Article

Bohm's Theory of the Relationship of Mind and Matter Revisited

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ABSTRACT

In this paper it is claimed that Bohm's holistic, realistic, causally deterministic, non-local theory of the relationship of mind and matter which is based on the key notion of "active information" suffers from an ill inductive reasoning. It is shown that the notion is a special case of the notion of pragmatic information as posed by Roederer which applies *merely* to natural living systems and artifacts (unnatural nonliving systems). So, the extension of the thesis of active information to the natural nonliving world would count as a violation of the key constituent concepts of pragmatic information and as an ill generalization of Bohm's thesis itself. Active information as 'mind' will be found in biological systems and in some artifacts which represent the biological mind. There is no reason to think of inanimate nature being driven by information. This, in turn, would lead to the substitution of empirical realism for realism, modifying Bohm's ideas to come even closer to the Copenhagen interpretation of quantum mechanics.

Key Words: active information, quantum potential, pragmatic information, information-driven interactions, force-field driven interaction

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1. Introduction

In quantum mechanics, nonlocal hidden variable theories can be alternatives to the unfortunate local hidden variable ones. The latter were experimentally proven to fail (Aspect, 1982a; 1982b). According to hidden variable theories, particles' motions and trajectories are predetermined. If there are no faster-than-light or simultaneous effects, such theories are local, otherwise non-local.

In 1926, Louis de Broglie proposed a non-local hidden variable theory. The simplified version of this theory suggests a construction involving a point particle guided by a continuous 'pilot wave'. According to this view, the wave field guides the classical particle to follow a path where the amplitude of the wave field is large. However, later, de Broglie's further discussions with members of the Copenhagen school led him to abandon his theory.

The Copenhagen interpretation is one of the earliest and most accepted interpretations of quantum mechanics whose initiators are mostly Niels Bohr, Werner Heisenberg, and Max Born. It holds that one can talk of the reality of the quantum system just after the act of measurement. This empirical reality stands as opposed to the objective reality defended by Einstein and Schrödinger. Before measurement, the system is non-local and this is the very act of observation which makes the system local causing the set of probabilities to immediately and randomly collapse into only one of the possible values.[1]

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[1] According to this interpretation, quantum mechanics is intrinsically probabilistic, and, thus, indeterministic in nature. Other key elements of Copenhagen interpretation are holism, uncertainty principle, and complementarity. The appearance of wave picture or particle picture of a quantum entity with respect to a certain experimental arrangement is the simplest form of Bohr complementarity principle

In the course of writing a book, entitled *Quantum Theory* (1951), the American physicist David Bohm became dissatisfied with the Copenhagen interpretation of quantum mechanics, the interpretation he had initially intended to advocate. Strongly encouraged by Einstein, Bohm initiated establishing a sort of hidden variable theory, which appeared through two papers in *Physical Review* (1952; 1953). As Bohm's hidden variable theory owes a lot to de Broglie's theory, as far as the notion of pilot wave is concerned, his theory is often referred to as the de Broglie-Bohm theory.

In Bohmian mechanics, particles, say electrons, are regarded as inseparable union of a particle and a field. Such a holistic view has some implications for his theory of the relationship of mind and matter, the final version of which was published in the journal of *Philosophical Psychology* in 1990.

Section 2 deals with the key concepts of mind-matter relation in Bohmian mechanics, the most important of which is the notion of 'active information' whose mind-like property guides matter through the activity of form, rather than substance.

In section 3, we claim that the notion of active information is a special case of another notion, that is, 'pragmatic information' as depicted by Roederer (2003; 2005). Pragmatic information is *only* applicable to natural living systems and some unnatural non-living systems (artifacts).

If the notion of active information cannot go beyond pragmatic information, as it is claimed in this paper, then Bohm's generalization of active information to the whole universe would count as an ill inductive reasoning. This is discussed in section 4 considering Bohm's example of two-slit interference experiment.

The conclusion, then, in section 5 would be that active information, also called quantum potential by Bohm in quantum domain,[2] represents human mind, not vice versa. In addition to the minds of biological systems, active information is present merely in artifacts which have purposefully been designed by originally intentional living systems. So, contrary to Bohm's claim, it is not the case that mind is part of more subtle active information in the universe, but active information is the mirror representing our original mind.

