**** AHA ! ****

MEMORY

PERCEPTION

INSIGHT

AND

PROBLEM SOLVING.

Scientists often make great discoveries or solve problems with an instantaneous flash of insight, the so called "AHA"!! This process will be shown to be very general and have properties in common with memory & perception.

A SANDWICH SEMINAR

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"The time has come," the Walrus said, "to speak of many things"

(Lewis Carroll, Alice in Wonderland).

PART 1 CHARACTERISTICS OF THE FLASH OF INSIGHT

Welcome. This a seminar on memory, perception and insight problem-solving. By insight-problem-solving, I mean the times when suddenly a light bulb goes on in your brain and you have a new idea and you say **"AHA -** There's, the way to do it!" Most people remember Greek mathematician, Archimedes, who had pondered long and hard how to prove that the gift of a heavy gold crown to his King was gold, and all gold, without tampering with it and thereby loosing face with the giver, a rival king. You will recall Archimedes was relaxing in the bath when he had a Flash of Insight: **AHA!!!** Weighing the object in and out of water would do it! He was so thrilled, so the legend goes, he ran naked through the streets shouting, "Eureka! Eureka! I have found it!"

I wish to show you, and have you experience, a variety of so-called "Flash of Insight* situations and discuss the general characteristics of Insight. I will illustrate how memory and perception have characteristics in common with insight, indicating that although we think of memory, perception, and problem solving as separate processes, they are really just different outward manifestations of a single intellectual process which in turn can be understood as Networks of Neurons(2) that can solve problems. The ideas I here discuss derive from discoveries and observations I have made during my physics teaching and extensive reading. Of course, many, many ideas come from other people and I will give appropriate references. However, by and large, this talk presents a new overall perspective which I haven't found in my reading. If anybody has or knows of articles that parallel my ideas, let me know right away.

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*I have library research notes showing that on or about 2 July 1985, I had my own moment of Insight (AHA) when in the course of library research on insight I realized that insight, perception, and memory had properties in common and thus were one and the same thing. "The problem solving AHA" character of humor I had come to understand prior to this date. These experiences lead to a seminar on 25 March 1987, which formed the basis of this paper on 30 September 1988. SIX months later in my file (dated 1978), I discovered an article by Prof. J. Kestin which discusses the relation of humor learning, discovery, and creativity. I believe my conclusions, although somewhat parallel to Prof. Kestin, were arrived by an independent path of discovery because I was completely unaware of Prof. Kestin's article in September 1988.

INTRODUCTION

When I was in college my professors told me about these great scientific discoveries. A scientist had worked on a particular problem for months and months and couldn't get the answer and then, all of a sudden, "boom" he has this Flash of Insight and then **"AHA"** now he has the answer. I used to think that these insights, these great discoveries, would happen to only the top scientists and would only happen typically once every ten years. I would like to show you by demonstrations that the "Flash of Insight" happens to all of us, and it happens all the time, and has regular characteristics. As you will see the Flash of Insight is interesting in its own right, and the Flash of Insight provides the first hint that memory, perception, and, insight problem solving are really one and the same. I will also show how neuron networks, recently discovered, help us understand memory, perception, and insight.

Since this is an unfamiliar subject for all of us, I will demonstrate what I mean rather than attempt a theoretical discussion. The demonstrations are exceedingly, important to get the meaning of this Seminar. The audience (and reader) must actually do the demonstrations honestly and exactly, and only at the time they are introduced.

Insight problem solving, memory, and perception are all one and the same process in our brains. I will illustrate how these processes make use of associative memory structures and show how they have the creative ability to use unexpected combinations of the familiar to solve completely novel problems. I also want to talk about associative memories and how researchers are actually trying to get problem solving associative memories operating in computers. Let us start with examples of insight problem solving.

PROBLEMS TO BE SOLVED BY SEMINAL AUDIENCE (or reader).

Since this is a classroom, I want to give you some problems to do. First, I want to show you a visual problem to be solved. I want you to look at this cartoon and see if you can figure out the problem. The reader should now study Figure 1 . (Audience laughter) One person got it! (More laughter) Four **"AHA".** So what you see here are three guys. (More laughter). OK more insight, more "AHA's" and a light bulb turns on! Did you see that these solutions did not happen immediately? There was a distinct delay of more than three seconds for some persons to get the point. You see the problem and you keep wondering what's the joke. You keep searching, what's the joke here? What's the point of the joke? You try out different things to solve the problem. Please notice how long it took you. Notice that during this time you were puzzled and did not see the point of the joke. But suddenly it "hit" you "out of the blue" and **"AHA"** you saw the entire point completely, and now the tension is gone and you laugh. I propose that you had a "Flash of Insight" as you solved this "problem". Now when I show these pictures to people, they worry if they don't get it right away, that something is wrong with them. One of my points is that everybody has these delays. One of the problems that I will present to you today, I did not solve for over four days and would not have gotten it if someone hadn't told me.

So what was the solution to this visual problem? Three brick layers are laying up a wall and the foreman comes up and says, "Are you the new guy?" And eventually you figure out that the center man must be the new guy since he had put up his wall differently. Suddenly solving the problem provides the tension release and laughter. I am going to give you a second problem. Notice carefully the delay between punch line and laughter.

Notice the feeling of ***puzzlement*** and *tension* that happens during this time; notice the sliding feeling as the solution the joke "hits" you and feel the sudden release of tension, changing to laughter and body motion after "the point of the joke" arrives.

Here's a word problem from the Reader's Digest: A young man, down on his luck, went house-to-house in a wealthy neighborhood looking for work. Finally, a sympathetic homeowner said he would like to have his porch painted. The homeowner told the man that the paint and brushes were in the garage. In an hour or so, the young man rang the doorbell to collect his pay for doing

the work. "Thank you, sir," he said. "By the way, you don't have a Porsche. It's a Ferrari." (Audience laughter) Do you see the pattern?

1. There was the punch-line, a problem to be solved.
2. Then there was a delay with tension, usually no motion.
3. You are puzzled.
4. You are blind to the point of the joke. You don't know how to seek an answer.
5. Then there was a Flash of Insight (solution) from "out of the blue".
6. It hits you all at once in a short amount of time, and then
7. Laughter, smiling, and joyous motion, which is release from tension and
8. Results in pleasure

Our next problem is an elephant joke. Please look for the above five steps as it happens.

Question: What did the little grape say when the elephant stepped on it? **Answer:** Nothing--it just let out a little whine.

