# The State of Cognitive Science: An International Perspective

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## Abstract

*Cognitive Science can be described as the scientific study of the mind, thinking, intelligence, emotions, and human action. When we use the term 'scientific study' we mean using science to study the mind, and how we think; human intelligence; and emotions, and action. Human action can be a person speaking – that is a motor act; or a person walking or exercising – that is an action. If a person is writing – that is an action. It must be emphasized that in Cognitive Science it cannot just be cognition as we think of it as "thinking", because the emotional part is very much related to it; and the motor and action part is very much related to Cognitive Science. It is not just one – it is all three of them. That is why, in part, we need to have this be 'interdisciplinary'.*

## บทคัดย่อ

*วิทยาการปัญญาเป็นการศึกษาทางวิทยาศาสตร์ในเรื่องของจิตใจ การคิด สติปัญญา อารมณ์ และการกระทำของมนุษย์ การศึกษาทางวิทยาศาสตร์ในที่นี้หมายถึงการใช้กระบวนการหรือวิธีการทางวิทยาศาสตร์ในการศึกษาเรื่องจิตใจ การคิด สติปัญญา อารมณ์ และการกระทำของมนุษย์ เช่น การพูด การเดิน การออกกำลังกาย และการเขียน เป็นต้น เป็นการกระทำของมนุษย์ สิ่งที่ต้องเน้นคือ วิทยาการปัญญาไม่ได้หมายถึงเพียงการคิดเท่านั้น เนื่องจากเรื่องของอารมณ์มีความสัมพันธ์เป็นอย่างมากกับการคิดของมนุษย์ การเคลื่อนไหวหรือการกระทำก็มีความสัมพันธ์สูงกับอารมณ์และการคิดเช่นกัน ดังนั้นวิทยาการปัญญาจึงไม่ได้หมายถึงเรื่องใดเรื่องหนึ่งหรือสิ่งใดสิ่งหนึ่ง แต่เป็นความสัมพันธ์ของทั้งสามสิ่ง คือ การคิด อารมณ์ และการกระทำ เพราะเหตุนี้ วิทยาการปัญญาจึงมีลักษณะเป็นสหสาขาวิชา*



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## What is Cognitive Science?

Cognitive Science is a relatively new field and the interdisciplinary element of cognitive science brings in: Psychology, and Neuroscience (where the study of the brain is focused); Linguistics (how we learn language and process language); Anthropology (the methods from anthropology also study cognitive science); Philosophy (has a lot of say in understanding how the mind works - cognition). The word "imagery" is about how we imagine events in our own mind, and there are ways that we can measure the process of imagery. The whole idea of Artificial Intelligence started with computer modeling and how the brain works and it is still a very important area, but we do not have to model as much anymore because we have techniques like fMRI to study the brain directly. For example, in the area of sport science we have much to learn there about how the motor system is tied into the cognitive system and the emotional system.

**The Emergence and Importance of Cognitive Neuro-Science**

What is happening in Cognitive Science in the year 2009 is the move towards understanding the brain, and how the brain functions, including thinking, and emotions, and action? We now have new techniques to study the brain, and although it is a bit expensive, it is the way we can best understand how people think and feel and act. We have the technology there, so let's use it. That is the part of research methods.

## Topics Studied in Cognitive Science

Some of the topics we see in Cognitive Science research around the world today include: **Visual perception; Attention/concentration; Learning & development; Memory; Emotion (**how emotion interacts with thinking and action); **Motor control** (In cognitive science research, this area relates not only to athletic performance and sport performance, but also for people with stroke and debilitating function – to understand how the motor system works, and how the brain controls action. So now there is a better understanding of how to rehabilitate stroke patients because we have a better understanding of the brain.);and **Language Processing.**

Some of the newer topics in cognitive science include**: Development of "Expertise" and Expert performance – or "how do people get to be 'great'?"** Among the newer topics that doctoral students are researching is the area of development of expert performance – a fairly new topic. Trying to understand who the really great performers are in different disciplines, and how did they get great. **Positive Psychology** (This is a new and exciting area.) **Emotional Intelligence.** This concept was popularized by Daniel Goleman (Harvard), where he went from Gardner's work on multiple intelligence. Gardner, who I am sure you have read in psychology – believes in more than one type of intelligence – he talked about six or seven different kinds of intelligence; from creativity to musical aptitude to motor aptitude – different kinds of intelligence. Goleman says there is something called 'emotional intelligence' and he makes an argument – particularly for leaders like Deans, and Presidents, Leaders of countries – that it's not so important that they be real 'smart' – that kind of intelligence, but that they have very good 'people skills', can work well with people, communicate well with people – and he called that 'emotional intelligence'. And I think he's right. But what is missing here in both "positive psychology" and "emotional intelligence" is some good empirical research, and ideally brain-based research, that in fact there IS that kind of intelligence.

## Professional Developments

In terms of professional development, cognitive science has been around since the 1970's when it was formed in North America and is still very active. In recent years there has been a big push towards bringing in the brain and cognitive neuroscience, so now there's a journal of Cognitive & Neuroscience.
When I checked on the internet, there are now over 70 universities around the world that have new programs in Cognitive Science, including Burapha University (Thailand) so that they are now one of 70 universities in the world who have a graduate specialization in Cognitive Science.

## Recent Critiques of Cognitive Science include:

**Human emotions research has been "understudied"**

When I looked at the critiques of people, particularly the philosophers, who look at Cognitive Science and say that human emotions is part of cognitions (which for most people 'cognition' means thinking and traditional intelligence). We're saying: No, that doesn't work independently; there is the human emotional intelligence system which is very much tied into it. It can't be separate. Most of the time your thinking is influenced by your feelings – your emotions. And your thinking can influence your emotions as well.

**Human action/motor responses also 'understudied' – But this is changing**.

There is also criticism that the action part, the motor part, is part of the cognition. You can have 'reflex action' without thinking about them, but for most of our motor acts, you have to think about them. For example, when I walk it comes very naturally, but it has been part of the 'learning process'. Initially, when you learn a new motor act, you think about it, and later on you want to eliminate the thinking. The fact is, those systems are all tied together. But, as I have pointed out in my comments: this is all changing because people recognize that you can't study just human thoughts by themselves, they are tied into emotions and action.

## Research Methods in Cognitive Science

How are people doing research in Cognitive Science? This is important because it is a combination of research methodologists and those who are interested in the broad field of cognitive science.

**Theoretical papers**: There are people who are writing theoretical papers (which are hard to do because you have to have lots of notes).

**Computer modeling**: We still continue to have computer modeling – cognition in motions and action. In Boston University we have a whole Department that for about 15 years has done a lot of this modeling research in cognition.

**Experiments with Human Subjects to test theories & computer models**.

We now have methodologies to look at the brain in real time.

### Experiment: Behavioral

**These are some Behavioral Experiments that are being done. For example:**

**1. Psychophysiological Responses:**

**Heart Rate (HR) & Heart Rate Variability (HRV), Skin Conductance (SC), Temperature (Temp), Respiration, Electromyography (EMG), Electroencephalography (EEG)**

When you are doing research experiments you will have to measure responses of people: how they think, how they feel, how they act, and so how do we do this? One of my favorite ways is to do what is called Psychophysiological Responses. We have fairly inexpensive methodologies for doing that. For example, Heart Rate (HR) has always been a very good index of cognitive activity, emotional responses, and motor responses because we know that when you walk fast or run, heart rates could go up. But heart rate will go up even if you are sitting there and you are forced to think about something, or to feel an emotion about something. In fact, what I do many times with students in my class – when I talk about human anxiety I will put a Heart Rate monitor on them, give them the microphone and ask them to come to the front of the class and say that "I want you to talk for three minutes about what you were supposed to read (for homework) last night." Of course, they get very nervous. I look at their Heart Rate – it might start at 70 beats per minute (bpm), by the time they start to talk it's 140-150 bpm, and they haven't even done anything yet. But it shows you how your thinking and your emotions can really affect Heart Rate.

