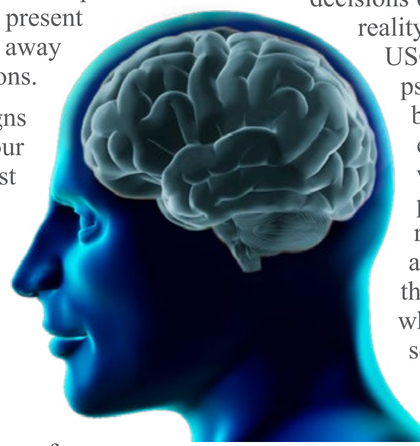
CONTENTS

In the real world, Mr. Spock from Star Trek would be paralyzed without the guiding power of emotion. The countless moment-to-moment decisions we take for granted would be impossible for him to resolve. Paralysis would result.

This paper is concerned with emotion and its pervasive, but unappreciated influence on life, learning, and memory. Emotion is the second of three canvases upon which one can paint a full portrait of the psychological self. This mental trilogy has an ancient Greek heritage and its modern scientific interpretation can be conceived thusly:

- Cognition (thinking) allows us to focus on information and circumstances so that we can then decide among possible courses of action. Cognition creates and draws upon forms of memory that operate in the present moment and also on forms that are stored away in conscious and unconscious brain regions.
- Emotion is a mental process that assigns value to our perceptions. It influences our thinking and behavior far more than most people realize.
- Motivation concerns how we order the drives, goals, and incentives that propel us to engage in one activity and vigorously avoid another.



Emotion

Without emotion we would be lost in a sea of conflicting values, bereft of any rational way to quickly decide on a course of action. Emotion, in this view, is the human trait that computes the value of incoming sensory information. Let the profundity of that deceivingly simple notion wash over you for a while. Emotion determines value.

In this view, emotion is constantly updating and influencing decision making processes. Modern theorists have become convinced that a character like Star Trek's consistently logical Mr. Spock would be at a serious disadvantage in a universe based on physical action and decision making. Without emotion, Spock would be forced to rationally compute the factors that influence the probable outcome of every trivial undertaking. How would he ever decide on a plan of action regarding the most basic or the most serious decisions in life? Should I go out to dinner tonight? Is it wise to do business with Mr. Jones? Is a career with Starfleet something I should pursue? Only feeling can guide those decisions.

The permutations of possible futures is utterly non-computable because their number grows exponentially. Very quickly, there are more possibilities during a walk to McDonalds than there are atoms in the universe. Hence, emotion and the "gut instinct" of heuristic decisions guide many, if not most, of our decisions. The big ones, like a career choice, surely need cognitive processes brought to bear. Still, think of the people you know who followed a rational process into a career rather than letting their "heart" inform some of the selection process. Some very unhappy outcomes flow from putting exclusive weight on reason while ignoring emotion.

Emotion is your guide

Most of us labor under the illusion that our lives are controlled by rational thought. This illusion is promulgated by two phenomenon. First, we live in a culture that prides itself on reason, logic, science, and engineering. True enough, rationality is, in fact, a simply huge underpinning for the modern world and humanity is, so far, the highest expression of cognition and reason. But, like Spock, we would be paralyzed with deductive and inferential calculations if we lost the ability to be guided by emotions that form in the brain. Culturally, that's been a difficult notion to bear.

Second, it's just a fact that it seems like we make rational decisions out of our moment to moment awareness of reality passing by. According to Joseph Damasio at USC, this is an illusion. Like the great American psychologist, William James, Damasio believes that the brain generates unconscious emotions which put the body into a state whereby we "feel" in order to consciously perceive the originating emotion. This is non-intuitive. Defying our notions of cause and effect, Damasio and others contend that emotion leads to sensations in the body, which lead to the mental perception of those sensations, which finally cause a feeling.

Ironically, science, that most rational of human endeavors, is now informing our understanding of emotion's power in life and in leaning. For a good portion of the 20th century, psychologists ignored emotion, except to the extent that feelings like guilt and embarrassment could be explained through Freudian interpretation, unconscious motivations, and dreams. The modern view argues that human beings are evolved social creatures and the source of many human emotions can be found in the pressures and forces of our ancestral environment. Contemplate our ancient circumstance for a moment: Humans are puny, clawless, fangless, plodding weaklings compared to the swift and scary creatures of the African savanna. Cooperation was the strategy that allowed us to survive then and to dominate the planet now. In this conception, emotions like guilt, embarrassment, envy, pride, friendship, and solidarity are universal features of all cultures in the world because they solved the life or death problems of our ancestors in deep time.

