Learning and Memory Series

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11 MOTIVATIONAL TRIGGERS FOR LEARNING

By Charles J. Smith, Chief Research Officer for Amplifire

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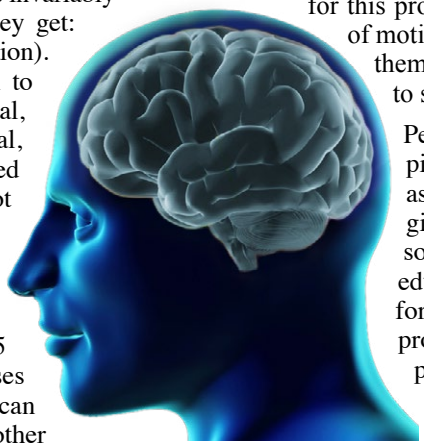
With some imagination, we can conjure up the slightly disturbing image of a disembodied brain living in a tank of nutritional fluids. Given the proper inputs, perhaps our brain in a vat could "live" contentedly with only its cognitive and emotional abilities (thinking and feeling). Reality, however, imposes requirements on all living organisms who must survive and reproduce in a highly competitive Darwinian world. Failure to seek out food, mates, companions, and information about one's circumstances invariably has consequences about as serious as they get: (namely: starvation, death, and extinction). It's no wonder then, that the motivation to attain all sorts of goals, important or trivial, is highly correlated with emotion, arousal, anxiety, and satisfaction. So closely allied are motivation and emotion, that the root Latin word for *motion* appears in both.



Motivation

As we have seen previously in papers 105 and 106, cognitive and emotional processes are major components of learning that can be described in evolutionary terms. In other words, we can understand why certain learning triggers allowed creatures, including humans, to survive and prosper under their guidance, and we can see how those triggers are instantiated in the living tissue of the brain.

One question looms however. How do cognitive and emotional components create behavior out in the real world? Thinking and feeling go only so far, as our brain in a vat might testify. Without a desire to transform cognition and emotion into physical action, how useful would those attributes be? Not very. This is the third and final pillar supporting the psychological architecture of a living creature that thinks, feels, and must act in the real world. What motivates us beyond merely existing,? What drives us to do anything at all?

> *"Motivation has many definitions. I use the term to refer to neural activity that guides us toward goals, outcomes that we desire and for which we will exert effort... Goals direct action and can be as concrete as a specific stimulus (for example, a particular consumer product) or as abstract as a belief or idea (for example, the belief that hard work will lead to success)."*
> *—Joseph LeDoux, The Synaptic Self*

All successful organism are motivated to engage with the world to accomplish biological ends, and human beings come equipped with the usual array of motivations plus an enormous variety of goals and incentives seen in no other creature on the planet. Like philosophical truths, motivation lies on a spectrum. It begins with the most basic requirements of life, the kind we share with all mammals, and proceeds to the pinnacles of achievement and human aspiration.

The questions that the designers of Amplifire have asked are: What are the factors that enhance the motivation to learn? How can a learning protocol utilize this last pillar in the mental trilogy? What psychological experiments demonstrate learning conditions that boost motivation? What brain circuits mediate motivation? How does evolutionary theory guide us in a search for optimal learning environments that foster motivated students? Does culture play a role?

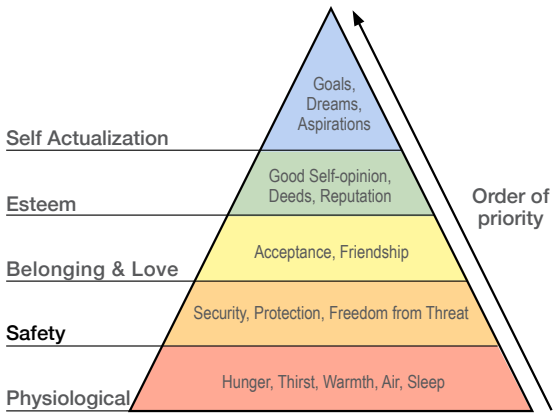
These seriously important questions, if answerable, may contain the keys to a prosperous and satisfying future for the better part of humanity if only educators successfully heed the answers. By no means is what follows a claim to a solution for this problem of problems. At best, it is a summary of motivational concepts, brain circuits that mediate them, and the environmental triggers that appear to switch motivation into high gear.

Perhaps it is the most interesting of the three pillars because one can conceive of motivation as the force that drives lifelong learning and gives rise to an educated civilization. If a society were to error badly by institutionalizing educational processes that damaged the motive force to learn, the negative consequences, while probably taking years to play out, would be potentially irreversible. On that somber note, lets' see how motivation works and how it might be made to serve the interests of the future—an optimistic note to spur us on.

Needs

In the 1940s, Abraham Maslow created his famous hierarchy of needs. He showed that the basic biological requirements at the bottom of the chart must be satisfied before higher levels of attainment and life satisfaction can be sought.

> *"A musician must make music, an artist must paint, a poet must write, if he is ultimately to be at peace with himself. What a man can be, he must be."*



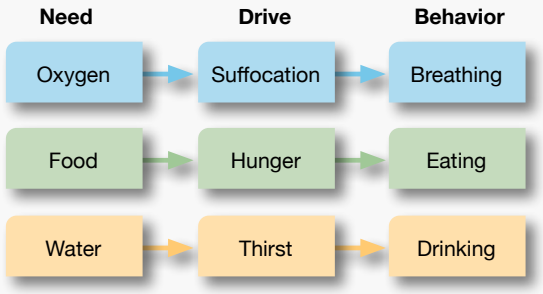
Maslow's hierarchy of needs.

Maslow's hierarchy is still widely used today, but it does not tell the whole story of motivation, which, as usual, is as complicated as the humanity it attempts to describe.

Drives

It's now thought that the lower levels of motivation on Maslow's hierarchy are driven by negative bodily states. A biological need creates internal feelings called drives that lead to motivated behavior that aims to reduce the drive. These kinds of drives arise in ancient circuits of the brain like the hypothalamus and the brain stem. We share these drives with all animals that have nervous systems and are motivated in very much the same ways using nearly identical brain structures. Consider three examples:

Hold your breath until you begin feeling a bit uncomfortable. The emotional state that results is a form of urgency and anxiety born of high arousal with negative valence (a bad feeling). This drive leads to a behavior—breathing, and the drive disappears since the need is now satisfied.



Incentives

If drives can be considered to push organisms towards certain kinds of behavior like breathing and feeding, then incentives can be thought of as pulling a creature towards a desired goal.

Incentives are as varied as the reward of good grades that motivate a student to study hard in school, or the sweet taste of apple pie that compels a diner to have two pieces, or social status that makes a businessman work late hours so he can buy a Mercedes Benz. Human beings have a nearly limitless ability to generate incentives. Motivations that derive from incentives and goals in the environment, like pie or grades, are called *extrinsic motivations*. Those that seem to derive from one's own internal ambitions, like reading a novel, traveling the world, going to church, or exercising are called *intrinsic motivations*.

An interesting phenomenon that runs counter to our discussion of incentives so far is that produced when intrinsic motivations are rewarded with an *extrinsic motivator* like money. Research shows that when people are performing a task for the sake of its intrinsic value, rewarding such behavior with money diminishes the motivation and performance then falls off. One theory notes that personal fulfillment, control, and the satisfaction of performing a task with competence are the main incentives driving these kinds of fulfilling behaviors. In these cases, monetary rewards only serve to diminish the intrinsic incentive value of the behavior and, consequently, outcomes and production suffer. Likewise, there is justifiable debate as to whether the extrinsic motivation of grades damages the intrinsic motivation to learn, especially in young children where the potential to create life-long learners is so very often nipped in the bud by current practices. We'll touch on this idea further when we discuss the mental state of *flow* that results when an activity is so motivating that the brain excludes other sensory information, and time and space seem to vanish.

Goals

Goals are aspirations for a desired state of being in the future. They can apply to the acquisition of an object like a home in the suburbs or to professional achievement like a degree in jurisprudence. In the 1930s, the Harvard psychologist Henry Murray proposed 27 basic psycho-social needs and goals that can be universally applied to normally functioning people. His list contained prospective and desirable items like achievement, affiliation, nurture, understanding, and play. These personal goals use a defined personal end-state as the incentive that propels people towards one particular set of behaviors and away from others.

