Notes on the Cognitive Science Behind *Lightning Cards*

(This is part one of a work in progress)

Lighting cards are: A mnemonic flash-card system—integrating visual-perceptual memory techniques, mind-maps, active learning games, and spaced repetition.

I. Intro to the Lightning Cards mnemonic flash-card system

Genius Dojo Lightning Cards, is a game and study method that facilitates a type of active learning. This specific form of learning is creative, visual, engaging, and ˙effective for learning and memorizing any subject matter. The creation and use of these cards develops the meta-learning skills of memory and creativity. The creation and use of these cards also engages the learner with the specific content of the cards, and that content is learned more efficiently.

Like conventional flash cards, the system employs cards with information to be recalled from a question or cue. But Lightning Cards differ from conventional flash cards. Lighting cards use an optimal form of visual-perceptual mnemonics in tandem with a spaced repetition recall scheme. Conventional flash cards tend to isolate one item per card. A more optimal structure of information is in clusters of related items, like a mind-map, in sets of two to ten. Lightning Cards have multiple related items in knowledge clusters. The knowledge clusters may include some text but they are mainly visual cues—encoded information in the form of Spark Sketches.

Core notes are distilled down into key phrases then to key-words & key-images as pictures that act as mnemonic techniques. The game variations can be engaged as a more solitary meta-learning training or study activity, or in group activities of co-creating.

The Lightning Cards is one of the 23 games of the *Genius Dojo* system. It actually integrates several of the games and techniques into one process of active learning.

These integrated meta-learning techniques promote:

- Engagement with the prosody and meanings of words
- Dynamic composition of symbols and metaphors
- Ability to notate ideas as spark sketches
- Visualization expertise

—all integrated into a playful humorous form of memorization and learning.

Why are they called Lightning Cards?

Because they are like flashcards, but different. Lightning is a specific and more effective and more powerful form than just a flash. And the goal is not just knowledge or memory, but epiphany. Illumination and epiphany are like a lightning strike. Lightning Cards are similar to a system called the Leitner system. Leitner sounds-like the word lightning. The Leitner system is a spaced repetition scheme for using flashcards. Lightning Cards use a similar spaced repetition technique, but Lightning Cards have a simpler scheduling method. The lightning box has four slots for the spaced repetition scheme, and is easier to make into a habit. Lightning Cards also employ a specific visual-perceptual mnemonic system. Lightning Cards are typically oversize 5 x 8 inch cards and they use clusters like mind maps and a game-like type of active learning.

The Lightning Cards have mind-maps or cluster diagrams made of spark-sketches that are like professor Edward Tufte's Spark-lines and his other descriptions of data-rich graphics. They are like flashcards but based on the *Genius Dojo System* and *Spark Sketching*. These sketches are similar to some of the cartoons and graphic elaborations in Medieval texts called illumination's. We have a mnemonic flash card game, made of cluster diagrams of sparks sketches, reviewed in a spaced repetition system. So… flashes of lightning, sparks, and illumination. Lightning Cards are a unique and optimal system.

II. The most Ancient prehistory of Lighting Cards

As with all wonderful things—Lightning Cards have an ancient and mythological origin story. The earliest written account is in Plato's Phaedrus. Socrates is telling the story about the Egyptian god Thoth, who had just invented a new super-technology, that will change the world. Thoth describes it to Thamus, the Pharaoh of all Egypt. King Thamus, is skeptical, and warns about what might be lost by this invention.

The supernatural being Thoth, is the inventor of numbers, arithmetic, geometry, astronomy, gambling, and… writing. Thoth approached King Thamus with his inventions, stating they should be shared with the other Egyptians. The king inquired about the purpose of each creation, and as Thoth listed their uses, the king praised or criticized the various arts. When it came to writing, Thoth claimed it would make the people of Egypt wiser and improve their memories, likening it to a healing elixir.

But the king responded, "You, the father of writing, have been deceived by your love for your creation, you believe it has a power that is the complete opposite of its true nature. Memory is a gift that must be kept alive by continuous training. This invention will cause

forgetfulness in those who learn to use it, as they will stop exercising their memory and rely on what is written instead. Their memory will tend to weaken from disuse.

What you have created is not an elixir for improved memory, but merely a convenience. And what you offer your readers is not true wisdom, but only the appearance of wisdom. They may read many things, but without the guidance of a living master, they will have book knowledge but not true empirical wisdom."

Like all new technologies, there is a hidden cost to this invention of writing. Real wisdom does not produce words, but profound meaning and truth. Memory is more reliable when it doesn't have this external aid to fall back on. As new technologies are often regarded today, so writing was considered a mixed blessing. All technologies have a hidden cost.

This story has been told and retold in many places and times. It is an allegory that introduces many ideas important to our consideration here. Threads from the stories of Thoth reach thru Antiquity to Medieval times, thru the Renaissance and to our epoch. So many alchemists, early semiologists, inventors, and mnemonic practitioners, studied the esoteric teachings of Hermes Trismegistus, another name for Thoth.

The mythology of Thoth says something about the origin of written language, as well the graphic illustrations of pictures. In the hieroglyphs of Ancient Egypt we see drawn symbols representing spoken language and also the illustrations of scenes. The two streams of sound and light—speech as written word, and the images of glyphs, both imprinted on papyrus and stone. Speech and pictures like the cognitive science of the dual-coding theory of Allan Paivio.