The range of emotion

Guilt and embarrassment are considered secondary emotions. For delving into emotion's sway over learning, let's turn to the primary emotions which are produced from a mixture of only two variables: *valence* and *activation*. The terms are really not so intimidating. Valence is merely whether the emotion is positive or negative. "Contented" has positive valence, while "sad" has negative valence. Activation refers to the state of arousal. "Elated" is an aroused state and "contented," while still quite pleasant, is less so. Below is an illustration of how they lay out in the *circumplex map of emotion*.

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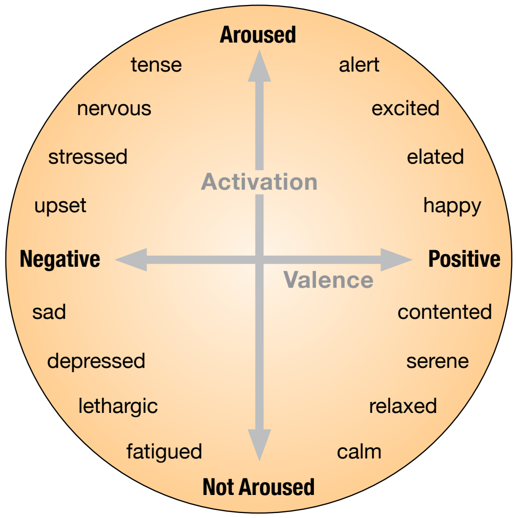


The circumplex map of complex emotions. Valence indicates how positive or negative. Activation indicates a person's arousal level.

The classic primary emotions such as angry, sad, and happy are here and we can also see how other feelings and moods like lethargic and excited are related to them through valence and activation. As most people know, its possible to feel two of these emotions simultaneously. For example, graduating from college is a bittersweet emotional moment because a student is happy about the academic accomplishment, yet also sad about leaving close friends.

We'll see that the brain generates emotion from independent circuits that interact to give us the complex feelings that all normal people experience. In reference to learning, we'll focus on three—the amygdala, the prefrontal cortex, and the hippocampus.

Let's first turn to emotion's role in learning and memory by considering both debilitating long-term memory and the emotional forces that undermine learning—two aspects of the dark side.

Extreme (and unfortunate) learning

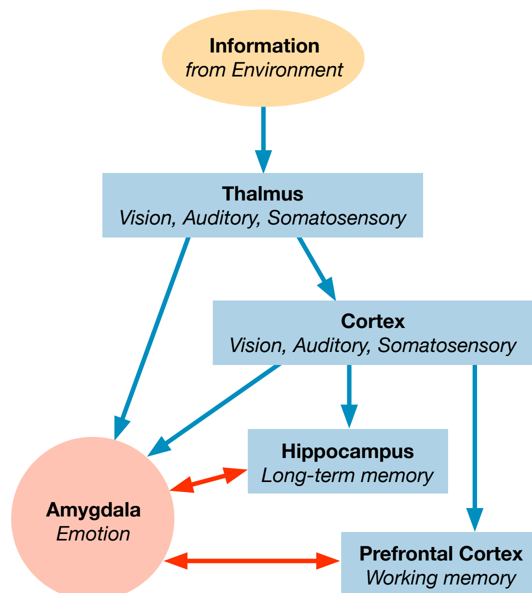
Emotion's power over learning is perhaps best demonstrated by considering the serious problem of post traumatic stress disorder and the extreme memory it produces. PTSD is a form of learning that produces memories that can't be turned off with conscious effort. The condition follows intense anxiety, violence, or bloodshed; emotional states of extreme arousal and negative valence as shown on the circumplex.

At this most extreme level, emotion encodes memory at such great strength that recall is ongoing and forgetting is impossible. The circuit that mediates this particular emotion is the amygdala and it is conspicuously attached to two vital areas of memory—the hippocampus (the structure responsible for long-term memory) and the prefrontal cortex (responsible for working memory).

Amygdala

The amygdala is one of the most studied brain circuits for two reasons. It mediates aspects of both sexual attraction and fear responses. These are among the most powerful emotions guiding behavior in all creatures (including us). Consequently, the amygdala can be tested using laboratory animals who express fear in easily observed ways.

