Opinion and Perspectives

A Few Questions About Consciousness Suggested By Comparing the Brain and the Computer

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ABSTRACT

A close look at what is common to and what is different between the computer and the brain at a functional level seems to reveal some areas that need further attention in a scientific, and in a quantum theoretic study of consciousness. A few questions related to phenomenal information, awareness, retrocausality, observation of one's own ongoing activity, feeling of self and subjectivity, and free will are presented here.

Key Words: consciousness, subjectivity, phenomenal information, quantum theory, quantum collapse, computer and brain

NeuroQuantology 2012; 2: 286-301

1. Introduction

Whether big or small, the task of a computer is to compute, which requires a certain level of intelligence and education if a human being needs to do it. Models of neural networks in the brain and how they process information are often used to develop computer architectures. Ever since their invention, computers are trying to compete with the brain by doing more and more of what the brain does and faster than the brain but they are not yet conscious. Some neuroscientists (Edelman, 2000; Pribram, 2004) have used the brain-computer analogy and contrast while explaining their work in consciousness research. Nowadays, the comparison is seen frequently in literatures of other disciplines such as psychology and philosophy as well. A close look at what is common to and what is different between the computer and the brain at a functional level seems to reveal some areas that need further attention in a scientific in particular, quantum theoretic study of consciousness. A few questions related to phenomenal information, awareness, retrocauslity, observation of one's own ongoing activity, feeling of self and subjectivity, and free will are presented here.

The main difficulty with consciousness is its definition as Chalmers (1996) describes: "*consciousness is an ambiguous term, referring to many different phenomena*". Chalmers (1997) points out that experience is central to consciousness but "trying to define conscious experience in terms of more primitive notions is fruitless". While acknowledging the difficulty of arriving at a precise scientific definition, Searle (2000) works with a "*common sense definition*" sufficient to identify the target of the investigation. To define any aspect of consciousness, one needs to introspect oneself to understand clearly what it is. Understanding one's own mind is not easy and the answers different individuals get by self-introspection may be different because consciousness is subjective to begin with. To see this difficulty, we begin our exploration of consciousness in this article with unscientific descriptions of some of our daily experiences because in what follows, we will come across instances of unscientific thought inadvertently creeping into scientific analysis (by even well-known researchers sometimes[2]). Comparison

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Received Sept 21, 2011. Revised Jan 14, 2012. Accepted Jan 17, 2012.
ISSN 1303-5150

[2]An example is the argument of Crick and Koch (2001) that consciousness is a puzzling state-dependent property of certain types of complex, adaptive systems and that the best example is a healthy and attentive human brain because consciousness ceases if the brain

of the brain with the computer reveals what the misleading observations are in each case.

Tulving (1985) defines consciousness as a particular ability of living systems[3] and awareness as an internally experienced outcome of exercising this ability in a particular situation; he defines remembering an event as being aware now, of something that happened on an earlier occasion. We will follow Tulving's definitions of awareness and remembering throughout. We will use the word consciousness in a broader sense to cover various aspects of the mind such as ability to experience, pay attention, executive control of action (*free will*), and sense of self but in some sections we will use it strictly in Tulving's sense; we will point out such usage when we do so. Following Chalmers (1996), we regard "experience" as a primitive notion and will not try to define it further, but take it as understood. We will use his phrase "phenomenal information" for experiential information (contents of one's memory such as past events, desires, and emotions) of which one may be aware or not in a particular instant.

An Unscientific Comparison of Life and Lifeless Matter

We say that rocks and all other lifeless things are not conscious (unless we are panpsychists). We think that birds, animals, and other living beings have various degrees of intelligence and of course, that a human being is more intelligent than all the other species because for example, people do arithmetic whereas animals usually cannot. Interestingly, our packet calculators can do arithmetic always accurately and much faster than we can. However, we do not think calculators are intelligent. At the same time, if a person does arithmetic like a calculator (and we hear about such people occasionally), he/she would be called a genius! Do we know what we mean by intelligence or consciousness?

One evening, I was sitting by the side of a lake and enjoying the sight of birds flying over the quiet waters. A feeling of admiration "how full of life these little birds are" came over me (probably because the thought that a dead bird cannot fly was also there in the back of my mind). The next day, while I was waiting to board my flight and looking out through the window, the parked planes all looked like fish in their shape and then one of them took off. In the sky, it looked like a flying bird. Then it dawned on me it is not just birds, an airplane can fly too; so flying is not something that distinguishes life from lifeless matter. Of course, it takes some years for us human beings to develop the necessary theory of hydrodynamics and some more years to design and build the plane. Nonetheless, a lifeless plane can swim through the air like a fish swims through water and can fly in the sky like a bird, even much faster. In this age of robots, we cannot be sure that a bird's ability to fly on its own whenever it wants to (without any assistance from a human pilot like the plane for example), is evidence that birds have some intelligence but airplanes do not; there are auto-pilot aircraft which do not need human pilots either. The so-called drones have computers in them and fly in enemy territories without human pilots. Nowadays, machines can see, hear, talk, walk, and even solve mathematical problems! They play music as well! Herbert Simon's statement that there are no discernible limits to the range of things that computers can be programmed to do (Simon, 1983) has come true. Again, if somebody has a good memory or solves problems quickly, we think they are smart; musicians are admired for their talent; if the computer plays music, we admire the talent of its programmers!

The point to note in all these examples is that there is a certain component of a human being's intelligent or talented behavior that does not involve consciousness and another which does. The latter is experience; desire to do things, and awareness of doing them besides simply doing them. Today's machines can realize the former component that is required for doing things but not the latter. This observation is not entirely new because for example, Chalmers (1996) emphasizes the distinction between performance of a function and the accompanying experience. Still, he does not

is anaesthetized. Then it looks like a healthy brain (or some other living being) is the best example because it is the only example. Can anybody name a complex and adaptive but lifeless system that exhibits consciousness? Self-organization may accompany as a consequence of consciousness, but it is not a sufficient pre-requisite (Kak, 2007).

[3]We will use a common sense definition of life and lifelessness sufficient to identify the target of the investigation. An appropriate definition taken from an English dictionary is: life is the condition that distinguishes organisms from inorganic objects and dead organisms, being manifested by growth through metabolism, reproduction, and power of adaptation to environment through changes originating internally.

talk much about how the brain initiates the performance by itself; we will discuss later in section 5, why this ability to initiate action needs further attention in a scientific study of consciousness.

Although there is extensive literature discussing phenomenal consciousness, qualia, etc., distinguishing them from reportable awareness and access consciousness, sometimes (but not rarely) the distinction is not clear. For example, McFadden (2006; p.390) says that an unconscious mind cannot read, write, or do arithmetic (and it is a daily experience); the implication is that these functions require consciousness. However, we know that the calculator, which does not even have a mind, clearly does it all! So why does the brain require consciousness to do them? It does not. That is exactly why the calculator is able to do them. The manifested behavior of reading, writing, or doing arithmetic has two components: one that does not involve consciousness and the other, which does. The calculator performs the former. The latter is *to initiate the whole process, which is done by an external command in the case of the calculator but by the brain itself in the case of a wakeful brain*, where there is also an experience of accomplishing the task. The confusion arises because the two components appear simultaneously in human behavior and comparing the behaviors of the computer and the brain helps to distinguish the two.