2. Mind-Matter Relation in Bohmian Mechanics

Let us start with a quotation from Bohm (1990):

> "[C]onsider a ship on automatic pilot guided by radar waves. The ship is not pushed and pulled mechanically by these waves. Rather, the form of the waves is picked up, and with the aid of the whole system, this gives a corresponding shape and form to the movement of the ship under its own power. Similarly, the form of radio waves as broadcast from a station can carry the form of music or speech. The energy of the sound that we hear comes from the relatively unformed energy in the power plug, but its form comes from the activity of the form of the radio wave; a similar process occurs with a computer which is guiding machinery. The 'information' is in the program, but its activity gives shape and form to the movement of the machinery. Likewise, in a living cell, current theories say that the form of the DNA molecule acts to give shape and form to the synthesis of proteins (by being transferred to molecules of RNA)."[3]

One should note that the first two examples have to do with artifacts while the third is concerned with the realm of biological systems.

What is common in all cases above is that the existence of a *pattern* (form) makes a *change* (activity) only in the *correspondent* component of the system so that the energy of the change is not provided by the form, but by a third

as he considered the two pictures as two complementary descriptions of the same reality (Heisenberg, 1958).

[2] In quantum domain, we will use the terms 'active information' and 'quantum potential' interchangeably.

[3] These three examples will be called Bohm's examples hereafter.

component. This means that the pattern-change system is an open system.

Take the second example, that is, the radio waves as broadcast from a station and are received by the radio. The electromagnetic waves, as patterns, are sent by a transmission antenna, eliciting a change in the radio. The radio will receive these specific waves only if it is tuned correctly with respect to the specific (correspondent) wavelength or frequency of the waves. The most important point is that the energy of the radio must be provided by power plug, not by the electromagnetic waves.

According to Bohm, in quantum domain, particles, say electrons, are regarded as inseparable union of a particle and a field. So, his theory counts as a holistic one. The field he speaks of has some new properties that make it different from what is conceived by the term in classical mechanics.

Generally in physics, fields can be represented mathematically. Such certain mathematical expressions are called potentials. A potential in physics describes a field with the possibility or potentiality that is present at each point of space to give rise to act on a particle at that point.

However, Bohm distinguishes between the use of the term in classical and quantum domain. While in classical physics[4] the effect of the potential is always proportional to the intensity of the field, Bohmian quantum potential depends only on the form;

> "Therefore, even a very weak quantum field can strongly affect the particle. It is as if we had a water wave that could cause a cork to bob up with full energy, even far from the source of the wave. Such a notion is clearly fundamentally different from the older Newtonian ideas. For it implies that even distant features of the environment can strongly affect the particle" (Bohm, 1990).

So, at quantum domain, this is the form, or pattern, of a field, not its energy, that deterministically guides the particle. Such a field is regarded as containing objective and active information which in quantum domain is called quantum potential by Bohm. Such information is potentially active everywhere, but actually active only where the correspondent particle is. Active information also implies the possibility of a certain sort of wholeness of the particle with distant features of its environment. According to Bohm, when particles interact, it is as if they are all connected to each other by invisible links consisting of a single whole.

The notion of active information also implies another notion to come into play, i.e., non-locality. When distant parts of the environment simultaneously affect the motion of the particle in a significant way, such effects are non-local (Bohm, 1990).

As regards the interdependence of things to each other, Bohm distinguishes two levels of implicate and explicate order. In his opinion, everything in some way implicates or enfolds everything. This enfoldment relationship between things is active and is not superficial at all. Things appear to be independent of each other just under typical conditions of our ordinary experience. At this stage, we are in the realm of explicate order. The claim thus is that the relative independence of things is just a sort of appearance;

> "The explicate order, which dominates ordinary experience as well as classical (Newtonian) physics, thus appears to stand by itself. But actually, it cannot be understood properly apart from its ground in the primary reality of the implicate order" (Bohm, 1990).

The general implicate process of ordering in Bohm's thesis can apply to both mind and matter. This suggests that mind and matter are at least closely analogous, if not two aspects of one thing. They are not so different as they appear at the level of explicate order. Further development of this idea leads to the consideration of the notion of implicate order to serve as a means of expressing the actual relationship between mind and matter. For Bohm, the activity of form is

[4] Classical physics here comprises both Newtonian physics and electromagnetism.

the very essential quality of mind, rather than of substance. This is what happens when we read a printed page. Indeed, it is the existence of the forms of the letters and words and their one-to-one correspondence to the neural patterns which leads to information acquisition, not the assimilation of the substance. "A similar mind-like quality of matter reveals itself strongly at the quantum level, in the sense that the form of the wave function manifests itself in the movements of the particles. This quality does not, however, appear to a significant extent at the level at which classical physics is a valid approximation" (ibid).