As the motivational theorist David McClelland showed in 1987, those of us with high levels of a trait called *achievement motive* find it easier to focus their energies towards attaining long-term goals. He showed that students in a college setting who possess high achievement orientation sit near the front of the class, do well on exams, and are realistic in setting challenging but attainable goals. People with less *achievement motive* often set goals that are either far too easy or impossibly difficult to attain.

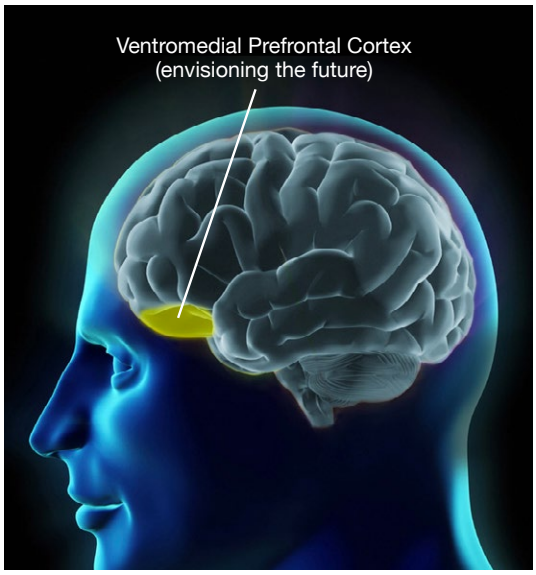
Valuing the future

So far, we have learned the basic terms in which researchers think about motivation in terms of *needs*, *incentives*, and *goals*. Now we turn to the brain structures that mediate motivated behavior and then to the triggers that activate motivation. The brain after all, is the physical basis for desires and goals inside very real heads. Where might the brain store neural representations of goals and incentives that lead to motivated behavior? It turns out that people with damage to certain parts of the prefrontal cortex can't understand how their actions in the present will affect their circumstances in the future.

The Iowa Gambling test, developed in the lab of Antonio Damasio, demonstrates this clearly. Players can turn over a card from any of four decks and, depending on what the card says, they receive cash or give cash. Two of the decks, A and B, consistently give $100, while C and D return just $50. The problem for players is that both decks also contain cards that require the player to give cash back. The A and B decks contain very dangerous cards that sometimes require the player to give back $1,000 or more. The game is designed so that it is impossible for players to perform any mathematical calculations. Nevertheless, people with normally functioning brains soon figure out that A and B are simply too dangerous and begin to consistently choose cards from decks C or D. They can override their immediate desire for $100 cards because they know they'll be better of in the future by avoiding the minus $1,000 cards.

Patients with damage to the ventromedial region of the prefrontal cortex never make this leap. Damasio believes that without a functioning VMPFC, they simply can't adequately envision the future, even one that is not far off. Consequently, they persist

in picking from the apparently high-paying, but actually disastrous card decks. Working memory is operating well since they can hold the rules of the game in mind, converse with the lab techs, and perform other functions of "normal" people. Their VMPFC deficit seems to negate a relationship with the future and their decision making ability suffers markedly.



The VMPFC envisions the future, applies emotional value to it, and guides behavior towards a best outcome.

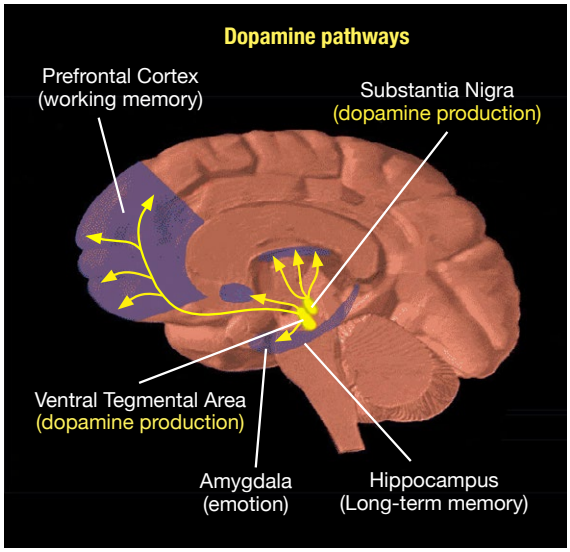
"One of the most distinctive human traits is the ability to learn to be guided by future prospects rather than by immediate outcomes, something we begin to acquire in childhood. In frontal lobe patients, brain damage not only compromises the repository of knowledge pertinent to such guidance that had been accumulated until then, but further compromises the ability to acquire new knowledge of the same type. The only redeeming aspect of this tragedy, as is often the case in instances of brain damage, resides with the window it opens for science."
—Antonio Damasio, Descartes Error

A neurotransmitter for motivation

The very idea that brain structures are responsible for guiding our hopes, goals, and aspirations is rightfully disorienting for the uninitiated. Perhaps the notion is less painfully conceived by thinking of the brain as encompassing myriad survival functions and one of them is determining the incentive value of an object, phenomenon, idea, or goal. Motivational systems in the brain rank the incentive quality of an input by either biologically pre-determined values encoded in organic structure or by values learned in an environment and remembered. Values lead to decisions and behavior. From the point of view of brain circuitry, the purpose of behaviors caused by motivation is to change the current emotional state in which the brain finds itself. Motivation, in this view, results from learned incentives or innate incentives that place the brain in a situation where an active response is likely to occur. In the view of Joseph LeDoux, incentives motivate people into action because emotional systems are triggered. Emotion is the great underlying cause:

"These emotionally primed instrumental responses have as their goal, their motive, the alteration of the brain state, the emotional state that the organism is in."
—Joseph LeDoux, The Synaptic Self

The brain system that appears to mediate LeDoux's "primed instrumental responses" is the circuit that distributes the neurotransmitter dopamine. Discovered accidentally in the 1950s during electrical stimulation experiments, researchers found that laboratory rats would press a lever incessantly to get shots of dopamine directly administered into their tiny brains. And, they would do this to the exclusion of food, even when starving. Dopamine became quickly known as the neurotransmitter of pleasure and its circuit, the pleasure pathway. The primary dopamine production centers and the general distribution pathways are shown below.



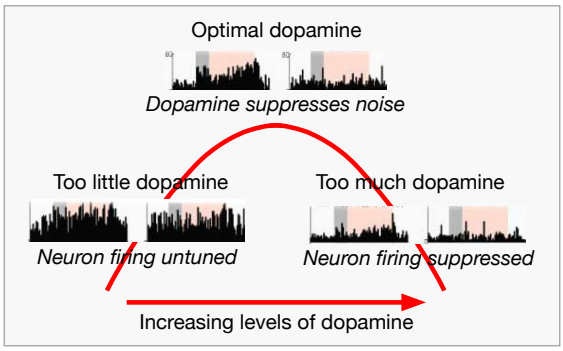
Dopamine production sites and pathways.

It turns out that the original equation of dopamine = pleasure did not capture the underlying processes very well. First of all, as can be readily seen in the illustration, the prefrontal cortex (the locus of working memory and conscious awareness) is connected to a major source of dopamine, the ventral tegmental area. This arrangement gives dopamine the power to focus a creature's attention on active goals while disregarding less interesting ones (the pathway is nearly identical in all mammals). In a way, dopamine defines "interesting." Attention and arousal are highly influenced by dopamine levels which affect the inhibition and excitation processes that control activity in the PFC system. This allows arousal

and focus to vary depending on the circumstances of the perceived environment. Focus and attention, as we have seen, are essential emotional ingredients for learning and memory.

Like all neurotransmitters, dopamine operates within the synaptic space between neurons. It is distributed in the PFC by axons (the long projection emanating from a neuron) that originate in the brain stem and the ventral tegmental area. Dopamine by itself can't do any motivational magic. Instead, it moderates the way neurons are activated and communicate with one another.

Technically, dopamine serves to *bias* neurons so that only strong stimuli are perceived in the attentional network and *noise* is filtered out. Dopamine, according to Amy Arnsten at Yale, biases neurons in the PFC to focus working memory onto strong inputs emanating from the external world and to ignore distractions. One can see from the results of her work that the maintenance of a fine line between too little dopamine and too much can make the difference between overload, attention, and shut-down—the trajectory of the red curve.