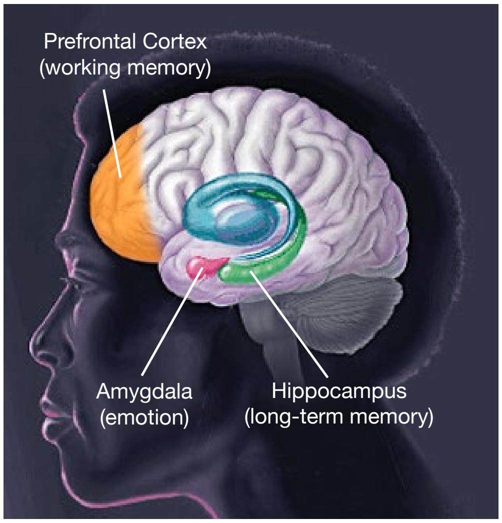
As shown in the illustration below—the amygdala is connected to many other brain circuits. The thalmus, which is the first location in the brain to process incoming sensory inputs, is directly connected. It sends information to the amygdala before your conscious awareness has been notified. This design feature allows creatures with this kind of circuitry to respond quickly to danger. In fact, they begin a behavioral response before they are aware of what they are responding to.



The array of Information inputs into the Amygdala and feedback to working memory.

The two connections in red show the amygdala's communication pathways with the prefrontal cortex (the seat of working memory and consciousness) and with the hippocampus (the seat of long-term memory). This is how you consciously experience what the feeling is about—the event that causes fear is also being experienced in working memory.

Emotional circuits are physically deep in the brain and more primitive than cortical circuits. In cases like fear, they have been conserved through evolutionary time for hundreds of millions of years. We see them clearly in all our animal relatives and for good reason—it's a jungle out there and nearly every living thing competes with or is eaten by other creatures. Remember, emotion is the way that organisms rapidly assign value to the incoming stimulus. Thus, the four F's of animal behavior—fight, flight, food, and sexual relations—display the emotional hallmarks of ancient selective pressure.



The amygdala in close proximity to the hippocampus. Prefrontal cortex is also connected.

The amygdala circuitry is an adaptive structure. That is, the behavior that follows was designed to deal with circumstances in the evolutionary environment to aid in survival. But, in other cases, the association between working memory and the amygdala becomes maladaptive. A strong emotional experience couples the emotion with the circumstances of the event and creates a self-perpetuating loop that grows stronger with every initiation of the sequence. When this happens, the next time working memory perceives a similar stimulus, an inappropriate amount of fear is produced. Anxiety disorders and PTSD almost always involve the amygdala in this way. A soldier who experienced a terrifying event in the outdoors may have difficulty in the future just leaving the house.

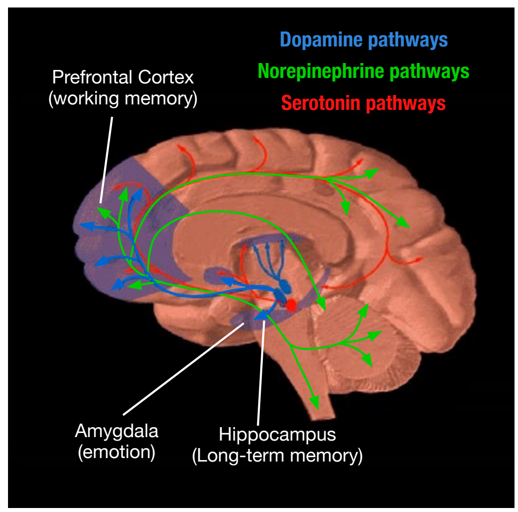
When we consider triggers for learning, the hormones that are involved in strong emotions like fear create the high states of arousal (activation) that we noticed on the circumplex map of emotion. The trick for effective learning is creating activation with positive valence. Fear is activation with negative valence. Let's turn briefly to considering the molecules that control arousal, attention, and focus—the emotional states necessary for learning semantic information.

Three neurotransmitters

Recall that emotional states (affect) can be located on the circumplex map with just the two factors of activation (arousal) and valence (positive or negative). Three neurotransmitters appear to be greatly responsible for the positive activation and negative activation components of the map. (By the way, neurotransmitters are called hormones when they are found in the bloodstream.) Norepinephrine (related to adrenaline) controls the kind of arousal that is associated with fight, flight, and fear. These are unpleasant, negative emotions. Dopamine, on the other hand, is associated with reward, anticipation, and positive activation on the emotional map.