Question: How do you get down from an elephant? **Answer:** You don't! You get down from a duck. (long delay of audience laughter) That's much better! There was a longer delay, about five seconds, much better laughter and release from tension. My point is that you are supposed to be slow, and you should notice the series of steps as they happen.

Question: Groucho Marx once said to a telephone operator, "Extension 4-8-2, eh? 4-8-2 .....**Answer:** sounds like a cannibalism story! (delay of audience laughter) OK... That was about three second delay. Do you see a familiar series of steps here? OK. That's enough fun, and we have to summarize.

Do you see that for each of these "problems":

1. There was the punch-line, a problem to be solved..
2. Then there was a delay with tension, usually no motion, and a blank face.
3. During this time there is puzzlement and tension as you contemplates various answers/solutions.
4. You do not see the answer to the puzzle. You are blind to the point of the joke. .
5. Suddenly, click, it hits you! You laugh and smile. AHA! This is the "Flash of Insight" (solution), which was
6. all at once in a short amount of time, and
7. then laughter and motion, which is release from tension
8. resulting in pleasure
9. The answer arrives in a split second, "Flash".
10. You do not really know how you got it--it arrives "out of the blue".
11. After the flash, **AHA,** suddenly there is new behavior.
12. The feeling of happiness and glow success linger for a long time.
13. Before the "flash"--you could not see "it". Now you see it all. Completely.
14. The point of the joke (puzzle solution) arrives totally, completely, all at once.
15. The next time you hear the same joke you think of the answer much faster.

16. Thus in the "Flash of Insight" you have accomplished *permanent learning!!*
17. Your learning results in new skills, knowledge, and memories. Your Memory has been "added to".

Now, I would like you to solve this (Figure 2) visual problem. (Audience laughter after two second delay). Already, several people got it. How many people have the solution to this problem? (Over Half of the audience). How many do not? (Perhaps 10 percent of the audience would admit it.

All right. I have shown this cartoon to my class, and I have seen cases where nearly the entire class did not get the joke! It goes on for quite a long time. Sometimes there is no response; the "no solution" can go on for days. This problem is a bit more of a stickler and that gives us some time to review. As in all problems, when you find yourself at Step A, you have puzzlement, lock-up, blindness, helplessness. You have no way really to solve the problem. In this case, about half of the class got their "bolt out of the blue" as they "discovered" the point. In a flash, ... their blank face and motionlessness vanished, ... to be replaced by success, laughter, smiles, "seeing". They saw it all; completely all at once. Now remember all this. You will see it again.

Some people are still puzzled. We won't say whom to avoid embarrassment. So what's the solution to this problem? (After 30 seconds the audience attention was directed to specimens the "bar code" symbol on respectively a cereal box, and a cookie box). See Figure 3. (laughter and/or OHHH's from members of the audience.) How many people now have the answer? (Three-quarters of the audience held up hands). How many people would admit that it took a while? (Here one person admitted that he did not have the solution until I showed him the bar code on the boxes).

At this time I hope my 13 points about the **AHA** event are now familiar because I will expect you to see them repeated in illustrations to follow. Let's turn to the topic of Memory and another major point I now can make.

MEMORY

Especially notice that to solve this problem you must have seen the bar code and remember it! In some way the bar code idea must be in your memory available to help you "see" this joke--and deduce the correct answer! Now think about all of the problems (jokes) I have been showing you. You will see that knowledge, experience, facts, and ideas must be in your mind, available to be remembered, and thus, generate the solution to the joke and fully "understand". The Knowledge must be in your brain, in your memory; thus, problem solving requires memory. But notice the two-way street after the Flash of Insight; You remember the solutions, so you have new knowledge, new memories. So memory is both required for problem solving, and (increased) memory is the result of problem solving. Let me illustrate another point.

Suppose you want to remember the name of an old acquaintance. Try and try as you may, you can't. Finally you give up, only to have it pop-up later, while you were not thinking of it! Does this memory event have commonality with the Flash of Insight? And how about the circumstance when suddenly, out of the blue, "O my gosh, I forgot to pick up my wife an hour ago", and off

you rush? Having suddenly remembered, you instantly have new, different behavior, whereas previously you had absolutely no awareness. Sound familiar? My conclusion: Memory has very much in common with Flash of Insight solutions.

PERCEPTION

Remember these problem solving circumstances. Now I would like to tell you a story that involves the kind of looking, seeing, and understanding that we call perception. Try to deduce why I am telling the story. Many years ago my son was interested in different kinds of plants and fishes. In fact, he supplied water plants to the local tropical fish store, so people could put plants in their aquariums. Often, he would collect these plants right out of the river and keep them in backyard plastic aquariums. With the passage of time, the plants and all kinds of little bugs (which came along with the plants) were growing in these aquariums. One sunny afternoon, my son said, "Dad, come here, I want to show you something in the water." I looked and looked and didn't see anything unusual. I saw perfectly clear water, and a few nice green plants here and there. I looked very hard and said, "there is a bug in this corner, and over here, but I don't see *anything* else." The water was really clear. I mean perfectly clear. I looked and looked hard for all together a full minute. Finally, he said "No, no... Look again". He started to raise his hand to point and just like that--suddenly all at once, wow, everywhere the water was alive with a thousand swimming bugs..., tiny black bugs..., perfectly obvious and clearly they had been there all the time. But just as clearly I had not seen them! For sixty seconds I had been looking, I had seen other things, but the tiny black bugs had not been there! But in that *instant* I saw, not just one, not just two or three, I saw them all, all at once! Completely! Everything! In an instant!!

Why do I tell this story? Do you notice the same thing happening as in the previous jokes--there's a circumstance where there is a problem, in this case non-seeing, during which the proper view is unavailable. In this case I was blind to the little swimming bugs.

At this point I think I need to convince you that perceptual blindness is possible. So take a piece of 8.5 x 11" paper and roll it up into a hollow cylinder about 1" in diameter as shown in Figure 4, and, as shown, 1) hold it in your dominant hand 2) hold your other hand to the side of the cylinder 3) look through this hollow cylinder with your dominant eye and keep both eyes open 4) look at something interesting as far away as possible. At this point aren't you looking right straight through your hand? This is a demonstration of what it's like to "not-see-something" even though it is before your very eyes. You looked right through your hand. It's not "there". We must be careful here. This is a demonstration, but not a proof of what I am talking about.