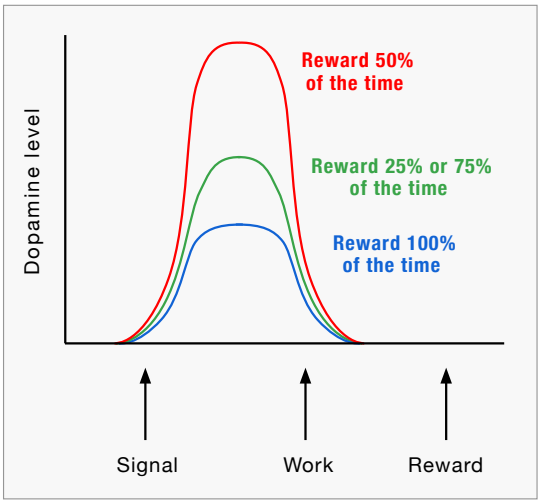


Dopamine suppresses noise when at optimal levels.

A further problem with the "dopamine as the molecule of pleasure" idea is that dopamine is maximally present during the anticipatory stage while a creature is seeking pleasure and much less so during the actual experience of reward. It is not involved in the pleasurable activity per se. What it does is more important than simple pleasure or reward.

Readily seen below are a set of truly fascinating experimental results with lab animals conditioned to expect a reward. First, notice that dopamine production goes up in the brain when a signal indicates that a behavior will produce a reward (blue curve). In lab animals this might be a bell indicating that pushing a lever will release a bit of food. In humans it might be the sight of McDonald's arches or the thought of a date with a romantic interest. Notice that dopamine falls off after the work is performed—the lever is pushed, the hamburger is on your plate, the date is underway (although other anticipations might now be in play).

Now, here's a really unexpected point. Dopamine levels skyrocket whenever the reward has a 50% likelihood of occurring (red curve). As Robert Sapolsky notes, "You have introduced the word *maybe* into the equation and that is reinforcing like nothing else on earth." Further proof that uncertainty is wonderfully arousing comes from the observation that dopamine levels fall from this peak when the reward is given either 25% or 75% of the time (green curve). This is because the reward is becoming more predictable at 25% and 75% and, as we now know, dopamine is all about anticipation of the reward, not the reward itself. Predictability reduces dopamine levels and arousal falls away.



Dopamine is not about reward. It's about anticipation of reward. Uncertain rewards profoundly magnify dopamine production.

For educators, these results are telling us why so many activities in school fail to teach and why students fail to remember. Fundamentally, biochemically, perhaps tragically, the predictability of a modern student's school experience is not what the human brain evolved to notice or learn from. *(Note: This biochemical point is critically important for educators who wish to make progress getting students focused, attentive, and interested in learning.)*

On the other hand, while human beings respond to dopamine in exactly the same way that animals do, there is one important caveat that should be kept in mind. Between the time of the signal and the time of the reward, people can hold out for an extraordinarily long time. Freshman college students know that after four or perhaps eight more years of work, study and tests, the payoff might be a job in a "rewarding" field. Don't miss the blatant language society uses to entice young people down the educational path. Satisfaction in a rewarding field can be theirs if they'll only keep those dopamine levels up and stay focused on their goals. Likewise, employees know that if they are nice to their boss, work hard, and avoid mistakes, they might be rewarded with a higher salary and a good pension. Rewards like these are oriented towards the future—a far distant land that Damasio's patients with damage to the prefrontal cortex do not comprehend (and indeed, they can't hold jobs).

"What's different about us is the lag time between the work and the reward. How long we can hold on, driven by that dopamine surge."
—Robert Sapolsky, Stanford Lecture

The Working Self

Dopamine is a molecular view into motivation, but how does this molecule square with larger concepts of mind at the level of thinking, feeling, and doing? For instance, how should we think about motivation in terms that embody our whole being, our conscious selves?

The *working self* hypothesis from Lantur and Markus proposes that our very being is a composite of past remembered selves and the desired future selves that we would like to become —rich, happy, famous, funny, commanding, satisfied, free, productive, or moral—the list is long. Working self is constructed on the fly. It's partly memory and partly expectation, combined with events happening in the moment.

With our understanding of the myriad circuits that transmit information and emotion into working memory, we can already guess that the prefrontal cortex is involved in the generation of the working self. Indeed, our working selves are constructed from the integration of circuits that are themselves massively cross connected with other circuits. The PFC is a massive convergence zone for cognitive, emotional, and motivational processes—the three pillars of the tripartite self that Plato suggested 2,500 years ago. Information enters through the senses and is integrated with information already in long-term memory. It is moderated, amplified, suppressed and controlled by the neurotransmitters working in the incredibly tiny synaptic space between neurons. The possibilities are just shy of infinite.

In his excellent attempts to explain how philosophy and neuroscience intersect, the modern philosopher, Daniel Dennet, uses the notion of "the self as the narrative center of gravity" By "center of gravity," he means that the self is an ever changing melange of interacting brain circuits generating its own storyline. He considers the self, as popularly conceived, a fiction. Dennet thinks our 'selves' are crafted from moment to moment, written autobiographically and continuously re-written immediately thereafter. His philosophical predecessor, David Hume, said something similar nearly 300 years prior:

> *"For my part, when I enter most intimately into what I call myself, I always stumble on some particular perception or other, of heat or cold, light or shade, love or hatred, pain or pleasure. I never can catch myself at any time without a perception, and never can observe anything but the perception.... If anyone, upon serious and unprejudiced reflection, thinks he has a different notion of himself, I must confess I can reason no longer with him. All I can allow him is, that he may be in the right as well as I, and that we are essentially different in this particular. He may, perhaps, perceive something simple and continued, which he calls himself; though I am certain there is no such principle in me."*
>
> *—David Hume, Treatise of Human Nature*

Our working selves are built to a great extent from the possibilities afforded by our current circumstances. It's our circumstances, ultimately, that give working memory and the working self something to actually work with. The contents of the working self—long-term memory, cultural habits, sensory inputs from the environment, emotional states, incentives and goals—are all contingent on the surroundings in which we find ourselves. The working self of a young woman attending an Ivy League school will necessarily be far different from that of a young man struggling in the ghettos of South Africa.

When it comes to the goals that a motivated working self must direct itself towards, the prefrontal cortex is somewhat like the director of a play who has at his disposal many actors with distinct talents and specific expertise. Too much emotion, and rationality suffers. Too much reason, and motivation flags. After all, why bother to act if emotion isn't present to convey the value of goals and incentives. And, perhaps most importantly, within the notion of working self, we begin to appreciate the literally trillions of contingencies that are causally but unknowably connected to the formation of individual personalities, somehow fixed yet ever changing. Within that notion, lies empathy for each and every personal circumstance—a pathway whereby science informs ethics and illuminates a moral landscape.

Motivational triggers for learning

With a pretty good sense of the biological forces that move the mind, we can now turn to thinking about the triggers that motivate people to learn and remember.

Needless to say, all the emotional or cognitive triggers in the world that we covered previously won't make a difference if a learner is unmotivated to use their mental toolbox in the service of some goal. It is plainly true that the difference in achievement between one learner and another is not necessarily found in differences in raw intelligence but rather in their respective levels of motivation. Silent Cal, the 30th U.S. president, laid out the power of motivation quite well when he noted that...

> *"Nothing in the world can take the place of persistence. Talent will not; nothing is more common than unsuccessful men with talent. Genius will not; un-rewarded genius is almost a proverb. Education will not; the world is full of educated derelicts. Persistence and determination alone are omnipotent. The slogan 'Press On' has solved and always will solve the problems of the human race."*
>
> *—Calvin Coolidge*

Here's a brief preview of 11 motivational triggers that switch on learning and memory.

- *Curiosity*— the drive that closes the information gap, often called "*the wick in the candle of learning.*"

- *Seeking*—the ancient imperative to hunt and forage for food, mates, companions, and ideas.
- *Rewards*—a classic motivator. The timing and certainty of the payoff determines a reward's incentive value.
- *Uncertainty and Risk*—a circumstance that causes dopamine levels to rise. Focus and attention sharpen as a consequence. Benign circumstances are crucial for learning.
- *Confidence*—an ancient primate incentive that aids survival
- *Anticipation*—the motivated state of mind characterized by high dopamine production.
- *Goals*—realizable goals have to be SMART: Specific, Measurable, Attainable, Realistic, and Timely.
- *Implementation intentions*—the language with which we set intentions has profound effects on the outcome.
- *Flow*—a highly focused state of mind coupled with masterful activity. Time and space pass unnoticed.
- *Progress and optimism*—Learning and achievement are highly correlated with an optimistic personal style.
- *Games*—observed in all mammals, especially the young, games cause effortless learning.