In what follows, we will present some open questions (new or already known) about consciousness which are suggested by differences in the behaviors of the computer and the brain, or which are clarified further by the comparison.

2. Is Consciousness Required for Remembering and Reasoning?

Our personal computer (PC) can tell for example, that an earlier memo from the boss is inconsistent with the one typed into it now! It remembers all previously entered memos; rather, because it has no awareness, it *pretends to remember* them and understand them. It can read, write, recall, compare the input with its stored contents, and even evaluate the input but it is aware of absolutely nothing!

The PC is able to recall and make judgments because it is equipped with a memory containing some data and some instructions to handle input or stored data. A simple typewriter cannot do what the PC can; the typewriter cannot retrieve the earlier typed memo and therefore cannot compare it with the one typed now because it has no memory with data and the necessary programs. Note that neither the typewriter that types the memo on the paper, nor the paper, which contains the memo, nor the PC into which the same memo is entered, understand the contents of the memo but the PC can judge the contents of the memo like we do! The point is *the act of recalling does not require consciousness!* Nor does arguing logically require consciousness because again, a machine can do it if it has a memory with some software.

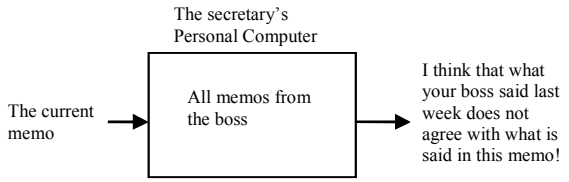

Figure 1. The PC recalls, compares, and judges, correctly but without understanding or awareness.

We are able to prepare the PC to pretend such intelligence because information residing in our brains (at least some of it) can be mapped into languages, then words can be mapped into the states of some hardware units, and therefore mappings of information from the brain can be stored in the PC's memory. The PC is then able to carry out all the operations of receiving input data, storing, retrieving, and processing them, and finally giving some answers to questions, solutions to problems, results, or judgments but none of these activities clearly requires consciousness because the machine does them all!

Open question: *since both the computer and the brain accomplish the functions described above and the brain does them consciously but not the computer does the brain require consciousness to be involved in their accomplishment although the computer clearly does not? On the other hand, is it that consciousness is not required to perform the functions and they do not produce awareness but the brain performs additional and accompanying functions such as initiation of the whole process and production of awareness?*

The question is relevant because all the above functions (receiving, recording, processing, retrieving, and outputting information) are usually attributed to consciousness (the benefit of answering the question eliminates unnecessary effort to look for consciousness in wrong places). For example, McFadden (2006; p.391) says that learning and memory in a brain require consciousness and recall may be unconscious. Another example is the observation by Baars (1996) that empirically, consciousness appears to be a necessary condition for discrimination, at least in creatures we believe to be conscious. The key word here is "appears". It is an empirical fact that in human beings, decreasing conscious access to the letter 'p' will change the ability to discriminate between it and other letters. However, it is also a fact that even in a robot; decreasing access to the letter 'p' will change its ability to discriminate between 'p' and other letters. Therefore, it is possible that both accessing and discrimination are purely mechanical processes but a successful access is followed by awareness in some living creatures whereas there is no awareness in the robot. Actually, the Chalmers (1996) list of "easy problems of consciousness" includes all the above functions.[4] From the computer behavior described above, it appears that they are easy because they do not involve consciousness! In Chalmers's view, cognitive psychology is concerned with the easy problems and what he calls the "functional explanation" is sufficient to explain them. However, such an explanation only explains how cognitive processes take place but not cognition itself, which has something to do with understanding because as Searle (1980) points out: "cognition is not solely a matter of formal symbol manipulation".

Unlike the computer, the brain seems to understand at least some contents of its memory. Of course, the physical apparatus and the memory structure of the brain are entirely different from those of the computer. Information processing in the brain is much more complex than what today's digital or even quantum computers can do. Therefore, it is difficult to challenge those computer scientists who believe that it is only a matter of time before they can implement similar complexity and produce conscious computers. One can only say "well, show and tell".

Not only computer scientists but many neuroscientists (except a few such as Eccles (1994)) also believe that the complex dynamics of biological matter in the brain is solely responsible for conscious experience and that no unphysical and unscientific souls or spirit is required to produce consciousness. It is not that materialists (those who argue that consciousness is a state of matter) think that a computer knows the meaning of its memory contents but they believe that the biological matter in a living brain somehow creates the meaning although any matter outside the brain does not. However, they have yet to explain how biological matter does it.

3. What Is Information Or Meaning? Is Information the Same As Its Representation?

Chalmers's statement that those who talk about consciousness are frequently talking past each other applies to the word information just as well. "Information" is used often loosely without a precise definition assuming that the reader should know its meaning because it is such a frequently used word by one and all. There are a number of phrases floating around: "physical information", "classical information", "quantum information", all of which stand for a set of numbers, in other words, symbols associated with a physical quality such as energy, position, and momentum. The meaning of those symbols exists only in the experimenter's head; it does not exist in the physical system being measured whether it is classical or quantum.

Even an outstanding physicist like Bohm can confuse people about what information is. According to him (Bohm, 1989), "Meaning is inseparably connected with information. The Operative notion here is that information has to do with form. Literally, 'to inform' means 'to put form into' something. First, information has to be held in some form, which is carried either in a material system (e.g. a printed page) or in some energy (*e.g.,* a radio wave). We find that in general a pure form cannot exist by itself, but has to have its subsistence in some kind of material or energetic basis; and this is why information has to be carried on such a basis." So he views

[4] Chalmers (1996) list of "easy problems of consciousness" includes abilities of a system to discriminate or categorize information, react to environmental stimuli, integrate information and exploit it in the control of behavior, access and report its own internal states.

information as a form carried in (a part of?) a structure of material objects or energy. He continues, "What is essential for a form to constitute information is that it shall have a *meaning*. For example, words in a language that we cannot read have no meaning, and therefore convey no information to us."[5] Really? A Chinese word conveys some meaning to a person who understands Chinese although it does not convey any meaning to others who do not know Chinese. In the minds of the latter, looking at the word creates the thought "I do not know what this pattern of symbols means", which is the meaning of the word, nonsense. Does it not? In the above quote, the unknown word simply does not convey a meaning which is already known to the reader. Once the reader is told what that word means to a Chinese person, the same reader will get the correct meaning of the Chinese word whenever he/she reads it again. Thought is only in the brain of the reader. *No form of matter or energy outside the brain has meaning when it is created. We assign some meaning to it. Even then the meaning does not become a part of the form or a "dual aspect" of the form.* Once we assign a meaning, whatever it may be, thereafter, whenever the brain sees or hears, or in some other way receives s sensory input from the form, the brain interprets the input and creates the meaning according to the assignment rules. That is how the form conveys its assigned meaning to all people who have accepted the assignment.[6]