What is it about this turning point where humans developed spoken language and then written words? What was gained? What was lost? According to King Thamus, we lost a range of abilities—a type of memory ability associated with the ancient preliterate human, who was more established in the dream-mind—compared to our more restrained gross-incarnate waking-state mind. That indigenous-shamanic dream-mind is more subject to superstitions and made-up stories. But in that deeper, more primary cognitive level can be found a range of abilities we, in our time, have almost completely lost.

This is not an argument against writing and books. But it reminds us that there was an oral tradition before literacy. That oral tradition had its own techniques and practices that we have lost—or at least forgotten how to employ. And this happens with all technologies, there is always a hidden cost.

Modern communications technology doesn't change our need to learn and remember, or make memory less important. In fact we have more information to manage—too many

things to learn. Computers do not really have brain-minds as if to replace the human brain-mind, but are only extensions of, reflections of, and tools for, the human brain-mind. But there is always a hidden cost to adopting a technology, and once it is adopted it is not apparent what that cost was. By gaining the computer and internet—what have we lost? By gaining the technology of written language, literature and reading—what did we lose? Is it so important now? We can't even remember.

The god Thoth was often pictured in ancient Egyptian art, Thoth was pictured as a baboon or monkey. Humans are superior to monkeys in all cognitive functions, right? Around the year 2007 articles started popping up in the news about monkeys that had remarkably superior memory as compared to human beings.

> BBC Science News 2007/12/03
> **"Chimps Beat Humans in Memory Test**
> Chimpanzees have an extraordinary photographic memory that is far superior to ours, research suggests. Young chimps outperformed university students in memory tests devised by Japanese scientists. The tasks involved remembering the location of numbers on a screen, and correctly recalling the sequence".
>
> And…
>
> "Ape trounces the best of the human world in memory competition,
> When scientists found out that chimps had better memories than students, there were unkind comments about the calibre of the human competition they faced. But now an ape has gone one better, trouncing British memory champion Ben Pridmore. Ayumu, a seven-year-old male brought up in captivity in Japan, did three times as well as Mr Pridmore at a computer game which involved remembering the position of numbers on a screen. And that's no mean feat - the 30-year-old accountant from Derby is capable of memorizing the order of a shuffled pack of cards in under 30 seconds".

So what is really going on here? The chimp had to first, go through some training to recognize the distinct numbers and use the computer keypad, just to accommodate the conventions of the experiment. But the real significance, is that a chimp actually proved it had natural visual memory superior to a humans. And not just any human, but a trained mnemonic expert! Perhaps… the chimp lacks ability in the higher mental functions and verbal conceptual waking-state mind, but has some superior ability related to the visual-spatial dream-state mind. These more primitive faculties point to our innate and lost superior memory abilities. The scientist in the study, alluded to the preverbal state of the chimp as being related to the demonstrated superior memory ability. These well-

documented experiments demonstrate memory abilities that are easy for chimpanzees, but beyond ordinary human ability. Perhaps this is what was lost by the invention of Thoth.

Subitizing is the sudden perception of a quantity of objects without counting. It is a type of instant pattern recognition. Terms from cognitive science: “chunking” “working-memory”, “the Seven Plus or Minus Rule”, “diviso” (Medieval Latin), and “subitizing” these are closely related terms—they are describing the same phenomena. The chimpanzee is demonstrating a superior short-term memory. The chimpanzee is performing a type of subtitizing, it is a spatially based, locational memory related to the Method of Loci. It is an inherent, more primitive ability that is preverbal, and a more essential state and habit of mind. Like being able to intuitively navigate through the jungle to find fruiting trees. And just looking at the trees you can tell which ones have the most fruit, without counting.

We are going to explore the functioning of human memory, especially its pre-verbal form as demonstrated by the chimpanzees in this experiment. But this lost preverbal ability will be reclaimed and integrated with the verbal mind. There is already a tradition for this art and science—with techniques to develop these cognitive abilities. This is a rediscovery of the preverbal dream-mind seen active in mythology and non-ordinary experiences. It is closely related to mnemonics, the art and science of memory. It is related to the phenomenon of locational memory. This preverbal ability can be reclaimed and better integrated with our common verbal waking-state mind. It can even be practiced in a system of techniques to amplify our abilities to remember, to learn, and to invent. This is our consideration of this cognitive science of learning and creating.

III. Sciences and ways of knowing

Human-kind’s known history stretches back through the written accounts, since the invention of literacy. Before that, we have oral traditions. Some bodies of knowledge and stories even survived from the preliterate oral traditions, and were recorded in writing. Before the invention of writing, we have the oral tradition, mythologies, knowledge that becomes more obscured the further back in time we go. Some artifacts and archeology survives as evidence of more ancient knowledge, but really we relegate our working beliefs to the time-span of our own individual life-experience and our specific culture’s written knowledge. Perhaps we even have some intuitions or non-ordinary epiphanies that inform us beyond our limited range of perception.

Human-kind has developed methods for knowing that have become cultural traditions. Science is one of those traditions, a very successful one, and one that has given us all types of technologies that are intertwined with our daily living. Science is not the only way of knowing. Your specific life-experience and specific culture is not the only point-of-view to operate from. And really there are many different sciences. So even what we call "Science" is many different branches, groups, and individuals.