Now, has perceptual blindness happened to you? (In this discussion please notice the interplay of perception, memory and insight problem solving). Let me mention two related examples so you can see how what I have been saying applies to what we call perception. Example 1. Suppose you are looking for something, your coat, a book, a letter, and you can't find it. Of course, this happens all the time. You look as hard as you can. It's not there! Later you go back and look again, and there it is; it has been there all the time. You surely were looking right at it and you did not see it. Once you see it the second time, often a day or so later, you realize you have loosened up a little bit, so you are looking a different way that time. Also you realize part of the problem was that you previously didn't remember well enough what it looked like. In effect, you

had an erroneous memory/template/mental image /whatever and consequently did not **see** what was actually there. That's why you didn't find it. Either way, you know you didn't find it the first time; you were perceptually blind.... Lock-up. You had a problem that was solved eventually by a new way of looking.

Another example that's similar. You have heard a person say, "I didn't see it at all until you pointed it out to me, and now it is so obvious see it all the time" - or another, "I didn't see the post until I hit it." "The post jumped suddenly up out of the ground". The same phenomenon.

Audience Comment:

"I think it is auditory also. You will suddenly hear something, like the tic-toc of a clock, that you realize had been all along but you hadn't "noticed" it."

Yes! That is exactly what I am trying to say to you. Note that this "delay and sudden resolution" phenomenon crosses over all modes. We have 1) blindness followed by seeing, 2) non-hearing followed by hearing, 3) can't solve a joke till then suddenly you got it, 4) science problems are followed by AHA's. I hope you are beginning to see that memory, trying to remember a name, is a problem to be solved. I hope you are beginning to see that perception, (i.e. looking, hearing, etc.) is a "problem to be solved. Are these separate brain processes or do they have something in common?

As you ponder that, let me give another example of perceptual blindness that comes to mind. In the movie *Bridge over the River Kwai*, you remember that this Colonel Nicholson was a Japanese prisoner, along with his fellow British troops, and they were under slave labor conditions to build a railway bridge for the enemy in a steaming jungle. Col. Nicolson was a high-powered, get it done best, British military man who could not see that building a really good strong bridge is cooperation with the enemy. His fellow prisoners cannot persuade him to build a weak, faulty bridge, so when the first train goes over it collapses and destroys the train. The whole movie is about this conflict. Finally, near the end of the story the blinders fall from Nicholson's eyes and he says, "God, what have I done?" According to Readers Digest it's a great scene from a great movie. I hope I am doing it justice.

Now let me tell you a story reported by Hans Freudenthal. Dr. Freudentahl[(3)] is a mathematician and an educational researcher who was trying to discover good techniques to improve public school education. He said that he had worked up a particular math exercise, a work-sheet; he wanted to have tried out on students. So he took it to a sixth grade class where he passed it out to all the students and gave instructions how to work the exercise. Well, can you visualize your sixth grade? You have this work sheet and now you've got to do it! The teacher gives you the instructions and you get busy doing it.

Freudenthal said that most students got right down to work following the instructions. They were really busy. However, there was one particular student, whom Freudenthal remembered very, very well. The student just kind of fiddled around. He scratched on the work sheet, drew little doodles off to the side, twisted in his seat, but made no progress. He was trying to do the sheet, but no progress, Extra blackboard *instructions* from Freudenthal seemed not to help. Finally he

thought, "This is pretty severe. This kid must be retarded or something. He's not done *anything* for thirty minutes. The sheet is simple enough. The rest of the kids can do it. And they were doing a pretty good job." So he went over to the boy to help him, and he did no more than the following. He started to raise his hand to point, and then there was sudden change. Freudenthal had not said anything. Something in his half raised hand redirected the boy's attention, and at that instant, the boy started working and correctly completed the whole worksheet in the remaining time of the class. So Freudenthal concluded that the child could not have been stupid because once started he completed the exercise in less time than the other students. The student was eventually faster than anybody else! But there was complete lock-up for thirty minutes, and the cure was a "re-direction" prompted by a mere raised hand.

The procedure for doing the sheet just didn't click; and when it doesn't click, it is <u>not</u> there. You can't do it. You are locked up. What I wanted to do is show you that Flashes of Insight happen all the time. You can watch it happening in yourself and watch it happening in other people. Anyway, let me give you a quick summary of the things I have pointed out so far. The Flash of Insight phenomenon occurs where there is a problem to be solved: (A) jokes (both visual and auditory), (B) perception, (C) mathematical problem solving, and as I mention at the beginning (D) scientific discovery.

EIGHTEEN CHARACTERISTICS OF THE FLASH OF INSIGHT/ PROBLEM-SOLVING EVENT

1. First there was the punch-line, a problem to be solved..
2. Then there is a delay time, some times short, some times long, during which a definite delay, during which time there is
3. Then there was a delay with tension, some times short, some times long, during which usually there is no motion, a blank face, puzzlement, a complete lock-up. Essentially this is perceptual blindness.
4. During this delay time, there is tension as you contemplate various answers/solutions. During this interval you really don't have any direct way of getting the answer. Of course, the delay can be shorter or longer depending on how much you know (i.e. Memory).
5. You are blind to the point of the joke. You do not see the answer to the puzzle.
6. Suddenly, click, it hits you! You laugh and smile. AHA! This is the "Flash of Insight" (solution),.
7. All at once in a short amount of time, the point of the joke (i.e. the solution) arrives "out of the blue".
8. Then you have instantaneous release from tension, laughter, motion, and free body movement are present..
9. This results in pleasure and glow of happiness.
10. After the "click", the answer arrives in a split second, "In a Flash". The blank face and tension are gone, completely, everything, all at once. The solution does not arrive piecemeal. You don't see half of it one second, the other half of it another second, not usually.
11. You do not really know how you got it. It arrives "out of the blue" All at once.
12. After the flash, suddenly there is new behavior: There are free movements that erupt with the "solution". AHA, Eureka, you "see!"

13. The feeling of happiness and glow success linger for a long time. You feel like a burden has been lifted and you feel more powerful.
14. Before the "flash"--you could not see "it". Now you see it all. Completely.
15. The point of the joke (puzzle solution) does not arrive in "pieces". It arrives totally, completely.
16. The next time you hear the same joke you think the answer much faster.
17. Thus in the "Flash of Insight" you have accomplished *permanent learning!!*
18. Your learning results in new skills, knowledge, and memories. Your Memory has been "added to".

Audience Question: Do you think this is universal? It seems to me, just introspectively, a lot of times there's a gradual process of seeing, of solving a problem.