A meaning is different from any physical form because the same meaning may be conveyed by different words in different languages. The meaning is different from but not identical with, or part of any of the words, which are used to convey it. Meaning exists only in the brain but not in the words nor in the paper on which the words are written. Sometimes language is not even used to communicate meaning. For example, a right signal flashing from a car is an indication to others that the car is about to make a right turn. The same meaning can be conveyed in many ways and the means of communication always needs and uses a mapping. The mapping may be in the form of words, sounds, electrical signals, and so on. A language is a mapping of meaning into words (symbols) which become sound energy when pronounced, and particles of matter when written on a paper, and become electrical energy when transmitted over a telephone line. *All communication that we use and know in the world outside the brain is physical.* Meaning exists only in the brain and is different from the language or signals that are used for its communication just like *water is different from its container without which it cannot be taken from place to place.* We are too accustomed to using material representations to store or communicate our thoughts (because we cannot help it), that we do not even recognize the fact that phenomenal information (thoughts or experiences, or meanings of words) and the material or energy pattern to which the information is assigned by us are different entities altogether. Meaning although subtle, exists independently of any physical form onto which the meaning is mapped.

Hence a statement such as "a form and its meaning are inseparable" may be misleading. Suppose one believes as does Bohm (1990):

> "The quantum potential is active information that is simultaneously physical and mental in nature .... These two sides are inseparable, in the sense that information contained in thought, which we feel to be on the 'mental' side, is at the same time a related neurophysiological, chemical, and physical activity (which is clearly what is meant by the 'material' side of this thought)".

Then we ask the ***open question****: there is no mental aspect in any physical process in which the brain is not involved; why should there be a mental aspect inseparable from its physical activity in the brain? Why does the brain's physical activity not require somebody else to assign some meaning to it?*

A dual-aspect theorist may answer the above question by saying that both living and nonliving matter have a dual-aspect which is mental but that it is dominant enough to be

[5] This is an example of how an unscientific thought inadvertently creeps into scientific analysis.

[6] In an interview with Weber (1986), Bohm says "It has been commonly accepted, especially in the West, that the mental and physical are quite different but somehow are related but the theory of their relationship has never been satisfactorily developed. I suggest that they are not actually separated; that the mental and physical are two aspects, like the form and content of something which is only separable in thought, not in reality." Does the last sentence imply that Bohm dismisses thought as not real? After all, is it not thought what he is trying to explain? Alternatively, does he mean that reality has two aspects one of which is unreal!

recognizable only in living matter and negligible in lifeless matter. Then his/her theory, if it is meant to be scientific, should also quantify "dominance levels" of the mental aspect using terminologies of biology, chemistry, and physics.

Dual-Aspect Theories

The relation between the brain and its mind is in some ways, similar to that between a computer's hardware and software. The existence of software in the computer can be recognized only when it runs and interacts with a user. Actually, software exists independent of any computer hardware because if the computer is broken, the same software can still run on another computer provided a copy of the software is saved on a storage device. Similarly, mind may have an identity of its own separate from its brain and ways to experimentally recognize it as such may yet be found! It may be too soon to dismiss dualistic interactionism as wild imagination.[7]

Because dualist theories are not yet experimentally testable, these days, mind-matter researchers seem to shy away from being labeled dualists or believers of even dualist-interactionism. So, they propose dual-aspect theories for which a basic notion is that consciousness and mind are not separate from matter. They assume that mind and matter are dual aspects of one physical reality similar to a quantum particle and its wave. As regards particles and their waves, we know when a particle's wave-like behavior is recognizable and when it is so negligible that it is not recognized. So, *one would expect any mind-brain dual-aspect theory try to explain why mind is manifest as dual-aspect only in living beings but not in lifeless matter*. As McFadden (2006) says "any theory of consciousness must explain why, thus far at least, only the wet systems that process information through neurons possess awareness".

In his dual-aspect theory, Bohm associates consciousness with an infinite sequence of quantum potentials at successive levels, each controlling the one below (Bohm, 1990; 1993). Bohm's collaborators, Hiley and Pylkkanen (2005) claim that their theory avoids dualism without falling into reductive materialism because a particle and its wavefunction on whose shape the quantum potential depends, are two different aspects of just one reality. If so, *why is mind not present in any lifeless quantum system as active information's dual aspect although the system has its own quantum potential? Why is content if inseparable from form, absent in these quantum potentials?* Moreover, the quantum potential guides the motion of the particle but the particle has no impact on the quantum potential; therefore from the Bohm-Hiley hypothesis (that the mind is nothing but a collection of quantum potentials at various levels), one can infer that mind acts on the brain but how does this hypothesis explain that the brain acts on the mind?

Another existing dual-aspect theory is that of Pribram who got advice in quantum mechanics matters from Bohm and Hiley. He often points out that *the medium is not the message* (Pribram, 2004; p.14) and clearly agrees with what we said above. But the "inseparability" principle seems to have its influence on Pribram (2000; 2004) because he also says that *communication is mental*. Is it? If a pattern of bits stored in a computer is not a message unless we assign some meaning to the pattern, why would a pattern of electrical signals passing through a telephone line be a message with meaning, when we have not yet assigned a meaning to it? Sometimes noise comes on the line; does it have a meaning? It may mean noise or nonsense to the listener like in the Chinese word example. Even these meanings are not created by the signal sequence while passing through the line. They are created in the head of the listener after the sound sequence enters his/her head. Once again, the point is: the psychological part of the communication process happens only in the listener's brain but not anywhere outside. So, *all communication is not mental*. Let us say that this criticism is interpretation out of context because Pribram never said that noise on a phone line has meaning; probably what he means is that *all communication in the brain or in his context, communication among cortical dendritic architectures is mental*. Yes it is; actually there is both physical and mental communication here. However, what brain scientists can observe and measure

[7] The main criticism of Eccles's dualistic approach is "the term *mind* was not well defined, and dualist-interactionism was not delimited in ways that it could generate hypotheses for empirical testing" (Watson and Williams 2003). However, the proposal by Hari (2008; 2010; 2011) that the non-material mind may consist of tachyons would provide a mathematical definition for the mind and a possible approach for experimental detection because it is suggested there that Eccles's psychons may actually be zero-energy tachyons.

today are properties of biological matter; they are positions, oscillation frequencies, energies, momentum, potentials, etc. of such matter. These are all quantities just as physical or chemical as properties of any lifeless physical system outside the brain. We regard them as indicative of mental aspects and associate them with mental aspects based on what the person subjected to an experiment tells the experimenter, or does not if in an unconscious state. *All communication known to us so far is physical and we are struggling to understand mental communication.*