Curiosity

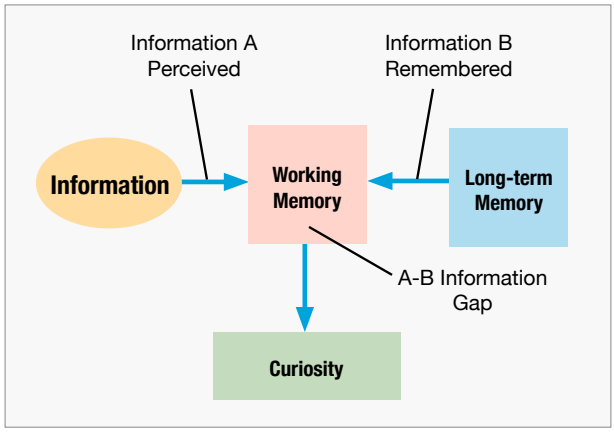
The remarkable feline brain has been programmed by roughly 30 million years of evolution into that of a dogged information gatherer and pattern recognizer. Cats are the epitome of curiosity and what they accomplish during their daily explorations is really knowledge mastery.

Felis Domesticus—curiosity incarnate.

Think about this little Russian Blue for a moment. Like all cats, she spends a part of every day on the prowl. The vast array of information that she seeks and obtains through the motivating power of curiosity gives her a near-perfect map of the property she inhabits and controls—a confident and correct sense of who is friend, foe, or food. And she updates her knowledge whenever doubt and uncertainty creep in. The famous curiosity of cats is really that updating process made plain. Move a chair in the living room or rearrange the garden and she immediately realizes the map in her head is not the same as the data now streaming in for comparison.

Knowledge is vital and she is unremitting in its accurate acquisition. She is especially attuned to what psychologists call an *information gap*. When something changes, our cat quickly sets about exploring the altered landscape and recreating a new map that is confidently navigable for pursuing prey or escaping predators. She closes the information gap. Doubt is banished and mastery is attained. It's a matter of life and death for her. She strives to master knowledge because it vastly improves the chances of mastering her fate.

This, in fact, may be the biological source of uncertainty in all mammals including the human variety. It's felt when sensory information about the terrain, an idea, or a face is held in working memory, but it does not correspond with the patterns being pulled in from long-term memory. As shown in the illustration below, it may be this conflict that produces the information gap that leads to both uncertainty and curiosity.



Curiosity is aroused when A and B conflict.

In psychological experiments, the effect of curiosity on student performance is profound. In a set of studies that looked at both the underlying physical circuitry involved in curiosity (prefrontal cortex, caudate, hippocampus, etc.) and its empirical effect on memory, Kang, et al., found a direct correlation with learning.

A memory test in which accuracy correlates to curiosity.

"Curiosity showed a strong effect on subsequent recall of the answers to the questions that were initially guessed incorrectly...Consistent with the fMRI findings, these findings suggest that curiosity activates memory regions differently in response to surprising (incorrectly guessed) answers."

"The fact that curiosity increases with uncertainty suggest that a small amount of knowledge can pique curiosity and prime the hunger for knowledge; this observation might suggest ways for educators to ignite the wick in the candle of learning."
—Min Kang, in Psychological Science

For good reason, the provocative title of Min Kang's research paper on the motive power of curiosity is "The Wick in the Candle of Learning." As Kang notes, people in the education industry would do well to figure out how to prime student's hunger for knowledge using small amounts of information tinged with uncertainty, a learning trigger we'll look at soon.

Seeking

"Seeking" behavior is so deeply fundamental to all animals that Jaak Panksepp, a primary investigator, has called it the "granddaddy" of motivational systems.

To get a sense of why seeking is the granddaddy system, first contemplate the sea squirt, a very primitive animal that apparently developed one of the first brains on the planet. It was a brain with one purpose in mind—to navigate around a reef until it could locate a suitable home upon which to permanently anchor itself. Once situated, a sea squirt proceeds to digest its nervous system. It's primal brain has no further services to offer after the seeking process has found a new home. That brain evolved about 500 million years ago to do one thing—seek.

Let's think about our hunter gatherer ancestors making a living on the African savanna. What was most important to them? The same thing that drives most animals—shelter, sustenance, and reproduction. For our ancestors, consuming some delicious berries or having sex with an attractive partner was easy compared to procuring them in the first place, which is difficult. While eating and sex are pleasurable (what psychologists call hedonic), it's really about hunting for the animal, or searching for those berries, or courting the love of your life. It's about seeking. Indeed, this makes sense because what matters is the motivation to find food, homes, mates, and companions. Once found, the consumption of food, water, sex, and other important items on Maslow's hierarchy activates opioid receptors in the brain and turns off the attentiveness of the seeking state.

"These chemistries lead our companion creatures to set out energetically to investigate and explore their worlds, to seek available resources and make sense of the contingencies of their environment. These same system give us the impulse to become actively engaged with the world and to extract meaning from our various circumstances."
—Jaak Panskepp, Affective Neuroscience

Researchers now think that the seeking system mediates "wanting" while other brain systems are in charge of "liking." Panskepp and other researchers have found that dopamine drives the seeking-wanting processes which are, as we learned, accompanied by elevated arousal levels. Opioid receptors, on the other hand, are responsible for the pleasurable feelings associated with shelter, food, sex, and companions once they are procured—feelings that are exactly the opposite of arousal. Taken together, the two form a dual feedback circuit whose purpose is to initiate aroused seeking behavior (wanting) followed by satiation (liking) once the desired thing has been obtained.

According to Kent Berridge, a neuroscientist at University of Michigan, and one of the first researches to show how drug addiction affects the brain's "wanting circuits,"

"A common brain myth is that dopamine mediates sensory pleasure, but our research has helped indicate that dopamine mediates only a form of ''wanting' for reward called incentive salience, and not pleasure 'liking." — Kent Berridge

The complementary brain circuitry for seeking (dopamine) and liking (opiates) goes a long way to explaining why the drugs cocaine and heroin cause such distinctively different emotional states and behaviors in their users. Cocaine (and methamphetamine) activates dopamine circuits that are arousing and put users into what is essentially a "seeking" state. Drugs like morphine and heroin, on the other hand, are opiates and amplify the brains own opioid circuits. They create a feeling of contented well being—the "liking" state, a state characterized by satisfaction and lower motivation.

So far we have discussed seeking in terms of basic drives for basic requirements, but it appears that the same dopamine circuits are causally involved in seeking long term goals—the kinds of goals that people hold onto for long periods of time when contemplating education, career, religion, and purpose.

"This harmoniously operating neuro-emotional system drives and energizes many mental complexities that humans experience as persistent feelings of interest, curiosity, sensation seeking, and, in the presence of a sufficiently complex cortex, the search for higher meaning. —Jaak Panskepp, Affective Neuroscience

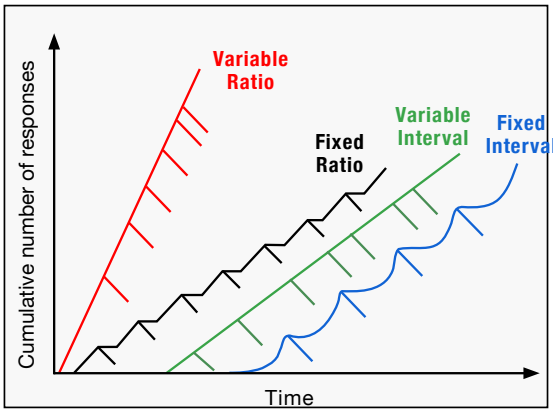
In the light of neural circuitry that causes seeking, including the search for knowledge, educators are faced with the task of figuring out how to a) avoid destroying a student's natural curiosity (do no harm) and b) turn naturally occurring seeking behaviors towards the acquisition of increasingly higher orders of knowledge.

Rewards

In classic experiments with both humans and laboratory animals, organisms can be motivated to behave in defined ways when the behavior is associated with a reward. Most everyone knows that the Russian psychologist, Ivan Pavlov, conditioned his dogs to salivate by associating the sound of a bell with the reward of meat. In short order, the dogs would salivate with just the sound of the bell. While human beings are far more complex than dogs, we too respond to rewards.

Rewards (incentives) are always given according to a timing schedule after a response (pushing a lever, ringing a bell). There are four basic schedules.