And there's a new method now called Heart Rate Variability (HRV) that is tied in with your Respiration (how fast you breathe) and so there are ways in which we can calculate this index called Heart Rate Variability which is the more recent way (and perhaps better way) of looking at cardiovascular response to thinking, and feeling, and action.

Skin Conductance (SC) is another measure. It is nothing more than the sweat on your fingertips where we have many sweat glands. And when you get nervous or anxious about something, you sweat a lot and this Skin Conductance picks this up and measures it.

Skin Temperature (Temp): With skin temperature, what happens is that when people are nervous the blood vessels in your fingers and feet will constrict and there will be less blood flowing to your fingers and your feet. Therefore your fingers and feet will be cold. But when people are relaxed, the blood will flow without constriction and you will have warm hands and feet. So you want the temperature to go up.

And a very important one is 'Respiration' – how fast we breathe. A device which measures respiration is put around the stomach of the subject, and every time that the stomach goes in and out is one respiration. We usually breathe the way we used to as we grew up. But it's good to train people to breathe about eight respirations a minute. Once people are stressed, they automatically breathe faster and shallower.

Another psychophysiological measure is the EMG – it is a long word 'Electromyography'. 'Myo' means muscle; 'electro' means electric signal; EMG is the measurement of muscle electric signals. When we want to measure the brain activity we call it EEG; 'electro' means electric signal; and 'encephalo' means the brain.

These are all very easy to do. Not too expensive.

For example, if we were to record the Heart Rate measures of a teacher giving a lesson to a group of students over a period of time, we will see that the Heart Rate at the start of the lesson may be in the 70-90 bpm range. Some time later in the lesson, something may happen which might make the teacher's Heart Rate go up quite considerably to about 130 bpm. For most resting Heart Rates it should be about 60-70 bpm. What about running/exercise? Marathon runners will have resting Heart Rates in the morning of about 45 bpm. What is the maximum Heart Rate you can have? The high Heart Rate is approximately 220 bpm minus your age: so, if you are about 20 years old your maximum Heart Rate should be about 200 bpm. With regard to Heart Rate during meditation: Meditation will slow down Heart Rate, because you will slow down your breathing. It is a good, healthy practice to meditate.

We can also examine a graph which shows the Heart Rate measures of an athlete doing an Olympic event called 'Biathlon". This is where athletes do cross-country skiing in the snow, and then they stop and shoot at a target. When you are shooting at a target, you want to be steady. But when you're tired your hands move up and down because you're fatigued. It's a wonderful sport because you have to learn to be steady. Looking at the graph, you can see Heart Rate going up as the athlete is skiing, then when the athlete goes down and lies flat to shoot at a target the Heart Rate goes right down. The lying down Heart Rate is about 130 bpm, and when the athlete gets up to ski again, the Heart Rate goes up to about 180 bpm. Then the athlete stops to shoot at a target, but this time the athlete is standing up. Notice that the Heart Rate does not go down as much (as when lying down) – now it is only down to about 150 bpm. You can notice how the Heart Rate goes up and down at different rates for skiing, standing and shooting, and lying down and shooting.

**2. Reaction Time**

In 'Reaction Time' there has always been an interesting measure. Back when they were developing Intelligence Tests in the early 1900s, they had 'reaction time' as part of the test and people kept saying: "How can reaction time be tied to intelligence?" The way we measure Reaction Time is for example, to press a button when we see a light and they measured it. Then they stopped this method, but now it is coming back because it is so easy to do using computers. You can measure Reaction Time by watching something come onto a computer screen, and just press a button. And the idea is that it is tied into cognitive processing – some people are quick at seeing a stimulus and they can react quickly, and others are slow. Not necessarily that this is bad, it's that they just process information differently. They want to be accurate – take their time. But, sometimes you have to be fast in your decision. For example, when you're driving your car and someone is about to hit your car or the red stop light comes on – you have to hit the brakes fast. So, there are lots of practical life experiences where Reaction Time is important.

**3. Psychophysical Responses – e.g. loudness of sounds, judgment about distance, color, etc**.

There are traditional ways of measuring in Psychology: Psychophysical Responses – for example, where we make judgments – is this sound louder or less loud than this one – where you are trying to make judgments about hearing. And also judgments about distance and color and so forth.

**4. Eye Tracking – perception and decision making.**

Eye Tracking is considered part of the outcome measure in Cognitive Science. People will scan their eyes in helping them make decisions. MIT (Massachusetts Institute of Technology) are conducting an experiment in Driving Skills where eye-tracking is an important outcome.

**5. Tests: e.g. Stroop Test, Wisconsin Card Sort, Serial 7's**

There are some conventional tests that used to be on paper and pencil, but they are now computerized. For example, the Stroop Test, and the Wisconsin Card Sort test – that is also on the computer (it measures flexibility in thinking). There is also the Serial 7's (how we do subtracting by 7 from a specific number).

These are traditional methods of measuring cognition and speed of cognition.

**Focus and critical thinking: Wisconsin Card Sorting Test**

The Wisconsin Card Sorting test used to be sorted by hand in the old days, but now we can do that on a computer.

**Focus *with quickness* in critical thinking: STROOP COLOR WORD TEST**

In the Stroop Color Word Test for example, the word Blue is typed B-L-U-E in red ink and the subject has to say the color "red" while reading the word "blue" (which is displayed in red-colored letters). It is confusing because the word and the color don't match. Some people are good at this, and some people not so good. But it reflects cognitive process. You will see that this is published in the *Journal of Cognitive Neuroscience*, where there is a move to integrate the Brain into Cognitive Science.

## Experiments using Brain Imaging and EEG

**Brain imaging analyzes activity in the brain while performing different cognitive tasks.**

Brain imaging is a more-expensive way of measuring (if you're doing research: how do we measure what is happening in the brain? - cognition). So we ask people to do different tasks that involve thinking, emotions. We use EEG, which is about putting electrodes on the brain.

**Brain Imaging Techniques**

Brain Imaging is a fairly expensive procedure. It is fairly new, maybe in use for the last ten years.

**1. Single photon emission computed tomography (SPECT).**

This rather long worded brain imaging technique is abbreviated to SPECT

**2. Positron Emission Tomography (PET)**

These techniques are called PET scans. They are still used, but are being replaced by MRIs.

Both techniques inject radioactive isotopes into the blood stream that goes to the brain. We can then see active regions of the brain.

These are evolving techniques – more sophisticated and much more expensive.