In the above view, this is active information that is simultaneously physical and mental. In other words, active information serves as a sort of bridge between mind and matter as two sides of reality, two inseparable sides that are aspects of a single whole. This means that what is felt to be the information contained in thought as the mental side of active information is at the same time the information contained in the physical side. The latter is the information which gives rise to neurophysiological, chemical, and physical activity.

So far, we have seen how Bohm applies the notion of active information to interactions in certain realms. It seems that the study of the everyday experience of interactions in certain systems such as radio waves/radio and DNA/proteins has been inspiring in extending the idea to the realm of quantum mechanics which finally leads to projecting a holistic, deterministic, non-local theory of wave/particle interaction. Bohm does not stop here and extends the idea using the notion of 'subtlety'.

Just as our thoughts may contain a whole range of information content of different kinds whose unfoldment may lead to the activity of their correspondent objects, they can also be enfolded by a higher order thought whose unfoldment may give rise to the mental activity (lower order thoughts) as if it were a material object.

There may also be a more subtle level of information which enfolds the original set of information having the potentiality to activate it and this can go on infinitely. From the material side, each level of potentially active information can actually activate the correspondent objects. As seen, at each level information can be seen from two aspects, mental and material.

Now Bohm is ready to extend quantum processes in wave/particle interaction to mind/matter interaction by the application of the notion of quantum potential as active information in quantum realm:

> "[A]s the quantum potential constitutes active information that can give form to the movements of the particles, so there is a superquantum potential that can give form to the unfoldment and development of this first order quantum potential" (Bohm, 1990).

This can go infinitely reminding us of the levels of subtlety in mind. Then Bohm bites the bullet and claims that not only are these two processes (wave/particle and mind/matter interactions) similar, but the same. Finally, Bohm extends his holistic idea to society and, from there, beyond human species as a whole (ibid).

In the next section, we will show that the notion of active information is a special case of pragmatic information as projected by J. G. Roederer (2003 and 2005) claiming that the above extension by Bohm is an ill generalization.

3. Pragmatic Information

As stated above, Roederer's interpretation of the notion of information comprises the notion of information Bohm might have had in mind. Let us start with Roederer's account of the term 'interaction' as an underlying basic, primordial concept in pragmatic information. Without attempting to define it formally, we can say that when two bodies interact, there happens a change in any of their properties such as shape, motion,

constitution, and so on. Roederer identifies two fundamentally different kinds of interactions between the bodies which fabricate our universe. The key notions to discriminate these two classes of interactions are 'information' and 'information processing' (Roederer, 2003). Thus, generally, interactions are fundamentally divided into two main classes: Force-Field Driven Interactions and Information-Driven Interactions which are mutually exclusive. In what follows we pin down these two notions.

3.1. Force-Field Driven Interactions

Both in quantum domain and in macroscopic world, when two bodies approach each other, they may interact. Under some *initial conditions,* such interactions may lead to stable, bound structures, while under some other initial circumstances they may lead to no new structures or unstable ones, which decay after a time.

When two bodies 1 and 2 in the classical non-relativistic realm,[5] isolated from the rest of the Universe,[6] interact, Newtonian mechanics tells us that there are two scalars m_1 and m_2 such that:

$$m_1 \vec{a}_1 + m_2 \vec{a}_2 = 0 \qquad (3.1)$$

$\vec{a}_1$ and $\vec{a}_2$ are instantaneous acceleration vectors. Each term in the above equation is called *force*: $\vec{f} = m\vec{a}$.