> *"Neurochemical evidence supports the idea that positive and negative affect are independent, suggesting that positive activation sates are associated with an increase in dopamine and negative activation states are associated with an increase in norepinephrine."* *—Gazzaniga, et al, Psychological Science, 2010*

Below we can see the pathways of dopamine, norepinephrine, and serotonin. Serotonin has a large effect on emotion. It is associated with impulse control and dreaming and low levels cause sad, anxious moods. Notice that all three neurotransmitters are hitched up to the hippocampus, the amygdala, and the prefrontal cortex. These molecules have the capacity to profoundly affect a person's emotional state.

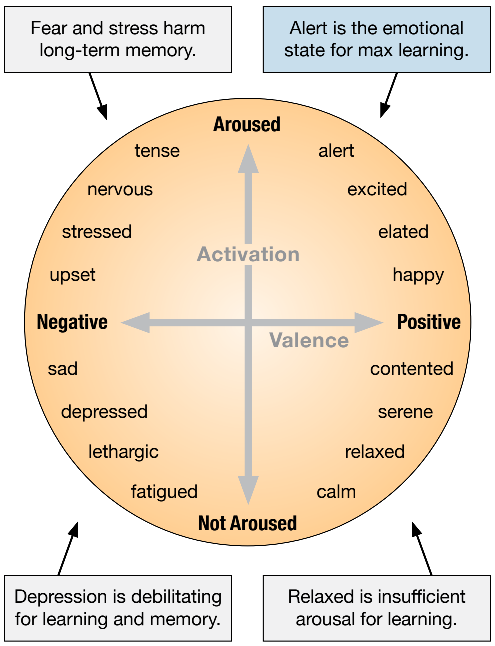


Dopamine production sites and pathways.

Now we can relate the action of these emotion inducing molecules back to the circumplex map. Low serotonin levels are implicated in the negative / low activation section of the quadrant (lower left). Here we find folks who are sad, depressed, and fatigued. Drugs like Prozac attempt to block the re-uptake pumps located in the synaptic cleft between connected neurons. Leaning is nearly impossible in this unfortunate state of mind.

Norepinephrine is responsible for high activation and arousal, but valence is negative and feelings here are unpleasant. They are necessary, though, when fight or flight responses are called for. If stress levels remain elevated for long periods of time, many bodily organs are damaged including long-term memory in the hippocampus.

Dopamine has a major role in the conditions that are most apt to foster learning and strong memory. Its role in reward and anticipation is double-edged because it plays a leading role in some of the most beneficial human traits like curiosity, but the same neural pathways are also utilized in drug addiction. We'll take a closer look at dopamine in the paper on motivation.

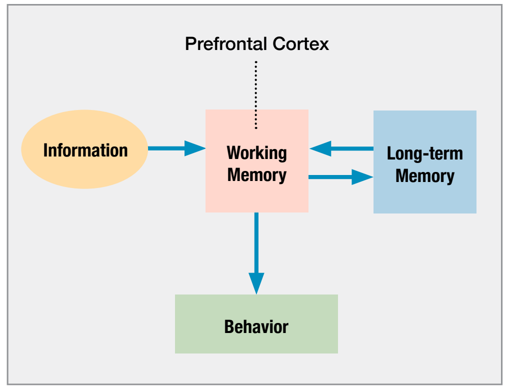


High activation levels are the emotional states that promote learning.

Consciousness & salience

If the amygdala is the source of ancient primal emotions, then the prefrontal cortex is its more civilized cousin, recently arrived on the scene. As we know from the paper on cognition, the PFC is the source of working memory, a major component of learning. Decades of research also show that it is implicated in emotion, and the emotional state that we are concerned with here is attention—the way we focus the spotlight of consciousness onto different stimuli in the environment.

Think about the difference between the words *look* and *see* versus *listen* and *hear*. See and hear are passive, but look and listen are active actions that call for the brain to switch on the attentional capabilities of working memory. The neuroscientist, Michael Posner, calls the pre-frontal cortex the "frontal lobe attentional network." It focuses attention using massive inputs from other parts of the brain so that critical behaviors can be executed in real time.