**Functional Magnetic Resonance Imaging (BOLD fMRI)**

**BOLD fMRI measures oxygenated blood to different parts of the brain (has more neural activity)**

At times we use the word 'BOLD' in front of the word fMRI. What 'BOLD' stands for is "Blood Oxygen" – so what it is really measuring is flow of blood to different regions of the brain. Sometimes you will see in journals the word "BOLD" in front of fMRI, but oftentimes people know that that is how fMRI works- it measures blood flow to different regions of the brain. So when there is more oxygen in the blood going to different parts of the brain it has more activity in that region. So for example, if the fMRI shows a lot of activity in the prefrontal cortex, we know that whatever that person is thinking about is activating that particular part of the brain.

**A new technique called Diffusion Tensor Imaging (DTI) looks at "sequencing' events in the brain.**

There's a new technique called DTI which is very sophisticated. In a study that is currently underway at Boston University, we are using DTI and MRI – we do it at the same time. For me to explain what a DTI is – for example, we would like to know where a certain activity starts in the brain, and where it ends. So, the activity might start in the emotional system of the brain, and the memory part of the brain, and then it moves up onto the prefrontal cortex. Well, the DTI will show you the whole sequence – where it started, the mid-point, and the end-point. And that's useful to know, and we can understand how the brain works. And of course there are computer programs designed to do that, because calculating the statistics on that fMRI is very complicated. But computer programs basically do all of those calculations.

**An fMRI machine:** has a person who operates the switches outside the machine, and the subject has their head inserted into a frame, and then the subject's entire body is slid into a tunnel in the machine where they remain for about an hour. That's a long time. So if you have claustrophobia, you cannot have an fMRI. You cannot have any metal in your body. For example, you have to remove all your jewelry and anything that is metal because the fMRI works on a very powerful magnet. We use university students as our subjects in the study. Inside the fMRI machine's tunnel there is a computer where the subject (who is lying down) can look up at the computer screen. In the model that we use, we run movies that we want the subject to watch on the computer screen. We want to watch them when they're happy, feeling good, and successful (like athletes when they've won a Gold Medal at the Olympic Games) and see what lights up in the brain when the subject feels success. We have other subjects watching movies where they have failed – they're sad. So, different parts of the brain light up and so we can tell the difference between happy and sad; success and failure. Although we may be studying high level athletes, I believe the same things happen with schoolchildren in schools where the teacher may say: 'you're not very good', and so the children don't feel very good – they have no optimism – so they start believing that they are not very good. On the other hand, where the schoolchildren may have been told that they're very good students, the same thing happens in the brain and they feel good and become motivated to work. So, we need to do those kinds of studies – I think it's the same thing. We see it with professional Olympic athletes, and I think the same thing happens with children in school. However, for people who want to do research studies, you don't have to use fMRIs – you can use other ways.

The fMRI machine costs millions of dollars. They are very expensive. Even in Boston which is a major research facility, there may only be about four or five machines. An fMRI is different from MRI which is used in hospitals. The magnetic force of MRIs is nowhere near that of the fMRI, so MRIs are much less expensive and hospitals can have them, but you cannot do 'functional' MRI on a hospital machine. The fMRI machines are at the very high-end of this technology and that is why they are so expensive. Maybe in years to come, there will be a cheaper way to manufacture this technology.

**Do these big magnetic machines do any harm to the human body?**

The machines do no harm to the body - there are no known-damage from magnets as we know can happen from X-rays. One of the things that we have to do though (which is sort of embarrassing) is to give our female subjects a pregnancy test. So I have to go to the Drugstore to buy these Pregnancy Testing kits, and before the female subjects undergo an fMRI they have to give a urine sample and do a quick pregnancy test on the urine sample.

**What is the problem with pregnant women doing an fMRI?**

It is not known if fMRI will harm an unborn fetus – and because we do not know, we have to exclude pregnant women from the study. So, if the females test positive to the pregnancy test we will exclude them – because we don't know if fMRIs do any harm to the unborn fetus.

**Electroencephalography (EEG)**

**EEG measures electrical fields of neurons in the cortex. Electrodes are placed on the scalp.**

EEG (electroencephalography): basically this is pretty easy; it measures electrical fields in the brain. All you have to do is place electrodes on the scalp. There are very sophisticated 16 placements on the brain on the top of the head. You have to put some conducting gel on the scalp and this is rather messy with your hair. With the Biograph equipment, you put one electrode in the centre of the head, one on the cortex, and the grounding electrode on the ear, but this is still messy. But you can get some good information about what is going on the brain: whether you're measuring alpha waves, or beta waves, or theta waves – it is rather good; it gives us lots of information.

**Brain Map; EEG and EMG on Golfer (Dr. Crews, 2003)**

Another complicated example relates to research that my colleague, Debbie Crews, was doing. She was looking at a golfer (in Arizona) who was wired up with electrodes to examine what happens in the brain when a golfer is playing this putting-game in golf. The study was published in 2003, so the measurements were probably done in 2002, where it was a complicated business with several wires attached to the golfer. Today, we can do the same thing with wireless equipment which sends radioactive signals without all the wires. So you can see how techniques have improved so much.

**In summary:**

1. **What is the difference between EEG and fMRI?**
   EEG is a much more global assessment so that for example, we look at your beta wave pattern where you are alert and paying attention, (in alpha wave you are kind of relaxed and not paying too much attention; and theta wave is when you're falling asleep) – so EEG will look at beta wave patterns and say that the subject is alert. On the other hand, fMRI will say not only is the subject alert, but that the prefrontal cortex is very active. So it is taking a very specific part of the brain seeing where the blood flow is – it is taking many pictures of the brain, very fast. So, fMRI is much more specific. Of course, there is a trade-off: EEG is relatively inexpensive today; fMRI is very expensive – you get more information, but it is more costly.
2. **Describe fMRI and DTI.**
   In the study we are doing at Boston University, we put the subjects into the fMRI machine and we look at three things. One, the thickness of the cortex, we want to see if there is something tied into the size of the prefrontal cortex that we are looking at specifically. Some subjects will have a more-developed one – it measures it in very small measures (millimeters). Then it does the DTI simultaneously where it looks at the sequence of where the activity is taking place. Remember, the subjects are watching a movie (they are not just lying there in the fMRI machine) we have very specific things for the subjects to do. The subjects also have a control in each hand, and they are given instructions that if they see a certain thing they are to press the controller to indicate for example, the number 2. They are asked to indicate on a Likert scale from 1 to 10 "how happy are you"? with 1 very unhappy to 10 very happy. So, when they are watching a movie they may be asked to press the controller to rate how they are feeling when they watch a particular scene in the movie. For example, we can see that they are feeling very good at a particular moment in the movie, and we want to see where is that feeling registering in the brain?– where in the emotional system do we see that feeling? fMRIs are very specific. When we ask subjects to see something negative and they rate themselves low, we want to see what is lighting-up in the emotional system of the brain. You can get so much information from fMRIs.
3. **Is fMRI dangerous for some subjects?**
   The answer really is 'No" – but the only one we are uncertain about is unborn babies, so we do not use pregnant subjects. But there are restrictions on who can go into the fMRI machines. For example, people with pacemakers cannot go into the fMRI machine. But there are not many other restrictions. If you are a normal, healthy person with no metal in your body it is OK. EEG is fine for people with pacemakers because there are no magnets there. EEG is a very harmless methodology. I will give you an example of fMRI restrictions. There was a medical student at Boston University and I wanted to use her as a subject because she was a fantastic runner. She was in third year medical school. She volunteered to be a subject. But then she said that when she was a young person she had a lot of metal fall into her eye, and they could not get all the metal out – some of these tiny pieces of metal were still in her eye. She asked if this would be a problem. Yes, it was a big problem. Because if she went into the fMRI machine the magnets would suck out all of the metal from her eye, and damage the eye. I think this has happened to people who did not know that

they had metal in their eye, and they went blind when the machine sucked out the metal bits. So, we have to be very careful. We ask: is there any metal in your body?