- Fixed Ratio schedules give the subject a reward after a set number of responses.
- Variable Ratio schedules give a reward after an indeterminate number of responses. Sometimes the reward arrives after a response, sometimes not.
- Fixed Interval schedules give the reward after a set amount of time has past.
- Variable Interval schedules use and ever-changing period of time between rewards.



Four kinds of reward schedule. Hatch marks indicate a reward is given. Variable ratio schedules create the highest response rates.

Variable ratio schedules of rewards are a far more powerful generator of behavior than any other type. We saw earlier how dopamine levels rise dramatically when rewards arrive 50% of the time. These results further demonstrate the power of an uncertain reward amplifying motivation. It is no accident that this type of variable schedule is used within slot machines to motivate players to feed money (the response) after receiving rewards (the payoff) that apparently occur randomly. Slot machine makers also vary the size of the reward which spikes motivation even further.

As we will see, the movie and video game industries have also used variable reward schedules to hook their patrons. In the case of games, "hook" is not hyperbole because some users exhibit all the signs of addiction, undoubtedly fueled by dopamine circuits which are correlated with cocaine and methamphetamine use. A task for the education industry rests in determining how these psychological lessons can be applied to their profession, one which matters far more than mere entertainment.

Uncertainty & risk

Robert Sapolsky has convincingly argued that uncertainty can produce either strong motivation or anxiety. The key variable that makes for the distinction is the environmental context. Are the surroundings during uncertainty benign or are they malevolent? This mental analysis makes all the difference when it comes to either driving behavior forward towards goals or avoiding uncertain circumstances and risks that carry a note of excessive danger.

Casinos exploit this attraction by creating environments of fun, entertainment, sociality, and alcohol—the perfect storm of benign components that make uncertainty and risk enjoyable to the detriment of millions of bank accounts. Hollywood movies also make use of benign uncertainty. Even though Princess Lea is in the hands of Darth Vader (malevolence incarnate) and her fate is uncertain, you the viewer are positive that you are at home on the sofa or in an agreeable theater with the smell of popcorn in the air (benevolence incarnate).

Moderate risk is one of the great motivators. Risk-taking is a powerful evolved emotional trigger for a range of creatures because risk is a mental state that was selected for over eons of time. Creatures that made the best bets were rewarded with the spoils when the bets paid off, hence, calculated risk feels good. Nature impels us to do her bidding, in this case, through dopamine receptors in the brain that are activated under risky, uncertain conditions.

As long as uncertainty does not move feelings toward the fear side of the emotional spectrum, it will help motivate learning and create long-term memory through arousal and attention. .

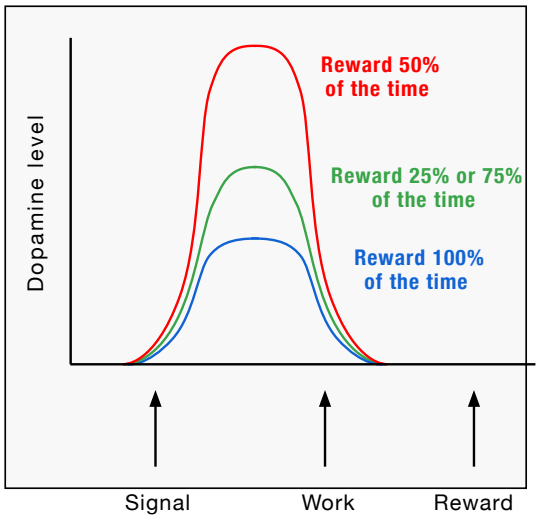
"Experience severe and prolonged stress, and learning, synaptic plasticity, and immune defenses are impaired. Experience moderate and transient stress, and memory, synaptic plasticity, and immunity are enhanced." —Robert Sapolsky, Why Zebras Don't Get Ulcers.

The key point is that people are motivated to go back for more of the mental charge they felt from a moment of uncertainty and risk, and they learn deeply in that state. This is the kind of mental trigger that should be deployed into the educational system if teachers expect to hold their student's attention.

Anticipation

As we saw in our discussion of brain circuits, anticipation is driven by the dopamine network that projects into the prefrontal cortex, the site of working memory and conscious experience. Dopamine is not about pleasure, it's about anticipation. We also discovered that *seeking* and *wanting* are extremely ancient components of the earliest nervous systems and are also driven by dopamine. (The opioid circuits, not dopamine, create pleasurable feelings of *liking* once that which is sought has been found.) In that light, we can say that anticipation is the motivating feeling that causes the behavior of seeking out a goal within the physical environment.

Importantly, anticipation is greatly heightened when the goal is somewhat uncertain because dopamine levels spike under uncertainty. In an educational setting we could sensibly theorize that anticipation + uncertainty = an antidote to boredom.



Dopamine is not about reward. It's about anticipation of reward. Uncertain rewards profoundly magnify dopamine production.

Confidence

While society rightfully champions egalitarian ideas like "all men are created equal," social rank remains one of the most sought after personal qualities in the human experience. Anthropologists have discovered over 200 traits found in people in every culture on Earth, a testament to our common human nature. These behavioral traits are called human universals and one of the strongest is a desire for social status. In fact, due to its supreme importance in achieving reproductive success, the quest for status also runs deeply throughout the social networks of our cousins, the great apes, both gorillas and chimps. Importantly, status is often conveyed through confidence—a trait with both ancient and modern benefits.

Confident people (and other primates) possess assurance, boldness, brashness, certainty, cool, courage, daring, dash, determination, fearlessness, firmness, fortitude, heart, morale, poise, reliance, resolution, self-possession, self-reliance, spirit, spunk, and tenacity. All of these trait descriptions are attractive to normally functioning members of every human society because they convey status.

Are people who are working through an Amplifire course consciously thinking about their social position via their confidence levels? Unlikely. Feelings are the result of hidden mental operations below the level of consciousness. Similarly, the desire for fine clothes, fancy houses, beautiful cars, and glamorous personalities are driven by mental modules that are mostly out of sight and, to varying degrees, beyond our control.

> *"The bias to claim greater accuracy than is warranted may be a self-serving bias to appear more expert and authoritative—basically to bluff, and according to the theory of self deception, the best deceiver is the one who believes his own deception."*
> *—Steven Pinker, Harvard, (personal note)*

Goals

As we've seen, the psychological state of attention is extremely important in determining if learning will form as long-term memory and a strong memory trace. We've also discussed how current learning environments present myriad distractions to students of all age ranges. If you are 16 or 65, some combination of email, tweets, Facebook messages, phone apps, pop-up advertising, or You Tube videos is attempting to distract you from study. On top of that, we are assailed by emotionally compelling distractions crafted by the most creative minds on the planet. Those take the form of Hollywood movies, television shows, and online games. All this gets in the way of student motivation for learning.

Thankfully, experimental psychology has demonstrated that some techniques for maintaining motivation in the face of this media onslaught work better than others.

The theories and techniques of goal setting as set out by Locke and Latham have clearly shown that the articulation of concrete goals has a major impact on performance and the achievement of those goals. Roughly 95% of the studies looking at this effect have shown that effective goals need to be difficult, yet possible to achieve. The SMART model,

originally devised for project management by Locke and Latham, has shown tremendous efficacy in helping learners attain desired outcomes. When goals are Specific, Measurable, Attainable, Realistic, and Timely, they have a much better chance of being realized.

Implementation intentions

It turns out that the manner and tactics in which students set their intentions to learn has a profound effect on learning outcomes. This has been demonstrated by Peter Gollwitzer in his 1999 paper that appeared in American Psychologist. Gollwitzer established that goals set with *implementation intentions* are far more effective than goal setting alone. Intentions instigate important effects in the mind when they are crafted to specifically touch on the "when, where, and how" of setting goals or avoiding distraction.

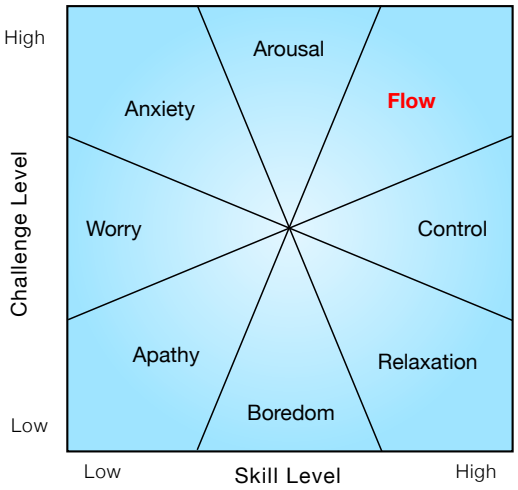
One experiment involving college students performing math calculations showed that the effect was large. Two groups of students were bombarded with award-winning TV commercials while performing math calculations. One group, who was instructed to think, "I will not get distracted," did, indeed, become wholly distracted and performed poorly. The second group who thought, "Whenever the distraction arises, I will ignore it," did far better. This type of *distraction-inhibition* intention also helped students more than an intention phrased in terms of *task-facilitation* such as, "Whenever the distraction arises, I will increase my efforts at the task in hand."