The scientific method is the great tool in all these branches. Ideally the scientific method is a form of questioning and free inquiry. To cut through ignorance and superstition, to discover the truth, evidence is the primary material. The precious diamond cutting tool is the scientific method. The scientific method has some steps and variations, but it is a formally codified practice of collective investigation. It starts with observation, and logic and reason… and also intuition. Hypothesize, based on the evidence, perform experiments that are repeatable by others, discover of what is real. Discover and assert conclusions that are based on that rigorous research using those scientific techniques that are verifiable and reproducible. This is the scientific method.

In our era, we have branches of science, and disciplines of knowing each with their own distinct purposes. Each branch is often unaware of the discoveries and virtues of other branches. So it becomes a superior method to work across disciplines. To design systems we need to communicate with others and find precedents in these distinct disciplines. Sometimes we may synthesize the evidence and disciplines, but always we must find evidence. Evidence is our primary material for discovery. To share our discoveries with others we must show precedents. These concrete examples become the pillars we build our architecture on.

Our specific purpose here is to learn and practice a system that will amplify our ability to learn and create. In designing this system, or at least to show precedent, there are several branches of the sciences that are most fruitful. The modern disciplines of "systems theory," "cognitive science," and "information theory"—provide many valuable terms, distinctions, and ways of understanding—and in these fields we see concrete examples of our discoveries from other contexts. These three fields are interdisciplinary and that gives them the strength of coming from multiple points-of-view—a synthesis of multiple paradigms.

Systems Theory: a system is a structure that is observed spanning many fields and disciplines. It is composed of interrelated parts or components that integrate in symbiotic processes. It is a way of looking holistically at the continuities of real life. In the dynamic model of a system, no one element is separate. We focus on complex interrelationships across the boundaries of insides and outsides.

We can't exclusively locate: meaning in the word, life in the cell, cognition in the brain, the person in the body, experience in the world. Meaning, life, cognition, person, and experience are extended or distributed across word, cell, brain, body, and world. These are all active, dynamic processes, existing only in the relationships of these apparent parts. Cognition is not a brain-bound activity, but rather is distributed across the continuum.

Cognitive Science: is a number of related interdisciplinary studies of mind and intelligence, spanning many fields: philosophy, psychology, neuroscience, linguistics, anthropology, sociology, education, and computer science. It is the beginning of the discovery of Consciousness in the scientific-world-view. It is one of the new sciences adapting to a more psychophysical paradigm.

Cognition and memory are "situated" in the context of body, perception, action, experience, and the real-world environment. It is an "embodied" cognitive loop of transmission and reception. Cognition is "distributed" across body, brain, and world. It functions in natural rather than experimental settings. In reality cognition exists in an "extended mind."

Complex human activity must be understood across the entire system, in a "cognitive ecology" which includes subjective attention, neurobiological and psychological processes, material artifacts, technologies, and cultural settings. These cognitive processes take place both inside and outside the minds of people, in between the boundaries of thought and the cognitive artifacts that structure it, "inside" and "outside," are in a single continuum.

Information Theory: Is related to, and (for our purposes) a subdivision of cognitive science. Initially developed through mathematics and engineering to facilitate signal transmission through a medium such as electricity. It is the foundation of communications technology and computer science.

Information—constraint, communication, control, data, form, shape, instruction, knowledge, meaning, and pattern. From the Latin "informare" (to inform) to give form to the mind or an idea. Information is a type of pattern that influences the formation or transformation of other patterns.

Electrical wave forms serve as a surrogate for sound and image, the sound of the voice, and images from the world are transmitted across wires and through the air as electrical fields. The telephone demonstrated that electricity could act as a surrogate for sound and voice. The telegraph demonstrated how meaning in the form of words and letters could be transmitted as dots and dashes of Morris Code across wires. That idea developed into the fundamental atom of information: the "bit". This theory made possible the development

of our modern communications technology: phone, television, satellite communications, computer, mobile-phone, digital media, and the whole internet.

Computer science had already been influenced by, and even imitated, our limited understanding of the brain and mind. Information theory was found to be so foundational, that it was extended into other disciplines such as biology, psychology, and physics. The neurons in the brain and nerves conduct information throughout the body. DNA and evolution conduct information across generations—the relationship between organisms and environments are conducting information. Even all of life and the universe are viewed as information processors performing something like computation. Even very simple algorithms repeated—iterated bit by bit, shift and replicate—are seen to give rise to immense complexity.

Our work in learning and creativity depends on human memory. The transmission of information across wires or through a field, is a very similar set of problems and solutions as the transmission of human memory— both are accurate transmission and reproduction of a message from one point in time and space, to another point in time and space.

Information (and also human memory) is stored and processed— it is encoded, encapsulated, compressed, transmitted through channels, received and error-corrected, it exists in packets and is propagated through networks. It is in dynamic-conflict and symbiotic-dance with entropy (interference, noise, decay). These same information dynamics also determine what we practice intentionally with the techniques of mnemonics.

Meta-cognition, Meta-memory and visual-perceptual mnemonics: The principles that Lightning Cards are based on, are a type of cognitive science which could be called meta-cognition or meta-memory. We will use the specific term: “visual-perceptual mnemonics”.