## Cognitive Science in Studying "Expertise"

**Excellence [also known in the literature as: Experts, Champions, Genius, High Level Performers (We know they are relatively rare)].**

The 'development of expertise' is a fairly new area of research which is exciting to me because I have always been interested in why some people become very good at what they do, and how did they get there? So that is the big question. In Thailand, there are many opportunities to study 'greatness' and how people got there. That could be good thesis topics for people – that's part of cognitive science. I want to tell you how broad this field is. Anders Ericsson (from Psychology) called them 'experts' – even in the English language, I don't think it's the best word, but that is what is in the literature now – 'experts'. In sport it is easy – you call them 'champions'. For example, the best tennis player, the best golfer (Tiger Woods) – you call them 'champions'. We know they are the best. Nobody calls Tiger Woods an 'expert' in golf. We just say 'champion'. Sometimes we use the word 'genius' – somebody is a genius. Einstein is called a genius. Another general term is called a high level performer. There's a book called "Outliers" (an almost statistical name – in statistics it means 'extreme') written by Malcolm Gladwell. He writes about examples of people who are outliers in different domains – that's where my interest lies. Not just in sport, but in medicine, etc. – who are these people who became the best surgeons in the world? who are the best journalists in the world? – how did they get there? were they lucky? What makes them exceptional? Natural Talent or ?
There is Tiger Woods (who has a Thai mother); Mozart, Einstein, etc. These exceptional people – did they have Natural Talent (born that way) or what?

**Evidence on the Growing Importance of Neuroscience to better understand Cognitive Science**

Are Experts Made? The 2nd View. Opportunities. Guidance. Feedback. Support. Practice, Practice, Practice ...What is the evidence?

If exceptional people were not born that way (that is, they had this exceptional ability at birth, inherited from their parents) – were they made that way with opportunities, guidance, feedback, support and lots of practice?

What do you think about these people who are the best in the world? Where do you think most of the evidence is? Is it genetic (they were born that way)? Or, were they made? Well what is very interesting is that, Anders Ericsson (Florida State) has done extensive research in many domains. He started with Chess players twenty years ago. He studied how World Masters in Chess got to be so good. If Ericsson were here today he would say that it's 100% practice, and opportunities, and being in the right place at the right time. He says there is no evidence that genetics has anything to do with this. I would disagree. I work a lot in the area of sport and I believe that there are some people born with superior nervous systems. For example, some are tall, some are short (good for riding horses) – these are genetic components and I think that if some people are born to be big then why can't you be born with a superior nervous system? For example, superior vision (you cannot really build your vision – it's part of the nervous system) – so I think that there are outliers of people who have superior nervous systems. And if they are put in the right place at the right time they can be, for example, the best violinist in the world because they have a great ear for music; for example I can practice singing for ever and still be no good because you have to have a good voice to start with. This is a fascinating topic and I want you to know that there is rather convincing evidence today for what Ericsson called this idea of 'deliberate practice'.

**Anders Ericsson – The Idea of "Deliberate Practice"**

Ericsson is the authority on expert development - Champions and the best in the world. He came up with this term "Deliberate Practice" that in order to be good at anything you have to do what he calls 'deliberate practice'. You cannot just pretend to be studying; you cannot just pretend to be practising the violin or the piano. You have to be focused and concentrated, and you have to do at least ten years of this or, ten thousand hours. And then you are at the top in your field. But not everybody makes the top. It's amazing, how across almost every domain – the best surgeons, the best of anything – it seems that they put in ten years of training to become the best.

This is a summary of what Ericsson says about Deliberate Practice:

> **There is a positive relationship between expertise in a given domain and the amount of deliberate practice (10 yrs. or 10,000 hours)**
>
> **A highly structured activity with the goal of improving performance. (**A person needs to be motivated.)
>
> **The practice activity must be relevant to the performance domain and is not inherently enjoyable. (**I speak to many people in sport and they tell me that they like to train, they enjoy it. But Ericsson says that piano players, and poets and artists don't always enjoy it. They know that they have to do it to become good, but they don't always like it. Or people who practise to be very good surgeons, working on rats and other animals, they don't like it, but they know that they have to do it.)
>
> **Practice is effortful (both physically and mentally) and therefore can only be sustained for limited time. (**It takes a lot of work (effortful) and so you can only do a limited amount of it.**)**
>
> **Constraints: motivation, effort & resources.**

So, it's the word "Deliberate Practice" that is so important here.

**B. Bloom (U. of Chicago)** is another person who worked in this field – where he studied young people who became very good. Those of you in Education will know his name from work on "taxonomies" but he did this brilliant work in the 1980s studying young kids across different domains and how they got to be the exception. And he called it Talent Development. **Talent Development according to Bloom:**

> **"Unless there is a long and intensive process of encouragement, nurturance, education, and training, the individuals will not attain extreme levels of capability in these particular fields". (Early, Middle and Later Years)**

So you can see how children need this support and encouragement.

**The Nature of Medical Expertise**

The work of Vimla Patel at McGill (1996) looks at **Contrasting physicians & students with Two outcomes: decision-making and problem solving.** Vimla Patel is still doing research where she is looking at doctors and students in medicine – looking at decision-making and how they solve problems as doctors.

**Experts in Psychology and Education. Who are they?**

Frank Eysenck (who died a few years ago) – was a famous psychologist in England; and there is Watson (in the United States); and the most-cited psychologist in the world – Albert Bandura, who is famous for 'self efficacy'. Albert Bandura is a very humble man – a brilliant psychologist. His theory of self-efficacy is famous all over the world, so I put him in that category of the most famous psychologist.

**Self efficacy at work**

Self efficacy is another word for confidence. We know that with children confidence is so important to do well at school. For athletes, confidence is important for them to perform well.

**Great Leaders in the Corporate World**

In the book 'Outliers' there is mention of Bill Gates (Microsoft) and how he got to be the best. There is a sociological explanation for many of these people who got to be Great Leaders.

**Some good Reading on "Expertise": "Outliers: the story of success" by Malcolm Gladwell (2008), and "Why Talent is Overrated" by Geoff Colvin (2008)**

I have already mentioned "Outliers" by Malcolm Gladwell. "Why Talent is Overrated" by Geoff Colvin – the word "talent" in the English language refers to 'genetics'. Most people in the scientific literature use the word 'talent' as a genetic explanation. If you ask most people how people got to be the best, and they will say that they were just born that way. There is little evidence even now in 2009, that that explanation ('they were just born that way') is true. The 'best' people were self-made, with some luck of being in the right place at the right time. But you have to aspire to be good. And you have got to want to be good. There's a great book that was done in the business world written by Collins – it's called "Good to Great". I like that phrase: "Good to Great". You may start as being "Good", but the goal is to be "Great" – and so you have to have that as your goal, to be 'great'. And if you don't have that mission you don't get to be great. It is true for institutions and organizations, and it is true for individuals. You have got to want to be 'great', and there's nothing wrong with being 'great'. It's better than being mediocre. So, strive to be the best.

