The Neurology of Self-Awareness and Buddhist Perspective.

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Developments in modern brain research have attracted the attention of present day scientists regarding epistemological issues associated with the age-old theories of self-awareness developed in ancient Indian traditions. What is "self" or how is "self" generated in the context of modern neuroscience? The first step in this direction is to resolve the mind–brain problem: the relationship between the brain, body and the external world. A common hypothesis is that this "mind," which may or may not represent external reality, has evolved as a goal-oriented device that implements predictive/intentional interactions between a living organism and its environment. Prediction may be localized in the brain, but does not occur at only one site of the brain. What pulls these functions together, or what is the repository of predictive function? Here, we refer to "self" as that which is the centralization of prediction. According to this view, the self can exist without awareness of its own existence. For the nervous system to predict, it must perform a rapid comparison of the sensory-referred properties of the external world with a separate internal sensor. A novel approach called internal geometry, or functional geometry, associated with the central nervous system has been proposed to understand the functional role of neurons and their circuits in relation to the predictability of the brain. This development sheds new light on the issue of "self" or "generation of self" and "self-awareness."

Sisir Roy: Some people might wonder, as a scientist, why I am here, or why the monks are here. For the last two days, a great deal of discussion has taken place between these two groups. My own view is that we scientists, especially the physicists, because I am speaking as a physicist, think that most of the physical phenomena in the Universe can be explained with the laws of physics and, hence, physics is the most fundamental of all the physical sciences. We are looking for ultimate reality, but we are only in the process of looking. We have not yet found a unifying theory of the Universe.

The Sanskrit meaning of the word "Buddha" is enlightened. An enlightened person means someone who has experienced ultimate reality. So, from the perspective of Buddhists, their teachers, their masters, experienced ultimate reality. Their teachings include reference to epistemological and ontological issues that are prevalent in all the physical and biological phenomena in the Universe. The Buddhist scholars who are here today can help to solve the epistemological and ontological problems that we scientists are facing. They might be able to share with us their insights on how problems might be addressed from the Buddhist perspective. And they, too, might benefit from the exchange. Let me give you one great example about Heisenberg, who was the discoverer of the uncertainty principle in quantum theory. After discovering the uncertainty principle, he faced a dilemma: he was uncomfortable and perhaps a little confused regarding epistemological issues related to uncertainty relations. He came to India and visited a place near the city of Kolkata where the famous poet, Tagore, was staying. He met Tagore and spent a few days with him discussing epistemological issues associated with the newly formulated uncertainty principle. After the discussion, he said, "Now, I feel comfort."

Western physical sciences have evolved from a classical regime, or Newtonian regime, to quantum theory, and with that shift a new set of epistemological problems have emerged. But what about neuroscience? In my talk, I'll try to describe the epistemological issues coming from modern research in neuroscience that might be of

interest to Buddhist scholars and where I think it might be possible to have a dialogue between the two communities.

Let me start by saying a few words regarding methodology, because the methodology adopted in physical science is rather different from the methodology used in consciousness research or even brain research. In physics, we start by constructing a theory, just as Einstein constructed the general theory of relativity. Quantum theories were initially formulated, and later verified experimentally. If you come at it the other way, trying to explain a phenomenon after you make the observation, there are many possible explanations. A good theory has predictive power. In neuroscience or brain research, and especially in consciousness research, people are finding associations or correlations between the activity in certain neural networks and different feelings or states of consciousness. If someone has a particular type of feeling and we take an EEG recording of his or her brain waves you can see that some portion of the cortex might be activated. As scientists, we say, "Well, there is a correlation and association with our thoughts and neurological activity."

So, what are the developments in modern neuroscience and associated epistemological issues that might be related to Buddhist ideas? The first question you might ask me, being a theoretical physicist, is why I became interested in studying brain science or neuroscience. There is a famous statement by Warren S. McCulloch from MIT, who was a theoretical physicist and later became a neuroscientist. In his statement he writes, "… by the term mind, I mean ideas and purposes, by the term body, I mean stuff and processes." Stuff and processes are familiar to every physicist as mass and energy and space and time. But ideas and purpose, he keeps only in the realm of discourse and will not postulate them with the phenomena he observes. The problem is that we have understood the dynamics of the galaxy, the dynamics of the stars, dynamics of the planet and system. We constructed another theory called quantum theory to understand the behavior of the smallest particles, like electrons, and protons. And we human beings are in the middle. We are here, in the middle, between these two

extreme scales, and we, too, have enormous complexity.

How do we understand this complexity in terms of physical laws? This is the debate. I am going to tell you something about self, or qualia, a kind of consciousness. I was fortunate to spend many years with the famous neuroscientist, Karl Pribram. He used to ask me, "Sisir, tell me where is my mind? Is it something outside my head?" It begs the question: What is the starting point? Being a scientist, I should have a starting point. In physics, we start with atoms, molecules, etc. You just aggregate. If we aggregate atoms to molecules, and than aggregate the molecules we get a macro object or material object. That's how that starting point works. So what's the starting point for mind? The basic unit is the nerve cell, a neuron, and the brain contains billions of neurons, which are active for different functions. Is the neuron the correct starting point?