Sure, there are the more gradual learning and solving processes. We are marvelously flexible in our abilities. Of course, sometimes there is a series of insight flashes. You see one piece and get an answer, but you are still puzzled. Later on, you see another piece, and then there is a second instant of discovery etc. You see pieces step-wise. I am trying to give an overview of a distinct phenomena that is recognizable and interesting. Now hopefully you will begin to see that I am giving a fair description of it. Once you are able to see the flash of insight in yourself and other people you will see how "slower" learning has steps in common. I am trying to give you insight to a very interesting ability in us that has wide implications. Anyway, one thing you will notice immediately is that when this "click" takes place, there are several behavior changes. There is also usually 9) Suddenly smiles, expressions of relief, plus relaxing movements replace the blank expression and or/ motionless posture. 10) A body shift, which is a kind of jolt. Mary Worth in the cartoons, for example, always has these little lines around Mary Worth when she hears something shocking.

A noteworthy jolt happened to me. I was walking up the stairs and suddenly remembered I was supposed to get something. I could feel my balance shift on the stairs and I almost fell down. You will see the jolt or posture shift when a student suddenly understands a puzzling part of a lecture. Whereas 11) before the Flash of Insight you couldn't "see it" at all, afterwards you have not the least trouble "seeing it". In fact, often you cannot not see it!! 12) The solution arrives "whole and complete" and 13) After the event the person, for example, can often draw new conclusions and further extend the topic that was previously total lock-up. In other words, the person has new abilities considerably beyond the mere resolution of his previous "problem".

Summary: All these thirteen actions or characteristics are seen at the moment of the punch line in humor. Of course a joke is especially tuned to be fairly easily solved and bring lots of relief and laughter--that's the whole point of humor. The same characteristics are seen in memory and perception, because they also are problem solving in the same way with the same response.

Audience Question: "I believe that this is a problem we as teachers present to our students. We have passed step number five and we can't see how they can not see what we have told them. Do you have any insight into how we can encourage this process, the stair stepping process?"

In answer to this question, one thing I hope you will do is learn how to watch people's faces. Years ago, I used to wonder how do you know what is going on inside peoples' brains. I have come to the conclusion that our faces are purposely hard-wired to our brains, so our facial expressions communicate our state of mind. We have muscles all over our faces for the very purpose of showing other persons what our brains are doing. For example, some people in this audience are smiling. Some people are bored and have sad faces. Learn to watch the face. You will find out more about a person's current state of emotion from his face than from his words!

Learn to watch the face.[(4)] I emphasize this quite heavily because it is the answer to the above question. Learn to watch the face and then you will know when something is wrong with that person. You get this blank look and then you know there is a lock up. If you have a lock-up, you are back here at characteristic #1). Often times when you are talking to a student he will nod yes at you. Be careful, because it means "Mr. Professor, keep on talking, so you don't find out that I don't know what you are talking about." That's what the yes nod often means.

At times like this the teacher must stop talking and start listening. Let me tell you a story. Many years ago I went to Dr. Paul Kurtz, who is in early childhood education, and asked him to help me learn about teaching. Paul Kurtz was into the psychology of Jean Piaget who is rightfully very, very famous in educational circles. Eventually Dr. Kurtz and I sponsored a workshop on our campus called "Logical Thought and Reasoning: How to Teach Science." During the workshop I got to talking to Dr. Robert Fuller, a physicist who was the workshop leader. He said "Watch the students. Listen to the students. Really, really listen!" I asked him, "How do you listen? How do you know what to listen for? " He didn't tell me. In fact, I remember that he made a studied effort not to answer my repeated questions. I couldn't figure that out, but I started listening. I stopped my habit of doing all the talking when trying to help a student who, for example, came for help in doing a homework problem. I worked out a new system. I now put the pencil in the student's hand and say to him, "Show me what you have been trying to do." I conduct the session so the student does all the writing, calculating, drawing and talking, and two important things happen: 1) The information necessary to figure out what the student knows (and doesn't know) flows from the student to the professor. And 2) the professor can never get ahead of the student and cause additional confusion! When the student "does all the work," I assure you that the professor will always be able to tell what that student is thinking. Although the student is confused, the professor will be able to isolate the difficulty. The professor will realize that if he were looking at things as is the student, he would be just as confused! This, of course, tells the professor what to do to solve the student's hang-up. In most cases, the hang-up is caused by ideas or scrambled concepts the professor would never, never discover any other way. I found one student had completely interchanged horizontal and vertical in his thinking. Consequently, he wasn't understanding the horizontal and vertical parts of projectile motion. You will know when you have correctly found the case of a student's hang up, he will have one or more of the indicators of Flash of Insight: His blank face and motionless posture will suddenly switch to smile, posture shifts, general relaxation and expressions of relief, such as "Oh ----Now I see it!" The more relief that you see the more severe the previous mental lock-up must have been. I have

(written) records of twenty four observations of hang-ups resolved by an insight jolt. I have helped students over some pretty big hurdles. I am reporting what happens based on this experience. For more information please ask for a copy of my paper Discover And Resolve Tutoring (DART).[4]

So, in Summary: Watch, you will see it happen. After a person has resolved a problem in humor, perceptual blindness, conceptual confusion, etc. he will smile, have a posture shift and expressions of relief. Indicators of lock-up will vanish and switch to discovery and pleasure. A feeling of power and success will be the result.

Audience Comment: It's also the following: When I look at a newspaper headline, what was an adjective I will have read as a verb, and leave out a little word, and consequently I will read it completely wrong the first time through. And I will say, "That doesn't make any sense." I don't say it consciously but at a very quick split second I will say: "That doesn't make any sense." And then I will say, "Oh, it's completely different. What I thought was the verb is the adjective, what I saw as a noun is a verb and etc, etc. It's very quick. You realize something is wrong ...you've got a problem. Then in the next split second the solution pops up. I also see this when my students are approaching a sentence in French. I see they are going through exactly the same process, but In slow motion. They try out one way and if it doesn't make any sense, they try another. But of course, word by word, it is very difficult because they can't see the sentence as a whole."

Excellent! Thank you for a very, very good example!!

A NETWORK OF NEURONS: A BRIEF INTRODUCTION

You have been asking: "What's going on? Help us understand why the Flash of Insight takes place." I will now attempt an answer, and I hope you will begin to see a lot of things begin to make sense. The ideas I will present are very tantalizing, but I must caution, nothing has been confirmed by any sort of test. These are ideas that just look good, and with a bit of luck, will stand the test of time.