## More Cognitive Science and the Growing emphasis on Neuroscience:

**"Learning and the Brain Conference" is held in Boston in November, and in San Francisco in February**

There's some evidence of the growing emphasis on Neuroscience. About 1,000 people from all over the world attend "Learning and the Brain Conferences" in Boston and San Francisco. There are many topics in many different disciplines and domains.

**Conference Topics include: Motivation and Resilience; Brain Based Learning; Brain Maturation & Stress; Connecting the Brain, Emotions and Cognition to Education; Music and the Brain; The Adult Brain: Aging, Memory & Alzheimer's; How Meditation Changes the Brain; Brain Research & Effective Teaching; The Brain and Learning Disorders; The Brain and Autism; The Brain and Dyslexia; "Positive Psychology"**

Some of these conference topics should not surprise people working in Cognitive Science. For example, 'Music and the Brain" – I have a PhD student who is a world-class violinist with the Boston Pops Orchestra. In her PhD studies she is trying to understand how violinists get to be the best. And, there's an interesting study being done at McGill University using the same equipment that I use, where they are studying the relationship between the musical conductor, the audience, and the players. They are all hooked-up with electrodes to measure heart rate, respiration rate, and EEG skin conductance. They are looking at the connection between the audience, the conductor, and the performers. There are many applications of Cognitive Science, trying to understand how things happen. With the topic of the Adult Brain: Aging, Memory & Alzheimer's, you see that there is quite a lot of work being done with pathology. I don't like to study pathology, but some people do. How Meditation changes the brain: We can examine that. The Brain and Learning Disorders looks at why some children have difficulty learning. The Brain and Autism: In America now Autism is a very severe problem. We don't know why. Then there is "Positive Psychology": which I like better.

**The Emergence of "Positive Psychology" and "Emotional Intelligence" in Cognitive Science**

**What is Unique about Positive Psychology? Function vs. Dysfunction; Strengths vs. Weakness; Health/Wellness vs. Pathology**

Briefly, what is Positive Psychology? I don't think of it as negative psychology, but the opposite. Here is what it is:

Function vs. Dysfunction. Historically in North America, when you think of psychology you think of mental health problems. There is a whole negative attitude because psychology, historically, has been seen as having a mental health application. This whole idea of Positive Psychology is to take normal people and make them super-normal. That's what this Positive Psychology is about – studying good health. So, looking at people's Strengths versus their Weaknesses and psychology for so many years has been about people's weaknesses. For example, 'you're not very good at this, we will fix you up". It's not about 'fixing them up'; it's about getting them better. Enhancing performance, without drugs. Health and Wellness versus Pathology – this is what Positive Psychology is about: Human strengths and wellness versus studying (pathologising) everything. Somebody has to study the Pathology, but not the Positive Psychologists. It's going to take a long time to change the world to thinking what psychology is. That there can be a pathology part, and there's also a positive part.

**Themes in Positive Psychology: Optimism; Flow; Hope; Aging Well; Happiness; Self-determination; Humor/Laughter; Need for competence; Enjoyment; Need for belonging; Pleasure; Need for autonomy; Excellence; Peak performance.**

If you accessed "Google Scholar" these are all the themes in Positive Psychology that you will see. They are all recent – you will see publications from within about the last five years.

**Prominent Thinkers & Writers: Seligman (authentic happiness); Czikszentmihalyi (flow); Diener (well-being); Deci & Ryan (self-determination); Bandura (self-efficacy)**

Seligman is a psychologist at the University of Pennsylvania; who went from disliking pathology to enjoying positive psychology. He collaborated with Czikszentmihalyi who wrote a fantastic book called "Flow" which is all about positive image. Diener (at Michigan) on well-being; and Deci & Ryan (self-determination theory and motivation); and of course, Albert Bandura on self-efficacy.

**Emotional Intelligence**

**See articles by D. Goleman on "Leadership and Emotional Intelligence".**

There is Daniel Goleman's article (published in the Harvard Business Review) on the qualities of very successful leaders. In most cases they were not 'smart' people, but they knew how to work with people, and he called that "emotional intelligence". And he's brain-based too, he looks at the emotional centers of the brain.

**Sample of Domains Studied**

There are several domains that people have studied in this rather exciting, new field: For example, electing somebody that was great at what they did, writing their biography, and see if it fits the theories of how they got to be the best. Some of these are: scientists (physicists, physicians, and engineers), artists (painters, sculptors, photographers), athletes (they're easier to study, easier to find), performing artists (musicians, dancers, actors), managers, attorneys, lawyers, composers, psychologists, revolutionary leaders, poets, writers, and teachers – we can identify who were the great teachers and how did they get there. It is fun to study that. You can find different people in different domains to study and how they got there. There's a nice literature on that. In fact, there's a big handbook by Anders Ericsson called 'The development of expert performance'.

## Cognitive Science Research Across Different Domains

Cognitive science is very interdisciplinary and you can help people in many different areas. For example, there is:

### Research in High Performance Sport

**Psychology Experiences in High Performance Sport (Experts)**

Helping athletes to become the best performers – going from 'good to great' and being mentally prepared. In high performance sport it means that athletes have to perform under pressure, usually with the whole world watching them perform. But many of us have to perform under pressure. A teacher has to perform under some pressure, surgeons and doctors, they also have to make quick, accurate decisions – they have to perform under pressure. Think of an airplane pilot – they have to perform under pressure. There's always pressure. So, can we train people to perform under pressure, to be real good under pressure? We can learn a lot from sportsmen. We can interview them, measure them and ask 'why are you so good under pressure?' Not everyone is good under pressure. They're good when they are training, but when they have to perform they're not so good.

My good friend from AC Milan in Italy uses the same equipment that I use– psychophysiology – to train AC Milan football players. He has a big room where he has eight reclining chairs, and he has the computer and psychophysiological equipment and a monitor where he trains them with EMG, EEG, and Skin Conductance, and Heart Rate. The players imagine things by watching videotapes of football matches where they are playing themselves, and they keep watching the tape and train their minds to be good players. And he has got a good, sophisticated protocol – he is a good scientist. This reflects the interdisciplinary nature of cognitive science going from sport, to medicine, and other areas. There is a similar set-up in Los Angeles – called the ‘Mind Room’ for training athletes, where they have a monitor for each subject, and the trainer has a microphone which is used to tell the player ‘try doing this’ or ‘in this video try to control your Heart Rate’, or ‘control your emotions’.

**Performance on Demand is about:**

Performance: No matter what [one time to be the best, under pressure]; Anytime, any place & under any conditions!

Sport Mastery: Has to be Repeatable, Predictable, at an Acceptable level

**Relationships between Anatomical and Physiologic Components**

- **Prefrontal Cortex**
  - **Limbic System**
    - **Center for Emotion**
      - **Thalamus – (perceives a threat)**
      - **Amygdala (triggers fear response)**
      - **Hippocampus (puts in context with past experience)**
- **Motor Cortex**
  - **Movement**
    - **Neuromotor templates stored here**
- **Sensory Cortex**
  - **Basal Ganglia**
    - **Motor Deterioration associated with ageing**
- **Cognitive Appraisal (Thought, Reasoning, Memory)**

I am going to describe a quick journey to the Brain, highlighting different parts of the brain. The **Prefrontal Cortex** is involved with your thinking and reasoning, and to some extent memory (though memory is also in other parts of the brain. This area we call ‘**Cognitive Appraisal’** – you start thinking about what you’re going to do. The **Limbic System** is a little deeper in the brain. It is the **Center for Emotion**. There is a specific part of the brain called the **Thalamus** which perceives a threat. All sensory information goes through the Thalamus in the brain and it’s right in the middle of the Limbic System. The **Amygdala** triggers fear responses in the brain. The **Hippocampus** area is where most of our memory is lodged.