Meta-cognition is a way of "knowing about knowing". Like when you're aware of your own thoughts and how you're thinking about things. It's a way of understanding how you learn and solve problems. It comes from the root word "meta", meaning beyond, and “cognition” from the root word “gnosis” meaning “to know about”. Among its different forms is “meta-memory”— knowing about memory and mnemonic strategies. This is the type of meta-cognition we are most interested in—intentionally applied techniques, self-observation, measuring and taking inventory, improving our ability and our training habits.

Meta-memory is about mnemonic techniques. These are methods that help us remember stuff. They can be verbal (like poems and songs) or they can be visual (like mental

images, art and symbols). Right mnemonics are always physicalized, relating directly to the body. The idea is to create associations between easy-to-remember (perceptual) things and the harder-to-remember (conceptual) things.

The root of all cognitive processes is memory. Perception, conception, critical thinking and creativity all rest on the foundation of memory. So a system of intentional memory becomes the essential foundation to our work in learning and creativity. We couldn't even make sense of perception if there were not some memory guiding and "filling-in" our recognition of things. Even our direct perceptual experience is mediated by memory—it takes time for the brain and nervous system to process present-time experience. So even present-time experience is really a type of memory.

What is visual-perceptual mnemonics? The practice of visual-perceptual mnemonics was an integral part of education in the Ancient Greco-Roman world, and many other ancient civilizations. Over the centuries, little written information about it has survived. During the Middle Ages, and particularly the Renaissance, this discipline was practiced and evolved—then it was suppressed in the late sixteenth century—so it is generally not taught in our modern educational institutions. But in our century it has persistently resurfaced: Psychology and Cognitive Science are rediscovering many of its principles. International Memory Competitions have regenerated an interest in the training of mnemonic techniques. Through digital technology and the Internet, we are seeing a revival of visual thinking and technological tools that express visually as well as verbally.

Visual-perceptual mnemonics rely on rendering perceptual attributes and connections in the imagination, like a form of intentionally directed daydreaming. This mnemonics facilitates memorization with more speed and accuracy and stability over long periods of time (years or a lifetime). In many traditional cultures visual-perceptual mnemonics is employed across generations so it effectively lasts many lifetimes—transmitting cultural information across hundreds and even thousands of years. It accomplishes this through: face-to-face communication; visual arts; and physical enactments of story, song, dance, and theater.

In our training games, we will practice to develop new habits. The basis for these games are the principles and techniques of visual-perceptual mnemonics. Our learning and our inventing and our critical thinking and our physical performance will be based on, and influenced by, this superior foundation.

Education, study habits, and training methods in our Era: Many educators in our era casually dismiss memorization and related meta-cognitive processes, and there is still a strong bias against visual-perceptual mnemonics and visual thinking—even the arts as a whole are casually discarded. There are many commonly held illusions and

misconceptions about human cognition and learning. The arts and sciences cannot actually be separated—rightly they work together to create human culture. The arts and sciences are sisters, in the same way the Ancient Greek Muses are all sisters, and the mother of the Muses is Mnemosyne the goddess of Memory. Visual-perceptual mnemonics is a well-proven framework for cognitive processes—but it has to be intentionally and specifically designed into the training, game, or art.

The cognitive sciences and cultural traditions have a wealth of overlooked and essential insights for educators and students. The training of memory is at the foundation of all cognitive functions. The training of memory is the key to enhancing other faculties such as imagination, creativity, logic and critical thinking. Memory provides a basis for our ability to carry out complex cognitive tasks, and to apply knowledge to new problems never before encountered.

Many common study habits, teaching methods, and practice routines, turn out to be counterproductive—this is because they only serve short-term memory and not the consolidation of information into long-term memory. What is learned should also be available for creative application to new situations. Habits like: highlighting, re-reading, and cramming are the preferred study strategies of most people. These habits can be useful, but these gains in knowledge tend to fade quickly—these techniques are not sufficient.

IV. Eight areas of research from cognitive science crucial to learning, memory, and creativity

These are the eight core areas of research from cognitive science to understand the Lightning Cards game. Each of these following eight sections is a summary of these authors research that relates to our system.

1. The universal creative process common to both art and science
2. Deliberate practice, expert performance, and Long-Term-Working-Memory
3. Cognitive science applied to learning & remembering
4. Forgetting curve, testing effect, and spaced repetition
5. Subitzing, chunking, and the 7+ or minus rule
6. Imagery, reminiscence effect, key-word/key-image method, mind-map/cluster diagram
7. Dual-coding and imagery
8. External memory field, extended mind, and artifacts

These are the source researchers we will consider here (and their colleagues and predecessors).

1. **Universal creative process in art and science**
—Robert Root-Bernstein is a Professor of Physiology at Michigan State University in East Lansing, MI, USA. He is a researcher who has written about the universal creative process in art and science.

2. **Deliberate Practice, Expert performance and long-term working memory**
—Anders Ericsson is a psychologist and scholar who researched deliberate practice, expert performance, and the role of long-term-working-memory in developing expertise. He was a Professor of Psychology at Florida State University.