I want to discuss sense-dependent geometry, self, and self-awareness. A renowned philosopher of physics, Ernst Mach, who had a great influence on Albert Einstein, discussed sense-dependent geometry. In his famous book, The Analysis of Sensation, he coined the term, "Hindu geometry" because of his inductive approach, and in contrast to Greek geometry, which is deductive. I think I need to have an extended dialogue with Buddhist scholars regarding this kind of geometry. I will try to explain what this geometry means later in my talk.

But let me first say something about the representation of reality. You know the famous allegory of the cave by Plato. You place a group of people in a cave with a light to their back. The rule of the game is that they cannot turn around to see what is going on. They have to look only towards the front. So they only see shadows. Throughout their whole life, they think that the world is full of only shadows. How can they then distinguish what is true in "reality" from what is false? So there exist two worlds: a world that's constructed only in our minds, made by our experiences and genetic predispositions, and another world of the domain of things themselves. So the issue is

what is the relation between perceptional entities and physical objects?

I am looking at the flowers here, the information is being processed by my central nervous system, and then I say that this is a rose, or another kind of flower. One of the curious things about perception is what is called the problem of time gap. In the nervous system, information propagates at different speeds so there is a time gap. We are looking at a particular instant: how does the brain recognize the object at that instant? This is called the time gap problem, and in the language of neuroscience it is known as the problem of simultaneity. In physics, we also discuss the concept of simultaneity. From the experimental point of view, neuroscientists can say that there exists a particular rhythm called 40-hertz oscillations that is responsible for, or at least correlates with, our conscious states. This exists both in the awake state, as well as in the non-awake dream state. So this existence of 40-hertz oscillation implies that there is a quantity of time, which is approximately 10 to 14 milliseconds. If you look at the different information propagating through axioms, coming through the same location in the nervous system, the time gap is exactly 10 to 14 milliseconds. So we have an instrument that has the same resolution as the 40-hertz oscillations associated with consciousness, and that's why we are getting simultaneous events. In this way neuroscientists address or approach the problem of simultaneity.

But let's see what the situation is from the Buddhist perspective. For Buddhist philosophers, the time gap problem is different. Different in the sense that objects and perception are discrete, so they can never be simultaneous. How then do we apprehend things, if they have ceased to exist when we perceive them? This was discussed by the followers of the famous Indian Buddhist philosopher, Dharmakirti. As I understand it, the common Buddhist view of perception is awareness directed to an object. Another definition of perception is contact with external reality. The first definition emphasizes the presence of the object to cognition, and the latter states the time gap between object and the subject. I would like to hear from the monastic graduates,

maybe in the panel discussion, on how they solve these issues.

What is the main function of the brain? Prediction, perhaps, is considered the ultimate function of the brain. So what do we mean by prediction? We mean that prediction is a forecast of what is likely to occur. Suppose you are playing Ping-Pong, the ball is coming, and you have to swing your paddle such that it strikes the ball at exactly the right moment. This is a kind of prediction. I do not think that the brain calculates the speed of the Ping-Pong ball, the time it will take to cross the table, and those sorts of details. I don't think the brain does these types of calculations in the way that a digital machine does. What about the movement needed to swing the paddle? Apart from sensory input, we also have motor output. A mosquito lands on your face; your hand rises to slap it. Likewise, the blinking of the eyes, all of these are examples of motor activity. Active movement plays a very important role in prediction.

Some have theorized that only organisms that move have brains. Plants don't move and we say they don't have brains because they don't have a nervous system. According to this theory, only entities that move have brains; entities that don't move don't have brains.

Let us imagine that there is a carton of milk in the refrigerator, and we are going to pick-up that carton of milk. So what happens in reality? From a functional perspective, even a simple movement often engages most of the body muscles, resulting in an astronomical number of possible simultaneous or sequential muscle contractions. It seems very simple to go and bring a carton of milk from the refrigerator. However, suppose there are 50 key muscles in the hand, arm, and shoulder that are engaged in the act of reaching for the carton. From algebraic calculations, you can show that there are 10^{15} combinations of possible muscles contractions. This is an astronomical, huge number. Further, suppose that during every millisecond of the grasping sequence, 10^{8} decisions have to be made: this would require a processor of a million gigahertz, or perhaps a million laptops.

Let us delve further into how the brain predicts. For the nervous system to predict, it must perform a rapid comparison of the sensory properties of the external world with a separate internal sensory motor representation. Once a pattern of neural activity has internal significance, the brain generates a strategy of what to do next. And that strategy represents another pattern of neural activity. This strategy can be considered an internal representation of what has become a prediction imperative. There is one school of thought in neuroscience that says we are born like a blank slate and up to a particular age, say six or seven years, there is a learning process happening and all these kinds of patterns or forms are being installed. As we grow up, and there is a stimulus from the outside world, our brains try to match this with the internal patterns developed during childhood. We have a kind of potentiality for storing these phenomena. What we call functional geometry or dynamic geometry involves a different type of learning. Here, geometric patterns or forms were created by our genes and all possible forms/patterns have been there since birth.