I will, with "hand waving," describe how a network of neurons might function and accomplish the actions I have been discussing. As I talk, try to see the previous ideas as being natural consequences of the network and say "Hey, that sounds familiar." I will be reporting results of researchers J. J. Hopfield,[5] G. Shaw, D. Silverman,[6] and PDP Research Group,[7] who have investigated these networks and established what such networks can and cannot do. After a somewhat theoretical discussion, we will get back to some more fun as I will demonstrate and illustrate the key properties of such a network.

J. J. Hopfield said, in essence, let me make a simple model of how neurons in the brain might be "hooked up", and see if we can draw any conclusions. First he made some simplifying assumptions:

1. In the brain there are billions and billions of neurons.

2. Any one brain neuron may have many, many inputs from sensory organs such as eye, ear, hand, etc.
3. Any one brain neuron may have many, many inputs from other neurons of the brain itself.
4. Any one brain neuron may have many, many outputs (to legs, arms, etc.)
5. Any one brain neuron may have many, many outputs to other neurons of the brain.

These are sort of obvious, but it will be a kind of complex network!

So Professor Hopfield simplified it. To simplify, he simply erased all the "Every's " and replaced each with "All". Now the rules looked like this:

1. Every brain neuron will have inputs from every external sensory neuron.
2. Every brain neuron will have inputs from all other neurons of the brain itself.
3. Every brain neuron will have out-puts to legs, arms, etc.
4. Every brain neuron will have outputs to ALL other neurons of the brain.

How does that simplify? It sounds worse than ever! Hopfield was able to show that if everything was connected to everything (where some connections are strong, some are weak, some are zero, he could then mathematically prove some very interesting results.

PROPERTIES OF A NETWORK OF NEURONS

Hopfield used certain biologically plausible assumptions about how the neurons connect to each other in the brain to show:

A) The network will be stable, and will always smoothly produce well behaved outputs.

B) If the inputs are changed, the outputs will change smoothly to new values.

C) Not surprisingly, the results depend on the various strengths of the neuron interconnections which may be adjusted by genetics, learning,

or specific instructions from another part of the brain.

D) All the neurons dynamically acting on each other produce a collective result.

E) The result is not vitally dependent on any one neuron. In fact, the loss (or gain) of hundreds of neurons does not change the result; it

only reduces the quality of the output a small amount.

F) The neuron circuit can function as a memory as illustrated in the following Problem:

(1) Given partial name of a person, what is his whole name and phone number? This slide (Figure 5) shows a telephone number look-up sequence done by neuron network computer

simulation which was asked to look up (from an information source) the telephone number of John S. shown at top of the diagram. You see a series of trials where each new result gets better and better. At the bottom is the correct (best) solution. Do you see that in these computer illustrations the network simultaneously (a) finds the closest match and (b) recovers additional information not originally
available.

(2) Notice that here the neuron network has solved a problem and acted as a memory. Are things sounding familiar? Notice that the problem solving memory is finding the phone number associated with the closest name to the given incomplete data. What's more it can do the reverse: What is the name of the person whose phone number is closest to the number 482? Did you remember Groucho Marx?

(3) A network of neurons will produce a good, but not perfect, result very quickly. This is in contrast to the usual computer that will produce a perfect, highly accurate, result but may take a very long time on certain problems. For a biological animal, this is clearly an ecologically advantageous trade off!!

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PROPERTIES OF A NETWORK OF NEURONS CONTINUED

(G) This type of circuit also can naturally solve biologically important problems as:

(1) What is the word that most closely matches the sound "wawa".

(2) What is the 3 dimension object that most closely matches this foggy incomplete 2-dimensional photograph.

(3) What is the fastest way to escape an attacking lion?*

(H) To further illustrate the problem solving ability of a neuron network Hopfield illustrates with the following task: Given that

a salesman must visit customers in 30 different US Cities, what city should he visit first, second, third, etc. so the mileage traveled is a minimum? This is a hard, time consuming problem for a big computer, but fairly fast and easy for a neuron network.

See Hopfield reference[5] for a description of how to implement the solution to find the least distance of all cities.

(I) The network always produces a solution, and despite weaker and weaker, and poorer data, it still produces the closest possible result. It gives you the best shot. It never leaves you "high and dry". And this is what you want in an unpredictable world.

(J) If two (or more) contradictory solutions fit the input but it can't tell which, (ambiguous) the neuron network will successively switch between them. Demonstrations that illustrate the successive switching property of a network of neurons will now be given .

(1) Fixate your gaze on this Figure 6, called the Necker cube. Just keep staring at it and the front and back will reverse and

keep staring, and it will reverse again.

(2) The same thing happens when you look "through" your hand. Make your tube again; Now just stare at it and you will see you hand drift into view and then later gradually drift away. It will keep doing this. You may have to move your hand slowly closer or farther to get the best action. (Keep your tubes rolled up. I have another demo with it.)

(3) This same thing happens to students learning the concepts pressure, density, etc. in physics. The physics text by Hewett[8] describes some 15 confusing concepts which people mistakenly interchange.

(4) The network does not present the two solutions simultaneously. It suppresses one view (turns it off) so it may show the other view. If it is still not "sure", it will suppress the other and show the first.

(5) The solutions that switch back and forth are those where both solutions fit the data equally well, but if new data arrives it may force one solution and make it stick . For example, with ballpoint pen mark a ***** on your hand where the rolled up tube makes its "hole", now look "through your hand", as we did previously, but avoiding the *****. Now slowly move the ***** into view. Watch what happens. Your eye will now see your hand (and the *****) because it is now the most interesting thing, especially if it is moving; but if you shift away from the ***** and stop moving, your palm will fade again.

(6) As you get time later today, experiment with relative light levels (or relative motion or interest) and the views will reverse. What you see through the tube will go away and your hand will come up. The views will alternate back and forth. The same will happen spontaneously if you just hold still and fixate you gaze and keep staring at the ***** continuously for a minute or so. This exercise shows you that your perception system not only:

a) sometimes turns off vision, it also

b) switches between states! You also learn that

c) the views that are selected depend on movement, illumination and intrinsic interest.

(7) These two exercises illustrate what's called bi-stable (or multi-stable) perception. I have an article(9) that can give you perhaps twelve different kinds of circumstances where bi-stable switches involving words, pictures, sounds, ambiguous sentences, etc. If the two "views"

are fairly close to being "balanced", it doesn't take much to switch to the other. It has been amply shown how prior suggestion shifts and distorts what a person sees or thinks. Subliminal advertising really does work! (Hypnosis must be in here someplace). The same kind of switching takes place as a student learns confusing topics. I could show you three more exercises if we had time (See Appendix I). All of these demonstrations are a natural consequence of a network of neurons.