In other experiments, Gollwitzer demonstrated that goals are far more likely to be attained when proper intention implementation are constructed. In a student assignment given to a large class, 75% of the students who made an intention implementation achieved the assignment by the deadline. Of those who did not make an intention implementation, a mere 33% attained the goal.

"Goal intentions have the structure of "I intend to reach x whereby the x can be a behavior or an outcome. By forming goal intentions, people translate their noncommittal desires into binding goals. The consequence of having formed a goal intention is a sense of commitment that obligates the individual to realize the goal.... It seems appropriate, therefore, to advise individuals who suffer from being distracted (e.g., students doing their homework) to resort to forming implementation intentions that focus on ignoring distractions, rather than stepping up efforts."
Peter Gollwitzer, 1999

Flow

Mihaly Csíkszentmihályi was the psychologist who first postulated this happy and productive mental state that accompanies highly motivating activity. Flow producing activities vary widely from person to person. Some people will experience flow while writing software code, ascending a mountain peak, playing football, or bird watching. Time seems to stand still because the brain is highly focused. It does not contain sufficient bandwidth for attending to other stimulus in the environment or for dwelling on other, perhaps less pleasurable emotions.



A person's set point is in the center of the chart.

In the chart above, flow is attained when a person's skills are matched with the challenge of the activity. Flow shows us that positive emotion can be generated by the performance of tasks. The activity itself is the cause of the resultant emotion. Skill level and task difficulty are the two factors that generate emotional response. When tasks are too difficult, negative emotions arise. When tasks are too easy, boredom ensues. When skill and difficulty match up, then the state of flow makes learning enjoyable.

Remembering back to the previous paper on emotion, we can see that Csíkszentmihályi's flow concept is very similar to the chart of human emotion. Recall that the two axis of arousal and valence (positive or negative) give us the full range of emotional experience from depressed to happy to anxious to contented.

Applying the concept of flow to learning, we realize that material that is too difficult will cause anxiety, while material that is too easy will create boredom. In both cases, learning and memory will suffer. Material must be well suited to a learners level of progress to ensure a positive experience, one that the learner might like to repeat.

"Flow is being completely involved in an activity for its own sake. The ego falls away. Time flies. Every action, movement, and thought follows inevitably from the previous one, like playing jazz. Your whole being is involved, and you're using your skills to the utmost."
Mihaly Csíkszentmihályi, Wired Magazine

The question for educators and technology providers is how can the experience of leaning generate the feeling of flow in a student's mind? How could a learner's current level of skill engage them deeply in different kinds of content while the challenge level is sufficient to stave off boredom. Clearly, the mental state of flow is a trigger for learning and memory, but since every learner will have their own distinct skill level, an effective online system must be able to discover that level and then offer up challenges that are just difficult enough to heighten arousal, interest, and focus without creating anxiety.

Music and movies are captivating, but no industry has perfected the art of flow and its motivating influence more than video games. We'll discuss their remarkable power soon.

Progress & Optimism

Education in both western and eastern traditions has emphasized personal improvement through the power of knowledge, self-discipline, hard work, and perseverance in the face of adversity. There is not much worse in life than feeling stuck in a rut in which nothing gets better. Pessimism is the result and learning suffers. We are wired to feel best, learn well, and perform productively when we are making some modicum of progress towards attaining our goals.

We can realize how progress and optimism are vitally interwoven by considering their polar opposite, a phenomenon known as *learned helplessness.* This effect was first observed in laboratory animals who were exposed to an uncomfortable and frequent shock through the floor of their cages. With nowhere to go and progress impossible, the animals eventually gave up, utterly helpless to change their circumstances. The truly strange part of the tale is that they maintained a sense of helplessness even after the doors on their cages were opened and escape became obviously possible.

Perhaps learned helplessness might be confined to animals with far less cognitive prowess than humans. Isn't it likely that the power of thinking and language would overcome helplessness once circumstances changed? Sadly, we too can give up all hope. Even when opportunity is present, people who have been subject to life situations in which their efforts never made a difference, or where the helplessness of parents,and teachers was transferred over time, suffer from learned helplessness.

In a remarkable study, English speaking students in a poor inner city setting were unable to learn how to read. No matter what learning techniques were applied, the students failed at every attempt and simply could not make progress. That is, until a very unusual idea was tried. Researchers used Chinese characters instead of English words as the basis for reading. Miraculously, within a few hours, these previously failing and helpless students could read Chinese sentences better than they had ever read English. Somehow, their previous experiences with parents, the educational system, and their general social circumstances of failure had imbued them with learned helplessness and extreme pessimism.

> *"Within hours, they were capable of reading more complex symbolic sentences than they could in English. The children had apparently been previously taught all to well that reading English was beyond their ability."*
> *—Robert Sapolsky, Why Zebras Don't Get Ulcers*

It doesn't have to be this way. Studies also indicate that the reverse is true. Martin Seligman, a former president of the American Psychological Association, has been instrumental in turning around the field of psychology from one that focuses on the multitude of ways things can go wrong in the mind to the strategies and strengths that give people resilience in the face of adversity. He strongly believes that a society focused on developing these virtues in young people would be far more productive and would also save billions in health costs due to mental incapacity from problems like depression.

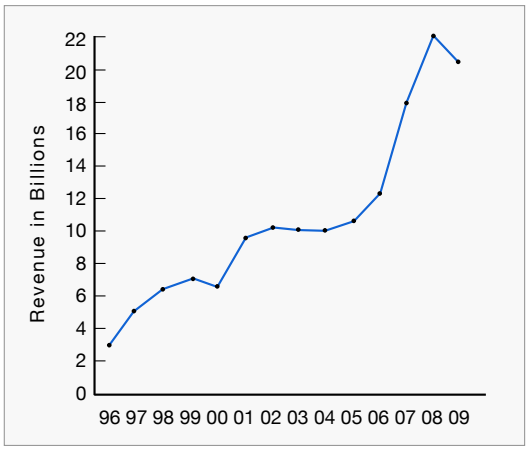
> *"We have discovered that there is a set of human strengths that are the most likely buffers against mental illness: courage, optimism, interpersonal skill, work ethic, hope, honesty and perseverance. Much of the task of prevention will be to create a science of human strength whose mission will be to foster these virtues in young people."*
> *—Martin Seligman, President of the APA*

Better still, people can move from a state of learned helplessness to a state of *learned optimism*. In his book of the same name, Seligman shows how techniques that go by evocative names like distraction, disputation, distancing, evidence, and alternatives can move the internal dialog of consciousness, what Seligman calls the *explanatory style,* in a positive direction. And, the evidence for optimism's effects on learning are unequivocal. Students with higher levels of optimism and positive explanatory style perform at higher levels than their "talent" (as measured by IQ and SAT scores) would indicate.

> *"I think "talent" is vastly overrated. Not only is talent imperfectly measured, not only is it an imperfect predictor of success, but also the traditional wisdom is wrong. It leaves out a factor that can compensate for low scores or greatly diminish the accomplishments of highly talented people: explanatory style."*
> *—Martin Seligman, Learned Optimism*

Games

If there is one datapoint that proves the power of games to motivate people, it is the fact that annual U.S. revenues in the online gaming industry have recently exceeded those of the music and film industries. How did they do it? By utilizing every single one of the previously discussed motivational triggers.



U.S. video game industry revenues (1996 — 2009)

First of all, play is an ancient mental motivation and probably goes back at least 50 million years. It is especially vivid in young or adolescent mammals but is also evident in adult creatures, especially adult human beings. Monkeys, wolves, antelope, lions, and nearly every other mammal on earth begin to engage in playful roughhousing shortly after birth. Play is really the motivated practice and refinement of physical and social skills which will soon fully occupy their full attention. In short order, playful babies will need to find their place in a social hierarchy, hunt for food (or avoid becoming food), find a mate, and successfully reproduce. The desire for fun and games is how nature inspires creatures to practice, learn, and remember.