The **Motor Cortex** is a little further back in the brain. Here all motor commands are processed in this part of the brain. So, if there is any damage to this part of the brain, it’s going to affect the motor responses. For example, in Stroke patients the motor damage that has happened is in some part of the Motor Cortex.

The **Sensory Cortex** is at the back of the brain. It is bigger than the Motor Cortex. All sensations are registered here in the Sensory Cortex. At the base of the brain is the Cerebellum.

Still lower yet, at the level of the mid-brain, is the area called the **Basal Ganglia**. That is where you get degeneration of motor responses, usually associated with age. People lose motor control – it happens at this level. You can see, it is rather deep in the brain. Then there is the brain stem, reticular activating system (arousal occurs here), and the spinal cord goes in here. Spinal cord goes to the Basal Ganglia, then the Pons, to the higher structures of the cognitive process. And the emotional system is there.

**Relations of Cognitions, Emotions, Physiologic Response, to Physical Factors and Performance**

- **Psychological Factors**
  - **Psychometrics**
  - **Limbic System**
- **Stress Response**
  - **Physiologic Factors**
- **Physical Factors**
  - **Muscle Tightness**
  - **Performance**
  - **Somatic Complaints**

This list shows more of a combination of factors - coordinates everything: the relations of cognitions, emotions, physiologic response to physical factors and performance. There are Psychological Factors, and Stress Response (physiologic factors associated with stress throughout the body), and Physical Factors (for example, somatic complaints with stomach problems associated with your nervous system).
The point I want to make is that this is a 'system' we are talking about - the thinking, the emotions, and the actions.

**Stress Assessment Protocol:**
This profile includes sixteen activities:

**1) Eyes-closed Baseline**
**2) Eyes-open Baseline**
**3) Stroop Test**
**4) Recovery 1**
**5) Math**
**6) Recovery 2**
**7) Game**
**8) Recovery 3**
**9) Positive Image**
**10) Recovery 4**
**11) Mouse Walk**
**12) Recovery 5**
**13) Anticipation**
**14) Brief Stressor**
**15) Recovery 6**
**16) Biofeedback**

This Stress Assessment Protocol incorporates EEG as well. We do two minutes with eyes-closed, two minutes with eyes-open, then the Stroop Test, and so on. There are different activities here which can be modified by the researcher. It doesn't have to be this long, it can be much shorter. Computer output off the machine for EEG will show the Theta activity, Low Alpha activity, High Alpha activity, Sensory motor rhythm activity, Beta activity, the Intensity of it, whether we've got a busy brain or not, and EMG noise. Normally, when we do EEG measures we are going to get some artifact noise from EMG. This output gives you a lot of information. It shows the Respiration Rate, Skin Conductance, and Skin Temperature - there is an incredible amount of output on this machine for researchers.

**Autonomic Nervous System**

Other examples of computer output will show values for Eyes-closed, Stroop Test (values go up), then Respiration Rate, breathing at about 6 respirations per minute, then for the Stroop Test it jumps up quite a bit, then down for Recovery, and up again for a Spelling Test. So, this is just an example for researchers – the wealth of information that is there.

**Science at the Olympics: Can Neuroscience Provide a Mental Edge? *(Science* magazine)**

A lot of scientists around the world read this *Science* magazine, and they had an article on how science is making a big difference at the Olympic Games. The interviewed me and a couple of my colleagues about 'Can Neuroscience Provide a Mental Edge?' – what is it that we have learned from neuroscience that can help people at the Olympic Games?

## "State of the Art" Neuroscience Research in Sport
## The Davis et al Research (2007) in "Brain Imaging & Behavior"

**fMRI (Functional Magnetic Resonance Imaging) and DTI (diffusion tensor imaging)** allows us to see what is happening in the brain. Sport performance (success & failure) lends itself for analysis.
My colleague Dr Davis published an article in a very prestigious journal, *Brain Imaging & Behavior*, and to summarize: fMRI and DTI allows us to see what is happening in the brain. This is not direct measures. What we have to do is, put people in the machine, and they have to look at a movie of themselves performing. We're assuming that when they're watching the movie, it's the same as when they're actually doing it. And, there seems to be lots of evidence that it's really the same thing. So, until somebody disproves that, we are going to assume that that protocol of looking at movies simulates real activity.

## fMRI Research at Boston University with Athletes

Studies are continuing at Boston University Imaging Center Looking at:
**Preparation: what primes the motor cortex?**

**Focus: what generates critical thinking?**
**Positive self-talk: what does it do?**
**Toughness: how is mood regulated?**
**Imagery: what is happening? Where?**

At Boston, in our fMRI study we are looking at success and failure: those who succeeded and those who fail; we are trying to understand what primes the motor cortex; how do we activate the motor cortex for performance? What generates critical thinking? Positive self-talk is people talking to themselves – so if you can imagine an athlete saying to himself "I am good" – self-efficacy – "I am good. I am the best in the world". As opposed to "I'm not very good." And, if you think that you're not very good, then you won't be very good. But if you think you're very good, you have a better chance of succeeding. So, we teach them that they have to never think in a negative way – never. Then there is 'toughness': how is mood regulated? To always be in an upscale mood, a positive mood, as opposed to being in a negative, sad mood. Imagery is an interesting phenomenon – the whole business of imagery. We have these subjects 'image' (with the help of videotape) – because the assumption is (and there seems to be twenty years of evidence) that when subjects imagine something it's just like doing it physically. So for example, they have done studies with skiers, with electrodes placed all over their body, and asked them to imagine skiing down a hill, going through the gates and turns. And, it is just like they're doing it physically. The muscles fire just at the time they make a left turn or a right turn. So, that's why the power of the mind on imaging is so powerful. So when we train people to be the best in the world, they have to practice not only physically, but also with your mind. Mentally rehearse it, in real time, not slow motion but in real time.

**Champion Athletes: Words associated with Tiger Woods: ambitious, focused, champion, driven, strong, unbeatable, generous, eloquent**

For my next fMRI study, I would like to get Tiger Woods into Boston and put him in the fMRI machine, because I think that his brain is different than most golfers for sure. And I'd like to get the best people and have them volunteer to go for an hour into the fMRI machine and see what we can learn from these people because I think that there is something very different about how they think and process information. In our study we have forty different adjectives and we ask our subjects to rate the adjectives that best describes them – so these are some adjectives that I made up to use for Tiger Woods. You could do the same thing in Thai, using words that best describe you. And for the people who were not successful, they would say: disappointed, sad – it's interesting. The brain lights up differently.

## Collaborative Research at MIT-AgeLab

**Research Project at MIT AgeLab: Cognitive Processing During Car Driving**

The MIT AgeLab is a laboratory designed to study people both young and old people. The driving study is: to understand differences, cognitively, emotionally, and the motor system. How different is it? And when people get older, they want to continue to drive. But sometimes they are dangerous because they have lost decision-making ability, perception is changed, motor skills have slowed down. So I have been helping MIT AgeLab with the cognitive science side of this Driving Study, and I have one of my PhD students working on this project. There is a Volvo Station wagon SUV, and in the back of the car they have about a US$ 1 million worth of equipment (just like I have, but more of it). They have equipment to look at Eye Movement, what the subject is paying attention to; they monitor the Heart Rate; the Skin Conductance with electrodes on the fingers; Muscle Tension is measured; Reaction Time (how quick the subject can press the brakes).