Information flow into working memory (the prefrontal cortex).

Cognition and consciousness are not quite the same but they are certainly related. You might be consciously focused on reading a book about Bolivia or talking with a friend, but parts of the brain are constantly attending to information about your physical surroundings—the pressure of the chair on your skin, the sound of traffic outside, the voices in the hallway. If someone quietly utters your name, attention is quickly shifted. Even though you were unaware that you were listening to all that background noise, your brain was processing the information below conscious awareness.

One way to think about consciousness is to consider it synonymous with working memory—the informational aspects of the world on which you focus your attention. The brain's lower level processors handle the information stream coming in from the senses and they may detect items that call for a shift in conscious attention at any moment. Consciousness, in this case, is directed by bottom-up salience—the kind of attention that shifts the executive to the new information. So, despite the lively conversation you are having with a friend, if someone mentions your name, the executive quickly moves attention to the salient stimulus. Your name is salience producing from the bottom-up. The PFC is alerted and shifts consciousness away from the previous task.

Emotional triggers that switch on learning

For any learning system to be effective, it must harness emotion. Leading psychologists like Joseph LeDoux and Antonio Damasio believe that emotion is the way a brain assigns value to the incoming stimulus. From that profoundly important notion, we can see why emotion is one of the three pillars holding up the edifice of self. It is a strong guide to behavior and learners today need all the emotional help they can get to find reasons to study. The Amplifire platform is designed to induce the emotions on the circumplex map of emotions that are most advantageous to learning.

"I really like this new Amplifire software. I have noticed that I learn more on this then reading the textbook. I believe the information really sticks in your head because it asks you the questions you got wrong or unsure about until you get them right."
—College student

In the category of emotion, the triggers that switch on learning and strengthen memory are:

- Assessment, which causes moderate amounts of arousal and attention via activating hormones that are conducive to learning.
- Confidence—a state in which consider our "feelings of knowing," the emotion with which we perceive our relationship with information.
- Honesty produces positive valence the low-stress mental state that helps create a context for leaning.
- Optimism for positive valence
- Reward for emotional activation (arousal).
- Risk for emotional activation.
- Uncertainty for activation and curiosity (mediated by dopamine, which plays the leading role in motivation).
- Feelings of Knowing—the emotions with which we perceive our relationship with information.

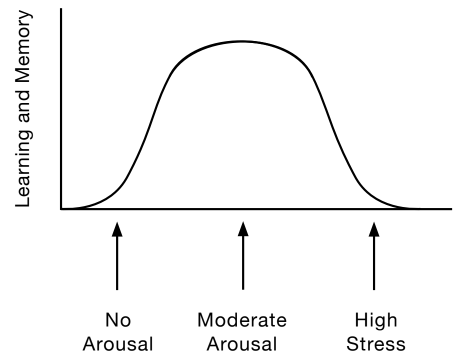
Moderate Activation (arousal)

As we have seen in our discussion of the amygdala, a highly stressful event is seared into memory. At the molecular level, when a person is under stress, the glucocorticoids, epinephrine (formerly known as adrenaline), norepinephrine and cortisol are released into the bloodstream under orders from the amygdala. These compounds activate arousal (the adrenaline rush) but are also implicated in the emotional brain state that creates anxiety in the body and the memory of anxious events in the amygdala. Under their influence, neural patterns in the amygdala are strengthened.

Under high stress, the opposite effect occurs in the hippocampus, the region that stores semantic memory—the facts, places, faces, and concepts about the world that we associate with education. In this case, the released cortisol binds to receptors in hippocampal neurons and precludes the formation of semantic memory. This is very bad news for anyone under stress who attempts to learn new semantic information. But, it's a bit more complicated. Moderate arousal, unlike high stress, actually boosts semantic memory formation.

Important research from Robert Sapolsky and others indicates that low levels of arousal strengthen neural connection in the hippocampus. High levels of stress like those produced by norepinephrine preclude those connections from forming, and, in some cases actually degrade them. The kind of learning and memory that we are concerned with in an educational setting is highly dependent on just the right kind and correct level of emotional activation.

The effect of arousal on the brain's ability to learn is an inverse-U phenomenon, as seen in the graph below. Low levels of arousal lead to very little learning, while moderate arousal optimizes learning, and high stress levels degrade memory and learning.To be effective, a learning platform must find methods for insuring that learners are in this middle zone.