Hamiltonian mechanics is a re-formulation of classical mechanics whose entire framework can be derived from (3.1) together with the fact that the acceleration of a body which is simultaneously subjected to different interaction mechanisms is proportional to the vector sum of all forces acting on it. Hamiltonian mechanics deals with a system of interacting mass points with geometric limitations on their motion imposed by given constraints. For a given classical closed system consisting of N mutually interacting material points, classical Hamiltonian mechanics allows us to determine the system's coordinates q_k and momenta p_k at any time t, once we have known the initial conditions, *i.e.,* the coordinates q_k^0 of the bodies and the associated momenta p_k^0 at the initial time t_o. Hamiltonian mechanics provides a correspondence between initial state of the system at initial time t^o and final state at time t. Such a system would be perfectly reversible as far as the interaction force is conserved. We can run the system backwards (for a time t) reaching the initial states again, this time with reverse velocities $-p_k^0$. This reversibility states that there is no preferred direction of the time. Thus, the relationships between the points are *inter*-actions not cause-and-effect. A very crucial point here is that it is *we* humans who set the initial conditions of the given mass points and also the time t of the final state. However, the conditions of the system at the final state are out of our choice.

As far as the concept of force-field in the classical, macroscopic, nonrelativistic domain is concerned, we have to turn our attention to gravitational, electromagnetic interactions. Gravitational interactions are available between all material bodies. Electromagnetic interactions act between some types of elementary particles as well as charged or magnetized bodies. Note that frictional, chemical and thermal interactions in the macroscopic domain are also collective interactions based on electromagnetic interactions at atomic and molecular level. Finally, there are also elastic interactions. They occur when a medium acts between the interacting bodies or when a special physical device intervenes the interaction with the condition that its mass is

[5] In order to consider the bodies to be in such a realm, the following conditions must be fulfilled: 1. the size of bodies must be negligible compared to their mutual distance; 2. their rotational energy must also be negligible with respect to translational energy, and 3. the velocities of the bodies must be negligible with respect to that of light.

[6] Strictly isolated systems (closed systems) do not exist since the gravitational field, as a geometric property of space-time, cannot be canceled in any given region of space.

negligible or can be considered an integral part of the system.

If all interactions mentioned above occur between bodies isolated from the rest of the Universe, and if the force acting on the mutual interacting bodies is conserved, then they will remain *inter*-actions. "Such interactions are bidirectional in the sense that neither of the two interacting bodies has a hierarchical ranking over the other. There is no "cause-and-effect" relationship as long as there is no external interference: no irreversibility or asymmetry, and no privileged direction of time" (Roederer, 2005).

Let us turn our attention to the quantum domain. At the microscopic, subatomic level, everything is reducible to the four fundamental interactions: gravitation, electromagnetism, strong, and weak interactions.

We are already familiar with the gravitational and electromagnetic interactions as they are present in our everyday life in the macroscopic world. Gravitation force is the weakest of the four fundamental forces, yet it is the dominant force in the universe for shaping the large-scale structure of galaxies, stars, etc.

Fundamental electromagnetic interactions occur between any two particles that have electric charge. These interactions involve the exchange or production of photons. Thus, photons are the carrier particles of electromagnetic interactions. Electromagnetic interactions are responsible for the binding force that causes negatively charged electrons to combine with positively charged nuclei to form atoms.

As stated earlier, in classical domain, for a closed system consisting of interacting particles in which force is conserved, gravitational and electromagnetic interactions are reversible and bidirectional and there is no privileged direction of time. This holds for quantum domain. Strong interactions in the quantum world are bidirectional. They are understood to represent the interactions between quarks and gluons. The strong force is mediated by gluons, acting upon quarks, anti-quarks, and the gluons themselves. Fundamental weak interactions occur for all fundamental particles except gluons and photons. Weak interactions involve the exchange or production of W or Z bosons. Weak interaction was first recognized in cataloging the types of nuclear radioactive decay chains, as alpha, beta, and gamma decays. Alpha and gamma decays can be understood in terms of other known interactions (residual strong and electromagnetic, respectively), but to explain beta decay, it required the introduction of an additional rare type of interaction, that is, the weak interaction. Quark flavor never changes *except* by weak interactions, like beta decay, that involve W bosons. Weak interactions are the only fundamental ones, which are not reversible.

Let us summarize the idea projected in this section. A classical closed system consisting of interacting mass points in which the force is conserved is bidirectional, symmetric, and reversible. There is no cause-and-effect relationship between the interacting bodies as far as there is no external interference. However, if a system of interacting pointes is under the effect of some external forces, it will no longer be reversible. Reversing all the velocities at a time t does not lead to the same initial state at time t_o with reversed initial velocities. For such a system to be reversible, all external interactions must follow exactly the same pattern in reverse. To fulfill such a condition, we have to have total information on and control of the external part. So, any, even very weak, perturbation would make a limited classical system of interacting bodies irreversible (ibid). In the quantum domain, all kinds of interactions, but weak interaction, are reversible and bidirectional.