The subjects drive for about 60 kilometres (a long way) down a highway, and they are asked to do different things. It is common now for people to talk on the telephone while driving a car – dual-processing – what happens to your mind and your emotional and reaction time when someone talks to you, or asks a question. What happens? We're trying to understand that. It is cognitive science for sure. I have these same people helping me trying to design a study with Real Madrid (the football team in Spain) – they want to understand how football players think and make decisions. They have young players in the football Club, and they also have the professional players. So, you see this same idea of psychophysiology measurement goes across many domains.

**Driving Study Data**

The researchers look at data at different points. So that they know that at a particular point the subject may have been answering the telephone while driving, or somebody interrupted them. You will be able to see peaks in the recorded measurements. The researchers try to make sense of this large amount of data.

## Proposed Research at Duke University Medical Center

**Duke University Medical School: Surgery Training Project: Developing "Expertise"**
**Laparoscopic Survery: Vichaiyut Experience**

Duke University is one of the top Medical universities in America, in North Carolina. They are very good, but they want to be the best. I got a call from Duke University Medical School about three months ago where they said that they knew I had done a lot of interesting research with performers under pressure – high performance people. Medical doctors/surgeons have to perform under pressure all the time. They asked if I could help the surgeons become the best. My colleagues and I are designing a project now to develop expertise so that the surgeons at Duke can be the best. And it's nothing different from what we use to train athletes. But we're going to do a Pilot Study first which we start in July.

**Surgeon Training Project: Why? Better surgeon decision-making; Reduce performance anxiety; Increase surgery team communication**

They want to train their surgeons because they want surgeons to be better at decision-making. Some people think that surgeons are good at that (have natural ability) because they were born like that. Not true. They have to train. In order to be great as a surgeon, they are going to have to train to be better at decision-making. Many surgeons, like athletes, when it comes to pressure (for example, when they're doing surgery and look inside the patient and see something that they never expected – and they panic – don't know what to do) – the patient may die. They want to prevent that, as well as all the malpractice issues. Another big problem with surgery (when they may have one or two surgeons in the room, and nurses, and other staff) – they have to have important communication skills to talk to each other and understand what's happening. Usually this communication is very poor, and can lead to costly mistakes. So, we have to teach them how to be a better team – to be effective and cooperate in the surgery room.

**Surgery Project: How? Use video assisted "imagery" with: iPod (music & video); Psychophysiology monitoring; Surgery simulator**

How are we going to make them the best surgeons? By using the same ideas we use in sports, and other areas. Using video assisted imagery with iPod (music and video). In many surgery rooms they have music – soothing music. Some surgeons don't like music, but most do. We use psychophysiology monitoring – except it is going to be 'wireless'. And, in most of the medical schools they have surgery simulators, where they work on simulators rather than real human bodies.

**Training with Video iPod**

Many people are familiar with the iPod. The technique is to take videotape of successful surgery – the surgeon sees how you do surgery very fast and very accurately, and the surgeon rehearses it. In your mind, you image it. You rehearse all the possible things that might happen. You imagine it. So that when you go and do the surgery, you have already practised it in your mind. I learned this from reading an article about a famous neurosurgeon from San Francisco. He would get up at 5 o'clock in the morning and go for a jog. And he would rehearse in his mind (while he was doing his jog) the first surgery he was going to do that morning. He knew the person, and he knew exactly what he was going to do. Neurosurgery is probably the most complicated – it is very delicate, very fine. And this surgeon was the best. He rehearsed in his mind the whole surgery. And he told people that he did this. But, not many surgeons do this – they don't rehearse it in their minds. So, we're going to try to teach surgeons to rehearse every surgery before they go into the operating room. In this way, they've done it once already in their head. And you can do this using an iPod, watching a videotape, or hear themselves doing self-talk.

**Surgery Simulation Lab**

There is a Surgery Simulation Lab in Duke University where the surgeons go to rehearse with the simulators – it is all computerized. And they get feedback. We are going to hook them up with the biofeedback and psychophysiological monitoring – we can monitor their Heart Rate, Skin Conductance, and Respiration.

### Duke University Research

**Experimental Group (Cognitive, Emotional, and Motor Training)**
**Control Group (Traditional Training)**

We are going to have an Experimental Group and a Control Group (using the Traditional simulator training), and I think that we are going to be able to convince them that there is going to be big advantages in the new methods of training surgeons.

### Dartmouth University fMRI Research

**Dartmouth University Research includes: The School Study; Brain Changes in Adolescence; Learning Styles in Children**

At Dartmouth University there are several related studies where they are using school kids with fMRI. There is a large Federal Grant of funding to study school children – looking at their brain development. There are different versions of it. For example, one research was interested in Children who take Music Lessons early in their life where they might start playing the piano or the violin at 5 years of age; what is happening to the brain development at the music centers of the brain? how does that change? They are looking at young kids playing football/soccer – looking at changes in their brain development – is that part of the motor cortex more developed or less developed? Somebody asked earlier about violent behavior in adolescents. They are also looking at that – brain changes in adolescence. And the other controversial question in the United States is the whole idea of Learning Styles. There are some people who believe that we all learn differently. Some are more visual, some are more auditory, some have to act/do things, and there are some people who say that there is no such thing as different Learning Styles. So one of the Dartmouth studies is looking at: are there different learning styles in children? and can we match up particular teaching styles with the learning style of the child? And they are doing that with very expensive fMRI studies.

## Summation of Pertinent Questions:

**[Question: If I am a student in cognitive science working on my doctoral dissertation, what sort of research can I do that does NOT require US$5,000 worth of machinery? Also, can you please give me some examples of N=1 research in this area?]**

We keep thinking of Group Studies. Many times N=1 research can be very valuable. And sometimes it is the ONLY way you can collect data. Here is an example of N=1 research that I share with my students: You may remember that maybe 10 years ago the Americans sent John Glenn into space. I think that he was 78 years old. They collected all kinds of physiological data: Heart Rate, Cognitive functioning and so on, when he was on earth. Then they sent him into space (I think that he was there for about 2 or 3 weeks) and they monitored his cognitive activity and his physiological reactions during the time he was in space. Then they brought him back to earth, and they monitored him again for several weeks to see his adaptation. Well, ONE subject. And you know what? There will probably never be another person (78 years old) sent into space. So, our research will be based on one person – John Glenn. I think that was one of the better examples where we learned a lot from just one subject. There are many good examples of N=1 research that basically inform policy, decision making on the kind of research we do, and so forth.

And I tell people too that the other N=1 research that is very famous is on Human Memory. The first published research on Human Memory – it was published in the 1880s in Germany – it was done on one subject. And the subject was the researcher. He did it on himself. You might want to say that that is biased research, and so all the American psychologists tried to disprove it. But, no. He was accurate just by studying himself. So, it can be done.