3. **Cognitive science of learning, memory and study techniques**
—Henry Roediger is a University Professor and researcher of Psychology. Particularly influential for his research on human learning, memory, and study techniques. He was a professor of Psychology at Rice University and Washington University in St Louis.

—Robert Bjork is a Psychologist and Professor of Psychology at the University of California, Los Angeles. His research focuses on human memory and the science of learning.

4. **Forgetting curve and spaced repetition**
—Hermann Ebbinghaus was a psychologist and philosopher who pioneered the experimental study of memory. He discovered the forgetting curve and the testing effect.

5. **Subitizing, Chunking and the seven plus or minus rule**
—E. L. Kaufman was a psychologist and researcher who coined the term subitizing, the ability to suddenly and accurately recognize numerical quantities and other perceptual attributes.

—George Miller was one of the founders of cognitive science. He clarified the concepts of: working memory, chunking and the seven plus or minus rule. He was a Professor of Psychology at Princeton University.

6. Visual imagery, Reminiscence effect, Key-word/key-image technique, Mind mapping
—Philip Ballard
—Allan Paivio
—Daniel L Schacter

7. **Mnemonics and dual coding theory**—Allan Paivio was a linguist, psychologist and Professor of Psychology at the University of Western Ontario. He is known for his research on mnemonics and dual coding theory in memory.

8. **External memory field and Extended mind**
—Merlin Donald was a psychologist and researcher who studied the role of external memory in cognitive processes. He was a Professor of Psychology and Neuroscience at Duke University.

—Andy Clark is a Professor of Cognitive Philosophy at the University of Sussex and was director of the Cognitive Science Program at Indiana University in Bloomington, Indiana.

—David Chalmers is a Professor of Philosophy and Neural Science at New York University

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(This first draft skips six of the eight crucial areas and includes only the first and seventh)

1. The universal creative process in art and science, Robert Root-Bernstein

This is an introduction to the research of Robert Root-Bernstein (and his colleagues and predecessors). It is based primarily on these two essays:

1) *The art of innovation: polymaths and universality of the creative process*
2) *Intuitive tools for innovative thinking*.

The research in these essays and also the book *Sparks of Genius* initiate us into an influential body of evidence, and a context from which we can begin. This work identifies a set of common principles for innovation and invention.

Based on hundreds of cases from biographies and interviews—with special attention to remarkable talents, Nobel laureates, and polymaths. The polymath (person of wide-ranging knowledge) is a Renaissance man as exemplified by Leonardo Da Vinci. These case studies describe their methods and provide generous quotations. The examples, and

statistics from these large scale studies, clearly show a shared approach. The key ingredient to excellence and innovation is multidisciplinary. The arts and sciences work to inform each other and push each other forward. Nobel laureates compared to a sampling of typical scientists are 15 to 25% more likely to be involved in the arts. Arts like graphics, music, writing, craft fabrications, and performing arts. But it is really their own testimony that is what is convincing.

> A mind all logic is like a knife all blade. It makes the hand bleed that uses it.
> —Rabindranath Tagore |

The process and insights of polymaths and geniuses are a subject of interest for us to model. Discovering these reoccurring methods in arts and sciences reveal there is a universal process. Yes, the domains are distinct with their own specific requirements. The creative products: a painting, a mathematical model, an engineered technology, a piece of writing—all require domain specific skills and training. However the core creative process is universal. The most productive approach is to distinguish between disciplinary products and trans-disciplinary processes. The process that leads to the generation of creative ideas is the same in arts and sciences.

> The Universality of Creative Thinking Innovation in science and engineering is often portrayed as if it were distinct from that in the fine arts, perhaps because most definitions of innovation center on the idea of effective problem-solving. Science and engineering are supposed to be objective, intellectual, analytical, and reproducible so that it is clear when an effective solution has been achieved to a problem. The arts, literature, and music, by contrast, are portrayed as being subjective, sensual, empathic, and unique, so that it is often unclear whether a specific problem is being addressed, let alone whether a solution is achieved. It therefore comes as a considerable surprise to find that many scientists and engineers employ the arts as scientific tools, and that various artistic insights have actually preceded and made possible subsequent scientific discoveries and their practical applications. These trans-disciplinary interactions must cause us to reconsider how we think about innovation.

Science fiction writers often get ideas from science. Scientists also get inspiration and ideas from science fiction writers. Artists often discover things not yet known to scientists. Artists create physical and mental tools that scientists use for problem-solving. Scientists rely on the arts to communicate their data and results through writing, illustration, and modeling techniques.

“Most of the greatest innovators in every discipline have been polymaths”. This work illuminates the creative process by stealing the secrets of creativity from some of the best minds in history. A cross disciplinary conversation with individuals like: physicist Albert Einstein, artist M.C. Escher, poet E.E. Cummings, physicist Richard Feynman, designer and polymath Buckminster Fuller.

> We show that Nobel Prize winners, such as Einstein, rely just as much on visual imagination, bodily feelings, emotional senses and empathizing as do writers such as Isabelle Allende and Stephen Spender or artists such as Pablo Picasso,…
>
> The process of invention is always emotional and sensual and the resulting ideas are translated into words or numbers only in order to communicate with other people.

The authors argue that creative thinking occurs pre-verbally and pre-logically, without the use of words, numbers or equations.