Pribram (2004; p.16) claims "Gabor function provides a good description of the architecture of activity in cortical dendritic fields to sensory stimulation. Thus, the same mathematical formulation describes an elementary psychological process, communication, and an elementary material process in the brain. The Gabor quantum of information can, therefore, serve the same function for the wetware/minding relationship that the bit serves for the hardware/software relation." It is true that the bit in a digital computer or the qubit in a quantum computer are both software elements and they are both mapped to hardware units in the respective computers but they are not the same as their meaning in the programmer's head; the programmer assigns meaning to the bit/qubit. Similarly, in the brain, the Gabor quantum of information may be associated with an elementary wetware process but that does not necessarily mean that the elementary wetware process is the same as an elementary psychological process. For example, *in the design of an optical hologram, Gabor function describes a material process but it does not describe any psychological process and there is none.* The open question is *why should a Gabor description of dendritic activity in the brain indicate a psychological activity?*

4. Quantum Theory and Awareness Production

The relation between quantum mechanics and consciousness has its origins in the so called measurement problem or wavefunction collapse. Before an attempt is made to measure an observable property of a quantum system, it is in a superposition of all possible states that it can get into, as a result of measurement. After measurement, the system actually ends up in only one of the possible states in the earlier superposition and provides the experimenter the value of the system's property in the actual state. It is as though the act of measurement chooses one state of the system from one or more alternative possible states and actualizes it. In fact, this collapse feature of quantum systems is used in a quantum computer to make probabilistic choices of its states (Hirvensalo, 2004). The ability to choose being one of the most commonly experienced property of consciousness, it is natural to anticipate that quantum theory may be useful in explaining brain processes related to consciousness when it not possible to do so using classical physics alone. There may be consciousness related or other biological processes, which require quantum theory for their explanation. Tarlaci (2010) gives a review of some well-known quantum theoretical proposals relating various brain processes to consciousness.

When one attempts to use quantum theory to explain consciousness (or even with no reference to quantum theory), it is useful to distinguish between consciousness and awareness as Tulving (1985) does. Tulving views consciousness as a particular ability of living systems and awareness as an internally experienced outcome of exercising this ability in a particular situation. We will use the word consciousness with this meaning in this section. The difference is important because the latter is *phenomenal information produced by the brain and therefore an effect of the brain's action on its mind as opposed to an effect on the brain by an action of its mind* (We will give examples of the latter below and in the next section). When we remember a past event, we become aware of it one more time. In deep sleep without dreams, we are not aware of anything. However, our memory must be still intact because after we wake up, we remember everything that we were aware of before going to sleep. Hence, it seems that the act of remembering a past event or being aware of a present sensory stimulus needs to be initiated somehow and the initiation does not happen in deep sleep. Hence, the ability to produce awareness is similar to a stored computer program that would not run unless initiated by an external agent (a human being or another program). We will see below how production of awareness is related to quantum theory.

When quantum physicists talk about occurrence of consciousness in the brain, they are usually referring to awareness as defined

by above. For example, to explain Libet's delay-and-antedating paradox, Wolf (1998) obtains a time interval in which awareness of the sensory stimulus occurs assuming that it occurs along with a quantum collapse of the brain. In different places of the paper, he refers to awareness as conscious experience, conscious event, and consciousness and so on, but they all mean the same. Similarly, Hu and Wu (2004) postulate that conscious experience (meaning awareness of an event) emerges from collapses of entangled quantum states of nuclear spin ensembles (NSE) in both neural membranes and proteins. In general, all quantum theories of consciousness assume that awareness of an event is created in the brain only if there is an accompanying quantum collapse of the brain. The assumption appears reasonable when one considers Edelman's dynamic core hypothesis (Edelman, 2000). He emphasizes that occurrence of a conscious state (awareness) rules out or discriminates among billions of other conscious states, each of which may lead to a different potential consequence and that this discrimination happens so fast that it is not achievable at present by a man-made artifact (Edelman, 2000; p.147). He calls this ability of the brain to actualize one state among several possible ones as differentiation. Stapp (1995) describes in mathematical terms, how occurrence of awareness of a belief or thought implies that the brain has just made a quantum jump.

Open question: *What still needs to be explained theoretically is: how does an awareness producing quantum collapse of the brain differ from those of a lifeless system because the latter collapses do not produce awareness in the system ever!*

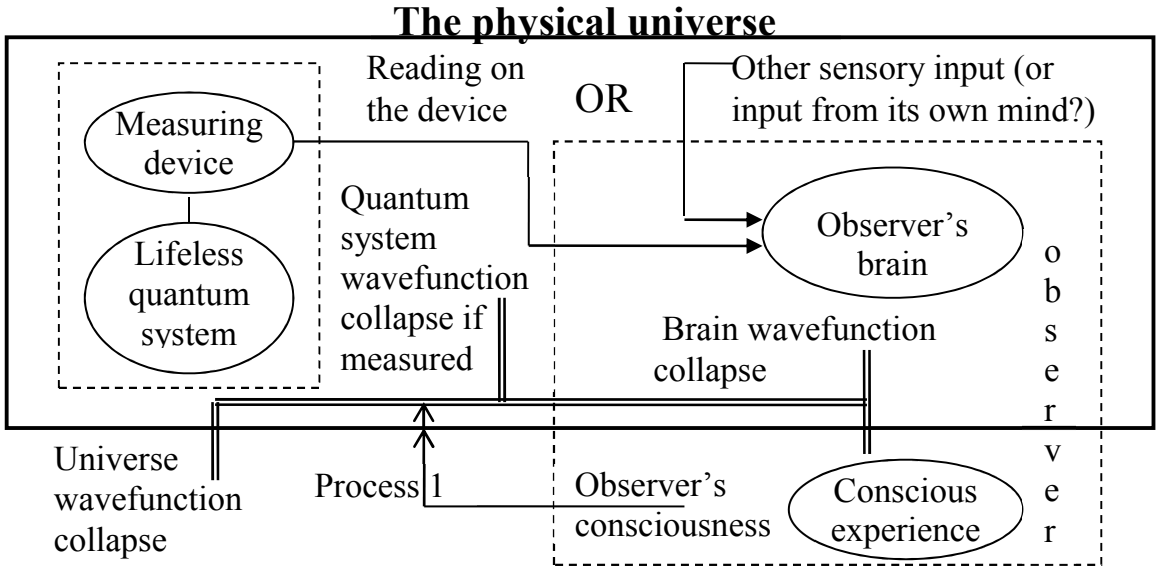

Figure 2. Simultaneous collapse of wavefunctions of the universe, the observer's brain, and the quantum system if it is measured, and awareness generation. Whether such a thing called collapse happens or not, if it does, whether it requires an observer's consciousness for collapse to happen, depends upon the interpretation of quantum mechanics. If the observer is not trying to measure any quantum system but simply recognizing a sensory input, according to Stapp, Process 1 consists in paying attention to the input.