In answering the first part of the Question: You don't have to have US$5,000 worth of equipment to measure cognitive outcomes. For example, you can do traditional tasks like Serial 7s (you can score that by hand); and you can do the Wisconsin Card Sort test (that can be done by hand). There are cheap computer versions which you can use. You can have your regular paper and pencil test, too. You can get very inexpensive computer programs to look at Human Reaction Times – how quickly the subject responds to a question. So, it doesn't have to be expensive. We have our traditional paper and pencil test which if they have been developed in English can be translated into Thai. Or they can be adapted, for example, when you're looking through the cognitive science literature you find out what kind of standardized test they use to measure these outcomes and you want to get a Thai version of it; and then you have to use a program (for example, Lertap) because you want to establish the reliability of the scale; the validity of the scale; - you see, it's all within your control. You can do that. And, it's not going to be expensive. So, you make adaptations to traditional paper and pencil tests. The best measures are typically those used by researchers in the best journals. You may have to have a Thai version of it, but you can convert that rather well.

Read the journals of the last few years because that is where the best ideas are for research. Some typical topics in cognitive science include: attention and concentration (there are many ways of measuring that easily); memory; emotion (paper and pencil test to measure your emotions – rate your emotions and mood).

I also like to measure psychophysiology measures of emotions as well – Heart Rate, Skin Conductance; and some new topics that I really encourage you to look at: the whole idea of Positive Psychology, because in the short time I have been in Thailand, it's a wonderful population to study with those characteristics that Seligman called "Positive Psychology" because I think that your culture is so full of beneficial Positive Psychology. Whereas psychopathology focuses on sickness/illness and sees a broken-down person with weaknesses, Positive Psychology sees the 'strengths' of the person and works with those strengths. So, I think that is another area that you can do without having to be trained as a clinical psychologist to do research. Or be psychiatrists to do that research. You can do lots of Positive Psychology work as well.

There are some ideas on new topics. And the whole idea of emotional intelligence. Take a look at Goleman's research, the publications on emotional intelligence. It is a wonderful area to be studied. We talked about cross-cultural studies, for example looking at how Thai subjects might be different from Australian subjects, who might be different from American subjects. Where there is an interest in internationalization, you can do this cross-cultural research, which is pretty exciting.

**[Question: What about internet references? If we are interested in cognitive science, are there Journals and references that you recommend?]**

Google Scholar has very good information on it. Some universities are subscribing to internet-based journals and you can access them on-line. If your question is about using the internet (for example, Google and Blogs, etc.) for scientific references then that is not 'real science'– you have to use the journals. There are on-line journals that are in cognitive science, or cognitive neuroscience, or Proceedings of Conferences (sometimes those are published on-line.) Conference Proceedings are good because they are right up-to-date, whereas the journal article may be a year old.

**[Question: In the area of cognitive science, what is an appropriate number of subjects to use in the research study? One subject, a few subjects, or many subjects?]**

There is not an easy answer to that because it depends on some factors. For example, with the study of John Glenn going into space, the N=1 was most appropriate because it was so expensive to send that one man into space. But, if somebody has a wonderful idea for an fMRI study, and you get two subjects ($2000) – we would call it an N=1 study with two subjects – and here is what we found. And I guarantee you that it would be publishable. But then what happens is that somebody with lots of money from a government grant will do a Group Study, and validate what we found with that N=1 study. That's the way science works. Sometimes it starts with almost a Pilot, with N=1 (two subjects), and then we do a Group Study. And so to answer the question: how many do you need, and in particular, Group Studies? An example is a study we are doing at Boston University now – we did a Power Analysis to estimate sample size. How many will we need to show statistical significance? So we determined that we probably needed 15 subjects for a Group, so it's about 30. We use that as a rule of thumb in experimental research too. Generally, a minimum of 15 subjects per condition is good. But it depends, because if you have got within-group variability which is very low, you will probably need much fewer subjects. So I think that it is probably true that most good research institutions will do power analysis to provide evidence of 'this is how many subjects we need'. (We don't see much of this in journals.) The argument was made, maybe 10 years ago, that everybody should do a power analysis before doing the study. And there are times where it is important – other times it is not important. So, if it is not expensive to do your research, if you can get a hundred subjects for a particular study (and it is not costing a lot of money) - then use a hundred. It is more likely going to show significance at .01, .001 level. But, if it is $500 or 1 million Baht per subject, then you will say: "how many do I need? Not a hundred!" That is why we do the power analysis. It is usually about how precise you want to be, and how much money you have to spend on subjects. Same thing with survey research. People ask: how many subjects do I need to do this survey? Well, there are rules of thumb for that too. And, with the internet these days it is not expensive to do surveys on the internet. It was different in the days before the internet when we would mail questionnaires out, or we would phone people, - it was expensive, and took a lot of time. Nowadays, this is not a problem.

**[Question: If we use only one subject, will there be any criticism relating to generalization?]**
About Generalization.

If I took that data on John Glenn (in the N=1 space study) and said: this is what I conclude about a 78 year old man who went into space for three weeks, people could argue: "how do we know that is true for every 78 year old man?" The answer is: "No". But, I guarantee you every major journal would want to publish that study because they will never see that data again. That is the best estimate we have. So, yes – we have very limited external validity when you have lower samples, but when you do Effect Size Estimates (journals want this) in addition to statistical significance be <.01 you would also do the Effect Size. And sometimes, even with small subjects you could be close to being statistical significant, but the Effect Size is very large and that is more important than using the statistical significance. So, I think in studying research methods and statistics that is something you should consider: studying Effect Size. And there are many programs to do that. And basically you need to know things like: how much power you want? You have to estimate (usually from other studies) what typical Means would be, what typical Standard Deviations would be; what the Variance is. So if you have an estimate of that (it may not be perfect), then you can begin to calculate how many subjects you would need for a study. So, for Graduate students it is good to know this. Both Power Analysis and calculating Effect Sizes. It will help you to be a better researcher.

**[Question: What kinds of jobs will a cognitive scientist do, outside of a university research appointment?]**

Over the many years that I have trained graduate students, and PhDs - where do they go?; all these people who have got this interdisciplinary knowledge in research, and psychology, and cognitive science, and neuroscience – where are they all going? Are they going to be university professors? So far, most of my graduate students are not. They are going in very different directions. I have two former students who are now university Presidents. They worked in different areas and got back in academic work and became presidents of universities. I have two students who work as psychologists at Olympic training centers; they work in high level sport. A number of individuals want to be in clinical psychology to help people with substance abuse, and depression and those kinds of things. So they're doing cognitive science and psychological science in therapy. Others have gone more into the physical therapy part, using EMG helping people with rehabilitation, particularly stroke victims and learning how to get people to be more functional again with the motor system. Graduates have gone into many different areas, because the nature of the field is so interdisciplinary. I had a PhD student from Brazil (about 15 years ago) who had worked in the university for a few years – I taught him a lot about instrumentation and psychophysiology – he went back to Rio de Janeiro and he was going to do clinical psychology and use psychophysiology to train people. When I talked to him recently, he said that he is now going to work for the Brazilian government to assess people who would be good for certain occupations, using psychophysiological assessments. He is going to try to predict who is going to be good for certain types of jobs in the government sector. The graduates are doing very interesting, creative work. The important thing is to be good at what you do. That will be my message for you. If you are good at what you do, you will be asked to work in many different disciplines because the concepts are very much the same. So, when people want to become experts, and they know you have been studying 'expertise' for a time and have a pretty good idea of how they get there, then it doesn't matter what field you are in, could be engineers, or medical people, or teachers, or athletes – it is the same idea. And so if you are good, people will come and ask you for your knowledge.

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