"So what". You say, "What you showed us are just tricks. Besides, those demonstrations might apply only to binocular vision where the two eyes compete". I show you this binocular bi-stable phenomenon: for two reasons: 1) It is the easiest and most dramatic demonstration of what I mean. 2) And now that you know what I am talking about, you will discover this bi-stable phenomenon in many areas of perception and memory and not just binocular vision. Here are some examples. Study Figure 7.

(a) Notice how your view alternates between a vase and two faces.

(b) How many of you recognize this picture? Figure 8. How many can see a young lady? How many of you can see an old lady? How many can see both? How many can alternate back and forth? Notice one view shuts off the other!

(c) How about the Flash of Insight itself? Is it not the person "looking" at the situation with one idea and that very idea blocks out other valid ideas? When the flash comes, the person switches views/ideas as I have here been illustrating. So if a person can't see your idea, it is probable he is seeing some other (to him) valid idea that is actively blocking yours. What you have to do is get him to "let go" some way. Show him, in an extreme example, where he is wrong; and perhaps he will switch to your view (maybe). Obviously in the case of the old lady-young lady picture you have very different results, depending on where you start. Also, if you didn't know the second picture is in there, you might not find it, especially if you looked only briefly. You usually have to be told there are two views. Then you have to actively look and look, possibly with another person pointing, to finally switch and **AHA!** The second, or third time it gets easier and easier. Finally, you can choose to switch back and forth, and its kind of fun.

I hope you can now see that memory, perception, and the AHA insight problem solving are all one and the same, and begin to see how these properties might be the consequence of a neuron network which finds "solutions" that best match the input. These networks are memories which can "solve problems". As discussed in the appendix, such solutions produce memory associations and explain much of our response to poetry, analogy, and allegory. Often several different solutions will fit the same data, in which case we will "see" a result that depends on our prior exposure. In selecting one "view", our brain often blocks out or excludes other "views". However, if there is a disturbance, or new input, often the system will switch. **AHA,** insight, a new view! Humor plays on this system and so illustrates its functioning. Humor is puzzle solving in which you must discover the multiple meanings of conflicting data and when the solution arrives .... AHA! Pleasure! success! laughter! fun! This also is true of other forms of problem solving such as discovery, invention, and learning a new idea. They are all Flashes of Insight.

APPENDIX I.

ANIMALS HAVE FLASHES OF INSIGHT!

Until now, I have discussed insight as an entirely human phenomenon. I believe it also happens to animals. Why do you laugh?? Cows have Flashes of Insight! Seriously! Let me tell you a story. It is just as clear as if it were yesterday. We had a big pasture (see Pasture (A) in Figure 9) and the cows had to go on this path to go in the barn for milking. Milch cows like to go in the barn because you are going to give them grain which they dearly love. All you have to do is say, "come on, cows." And they will just trot to the barn all by themselves to be milked!

For a variety of reasons, we wanted to open up pastures B and C as shown. We constructed the gates M & N as shown, and put the cows in pasture B first. From this pasture the cows could find their way to the barn easily by path G. However when later we opened up gate M and put the cows in pasture C, we had a problem. The cows can see the barn and go in a straight path toward it. Now they've got a problem. They can't understand that they must go away from the barn to get to it. This lock-up goes on for easily five minutes. When this happened we had to chase them, but with difficulty, away from the barn to Gate M. But the next day, it was the same problem. They couldn't remember. After three or four successive days like this, I remember the cows got over by the barn, as before, and milled around in frustration. However, before I started my chase routine, one cow spontaneously got the idea. "Click".... her tail went up and off she would gallop through Gate M as fast as possible. As soon as one cow did it, all of the rest would instantly see the solution and off they went, also tails in the air!!

Believe it or not, our pet dog, Suki, did much the same thing. We were building a house, and there was a large area that was dug out like this. See Figure 10. The incomplete house was open in the front but there was no "line of sight path" to get to the opposite earth bank. But it was easy to get there by means of the side door as shown. My son decided to test Suki to **see** how smart she was. He would stand at point (A) and throw bites of food ten feet on to the dirt bank, point (B). Of course, Suki would want the food. But she couldn't go directly to it. Complete lock-up. He avoided showing Suki how to get the food and she would forget it was there, but surely find it later by accident. He said he repeated this test about twelve times. Each time Suki would go to the edge here, look at the food, think how was she going to get it and she couldn't do it. My son said that one time "bingo", he didn't even finish throwing the food--off she went, out door, and got the food. He said that ever thereafter she always instantly remembered the solution. There was never any hesitation. As soon as his arm went up, she was on her way to the food. Make similar tests on your pets. Watch and see if you don't agree with me. Animals have this problem solving ability--perhaps you will see the Flash of Insight moment. I can't imagine that reptiles have it, but certainly mammals do. Clearly, Suki had better problem solving, at least better memory, than cows have.

APPENDIX II.

CHANGING VIEW => ANOTHER DEMONSTRATIONS OF BI-STABLE PERCEPTION

The following example involves viewing pictures of impact craters and should help you understand what I previously said about insight, because a similar kind of switch takes place. On your hand-out sheets, I show two additional exercises that are related. Figure 11 shows the way impact craters are formed. A series of diagrams show a meteor hitting a flat rock surface. You see a hole dug in the surface and a ring of rock piled up around the outside. It's believed that is how a meteor impact makes a crater on the moon. This also happens on earth; for example, Meteor Crater in Arizona. So craters are supposed to look like Figure 12 from the side view, high on both sides, with low centers and sometimes, with a little tip in the middle. Now if you look at the moon crater picture Figure 14, sometimes you don't see this. You will see a 3-D view "reversed". You will see as in Figure 13 both sides "down " with the bottom "up" in the center. Even the tip is reversed! What's more, all the craters in the picture will be reversed! If you happen to get the craters backwards, take the picture and rotate it on your desk so the picture has a different direction of illumination, and often the 3-D view will pop from wrong to correct or conversely. It goes back and forth between the two possible 3-D views. You don't know it, but your brain includes the direction of the illumination of the room you are ***now in***, as it interprets crater pictures. Your system uses the "Now," as it attempts to figure out what the picture looks like!