Now, if awareness is indeed the outcome of a collapse of the brain's wavefunction as quantum theorists usually assume, then the collapse requires an agent to cause it. In many interpretations of quantum mechanics (not considering spontaneous collapse theories), a quantum wavefunction keeps evolving according to Schrodinger equation and makes a quantum jump only if there is a measurement or some appropriate interaction with an outside agent. In Copenhagen, Von-Neumann and Wigner interpretation used by Stapp (2007), observer's consciousness is the agent, which is partially responsible for the collapse (its role is in the so called Process 1 that prepares the system for collapse) and assumed to be outside the physical universe which includes the observer's brain. In wolf's paper (1998), the

agent is a sensory input but not consciousness because he uses the transactional interpretation of quantum mechanics (Cramer, 1980).

Open question *(same as above but in different words): Whatever the interpretation of quantum mechanics, the question to be answered is the same; why collapse of a lifeless system's wavefunction never produces awareness in it whereas some collapses of the brain wavefunction do so?*

The proposal of Hari (2008; 2010a; 2011a) (that phenomenal information consists of faster-than-light moving objects) describes a two-way interaction between the brain's neural system and tachyons; it is shown that tachyons act upon neurons and initiate neural processes and tachyons are created when the neuronal quantum system collapses thus producing awareness. In this proposal, production of tachyons is the distinguishing aspect of the brain's quantum collapse from that of a lifeless physical system.

Stapp's theory of mind (2007) is primarily about mind's action on the brain. Following Von Neumann interpretation he shows that rapid probing of a person's brain by the person's conscious intent produces Quantum Zeno Effect which allows the brain to sustain its plan of action without suffering decoherence from the environment (Stapp, 2008). Therefore, the brain is able to direct the body to act in accordance with the person's conscious intent. He talks a lot about the Process 1 of Von Neumann interpretation. Process 1 first chooses a property of the given quantum system to measure (which Stapp calls choosing a yes/no question) and then submits the question to the physical universe that includes the brain and body of the experimenter/s and excludes the consciousness of any living being. The question is submitted to the universe by setting up the experiment and then looking for the reading on the measuring device at the end of the experiment. When the device is read by an observer (who may be the same one that set up the experiment or another), this sensory input produces awareness of the reading in the observer's brain and changes the observer's knowledge. The whole process of measurement begins with an intention to measure and then ends with awareness of the result in the brain/mind of the observer; the physical universe undergoes a quantum collapse sometime during the process. Here, intention and awareness are both properties of consciousness but they are not the same. Intention initiates action by the brain whereas awareness is the response of the universe after implementation of the action. Stapp says that how the experimenter chooses the question cannot be explained by any existing laws of physics (probably he implies involvement of free will). However, once the question is chosen, intention takes advantage of Quantum Zeno Effect to make the brain act according to the intention. This is an example of mind's action on the brain. If the observer is not trying to measure a lifeless quantum system but simply recognizing a sensory input, according to Stapp, Process 1 consists in paying attention to the input.

5. Are Desires and Purposes Retro-Causal?

A chess-playing program may play chess very intelligently but it does not care a bit about winning or losing like one of those enlightened Buddhist monks! The program is neither happy when it wins nor sad when it loses because to begin with, it does not ever have a desire to win the game! An emotion occurs as a response to fulfillment or non-fulfillment of some desire or the anticipation of fulfillment or non-fulfillment of something that we want or need; obviously, lifeless objects do not have desires or needs. In our daily life, actions of human beings are often initiated by desires, purposes, needs, and goals, which are closely associated with future states of the living being (activities of other living beings have purposes too; *this initiation of action is an example of the mind's action on its brain*). The search for an appropriate course of action and the action itself depend upon some information about a future state; for example, if I want to go to New York I will take a bus to New York but not to Philadelphia. Therefore, the change from my present state depends upon information regarding a future state.[8]

This state of affairs seemingly violates the causality principle of classical physics that a cause should always precede its effect. It also seems to violate the relativistic causality

[8] Stapp (2008): "Intentions are formulated in terms of a *projected* (into the future) body-world schema: they are expressed in terms of an image of how the body in its environment is intended to be at a slightly future time (Thus, for example, the tennis player imagines how he will strike the ball, or where the ball he is about to hit will land in his opponent's court)."

principle which limits causes to the past light cone of the effect, and which is based on the principle that causal influences cannot travel faster than the speed of light. Hence, if actions of living beings take place because of information about some future states as said above, then an interesting and yet-to-be-answered question is "Are such actions consistent with the principle of causality of either classical or relativistic physics, and if not how does one justify them?" One can argue that this is a non-existent question and there is no causality violation because the goal state information is already present in the brain. Note that the goal state in my *present imagination* is not the same as the future physical state of my body because I am not in New York yet. The imagined goal is a mapping of the future physical state (different from the present physical state, else no action happens), into my present memory. Therefore, *the present memory content does depend on a not yet realized physical state*. Hence, one may formulate the above question alternatively: ***Open question:*** *How does the brain create in its present memory, a mapping of a future physical state of itself?*