Young mammals are compelled to play. Resistance is futile.

This practice period is delayed a bit in humans who have an unusually long childhood because we are born many months early so that the brain can grow to its full size outside the womb. Millions of years ago, the evolutionary trade-off was between the size of the female cervical opening and the size of the infant cranium. Childbirth is the rather agonizing aspect of that evolutionary compromise between baby brain size and female hip width.

In order to get across the idea that fun is a big part of our genetic heritage, one more evolutionary point is worth mentioning. Contemplate the observation that no other animal on the planet can pick up a rock (or baseball) and accelerate it to 90 miles per hour, much less deliver the speeding projectile to its target with near pinpoint accuracy. This ability was superbly useful both offensively and defensively in the ancestral environment of the African savanna. Indeed, some anthropologists think our ancestors developed an intimidating rock throwing ability that could drive a pride of lions off their kill (which we then appropriated as our own). Before the invention of spears and arrows, throwing rocks was also an early form of tribal warfare. Hence, it was utterly critical that members know how to defend against invaders (or, to attack another tribe during a food shortage).

Now, couple that notion with the observation that a group of young boys can't help but throw rocks when the opportunity arises. They compare their targeting accuracy as a game of points and will do so for hours (an early experience of flow). Rock-throwing is a form of playful practice still with us today and it derives from deep motivations that go back at least a few million years in human (hominid) evolution.

That is the bottom-line explanation behind both the sports and video gaming industries today—we are motivated to play, or watch other people playing, because it kindles ancient memories that were once essential for survival—namely, hunting and warfare. Psychologists like Jonathan Haidt have quipped that, "Sports is to war, as pornography is to sex."

Today, the best game designers are consciously manipulating the ancient mental machinery that is attuned for war, hunting, sex, and even agriculture (Farmville has 60 million users). They scrutinize massive amounts of user data to figure out which psychological motivations are working and which aren't. Billions of bits of behavioral information enter the analysis departments of companies like Sony, Blizzard, Microsoft, and Nintendo. And, game companies utilize the services of neuroscientists and psychologists who are fully aware of the role of dopamine, reward schedules, mirror neurons, evolutionary psychology, and uncertainty in motivation and behavior.

All the triggers we have discussed so far are present in abundance in activities that span the gaming landscape; from the violent battlefields of World of Warcraft (WOW) with 12 million users to the bucolic agricultural pursuits of Farmville. Let's look at the learning triggers that games employ:

- *Curiosity* is manifest in all games. Visual and auditory data flow to users in copious quantities, yet information gaps are ever-present. The gaps draw users forward from one level to the next. Characters, clues, and landscapes give some information about what might be coming next and some kind of epic finale awaits, but no one can be sure exactly the form it might take.
- *Seeking* is fundamental to the brains of all mammals and is found in nearly all games in some form. Highly driven by dopamine circuits, some researchers think it is one of the most ancient animal brain systems powering behavior since the search for food, shelter, and mates is fundamental to

survival. A majority of games and also web-based services like Google, Ebay, and YouTube should be considered seeking exercises that use a hierarchy of clear motivational rewards within a boundless virtual world of exploration.

- *Imitation* arises through the brain's mirror neuron system—well developed specialist neurons seen mostly in primates, especially in humans. Mirror neurons give us a unique ability—observe another's behavior and learn from it. Players often acquire gameplay by watching more advanced users operate the controls. In multi-player games, users imitate the play and strategy of experienced veterans in order to advance as quickly as possible.
- *Rewards* within games are obvious motivators. They can take the form of game points or social points that drive continued usage. Levels are actually a shorthand method for conveying points and showing off mastery (I'm a Level 20 Cirulean Lord, for example). YouTube encourages users to rate videos with their star system, and of course, every video is rated by user views, essentially a leaderboard point system. Redeemable points that can be traded for something physical and real are particularly powerful with females who often find many games a "waste of time."
- *Anticipation* is used brilliantly by game designers who foster the feeling that a reward is close at hand but it will take effort to achieve it. The Sims from Electronic Arts is the biggest selling PC-based game of all time and its users anticipate that thoughtful input into their virtual characters will have an effect in the simulated social landscape they inhabit. Farmville's farmers expect that tending their crops will produce a bountiful harvest. WOW players anticipate destroying a "boss" at every level, but their certainty is constantly challenged through repeated failure which spikes dopamine levels and seeking behavior (perseverance).
- *Uncertainty* propels players who rarely know exactly what is coming next. Even users who explore YouTube videos can't predict what might show up. In World of Warcraft, 12 million users are constantly progressing through the game but never have a clear idea of what the next level holds in store. But, as Sapolsky and others have pointed out, the environment is actually benign and this makes uncertainty attractive. The mind knows it is playing a game from the safe confines of home (or office) and uncertainty in agreeable circumstances creates motive force in brain circuitry.
- *Risk* lurks in nearly every game. A player can easily "die" in games like WOW or lose their crops to drought in Farmville. The feeling of risk is similar to uncertainty but carries the actual danger of loss while uncertainty is more concerned with the unknown. Again, just as fans of horror and action movies feel safe in the theater, gamers know that they can't lose real money or their lives. Consequently, their state of arousal through glucocorticoid, norepinephrine, and dopamine circuits stays high while emotional valence remains positive (alert).
- *Status* is the ancient imperative for all primates and is clearly one of the chief motivators for gamers who are highly attracted to comparing their performance level to others. Status is shown off with points, tokens, weapons, and special apparel. In "one person shooter" games, users will often text or Skype their approval of a fellow gamer's performance. In World of Warcraft, ten to forty tribe mates can see by your apparel and armor and instantly know how you are doing in the hierarchy of rank.
- *Goals* have been perfectly defined in evolutionary and motivational terms by the psychologist who crafted the concept of *flow.* He put it this way: "Goals transform a random walk into a chase. You need clear goals that fit into a hierarchy, with little goals that build toward more meaningful, higher-level goals. Here you are, tracking the footprints of some animal you haven't seen." That perfectly describes many of the most popular video games.
- *Flow* is apparent in users who lose track of time and space during gameplay. Game design theorists propose that three high-level components are present in all games and they conform well to Mihaly Csíkszentmihályi's conception of flow:

  1) Challenge—without clear challenges that begin easily enough but become progressively harder as skill improves, users will experience boredom and stop playing.

  2) Response—this is where motivation becomes action. A weapon is fired, a field planted, a simulated character engages another.

  3) Applied skill—amateur status is how everyone begins a game, but expertise builds gradually with each session and challenges are matched to player aptitude. When skill is applied successfully to challenges, flow results.
- *Progress & optimism* and the feeling of personal improvement is achieved in virtually every successful game like WOW, Fable, Everquest, and Farmville. Often the goal is not fully understood but the feeling that one is improving towards a better state is paramount and made explicit through points, levels, and social interaction. Optimism is precisely the opposite of learned helplessness, the mental state akin to depression. Gamers are motivated to return to experiences that demonstrate progress and the consequently buoyant feelings of optimism.

An analysis by the neuroscientist and psychologist, Amy Jo Kim, has shown that additional triggers drive gamers forward. Her research into video games, online experiences, and YouTube, the world's most popular non-search website, has revealed four additional characteristics of compelling games.

- *Collecting* is embodied in networks like Ebay. With nearly $9 billion in revenues, Ebay is built upon the powerful human urge to collect. In many cases, buyers are building collections within a narrowly defined category—from beanie babies to antique globes. YouTube encourages users to collect favorite videos for sharing with others. The nuanced idea of *partial completion* is also a powerful motivator. LinkedIn shows its users that they are x % away from completing their cadre of friends and associates.

- *Feedback* is a critical component that helps users move quickly to mastery. Games like Brain Age which help people sharpen their cognitive skills show charts over months and years to keep users engaged with their personal progress. Social feedback is another powerful form that has been used effectively by Facebook with its 500 million users. Feedback let's users feel connected to a defined community even if some comments exceed the bounds of good taste.
- *Exchanges* are based on the massively important and uniquely human abilities of conversation and trade. Ebay is a good example of not only the exchange of items, but also the exchange of feedback regarding buyer and seller experiences. YouTube allows users to post video responses and to re-edit original works so that whole reconstructions and even parodies are exchanged within the network.
- *Customization* is apparent in apps like MySpace where users can personalize the layout, colors, and graphics of their pages. World of Warcraft gamers can choose among many types of avatars with varying costumes, powers, and skillsets. YouTube users are able to "skin' their personal channel with themes, colors, modules, and events.