Let me jump directly to what is self in terms of brain function. We can call it the neurology of self. We say that self is the centralization of the predictive imperative. So, what does that mean? Suppose the brain predicts a particular event, taking a particular duration of time, and at the same time makes a second, alternate, prediction for the same event, which takes a different duration of time. So you have two different time durations needed for the different predictions for the same event. Interestingly, prediction is not a localized phenomenon. You cannot pinpoint the neuronal circuits responsible for the self, but you can perhaps say that it seems to be distributed over a particular region, and that there is a particular abstract mental state we refer to as I, or self. According to this view, self can exist without awareness of its existence.

According to the Tibetan Master Tsongkhapa, there are two definitions for the term self: (1) a self conceived in terms of an intrinsic nature that exists by means of intrinsic being, and (2) the self conceived in terms of the sense of the object of a simple natural

thought, "I am." Of these two, the first is the objection of negation by reasoning, while the second is not negated, already accepted as conventionally real. For Tsongkhapa, whether or not self exists is not merely an epistemological question, nor is it solely a therapeutic one. It is an ontological question. That is to say it is a question regarding ontological status of person. Tsongkhapa understands the concept of self to be highly complex with degrees of reality that are constructed through different thought processes. So here I ask the Buddhist scholars: What is your understanding of self?

We are saying self is nothing but a particular mental state of the brain. Debates have been going on for many centuries regarding self-awareness in Indian and Western traditions. Here when we say Indian traditions, this also includes Buddhist schools. There are theories of self-awareness specially developed in two main Buddhist schools: one we call reflectionist or other-illumination, and the other reflexivist or self-illumination. The self-awareness thesis says if a subject is aware of an object, then the subject is also aware of being aware of that object. The other-illumination thesis says self-awareness is the product of a second order awareness. The self-illumination thesis states self-awareness occurs simultaneously through the object of consciousness and the aspect of the conscious state itself.

It seems the more neuroscience progresses, the greater the opportunities for Buddhist scholars to compare their debates with the findings of neuroscience. Let us talk a little bit about the philosophy of perception. We want to gather information from the outside world through our physical senses. Post-cartesian philosophy distinguishes three positions on the nature of perceptual experience: direct realism, representation realism, and phenomena realism. Although these positions do not necessarily exclude each other, they represent three distinct strategies adopted by Indian and European thinkers to explain the perception of the subject.

We say that a central issue in brain function is the internalization of the properties of the external world into an internal functional

space, the functional space of the neurons. By internalization, we mean the ability of the nervous system to fracture external reality into sensory messages. In other words, the firing of neurons, and patterns of firing of neurons, simulates each reality in different brain systems. We call this dynamic geometry or functional geometry.

We call dynamic geometry the very minimal time resolution or quantity of time associated with 40-hertz oscillation, which is responsible for the conscious state that is considered to be responsible for recognizing external events, and generating the concept of simultaneity. So we have an instrument that has a defined resolution. Recall that Ernst Mach coined the term Hindu geometry. He says that there might be geometry that is inductive and sense-dependent and he said it is Hindu geometry. On the other hand, Greek geometry is deductive geometry. So another question for the Buddhist scholars: Do you have any thoughts about this kind of inductive geometry in relation to understanding the brain?

In functional geometry or dynamic geometry we have many patterns, infinite patterns, stored in the geometry of the brain. Stimulus from the outside world modulates the brain. If you think of a musical instrument, like a violin, you can modulate the strings to produce harmonics and other sounds. So our brain is like a musical instrument. When there is a stimulus, our brain modulates and patterns are formed. Now there is another aspect of consciousness called intentionality. We discussed prediction, but prediction must have a goal. If it is not referentially based, it is purposeless; it is not only wasteful but can also be quite dangerous. So the goal or object of movement must be well defined and we may define it here as that which one intends to do in relation to that object. So intentionality is another aspect of consciousness.

And then comes qualia. This is one of the major issues of debate among philosophers and modern neuroscientists. Qualia refer to subjective experience of any type generated by the nervous system such as pain, color, etc. Qualia are manifestations associated with

the functional state of the brain. There are a lot of philosophical issues related to this. We face a serious philosophical problem in our framework, but perhaps that's not the case in the Buddhist framework.

Is functional geometry a unique feature of the human brain? No, this type of functional geometry is not unique to living organisms. At the same time, the outside network and internal network are both evolving, but, why this peculiarity? We say that only living organisms have qualia, or subjective experience. Why not the outside world? What is the transformation from external geometry to an internal one? This is a mystery we have yet to explore.

The goal of my work is not that of reductionist looking at just neural activity, instead we are looking for unifying principles. Thank you for listening.