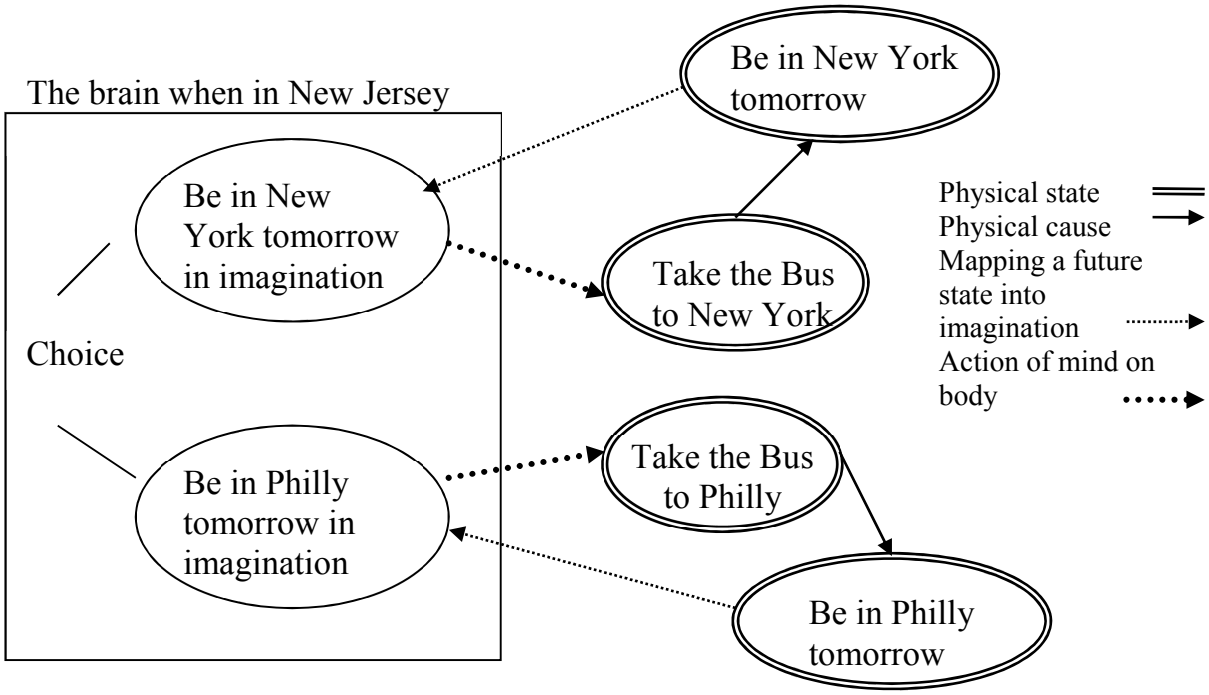

Figure 3. Action at present, with a purpose in mind depends on the chosen future state information.

It is true that the computer's memory also has the goal state (the win state) information which initiates the chess playing program to play but the required information is already entered into the computer memory by the programmer; the computer cannot create it by itself. On the other hand, the brain creates the goal by itself.[9]

In the quantum physics literature, there has been an extensive debate about the compatibility of quantum non-locality with the causality aspect of relativity physics. For now, most physicists seem to agree that quantum physics is consistent with what some of them call the weak causality principle (Cramer, 1980). This principle states that a controllable message cannot be sent backwards in time in any reference frame. It is possible that an explanation of the apparently peculiar causality of desires and purposes may be found using quantum physics since there have been instances of apparent causality violations and their explanations in this literature. Actually, Wolf (1998) believes that occurrence of an experience of a sensory stimulus (not

[9] Among the several papers written on causality of or its violation by tachyons, the paper "*Causality and Tachyons in Relativity*" written by Caldirola and Recami (1980) has a section with title '*Can a Tachyonic Observer Inform Us about Our Future?*' Here, the authors conclude that a tachyonic observer can convey to an ordinary observer the effects on a future event E of the anti-signals (negative energy signals) sent by himself to E so as to physically influence E. To me, this seems to be how we think when we try to achieve a goal whatever it may be; we first think about the effects on the future event of present actions and then act. To me, the tachyonic observer seems to be our mind.

related to purposes and desires), earlier than neural adequacy implies violation of causality by the brain. While proposing a quantum physical resolution of delay-and-antedating paradox (Libet *et al.,* 1979), Wolf explains how "Pairs of causality-violating events must occur in the brain in order that a *single* experience in consciousness occurs".

6. How Does The Brain Know What It Is Doing?

One difference between a computer of today and a human being is that a human being knows what he/she is doing at least when awake whereas a computer does not. What does it mean to know oneself or even to know something mean? Nowadays, we are very much used to expressions like "the computer knows", "it understands", "it thinks", etc. In fact, we can precisely define what it means for a computer to "know" an object.

Definition: *A computer behaves as if it knows an object (a data item or a program instruction), when a representation of that object as bytes of "0"s and "1"s in a digital computer or qubit states in a quantum computer, in other words, as a sequence of states of some hardware elements (let us call them hardware correlates), exists in its memory.*

Note that the above definition of awareness applies to a human brain with the following difference:

Definition: *A brain knows an object (which may be an experience) when a physical representation (neural correlate) of that object together with its "meaning" exists in its memory.*

The nature and structure of "meaning", the mental record is not yet known. Dualists think that it is nonphysical and exists independently from its neural correlate; dual-aspect theorists think that it is subtle but one of the two aspects of the neural record, and monists think that it is a property of the neural record. However, the above definition holds in all theories. In a dualist theory, this definition suggests the possibility of presence of unconscious thought in the brain. In a dualist theory, the definition also allows for the occurrence of Libet's delay-and-antedating paradox and the readiness-potential paradox because a neural record and the associated mental record can be created at different times.

Once such a mapping is entered into a computer's memory, it can perform any number of operations with that representation. The computer can compare the object with other objects also known to it similarly. It can add, subtract, compute functions of it, draw a picture of it, and so on. The computer can do almost anything that a person can do with that object and behave as though it "knows" the object without really knowing anything! On the other hand, we, human beings not only know the meaning of what we are saying but we also know whatever we are doing; for example, while walking, we know that we are walking; while reading a book we know that we are doing so, and so on. From the above definition of a computer's knowing, we can see why a digital computer cannot know what it is doing (call it self-awareness for brevity) as follows: Suppose that a computer knows an object O; hence a representation of O as a sequence of '0's and '1's is already written in its memory. To be self-aware, the computer must know that it knows O, so it must also contain in its memory the sentence "I know O" and for the same reason, it must also have the sentence "I know that I know O" and "I know that I know that I know O", and so on. So, the computer must be equipped with a mechanism which would write all the sentences in this infinite sequence, as soon as a representation of O is written in its memory. Then the machine enters into an infinite loop and write, and write, and write. Since writing each sentence in the loop takes some time however small it may be., the computer with a finite (not infinitesimal) writing time cannot complete the infinite loop. Therefore, it cannot be self-aware. It can write a finite number of sentences in the loop but clearly, it does not know what it is doing even then because the computer usually produces logs of its past activities. Even a quantum computer cannot complete the loop because a quantum computer cannot compute something which a digital computer (a Turing machine) cannot (Hirvensalo, 2004; p. 40). The nonhomogeneous Klein-Gordon equation for example, can be looked upon as a wave filter which outputs $\varphi(x,y,z)$ from the input f(x,y,z) and the feedback $\pm m^2\varphi$. Therefore, the wave filter represents a memory, which performs the infinite loop of writing described above.

*Hence the **open question is**: Since the brain does know what it is doing at least when awake, does it complete such an infinite loop of writing in a short enough time to produce the experience?*

Although Edelman does not mention any infinite loop explicitly, the *reentry, a recursive process crucial for consciousness*, in his theory of dynamic core hypothesis, may actually be doing this loop. Edelman defines reentry as "the dynamic ongoing process of recursive signaling across massively parallel reciprocal fibers…" One function accomplished by the reentry process is called recursive synthesis, which allows higher-order perceptual constructs to be used as inputs for lower-order maps through repeated reentrant signaling (Edelman, 1989; p.70).

If the answer to the above question is found to be yes, in other words, if the above mentioned infinite loop of writing into memory is completed in a short enough time to create the records necessary for awareness to occur in the brain, then the ability to do so may indicate tachyon existence and tachyon interaction with matter in the brain. It is possible that the brain's experience of knowing what it is doing is what we feel as "*the observing self*".