Although these demonstrations involve binocular vision, I believe the conclusions are quite general. I would like to show you another example. I discovered that similar effects happen when with both eyes open, you hold a pen (or pencil) like this, at arms length, and superimpose it over something that is the same size as the apparent size of the pen. You adjust the pen position so that it is about the same size (to your eye), as say, the door frame. Keep both eyes open and fixate your gaze (stare at it). Now I **see** the pencil. Now I see the door frame. Now I see the pencil. Now I see the door frame. Now I see the pencil. Now I still see the pencil. Come on door frame ... Practice this at home and you will learn how to get the two views to trade back and forth.

What causes this? Your brain is receiving conflicting messages of approximately equal importance. It somehow chooses not to show you both, but will rather alternate between them. It tried one message, but if you fixate (stare at it), it gets tired of that view and tries the other. It just bounces back and forth.

This is a general human property. Psychologists have extensively studied this bistable perception phenomenon and these things I have shown you are all well documented properties of humans across all cultures..

APPENDIX III.

SLOWED DOWN PERCEPTION => AN EXAMPLE OF LEARNING A HARD. CONFUSING TASK.

I think these pictures (Figure 15) will show you your perception system in slow motion. It illustrates what it is like to learn a difficult, confusing topic. These pictures are called stereograms. How many of you have looked *through* a viewmaster? You look through the viewmaster like a pair of binoculars and use both eyes. Now, to see things in 3-dimension each eye must have two somewhat different and the viewmaster in instrument helps you to "fuse these two pictures so you can easilly see the itwo pictures as one 3-dimension. pictures. However, it is not necessary to have the viewmaster. You can learn to do with it as follows.

The chemists these days are very, very proud of their ability to use computers to figure out the shape of 3-dimensional molecules. They are constantly publishing articles in magazines like this, where they must use flat paper to show you their 3-D results. Your hand-out shows one of these stereograms copied from a magazine like the one I will pass around. You will notice that both pictures are almost identical. Now I want to show you how to look at a stereogram without using a viewmaster. As you look at your stereogram, please take note of your vision system as it goes about putting together a new view. Your perception system is slowed down, so you can see the steps of learning a "confusing topic". Now how do you do it? Hold (Figure 15) at arm's length, like that and look over it at something far away. Then look slowly down at the picture (Fig 15a) without changing focus. What you should see instead of two pictures, is more or less, three pictures. Now if you work on the scrambled "double pictures" in the center they will "come together".

Let's start again. Look out at the hallway over the top of Figure 15a. Relax your eyes, then ease down at the paper. Then you are going to see three pictures. As you look at the scrambled double picture in the center, shift your attention on the hexagon at the top left. You are going to see, if you are doing anything right, two hexagons close to each other and otherwise a kind of scramble. Now keep your attention on those two hexagons. Just watch them and then just relax. Finally, your perception will get those two hexagons on top of each other and when you've got there, you will suddenly see the whole picture in 3-dimension.

One person in audience says, "Ohhhhhhh...." and starts laughing. There you go!. It's great 3-D!!. You try and try ..... then suddenly the 3-D view jumps out at you. Are you getting there? You are going to have to take this home and practice. You will have a funny feeling the first time you get it to work because you really are accomplishing a lot of internal adjustments. Once you see it a couple of times on one day, put it away and rest so you don't get tired. Come back and do it a couple of days later. You will gradually get better and better, and it will be more and more fun. You will see yourself almost get it, and then it will drift away, then it will come back. Meantime, you will have these scrambled feelings, until suddenly lock-on and great view and relief but also residual tension. Don't do this too much at first. You can get tears in your eyes and headaches.

APPENDIX IV
HUMAN MEMORY IS ASSOCIATIVE

I think this particular cartoon (Figure 16) helps you understand a lot about memory and how we associate one idea with another. What you see here is how we organize and categorize and associate information. This guy is a chemist, who wishes for more money to build more experiments. In his daydream, he pictures a genie giving him bags of money. Read the labels on the lab drawers, and you see how one thought leads to another by rhyme, by analogy, by formula/chemical relationship. He wants an open sesame, but he is worried about a closed sesame,, and that in his brain is connected with sesame seed, which is connected with Sesame Street. You see the associative structure of his brain, Here's abracadabra, candelabra, labrador, ladders. Over here you see: miscellaneous wishes., three wishes, evil desires, wish bones, fairy godmother and guardian angel. That's a pretty obvious linkup. Here's tight budgets, tight belts, tightwads Shoestring research, high-strung research, hung-up research, strung-out research. High pitched research, low pitched research (you know-petroleum pitch), relief pitchers. It's fun to look at these because it reminds you of your own free association. Do you see how this illustrates our problem solving associative memory? I believe we are very near a theory of poetry here.

An Additional Associative Memory Illustrations

Another illustration. How often have you left your room to go to the kitchen to get something but when you got there you absolutely could not remember what it was? AND have you noticed that if you go back to your room you will instantly (and always) remember? What you wanted was evidently stored in your memory with all data having to do with your room[(10)] What you were doing and what you needed are associated and linked (in your mind) with the memory of your room. Leaders in Roman times, who could not write, memorized their speeches by rehearsing what they wanted to say in front of successive objects around a familiar room in their house. To give the speech, all they had to do was visualize the familiar object and all the words would pop up on cue.[(11)] The familiar object called up the needed words. We call this memory by association (an associative memory).

APPENDIX V
HOW TO STUDY THE HUMAN AWARENESS OF A CULTURAL ARTIFACT.

When the MrCrysdale bar code cartoon (Figure 2) first came out, my whole class got it immediately. This was 1975, when the bar codes were first being printed on supermarket packages. The bar codes were **new** on the grocery store boxes and thus caught everyone's attention. Therefore, the entire class caught the joke very fast. The next year, only half the class got it, and several years after that no one solved the puzzle, and I had to quit showing the cartoon. No one got it. No Fun! But so much the better to establish my point--you often stay stuck for a long time before the insight.

Although the bar codes were abundant on the supermarket packages in the "70's", no store in our part of South Carolina actually used them at the check-out counter. This combined with the fact that they were no longer "new" resulted in gradual loss of bar code awareness, and consequently loss of ability to solve the puzzle. (Bar Code--Blindness?) Recently laser bar code readers have come into general usage in grocery stores in South Carolina, and this must raise bar code awareness sufficient for an audience to again, readily solve the cartoon. We may conclude that

when the bar codes were on the packages but not used, people were insufficiently aware of the symbol, to solve the cartoon puzzle. But when the bar codes are actively being used to price the package at the cash register, then this supplies enough "Memory Input" to enable people to solve the Mr. Crysdale bar code cartoon.