Inverse U: Moderate arousal is the best activation level for learning.

Attention

"The image of an object or event is capable of revival, and of complete revival, in proportion to the degree of attention with which we have considered the object or event" —William James

It's common knowledge that paying attention is an essential element of learning and, indeed, every psychological experiment performed on this mental ability has highlighted that point. Two distinctions are important, however. As we noted earlier, one kind of attention is produced by top-down executive processes that normally functioning people employ at will. This is one of the responsibilities of working memory. For example, you deliberately decide what activity to attend to—the television, your email, or a conversation. In these cases, you purposefully direct the spotlight of your consciousness towards a sensory stimulus. You are in charge. Working memory will automatically integrate the information coming in through the senses with information pulled from long-term memory and combine those in the pre-frontal cortex.

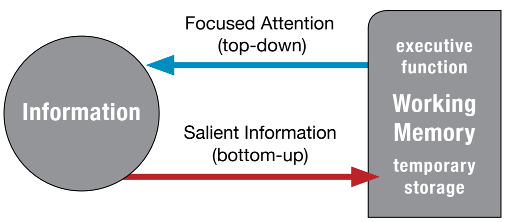
As we have seen, the other kind of attention is unconscious. It emerges bottom-up through circuits that force your attention to a certain aspect of the environment. These stimuli impose themselves on the mind by their unexpected nature—their salience. Salient things force their way into consciousness.

Executive attention can't help but shift from its current preoccupation to re-focus instead on the salient item.

> *"Remember to pay attention or, pay attention to remember." —Anonymous*

It is easy to imagine the evolutionary roots of this two-part attentional system. A successful creature needs to consciously direct itself to places that experience has shown might have plentiful food, or reproductive opportunity, or is particularly safe. This mental executive gives organisms their volition. On the other hand, if something unexpected appears, salience activating circuits focus the attention sharply and conscious control is forsaken. Volition is pushed aside and other mechanisms take charge.

Since the brain is designed to predict what is likely coming next, salience can be thought of as a prediction violation, "I didn't expect that, and now I'm focused on it." It can be as simple as the cat walking into your room while you are attending to drafting a paper. The brain's continuous prediction of a desk, a lamp, and a quiet office has been broken. Attention is brought to this salient furry thing now rubbing on your leg.



Attention (top-down) and Salience (bottom-up)

A serious attentional problem for learners has recently arrived through technology and cultural change. The salient distraction (activation and arousal) of a Facebook account, cell phone, texting, online games, and streaming video appears to be interfering considerably with working memory and other processes critical for learning. We now have so many reasons to shift executive attention to these myriad salient stimulus that learning is necessarily handicapped.

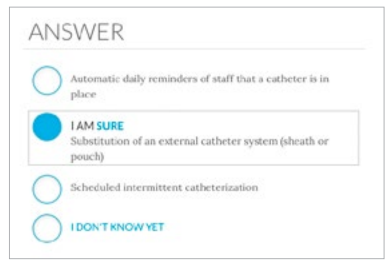
Research shows that the mental processes required to encode, store, and retrieve information are impaired by multiple streams of information. Multitasking is not really a possibility because of the limitations in the design of the prefrontal cortex. Working memory can't transport learning into strong new synapses in the hippocampus. Under these conditions, the neural patterns that should have become registered in storage exhibit weak signal strength, and they will be difficult to retrieve and liable to rapid forgetting.

Therefore, for any educational technology to be effective in today's distracting reality, a key requirement is salience. An effective technology cannot rely merely on top-down executive processes and conscious attention. Rather, it must be able to command bottom-up processes and direct attention away from distractions and into the learning.

Positive valence—honesty

We saw that learning takes place in the upper right quadrant of the circumplex. We noticed that activation (arousal) levels need to be moderately high but, importantly, that valence also need to be positive. People learn semantic information when they are basically happy, not sad or stressed. To this end, the Amplifire attempts to make the learning experience fast yet stress-free.

Amplifire is the only learning system that encourages honesty by allowing learners to say "I am not sure" without penalty. The inventors of the system realized that there is nothing inherently wrong with not knowing—it's the state that all of us are in with respect to the vast bulk of the world's information.