> "Ideas emerge in the form of feelings, emotions, movements, images and patterns," he said. "When we truly understand something, not only can we describe or explain it in words, numbers or art forms, but we can sense and feel it too. Thinking cannot be separated from sensation and emotion.”

Examples and quotes from polymaths & innovators “Thinking With Feeling”. Most major figures in arts and sciences say that creative work is done in a preverbal form. Even the most verbal writers, mathematically oriented scientists and engineers describe their creative process as being initiated from feelings, emotions, and perceptual-based imagination. Root-Bernstein found many scientists have left accounts that describe their inspiration and process. For example, Albert Einstein said in many interviews that the theory of relativity came from his musical thinking. "No scientist thinks in formulae”—Albert Einstein. Einstein described the essential feature in productive thought as a type of perceptual imagination that includes images and muscular feelings.

> The words of the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined .... The above mentioned elements are, in my case, of visual and some of muscular type. … Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the associative play already referred to is sufficiently established and can be reproduced at will". — Albert Einstein

Many polymaths and geniuses described problem-solving in perceptual terms like: “kinesthetic, acoustic, and visual”.

> The acute problems of the world can be solved only by whole men (and women), not by people who refuse to be, publicly, anything more than a technologist, or a pure scientist, or an artist. In the world of today, you have to be everything or you are going to be nothing. — CH Waddington, biologist and polymath

> "Mathematics is the form in which we express our understanding of nature, but it is not the content of that understanding. —Richard Feynman, Physicist, Nobel prize winner

> Overspecialization leads to extinction. We need the philosopher-scientist-artist—the comprehensivist, not merely more deluxe quality technical mechanics" —Buckminster fuller

> It's all inspired picturing .... In certain problems that I have done, it was necessary to continue the development of the picture as the method, before the mathematics could really be done. — Richard Feynman
> I have to have a visual model or a geometric model or else I can't do it (physics). Problems that don't lend themselves to that I don't do. —Harvard astrophysicist Margaret Geller

> When you suddenly see the problem, something happens that you have the answer-before you are able to put it into words. It is all done subconsciously .... You work with so-called scientific methods to put it into their frame after you know. — Barbara McClintock, biologist and Nobel prize winner

The thought processes that these scientists describe are a form of intuition. **Logic and mathematics, are the translations that scientists use to communicate their insights,** just as writers use words. Only intuition combined with understanding, can lead to insight. "It is by logic that we prove, but by intuition that we discover". — Henri Poincare, mathematician. Our daily work comes, not so much from any prescribed program, but “straight from the heart”.

> New hypotheses come into the mind most freely when discursive reasoning (including its visual component) has been raised by intense effort to a level at which it finds itself united indissolubly with feeling and emotion. When reason

> and intuition attain this collaboration, the unity into which they merge appears to possess a creative power which is denied to either singly. — Agnes Arber, botanist

What we determine as important, is first deeply felt and then made clear. We begin to solve problems by thinking and feeling. Root-Bernstein goes into detail and gives historical examples and quotes from scientists, mathematicians, and engineers who use a set of thirteen tools. In the paper *Intuitive tools for innovative thinking* and in the book *Sparks of Genius* he goes into detail about these tools.

Principles of innovation employed by Polymaths. This is the basis of creative thinking. The polymath's combines diverse, and even contradictory ideas, problems, skills, and knowledge in original and practical ways. These cognitive skills and habits must be cultivated and practiced. Out of those original thirteen thinking and feeling skills he explores, these three are perhaps the most foundational. Thinking and feeling skills like: observing, visualizing and pattern recognition are as essential to a scientist as to an artist.

- **Observing:** is the beginning of all knowledge and goes beyond visual perception to encompass all the senses. Ultimately all creativity is based on observation.

- **Visual imaging**: reinforces the ability to recall, and acts as a scaffold for somatic skills like shooting baskets or golfing. Through visualization we create mental images that can be translated into other mediums like literature, music, dance, painting, diagrams, models, media or mathematical formulas.

- **Recognizing Patterns**: is the discovery of natural laws and the structure of shapes. Subitizing is the instant pattern recognition of shape and number. It is also sudden recognition of the rhythms and harmonics of song and language, and body movement. Recognizing patterns is the first step toward creating new patterns.

This work shows overwhelming evidence that the best scientists are using these creative tools. These same tools are typically not taught in science textbooks and are not generally part of standard curriculum. Yet the best scientists, engineers and artists are using these tools. Across disciplines and researchers and scientists and artists, they all describe their process and work. It's about creative thinking.

> The resulting ideas can be translated into one or more formal systems of communication, such as words, equations, pictures, music, or dance only after they are sufficiently developed in their prelogical forms. Regardless of the infinitely diverse details of the products of this translation (paintings, poems, theories, formulas, and so on), the process by which it is achieved is universal. Learning to

> think creatively in one discipline therefore opens the door to understanding creative thinking in all disciplines. Educating this universal creative imagination is the key to producing lifelong learners capable of shaping the innovations of tomorrow. Because our approach to creative thinking is integrative and transdisciplinary, we have had to unravel certain strands of disciplinary knowledge in order to posit a new fabric of unified understanding.
>
> A new synthesis is necessary, not only in order to understand thinking itself, but for pedagogical and social reasons as well. Ever-increasing specialization is clearly leading to a fragmentation of knowledge. People today have so much information and so little grasp of its origins, meanings, and uses that overall comprehension has frayed beyond repair. Even as specialized knowledge increases, communication between fields decreases. Within fields experts address larger and larger problems in smaller and smaller bits. Modern society faces a dark age in the midst of intellectual plenty, a paradox that can be resolved only by reintegrating knowledge in new ways and by training a new generation of Renaissance people to weave new syntheses for themselves.