All above-mentioned physical interactions, occurring in nature, have some fundamental characteristics, *i.e.:*

> "The end effect of a physical interaction will always depend on some "initial conditions," such as the initial configuration (positions, velocities) of the interacting bodies. A most fundamental characteristic is the fact that during the interaction, there is a direct transfer of energy from one body to the other, or to and from the *interaction mechanism* itself (in case of fundamental interactions force field; in more complex cases, some process linking the two bodies)" (Roederer, 2003).

A clearer understanding of physical interactions will be possible when the other main class of interactions, i.e., information-driven interactions are dealt with. So, we postpone going through the details of the former until the reader has been familiar with the latter.

3.2. Information-Driven Interactions

Consider Bohm's examples at the beginning of section 2 and again take the second example, that is, radio waves/radio interaction. In what follows, we restate the example adding some key new notions.

The electromagnetic waves (radio waves), as *patterns*, are sent by a transmission antenna, as *sender*, with the *purpose* of eliciting a change in the recipient, namely, our radios, as the *receiver* and, ultimately, in our cognitive state. The radio will receive these specific waves only if it is tuned correctly with respect to the specific wavelength or frequency of the waves. This means that there must be a *one-to-one correspondence* between the sender and the receiver: only a specific wavelength will trigger a specific change in the radio. To guarantee such a one-to-one correspondence once the sender is present, there must be a *common code* between the sender and receiver. Common code is a kind of memory operating between sender and recipient assuring a univocal change to occur in the recipient in presence of a specific pattern. In other words, to ensure a specific change in the recipient, the presence of a specific pattern must have a *meaning* for the recipient. Common code is responsible for such a univocal correspondence. If common code changes, we will no longer have the same correspondence and the purpose of the sender will have no meaning or another meaning for the recipient. The last and the most important point is that the energy of the radio as the receiver must be provided locally, i.e., by power plug. It is not supplied by the energy of the electromagnetic waves themselves. In other words, the sender and the receiver are *decoupled energywise*. Note that the correspondence between the sender and the receiver has not been established by chance. It is *repeatable*.

The terms written in italic in the above paragraph represent the fundamental elements of information-driven interactions occurring in pragmatic information. Concerning above, the very first question for a curious reader would be: what really is the difference between information-driven interactions and force-field driven interactions? At first glance, one can see some anthropomorphic new terms such as 'purpose' and 'meaning.' So another important question would be: where do these terms come from? Is it us who attribute these terms? Isn't it possible to use the same vocabulary for force-field driven interactions? In what follows, we will try to pin down these questions. For the start, Roederer's (2005) example as explained as follows will help.

Consider some billiard balls on a frictionless table as shown in Fig. 3.1. Three layers are distinguishable: balls in input layer, output layer, and a few intermediate balls. At initial time t_o, a given distribution of velocities at the input layer triggers a chain of collisions in the intermediate layer, which in turn impart velocities to the output layer. All collisions are *mutually* elastic and thus reversible. In such a case, Hamiltonian mechanics enables us to calculate the state of the system at any other time *t*. So, the final

velocities of the balls at any time *t* in the output layer will be computable. Now we increase the number of the intermediate balls making the interaction mechanism occurring in the intermediate level more *complex*. This brings about two important consequences: the system becomes more irreversible and the input-output relationship gets more decoupled energywise. By adding more balls to the intermediate level, the energy transferred to the output layer becomes more dependent on the interaction mechanism than input layer.

Let us further assume that we put the intermediate balls in a black box such that we have no access to the balls comprising the interaction mechanism. Now, the entire process can be seen as a system in which the input is coupled to the output by an unknown complex interaction mechanism.