Although students can make "best-guess choices" on a test, it is unlikely that low-confidence guessing is a good strategy in the natural world. Humans did not evolve brains that are especially comfortable with guessing. Rather, we can sensibly speculate that humans evolved a desire for both correctness and confidence because survival is more likely with that combination. Over many generations, those humans who coupled confidence with correctness to achieve a high level of mastery would have enjoyed a reproductive advantage over their less masterful competitors. Amplifire motivates people who feel the ancient imperative to know something with certainty. Guessing is precarious whereas justifiably confident knowledge is a strength and an aid to survival.

While curiosity and a moderate amount of arousal and emotion strengthen memory, in the last few years it has become clear that stressful emotions are highly implicated in poor memory. As we learned in our discussion of the amygdala, stress appears to alter the function of the hippocampus. Under stress, the amygdala first causes levels of the hormone cortisol to increase in the bloodstream. Cortisol then binds to receptors in the hippocampus and impairs its ability to form explicit long-term memory.

As Larry Squire has noted, learning is enhanced in stress free environments when the learner's mood is positive:

> *"Memory is better the more we have a reason to study, the more we like what we are studying, and the more we can bring the full breadth of our personality to the moment of learning." —Dr. Larry Squire—Memory, From Mind to Molecules, 2009*

In the more traditional multiple-choice test, learners are forced to pick an answer even when they know they don't know. A student is, essentially, forced to lie by saying something like, "it's choice A, the House of Representatives has 435 members" when they know, full well, that they really have no idea.

For normal people, lying is uncomfortable and it shows up physically when forced to do it. Even the most accomplished prevaricators are given away by a change in skin conductance—the change revealed by a lie detector. And recent fMRI brain scans show changes in the brain when people consciously lie. (There is now talk of using fMRI to test the honesty of suspected criminals and/or witnesses whose testimony is deemed critical.)

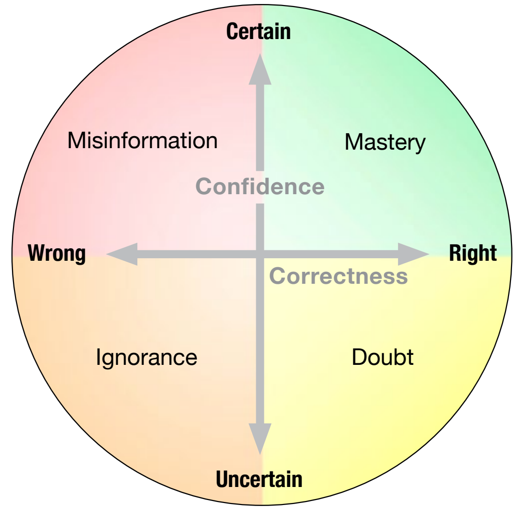
Feelings of knowing

> *"The feeling of knowing and its kindred feelings should be considered as primary as the states of fear and anger. The recently defined relationship between fear or anxiety and conscious thought has spawned the concept of emotional intelligence; it is time for a similar examination of the role of the feeling of knowing in shaping our thoughts."*
> *—Robert Burton, On Being Certain, 2008*

According to Robert Burton, a neuroscientist at UCSF, the feeling of knowing is a core emotion similar to love, fear, sadness, or hate. Only recently has the feeling of knowing been considered in this context—as the emotion of knowledge. In every-day usage, these feelings show up in phrases like: "I'm not sure," "I'm totally positive," "I haven't a clue." In the ***Amplifire*** format, feelings of knowing are expressed in terms of doubt, certainty, or ignorance—***Amplifire***'s *shades of knowledge.*

The deeper evolutionary perspective tells us that the feeling of knowing is of utmost importance because it leads directly to behavior. It is an adaptive mental feature for creatures that receive sensory input from the environment and then need to act correctly to survive and prosper. They first make a prediction of the likely outcome through an emotional response—their confidence in their correctness.

The circmuplex map of human emotion showed us that the two factors of activation and valence can express a wide range of feeling. The makers of Amplifire invented a comparable circumplex that extends current thinking about emotion into the realm of knowledge. Shades of correctness combine with shades of certainty because people can be deeply misinformed, or nearing mastery, or completely ignorant, or somewhat doubtful.