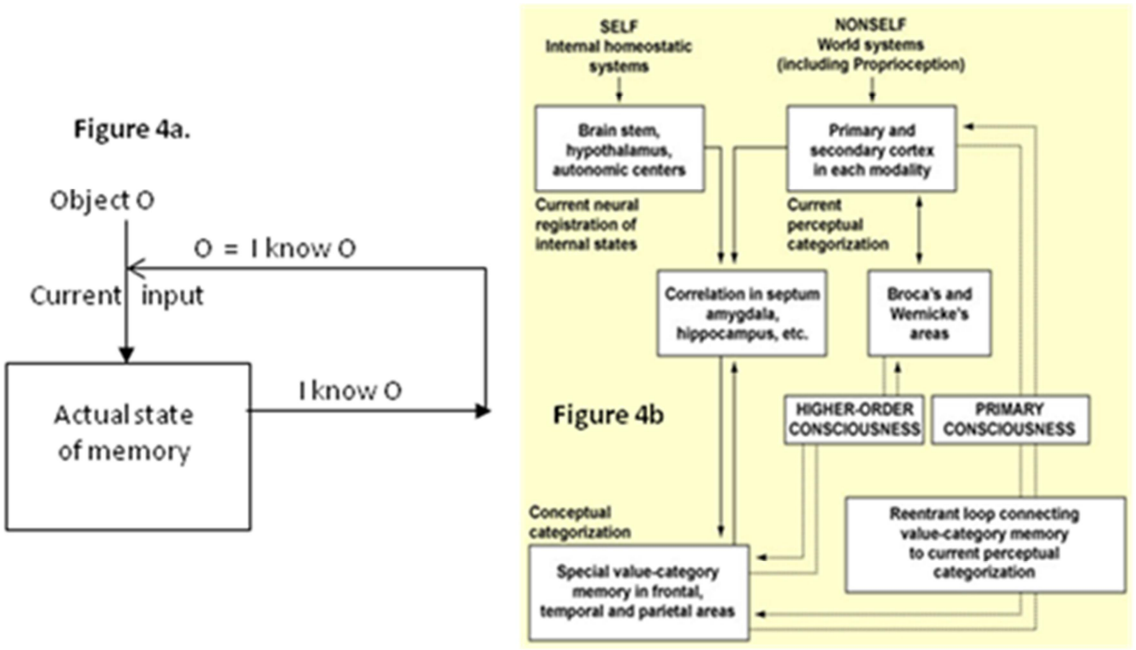

Figure 4a. Infinite loop of writing in a computer; we know it is not completed in a digital computer; probably not even in a quantum computer but requires mathematical proof not attempted here. **Figure 4b.** Taken from Edelman (2000; p 108). Reentrant loop connects value-category memory to current perceptual categorization in a recursive way.

7. Is Subjectivity the Crux of Consciousness?

Searle (2000) explains subjectivity as follows:

> "Conscious states only exist when they are experienced by some human or animal subject. In that sense, they are essentially subjective. ….qualitativeness implies subjectivity, because in order for there to be a qualitative feel to some event, there must be some subject that experiences the event. No subjectivity, no experience."

Searle calls subjectivity a first-person ontology "as opposed to the third-person ontology of mountains and molecules, which can exist even if no living creatures exist. Subjective conscious states … are experienced by some "I" that has the experience, and it is in that sense that they have first-person ontology." (Bohr probably would not agree with the mountains and molecules part of the statement!) Searle (1992; p.95) also points out that a subjective experience is not *equally accessible* to any observer. Because experience owes its existence to the subject, perception is not independent of the individual perceiving it but conditioned by personal attitudes, personal views, previous experience, or background.

Let human beings alone, and consider a robot for a moment. First, an experience by a subject (a living being or a robot) is nothing but a record created in the subject's memory. Most probably, the robot's record does not have any associated phenomenal information but as seen earlier, the robot's outward behavior is not in any way disadvantaged by lack of this mysterious phenomenal information! Therefore, when a robot records an influence from outside, the record is its experience and the robot is its subject. A robot's inferences and conclusions are always subjective because they depend upon the knowledge it already has in its memory, which includes the heuristics entered by the robot's programmer as well as all the external inputs (vision, sound, motor, etc.) received so far. For example, two robots may read the same answer sheet of a student from an exam, and one robot may give a "pass" grade to the student whereas the other robot may "fail" the student; this happens if the definitions of "pass" entered into the robots' memories are different. So, a robot can have its own point of view. The point is that human perception is subjective for a similar reason. The mind of a human being (in general, many living species) is software-like because in fact, any software in any computer is only a representation of some phenomenal information contained in a human brain. Therefore, what two human beings learn, perceive, remember, or experience from same situation in the external world tend to be different because their pasts are generally different.

Whatever the robot reports is what its experience is; therefore, it is accessible whereas living beings' experience which we called phenomenal information is inaccessible. As to the "I" aspect of the experience, the essence of "I" is to distinguish oneself from everything else in the universe; the robot certainly does that. That is why we are able to develop and use computer communications. If the programmer gives the name 'I' to the robot, it will thereafter say "I know this", "I did this" and so on. However, it will not know itself because it will fall into an infinite loop of self-reference if it tries to write a representation of itself into its memory. Moreover, *a living being's "I" is accompanied by an urge for survival and continuation and this urge may give strength to the "I" feeling. the computer has no such urge.*

In the author's view, whether this urge for survival is purely biological or has some accompanying mental aspect is an open question. Baars (1996) talks about "the self as observer" notion. The observer in this notion is a constant observer although Baars does not emphasize it. In other words, the observation is continuous and includes the act of observation itself, which brings us back to the notion of the infinite loop of writing into one's own memory. Thus it is possible that the infinite writing loop completes in the waking state and might be what is felt as "I" experience in the brain. The self and subjectivity notions are areas of current investigation. We hope we threw some new light on these notions by comparing the brain and the computer.

8. Is Free Will Beyond Causality?

Depends on how one defines free will. In any given situation, prior to taking an action, one first thinks about what one wants (called volition, passion, desire...) and then how to get it (reasoning). In the New York example, first I have to choose between going and not going to New York. Then I have to decide whether I want to drive, or ride a bus, or take a train, or fly, etc. The ability of human beings to create a goal for oneself and then choose a strategy to achieve it is usually considered as free will. Note that the mere act of choosing one from two or more possibilities is not a manifestation of free will because again, there are decision-making computer programs, which make choices. Of course, the difference between the brain and the computer is that the former is aware of its decision whereas the latter is not but that is not all. We already saw that the computer although not conscious, can still store a goal in its memory but that somebody (whether it is a human being, or another program, or a physical device), needs to enter the goal into it and initiate the program to achieve the goal. Clearly, the brain does create goals by itself and does initiate actions to achieve those goals as well as what Libet calls the veto power to stop the action before it starts if the brain/mind changes itself. These abilities make us feel that we have free will. The question "how does the brain create the goal by itself?" is already discussed in the section on retrocausality.