APPENDIX VI

THE FLASH OF INSIGHT IN INVENTION AND DISCOVERY

Let me give you two other examples just so you can't miss the point that the flash of insight phenomenon shows up in wide variety of circumstances and cuts across many different human activities. The first is similar to a scientific discovery--the invention of the sewing machine. Somebody had told Elias Howe that if he could invent a sewing machine he could "make a million". He worked for months or years, I don't know which, trying to get his sewing machine to work with a needle like that of an ordinary hand sewing needle where the hole in the needle is at the non-pointed end. I don't know the details but he couldn't get it to work. The lock-up went on for months and months. It really, really just boggled him. He couldn't do it. He couldn't make a sewing machine. Eventually he had a moment of insight after awaking from a dream... Insight!... move the hole to the pointed end of the needle and then it works! Of course, you know why. Because the hole will now push the thread down completely through the fabric, where the thread can be pulled around the bobbin, which you can't do if the hole is in its conventional hand sewing needle place.

This is a good illustration of characteristics discussed in this paper. Once you had the Flash of Insight, not only do you get immediate behavioral changes, feelings of joy and power, but the person now has new abilities permanently. The new ability allowed Howe to make sewing machines and to make a million dollars. He couldn't do it before that. Of course, for students learning a new concept they can now do things they couldn't do before. I think this is a genuine example of what you would call instantaneous learning. They have something now they didn't have before. I don't say all learning goes this way, but I would like you to watch this in yourself and you will see it happen. It's very systematic and you will notice the characteristics I have discussed. http://www.history.rochester.edu/Scientific_American/mystery/howe.htm http://inventors.about.com/od/hstartinventors/a/Elias_Howe.htm

I want to give you one more example. I am going to read from this book, *Zen and the Art of Motorcycle Maintenance*.[12] The author, Robert Pirsig quotes to us what Henri Poincare', a French mathematician, says about his own personal experiences with the mathematical functions that established his early fame as a mathematician. "I had left the town of Cannes, where I was living, to go on a geological excursion. The changes of travel made me completely forget about mathematics. I was about to enter the tour bus, when at the moment I put my foot up on the step, an idea came to me. I realized that the transformations I had used to define the Theta Fusion Functions were exactly identical to those of Euclidean geometry. I did not verify the idea at the time. I just went on with a conversation on the bus but I felt a perfect certainty.

Later, I verified the results at my leisure." He goes on to say that there was nothing in his former thoughts that paved the way for this realization. Suddenly, and with no apparent prompting, except the prior struggle and preparation, the idea arrived, whole, complete. I propose that the words "realized," "crystallized", and "Flash of Insight" all describe the same phenomena and all are a result of a form of problem solving in our brains. Let me read some more of what Poincare says: "I hypothesize that (our) subliminal self looks at a large number of solutions to problems, but only the interesting ones break into the domain of *consciousness.* Mathematical solutions are selected by the subliminal self on the basis of mathematical beauty, harmony of numbers and geometric elegance. This is a true esthetic feeling which all mathematicians know."

Now I want to go on reading *from Zen. and the Art of Motorcycle Maintenance.* The author, Robert Pirsig, summarizes. He says, "Suppose you are trying to solve a big problem, such as fix your motorcycle that doesn't run. The facts are there, but you don't see them. You are looking right at, them, but they don't have enough value. That is what (my) book is about--quality and value. They (together) create, the subjects and objects of this world. If your values are rigid, you can't learn new facts". Notice that he is saying we create, (construct) our world by our minds. The AHA event is this creation in action.[13] He goes on to say "The birth (creation) of a new fact is a wonderful thing to experience. It's dualistically called a discovery because of the assumption that it existed already, independently of anybody's awareness of it. When it comes along, it always has at first a very low value. But you've got to nourish it a little bit and depending on the value looseness of the observer and the potential quality of the fact, its value increases, sometimes slowing, sometimes rapidly. Of course, possibly, sometimes the value wanes and the fact disappears." As a matter of fact, Pirsig's whole book gives you insight into the entire process of insight and follows up relevant ramifications and extensions. As he is talking about the motorcycle maintenance, he is really giving an allegory about life. He is trying to tell you how to solve problems and maintain a good life.

One of my research colleagues says, "It is a good read--just a fun and rewarding book to read." There's an awful lot of really good philosophy in here. If you decide to read the book, I would like to hear from you whether or not it is any good to you. I am trying to see if the book's philosophy has a really good, solid foundation.
http://venturearete.org/ResearchProjects/ProfessorGurr/Main/HomePage http://www.design.caltech.edu/Misc/pirsig.html

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REFERENCES

1. J. Kestin, American Scientist, 58, 250 (1970).

2. J. J. Hopfield, Proc. Natl. Acad. Sci. USA, 79, 2554 (1982)

3. H. Freudenthal, Weedinq and Sowing. Netherlands Institute for Development of Mathematics Education (' 1980) See pp.250-260.

4. You may ask the author for a copy of his paper "Discover And Resolve Tutoring (DART)."

5. J. J. Hopfield, D. W. Tank, Science, 233, 625 (1986).

6. G. L. Shaw, D. J. Silverman, J. C. Pearson, Sci. USA, 82, 3364 (1985).

7. D. E. Rumelhart, J. L. McClelland, Parallel Distributed Processing (Explorations ın the Microstructure of Cognition), Vol. 1 and 2. MIT Press, Cambridge, MA (1987).

8. P. Hewett, Conceptual Physics, Little, Brown & Co. 4th Edition (1981). See "It is Easy to Confuse...", pp. 21, 27, 29, 83, 95.

9. H. Kawamoto, J. A. Anderson, Acta Psychological, North Holland,, 59, 35 (1981).

10. Remembering Reconsidered (Ecological and Traditional Approaches to the Study of Memory), Cambridge University Pres,, New York, (1988).

11. D. Norman, Memory and Attention, Freeman (1982). See Chapter on Method of Loci.

12. R. M. Pirsig, Zen and the Art of Motorcycle Maintenance, Bantam Books, William Morrow, New York (1974)-(32nd Printing!) See pp. 239, 240, and 280.

13. D. N. Perkins, The Minds Best Work, Harvard University Press (1983). The best overall reference I know for subject of creativity.

14) "Knuth's Eye View - Behind the Lectures" Discusses Lab Measurements of AHA's!! (Scroll about one half way down on http://scpd.stanford.edu/knuth/)