Up to this point, everything was purely physical without any need to mention the notion of information. However, the wish to construct a univocal relationship between input and output layer every time the system operates requires an extra device to reset the system exactly to the same initial position it was before the operation. In other words, a system with the purpose of establishing a one-to-one correspondence between input and output layer through a complex interaction must be reset every time it operates. There are three ways of fulfilling such a task:

1. Purposefully designing a resetting device (an artifact) with the ability of recording all the initial conditions in its memory and adding the device to the system to reset itself once it is activated;
2. the intervention of a purposeful, intelligent biological system, which has recorded all the initial conditions in mind, and
3. by chance in any natural system. Here, any purpose will disappear.

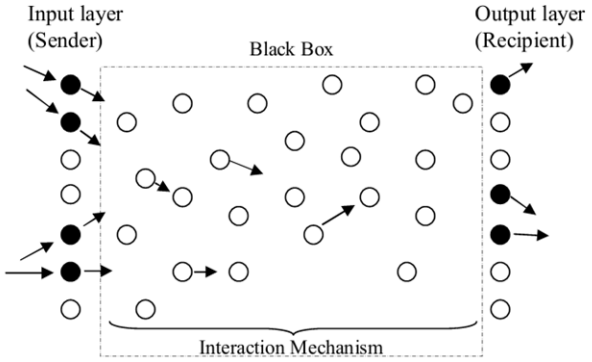

Figure 3.1. Billiard balls on a frictionless table. See text for details.

Among the three ways of establishing an input-output univocal correspondence mentioned above, 1 and 2 do not need any further explanation, but 3 seems to be a bit ambiguous. How would Nature do such a task just due to stochastic processes? Consider a large number of identical copies of the above system with the same initial setup of the black box except for small random differences (errors) in the reset mechanism. Only the fittest systems evolving in the right directions would survive, while the less fit copies would disappear (Roederer, 2005). This is the simplified hypothetical foundation of Darwinian evolution. Such systems do not arise spontaneously: "They must *evolve* – in fact; Darwinian evolution itself embodies a gradual, species-specific information extraction from the environment. This is why *natural* information-driven interactions are all *biological* interactions" (Roederer, 2005). Therefore, the above mechanism provides the basis for the appearance of biological systems (number 2 above) which in turn can be the basis for the creation of artifacts (number 1 above). Such mechanism can be a good metaphor for explaining two important cases: neural networks and genome. In the former, the role of initial positions is played by synaptic connections and in the latter, the position of the bases in the DNA have the role of initial positions (ibid).

Now recall that there were two ways of achieving purposefully the goal of

resetting the system of the billiard balls on a frictionless table, the goal that makes the system information-driven: resetting the system ourselves and designing a device to fulfill the task. The latter shows that artifacts[7] can also be information-driven systems (recall Bohm's example of the radio wave/radio interaction).

Let us summarize the fundamental characteristics of a system depicted in Fig. 3.1, which also benefits from a resetting system. The following properties specify information-driven interactions versus force-field driven interactions.

1. There exists a specific *pattern* of velocity distribution at the input layer. This specific pattern makes a *specific change* at the output layer.
2. The system has a *complex interaction mechanism*, which leads to the irreversibility and unidirectionality of it. Force-field driven interactions can also be complex. Thus, mere complexity does not characterize an interaction to be information-driven.
3. To achieve a certain goal by every run, that is, to obtain purposefully (not just by chance) the same result every time the system is operated, the system is attributed a *purpose*. In force-field driven interactions, no purpose can be identified.
4. There is a *one-to-one correspondence* between the input and output layers. In other words, there is a univocal relationship between the distribution of velocities in the input layer and the velocity of out-flying balls in the output layer. This correspondence is guaranteed by the role that 'purpose' plays in such interactions. Such a purpose in the input layer has a meaning for the output layer, i.e., with such a purpose, the correspondent change will be elicited in the output layer.
5. The input and output layers are *decoupled energywise*. There may be many input constellations totally equivalent energywise, yet triggering different outgoing distributions. This shows that information-driven interactions are dependent on the initial conditions very little, while in force-field driven interactions the end effect of the system always depends on the initial conditions.

Having all this in mind, information-driven interactions can be described as what follows: In an *open* system comprising pattern A and system B, pattern A has a "purpose" where its presence triggers a change in system B so that such a change would not happen if pattern A were not present, or would happen just by chance. In such an interaction, energy must be provided locally. If the correspondence between the sender and the recipient has already been established, that is, if every time pattern A is present, the same change happens in system B in a repeatable manner, we say the purpose of pattern A has a "meaning" for system B. This requires the interaction mechanism to contain some memory device. This memory device, which guaranties the purpose of the sender to have the same meaning for the recipient in every run, is called *common code*. Changing the common code will result in the purpose of the sender to have no meaning or another meaning for the recipient.