Games and play are powerful tools of creativity. Play is an activity that strengthens mental and physical skills, allows free combination of symbols and metaphors. Play is an enjoyable, free, low-stakes means of improvisation and experimentation. It provides new perspectives and structure for simulations and developing new habits.

> Play transforms knowledge and builds understanding as new worlds, personas, games, rules, toys and puzzles are created—and through them new sciences and arts.

This research is an impressive body of evidence, and provides a context to begin from. But our work is to design practices and games and study methods that will project us into the skill-set. Actions that are repeatable and that cause excellence in our individual chosen fields. We will initiate and cultivate expertise and even genius, one-by-one with each reader who is motivated to this end. These principles will show up in our practice and games. Our focus is on action in body and mind. The goal is to increase general cognitive capacity through the exercise of memory and the related metacognitive processes. We will discover a hidden user-interface by going deep into the body and mind. Our focus, our point of leverage, is memory. Even prior to memory we find that observation and perception itself is the root. The development of perceptual awareness is the absolute root and foundation of our work. We will discover hidden knowledge in historical literature. We will see just like the chimpanzee story earlier, that the solution to this problem was already there. Just at a deeper level of understanding, understanding the

primitive. These researchers, psychologists, and cognitive scientists, will point us toward dynamics. These dynamics already exist in our own human body-mind-process. By observing and understanding these processes we become consciously aware. We can then deliberately practice application of those innate abilities.

We will inquire about issues like: “deliberate practice” and what is the optimal use of study time. How can we take notes so that they are available spontaneously in memory as learned knowledge? We will learn how to visualize, then draw and write on paper, and then place physical artifacts in our environments, and even fabricate new artifacts. These simple practices will grant us superior perception, memory, knowledge, and creativity.

(This first draft skips six of the eight crucial areas and includes only the first and seventh)

7. Alan Pavio Dual-coding & Imagery

> “**What is mind? No matter. What is matter? Nevermind.”**
> —George Berkeley, philosopher
>
> **“Mind exists only in time, body exists only in space.”**
> —Adi Da Samraj, philosopher, spiritual teacher

The string of perception is composed of multiple perceptual strings or “channels”. It is primarily two intertwined strings. There are two primary channels, visual-spatial and sonic-temporal. Then there are many secondary channels. These distinct channels are related to perceptual attributes. These perceptual attributes are used (along with affordances) to connect images into association pairs. Then the pairs are connected into chains and clusters. The two streams are analogous to the classical Latin terms “verba” and “res” (words and things), or “memoria verborum” (memory for words) and “memoria rerum” (memory for things or subject matters).

> "two functionally independent (although interacting) systems or stores" – Pavio

Researchers in psychology and cognitive science often rediscover useful wisdom from ancient traditions. Those bits of wisdom are then reclaimed for modern times. Traditions such as Shabd, Nadi, and Kundalini Yoga, all described the psycho-physical properties of sound and light. Sound and Light are fundamental to Consciousness and the apparently physical universe. These traditions describe the human body-mind and even the universe as a "field" of sound and light.

DUAL CODING THEORY

"The Dual Coding Theory of memory was initially proposed by Paivio (1971) in order to explain the powerful mnemonic effects of imagery that he and others had uncovered, but its implications for cognitive theory go far beyond these findings. It has inspired an enormous amount of controversy and experimental research in psychology, and played a very large role in stimulating the resurgence of scientific and philosophical interest in imagery. Indeed, it has been described as "one of the most influential theories of cognition in this [20th] century" (Marks, 1997), and has been fruitfully applied to a wide range of psychological issues…

The core idea is very simple and intuitive. Paivio proposes that the human mind operates with two distinct classes of mental representation (or "codes"), verbal representations and mental images, and that human memory thus comprises two functionally independent (although interacting) systems or stores, verbal memory and image memory. Imagery potentiates recall of verbal material because when a word evokes an associated image (either spontaneously, or through deliberate effort) two separate but linked memory traces are laid down, one in each of the memory stores..."

—Stanford encyclopedia of Philosophy, Dual Coding and Common Coding Theories of Memory

There are two coincident streams of memory. This is the dual encoding of memory. The first stream is sonic-temporal song-spoken word (corresponds to mind and time). The second stream is the visual-spatial images and perceptions (corresponds to body and space). “Res”, things that exist primarily in space; and “Verba”, spoken words, that exist primarily in time.