To make a decision, a computer program depends upon some rules stored in the computer memory and strictly follows

them to arrive at the decision; the program never violates any stored instruction. What about the brain? Does it always need and use only stored information to make a decision? Here is what Roger Sperry (1979) said about free will:

> "A given volitional choice may depend additionally on things like the memory and the mental perspective acquired by the subject (and any consultants) over a span of many decades preceding the decision. Data from the information store of one or more libraries may be called on and funneled into the brain code sequence that leads to the given choice. Compared with the kinds of determinism that science deals with in other systems, the degree and levels of freedom in the operations of the human brain clearly set the brain and mind of man apart with the dignity of an apex post in the universe far above all other known systems in terms of its ability to choose and to control a course of events. Having degrees of freedom does not quite make for complete freedom from causal control. The answer here is that complete freedom from causation would mean behavior purely on chance, on caprice and would result in meaningless chaos. What one wants of free will is not to be totally freed from causation, but rather, to have the kind of control that allows one to determine one's own actions according to one's own wishes, one's own judgment, perspective, cognitive aims, emotional desires and other mental inclinations."

Hence, a human being's decisions and choices do depend upon desires, ambitions, goals, etc. all of which already exist in his/her memory. That is why many neuroscientists and computer scientists think that a free will *not subject to causality or chance* is a delusion. Minsky (1965) is a well-known disbeliever of such free will. *Assuming that the brain uses only stored information to make a decision and that it never violates any stored rule in the process*, such a decision is subject to causality irrespective of the fact that human beings are aware of their decisions unlike computers, which also obey laws of causality. Why does it matter whether a free will not subject to causality or chance exists or not? Because if the answer is yes then science cannot explain such free will, science being a set of descriptions of cause-effect relations and their verifications.

The Appendix has some examples of decision-making circumstances in an attempt to show that a free will not subject to causality or chance may not be an impossibility.

Appendix

Does Free Will Free from Causality and Chance Exist?

It is possible that the following incident (Hari 2011b) happened: "Amar Ali was swimming near the Konodas Bridge in Gilgit, when the tides swept him away, into the roaring Hanisara (local name of River Gilgit). Israr, a fifteen years old teenager, jumped into the river, seeing Amar drowning. To the surprise and delight of hundreds of onlookers, Israr fought against the wild currents and was able to save the life of Amar. With compassion, courage and skills, combined together, Israr was able to save a human life, a noble and laudable work indeed." Let us assume that Amar is a stranger to Israr and that Israr is not aspiring to be a soldier, firefighter, police, *etc.*; hence, he is not on the lookout for opportunities to practice saving lives of people in danger. In this episode, Israr was not expecting to see a stranger downing in the river. He had no duties of job requiring him to risk his own life to save the stranger; he could have just passed by. Israr had nothing going on in his brain/mind related to the incident before it happened. To protect one's own life takes priority over helping others in anybody's mind even if he/she was taught at home, or in a place of worship, to help others and have compassion for others; no religion would teach one to risk one's own life to help others. Hence Israr's decision to jump into the river did not follow from the rules existing in his memory. The rule "I should protect my life" which had been in his head since birth was changed by him on the spot. The only purpose of his action was to save the life of the stranger and the purpose was chosen by free will from two possible alternatives: one is the constant purpose to protect his own life and the other purpose is to protect the life of the stranger; the latter is created instantaneously by free will itself. This choice does not seem to be the result of any internal or external cause.

The above is an example of risking one's own life out of compassion. On the other hand, suicide bombers do more than risk their lives; they give up their lives not out of compassion but out of revenge towards a

community or for a political purpose. This act is not initiated by free will without a cause because a lot of preplanning went into the act with the already established purpose of killing members of the other community. Harming the other community was already given a higher priority in their brains/minds over their own survival.

Another example (Hari 2010b) is as follows: Once upon a time, there was a very religious person who spoke nothing but truth all his life. Let us call him Truth Speaker. One day, he was sitting in a grove and doing meditation with closed eyes. Suddenly, he heard the sound of running footsteps. On opening his eyes, he saw a scared man running for his life. The man stopped when he saw Truth Speaker, and said with a gasping breath, "I am being chased by robbers. I am running for my life. I cannot run any more. I will go behind the bushes over here. Please do not reveal my where-about to anybody". So saying, the man ran and hid behind the bushes without even waiting for Truth Speaker to reply. Truth speaker went back to meditation. A few minutes later, he again heard thundering footsteps and opened his eyes. He saw some armed men running. When they saw Truth Speaker, they too stopped and said "We are looking for a man whom we saw come this way. Did you see anybody running past you a short while ago? If so, do you know which way he went?" Truth Speaker thought that he should never tell a lie. Therefore, he pointed to the robbers the bush where the scared man was hiding. The robbers then caught the man and killed him. After some days, Truth Speaker died but was taken to hell instead of to heaven. There, Truth Speaker asked the ruler of hell (a personification of justice according to Hindu Religion) why he was brought to hell instead of to heaven where he should have been on account of speaking nothing but truth all his life. The ruler of hell replied, "You spoke truth alright but by telling a lie you could have saved the life of the man being chased by robbers. You did not have a tiny bit of compassion. You were carried away by your arrogance of sticking to your principle and your selfishness to go to heaven. That is why you deserve hell." Our interest in the story is not at all whether Truth Speaker went to heaven or hell after death nor whether there is a heaven or hell. It is a person's ability to see when to speak truth and when not. Truth Speaker was following a rule which firmly stuck inside his head and his mode of thinking was that of a machine which was programmed to tell truth and therefore never lie. On the other hand, imagine that in the story, Truth Speaker told the robbers that he did not see anybody around earlier that day and they were only the people that he saw until then. In this case, his mind did not execute like a machine, a memorized instruction expected to be carried out. Nor did it care for a future benefit, namely going to heaven. Thus, the action of lying was directed neither by the past nor by a future goal. One may argue that to save the life of the stranger is the reason for lying in the alternative version of the story. True; however, this reason is created by his free will instantaneously on the spot because until that moment, "speak truth" was the rule stored in his memory with no conditions under which it can be violated. The situation in the story was completely new to Truth Speaker and therefore was not already in his memory. This ability to violate a rule of the past but not because of already established goals, and act on one's own is a self-starter or spontaneous and is the true free will. This ability refuses to be told what to do and refuses to be told by somebody or something else; it is above and beyond all causality. Now, one may say that Truth Speaker might have been taught that he can violate his principle if doing so saves the life of another person. This would be an instruction in his memory, which causes him to act as in the alternative version of the story. Then clearly, this action in the second version is not initiated by free will.

Does such a free will exist? The problem *is* even if such a free will exists, we have no way to distinguish it from an event that occurs by chance. The latter event may have a cause. We simply may not know what the cause is; we do not know why an event with a small probability has occurred when the probability of its not happening is larger; we do not know what changed the probability. Therefore, it is possible after some investigation (which may take several years!) that the cause may be found. In the case of free will not subject to both causality and chance, there is no cause to find!

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