As can be seen from this rather lengthy list of mental triggers, game companies and other web-based enterprises have spent a lot of time and capital getting their offerings in sync with how the brain works. One of the leading game theorists, Raph Koster, has argued that games are compelling learning environments.

> *"Games are something special and unique. They are concentrated chunks ready for our brains to chew on. Since they are abstracted and iconic, they are readily absorbed. Since they are formal systems, they exclude distracting external details. Usually, our brains have to do hard work to turn messy reality into something as clear as a game is."*
> *—Raph Koster, A Theory of Fun for Game Design*

The challenge for the educational establishment is to begin experimenting with some of these triggers for learning in their own formal system—schools.

Game design principles

Nicole Lazzaro, a leading designer, has articulated the precise components of best-selling games. Keep in mind that underlying nearly all these principles of game design are some aspect of our universal human brain circuitry that drives the attraction and motivation.

1. Easy to Learn, Lifetime to Master
2. Simple obvious controls and rules that are easy to master
3. Allow players to discover controls and goals through simple exploration.
4. Provide clear, immediate, and meaningful feedback.
5. Offer clear and obvious short term and long term goals.
6. Players should be able to succeed in the first 10 minutes or earlier.
7. Support short session times of 10-15 minutes as well as longer.
8. Offer consistent controls and labels.
9. Vary the type of challenges so play does not become routine.
10. Support multiple player styles such as Bartle's 4 types: Achievers, Explorers, Socializers, and Player Killers.
11. Offer more than a high score as a reward, make gameplay intrinsically rewarding.
12. Offer community/social features such as high score boards, in-game chat, and message boards.
13. Use audio feedback and sound effects to increase excitement and make interaction more real.
14. Include the option to turn audio off, so games can be played anywhere.
15. Test all aspects of the Player's experience with real users.
16. Adjust spacing between play and reward to keep players motivated and to imply progress.
17. Allow player's to save their high score, at least between consecutive games, or otherwise show player progress between games.

Summing up motivation

As we discussed, the mental source of motivation in terms of two over-arching ideas—dopamine and the working self. Think of those two as the bookends of a motivational continuum on which every human being moves about over the course of their lives. The molecular neurotransmitter dopamine creates the source feelings of anticipation and curiosity which drive creatures to seek out objects, patterns, and information in their environments. The environment then pushes back with risk and uncertainty which further spike dopamine levels causing heightened focus and attention towards the goals at hand. Finally, the attainment of a reward reduces dopamine and the relaxed pleasure given off by the opioid receptors takes over (for the time being).

If dopamine is the molecular motivator working at the deepest levels of the brain, then the *working self* is the high-level construct that emerges from a complex mind, one that has learned and integrated countless lessons from the environment. True, the mind must be constructed from a changing pattern of billions of neurons, but the pattern is astonishing in that it can create a sense of self, an ongoing narrative storyline that desires abstract goals found only in the distant future.

Within this continuum, from molecules to self, is the domain in which people and society writ large must find

their way forward. It's not a stretch to say that the current school system, especially K to 12, aligns poorly with the motivational nature of human beings. We are designed as anticipating, seeking, curious creatures compelled to engage with the world and learn from it. With human nature as our backdrop, it is then not surprising that the modern American educational experience, in its current factory format, appears to dampen the motivational drivers discussed so far. If *seeking* truly is the granddaddy of all motivators as leading neuroscientists claim, how much learning can transpire when it is prescribed en masse rather than discovered by individuals on their own terms? Were seeking and curiosity to become mostly extinguished from society, the cognitive malaise that would set in over the long haul would convey extraordinarily negative effects on its citizenry.

Summing up the tripartite self

With a sense of the drives, incentives, rewards, and goals that cause motivation now under our belts, we have traversed the three domains in which one can conceive self-hood. Cognition allows creatures to use the executive functions of working memory to consciously integrate long-term memory with present events and direct behavior towards a desired phenomenon and away from others. Emotional components of the brain calculate the value of phenomenon, both positive and negative. Learning takes place when arousal is high and fear levels remain low. Finally, motivation moves thinking and feeling into the physical world as creatures seek out incentivized rewards. Human beings are particularly gifted at maintaining motivation towards goals for many years.

There is much yet to learn. The human brain is composed of around 100 billion neurons and 500 trillion synaptic connections. The circuits that mediate cognition, emotion, and motivation are massively cross connected and, as yet, not fully deciphered. No one, for example, can describe exactly how semantic knowledge is stored in the brain. Is it 50 synapses or 50,000 that form a representation of the abstract concept of the Panama Canal? How are those synapses distributed?

While we have some understanding of the likely hierarchical nature of the representation, no one can really describe how facts, ideas, theories, concepts, and higher order thinking are held in organic tissue. Despite our inability to fully comprehend the secrets of mind and memory, remarkable progress has been made. Experimental psychology, neuroscience and gameplay clearly show that all of us move through life with mental triggers that can be turned on to enhance learning, even if we don't perfectly understand their precise underpinnings in the brain. The designers behind Amplifire and the accelerated memory protocol continue their quest to employ those triggers and instantiate them in online software applications that help students absorb knowledge and attain success.

Postscript—the even bigger picture

Perhaps one last point should be made. Theorists at the deepest levels of physics contend that, at the end of the day, there are really only three large-scale classes of stuff in our universe: energy, matter, and information. Think of those three in the context of economic well-being and how your present circumstances are so remarkably different from that of your hunter-gatherer ancestors. All the wealth and prosperity that ever existed, or ever will, derives from some combination of those three. Not only are energy, matter, and information the sources of modern prosperity, they are also, by definition, constraints on future prosperity.

Among economist's many current worries, one in particular should interest every educator with a reasonable ability to see into the future (using that prefrontal cortex). Information, it turns out, is the essential ingredient that allows homo sapiens (the wise hominid) to exploit matter and energy in our enormously complex economies. Information appears to have become the critical constraint slowing down the march towards greater wealth, equitable distribution, and long-term sustainability. This constraint may be especially acute in the American economy, now at risk of being informationally out-competed by other cultures.

In his enlightening book, The Origin of Wealth, Eric Beinhocker discusses the informational capacity of creatures embedded in Darwinian nature with the circumstances of modern man, embedded in a complex economy. He finds that the principles of life and the origin of its complexity, so painstakingly teased out by Darwin, operate fundamentally unchanged in economic systems.

> *Evolution is a knowledge-creation machine. Think of all the knowledge embedded in the ingenious designs of the biological world. A grasshopper is an engineering marvel, a storehouse of knowledge of physics, chemistry, and biomechanics -- knowledge that is far beyond the bounds of current human ability to replicate. A grasshopper is also a snapshot of knowledge about the environment it evolved in: the foods that were good to eat, the predators that needed to be defended against, and the strategies that worked well for attracting mates and ensuring the survival of progeny. There are terabytes of knowledge embedded in a single grasshopper. Now*

think of the mind-bogglingly immense amount of knowledge embedded in the entirety of the biosphere. All the order and complexity, all the knowledge, was created and assembled by the simplest of recipes: differentiate, select, replicate, and repeat.

Now, look around the room you are in and think of all the knowledge embedded in the objects around you. The carpentry involved in making your chair, the cotton-growing, fabric-making, and fashion-designing knowledge embedded in your clothes; the knowledge of electricity and the materials embedded in your light; and all the knowledge embedded in your books. The sheer volume of knowledge in the econosphere is as staggering as that in the biosphere. The econosphere, too, was created by differentiate, select, amplify, and repeat. We have found the answer to our quest...Wealth Is Knowledge.

If Beinhocker is right, then society should contemplate the deep implications. It means that, while every profession is important in an economic system—people busily using their skills (embodied information) to convert energy and matter into useful products and services—it also means that those who are dedicated to education are critically important.

Information brought us this far. It is the key that unlocks access to the power and wealth within energy and matter. It created stone tools, spears, pottery, agriculture, and art. It eventually gave us science, the Enlightenment, the Industrial Revolution, and the Age of the Internet. No one can deny that astonishing progress has been made. Yet, one thing has not changed. Knowledge remains crucial. The physical and social circumstances of the 21st century carry unique and daunting problems that homo sapiens has never faced before, much less solved. If wealth is knowledge, then it falls upon knowledge to, once again, show us how to adapt to our new circumstances and prosper.