DUAL CODING THEORY AND EDUCATION

Dual coding theory has its roots in the practical use of imagery as a memory aid 2500 years ago (Yates, 1966). The memory emphasis evolved into broader applications of imagery aimed at accelerating the acquisition of knowledge. Language was always implicated but became explicitly involved as an educational partner when imagery began to be systematically externalized as pictures. The language emphasis increased during the Renaissance when influences from imagery mnemonics systems and formal logic brought words and things together in a "new logic" in which language was intended to mirror the structure of the world (Rossi, 2002). Religious iconoclasm and other influences raised doubts about the efficacy and morality of imagery and elevated language to the dominant

> position that it still occupies in education. Modern empirical evidence led to a revival of imagery and the beginnings of an educationally relevant DCT. (Dual Coding Theory)
>
> The apex of the imagery mnemonic tradition was Giordano Bruno's 16th century occult memory system (Yates, 1966), which sought to unify earthly knowledge and the supercelestial world of ideas using variants of the ancient method of loci linked to magical star-images organized according to the associative structure of astrology. For example, one Brunian method combined (a) a square architectural system of rooms subdivided into places for storing images of everything in the physical world with (b) a round "Lullian" memory device (Yates, 1966, pp. 173-198), in which moveable concentric wheels were used like a slide ruler to combine different subjects and predicates to generate new propositions. Bruno's version of the round system contained the celestial figures and images that were to animate, organize, and unify the earthly images contained in the memory rooms. —Allan Paivio, University of Western Ontario, September 29-October 1, 2006.

Encoding mnemonically to "perceptual-attributes" is a systematic way of chunking, and turning hard-to-remember information, into easy-to-remember information. In visual-perceptual mnemonics, we encode by symbol (figurative) or by sounds-like (homophonic). Perceptual-attributes are multi-sensory cross-modal streams, such as: shape-size; motion-action; and spatial-position. Learning, communicating, and memory are the transmission and reception of information. This involves the encoding and decoding of that information. You are always doing this, without thinking of it in these terms. When you read, you decode the written word to oral speech (often silently). When you write, you encode oral speech to written word. When you gesture or point at something you are transmitting an encoded meaning. When you enact any social behavior or any discipline such as painting, music, or mathematics you are coding and decoding information to that specific form. Technological devices such as computers, cell phones, and the internet are all extensions of this encoding principle. But the first encoding machine is the brain-mind.

> **"Language is based on perception, not the reverse."**
> – Essentials of Human Memory, Alan D Baddely

Word and picture are not so discrete but are interrelated in their functions. The theory of "Dual Encoding" describes one level that is a stream of words and a second coincident level that is a stream of images. This is true even in people who say they have no imagination or ability to visualize or dream, it's just that this level is more unconscious to them. Every word derives its meaning from its relationship with other words. It is this

context that is meaning. The meanings are rooted in perception, and the dominant allocation of resources in the human brain is through vision. Words that are not associated with perceptions have no meaning. This is why we do not understand the words spoken in foreign languages, because they do not invoke any images, or perceptions. They are divorced from, and do not invoke, the network of meanings—unless you notice the homophonies to your native language. This has actually become a prominent technique in second language learning.

> "In the words can be found many pictures—in the pictures many words. Moreover, it is not so apparent where one medium leaves off and the other begins, for many of the pictures are visual puns and pictures of words and many of the words are verbal paintings and drawings.
>
> Memory was conceptualized spatially as well as temporally; it was a linkage of mental spaces, leading to the creation of vivid mental pictures. Tracing notions of memory from the Classical through to the Medieval periods in Europe, … aspects of medieval figural art that to the modern viewer appear as failures in the rendering of perspective are, in fact, successful mnemonic renderings intended to create for the viewer new linkages between various aspects of memory.
>
> Thus, medieval art is not merely intended to evoke in memory a replica of a known subject matter, though they clearly make direct reference to biblical passages as rendered in paintings or illustrated bibles. Rather the differential renderings of these mnemonic devices created a sort of play whereby the viewer is forced to recreate present perception from memorized knowledge evoked by those devices. In so doing medieval artists provided a creative device in the form of memory that was intended to provoke meditation."
> —Mary Carruthers, Medieval Scholar
>
> But one achieves recollection in two ways: in an easy way, that is only by the subject matter (i.e. memoria rerum); in another difficult way, that is by the very words (i.e. memoria verborum). You need to have this twofold art of remembering.
> — Thomas Bradwardine, On Acquiring a Trained Memory, translation by Mary Carruthers
>
> Here Alan Pavio is quoting Francis Yates, and Paolo Rossi, as an influence on his work. Through the scholarly work of Yates and Rossi, Pavio is able to reach back through time and reclaim an ancient way of knowing. He brings that way of knowing into the system of knowing from his own era. He compares notes with people from history who represent that ancient tradition, Raymond Lull, and

> Giordano Bruno. He asks, what were these guys up to? Those Ancient Greco-Roman techniques find confirmation in modern neuroscience and psychology.

There are distinct channels through the brain. This corresponds to the subjective experience of distinct but related perceptual attributes. It is primarily the relationship between the perceptual channels of sound and light. Mary Carruthers is another scholar (like Yates and Rossi) who has brought forth this ancient tradition. The similarities to cognitive science and even many practical details found in these ancient traditions is impressive. This is evident in the visual-spatial techniques such as the Method of Loci and in the sonic-temporal techniques such as rhyme in the Oral Tradition. This subject is worthy of further consideration. But for now, just take note of the primacy of the visual-spatial and sonic-temporal. These are crucial distinctions to inform the engineering of our mnemonic techniques.

(This is part one of a work in progress, citations will be in a later version)

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