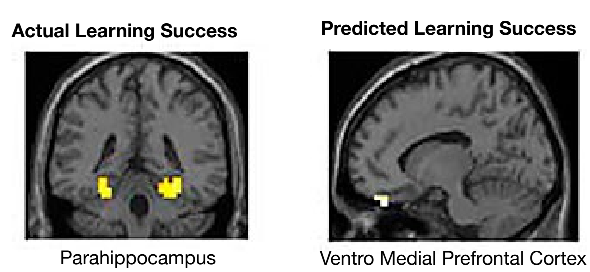


The circumplex map of knowledge states. Correctness indicates correspondence to reality. Confidence indicates a person's feelings about their retrieval of stored information.

For the first time in any learning environment, Amplifire brings these emotions of knowledge to a learner's conscious awareness. This overt expression of the feeling of knowing helps learners encode and store an enduring memory of the information.

As discussed above, if you are confident, you act. If you have doubt, you hesitate. If you don't know, you go no further. This is the linkage between knowledge, encoded and stored in the brain as memory, and behavior in the physical world. An organism must have a way to gauge the likelihood that knowledge is correct before acting on it—to make a good prediction.

One of the most remarkable traits that humans possess is our ability to hold knowledge about the state of our own knowledge. This is known as meta-memory or meta-cognition. Using fMRI scans of the brain, researchers at MIT recently visualized the neural source of this ability by directly imaging the brain. Psychologists had proposed that being able to assess your "judgements of learning" about a fact makes you a better learner. (JOLs happen at the time of learning, whereas FOKs (feelings of knowing) occur during memory retrieval.) Interestingly, the researchers also discovered that the judgments of learning and knowledge itself occur in two different circuits of the brain.



Stored knowledge and the judgements of learning.

According to John Gabrieli at the GabLab, the McGovern Institute at MIT, and the lead author of the study,

> *"We've known through psychological studies that the brain performs these two functions, encoding the memory and predicting whether the information will be later recalled. This is our first insight into the different brain mechanisms for memory and prediction, what psychologists call judgments of learning." —John Gabrieli, MIT, 2006*

Researchers like Gabrieli have concluded that parallel processing is occurring in the brain when we access semantic knowledge. One circuit, the parahippocampus, is working on retrieving semantic memories, while another, the ventromedial prefrontal cortex (VMPFC) is processing clues for familiarity. In terms we are more familiar with, the parahippocampus is part of the complex that stores long-term memory. The VMPFC is part of the complex that produces working memory in the prefrontal cortex.

It appears likely that the VMPFC may account, in part, for the judgements of learning that Amplifire makes plain—the mental states we call confidence, doubt, and ignorance. Doubt may occur when the VMPFC circuitry reports a weak signal. Ignorance is felt when it has nothing to report. And the feeling of confidence occurs when the VMPFC reports a strong signal.

Thus, learning with Amplifire appears to be directly stimulating the VMPFC to report on its confidence level while the parahippocampus is busy retrieving the actual information. Amplifire users are engaged and learn rapidly because the circuit that stores memory and the circuit which predicts the memory are active and engaged. Amplifire brings Gabrieli's judgements of learning directly into consciousness in the form of confidence, doubt, and ignorance No longer is that crucial distinction left to unconscious processes. Now, it can be utilized directly by the learner, thereby improving encoding, storage, and recall.

> *"In the present study, greater accuracy in judgements of learning was correlated with greater accuracy in recognition memory and greater VMPFC activation. Thus, these processes, and the neural circuits that mediate them, constitute a critical component of the way in which knowing how to learn empowers learning itself. —John Gabrieli, MIT, 2006*

Concluding thoughts

It's an astonishing revelation: emotion is the way that organisms apply value to information perceived in the environment. Fear, happiness, alertness, and fatigue are a few of the myriad feelings that color the lives of all people—nature's method for imbuing organisms with an ability to rapidly make decisions because time for thoughtful contemplation is rarely an option. It's likely that no other organism has a more complex set of contrasting feelings than homo sapiens as illustrated by the circumplex map of emotion. Amplifire extends the standard emotional map into the realm of learning with a circumplex based on confidence and the feeling of knowing.

As we have also seen, emotion is intimately aligned with cognition. Working memory pulls both cognitive and emotional information into the workspace of consciousness for consideration and decision making.

Questions still remain: What turns mental activity like decision making, emotion, and memory into actual behavior in the real world? What forces drive us into action? What mental circuits get us out of bed in the morning to do what must be done? For those question we must consider the last pillar of self-hood—motivation. This is the realm where human goals, incentives, and aspirations are driven forward through a distinctive set of mental circuits and chemical pathways.

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