What is information itself according to this view? "Information is the agent that embodies the above-described correspondence: It is what links the particular features of the pattern in a source system or sender A with the specific changes caused in the structure of the recipient B" (ibid). The above-described features of an information-driven interaction can reliably be illustrated in Figure 3.2.

Notice that the notions such as 'purpose' and 'meaning' used in pragmatic

[7] Note that when we speak of artifacts in this paper, we are speaking of artifacts which can in a way fulfill the conditions of being information-driven systems.

information are *perspective notions;* "Perspective notions are terms which– beyond the well-known context-dependence of word meanings in general – require an *explicit* statement of the context" (Gernert, 2006).

Consider the term 'categorization.' Knowing the meaning of the term *per se* does not suffice to fulfill the task of categorization. The rules or criteria according to which the task is supposed to be done should have already been mentioned explicitly. In order to categorize things, one should already be aware of the purpose of the task. Things can be categorized based on many different properties they have such as shape, size, color, etc. Terms like 'purpose' and 'meaning' used in information-driven interactions are also perspective notions. They depend on the involved sender and recipient in the interaction. The presence of a pattern, as the sender, has meaning just for the correspondent recipient in a specific context.

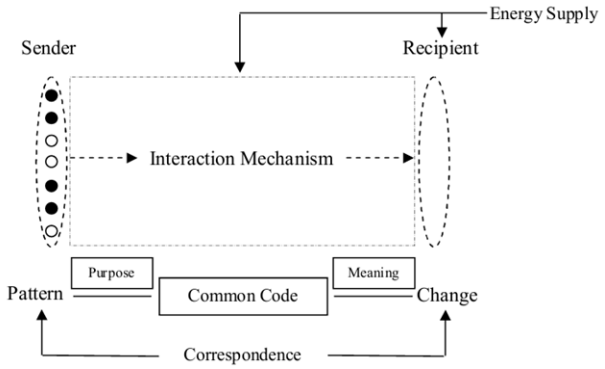

Figure 3.2. Elements of an information-driven interaction and the way such elements are connected to each other. See text for more details.

Two expressive examples will show the major differences between information-driven and force-field driven interactions. Consider a moon of a planet orbiting around it (Fig. 3.3). Given the initial conditions at time t_o together with Newton's law of universal gravitation, according to which the force of gravitational interaction f is a function of positions and masses of the mutually interacting bodies, one can know of the position of the moon at any later time t. Thus, the specifications of such an interaction can be summarized as the following: 1. for each given initial condition of position and velocity at the initial time t_o, there exists a well-defined orbit for the motion of the moon. The position and velocity of the moon at any later time is totally dependent on the initial conditions; and 2. the central body and the moon are coupled energywise. There is mutual energy give-and-take between the gravitational field of the planet and the moon spinning around it. Roughly, such a system consisting of the two interacting bodies can be considered a classical closed reversible system. In such a case, no 'purpose' can be identified.

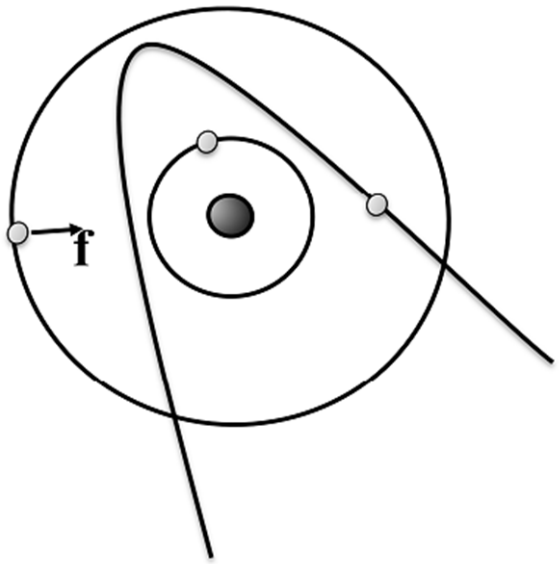

Figure 3.3. Three different orbits for a moon of a planet in orbit around it.

Consider now the motion of a butterfly in orbit around a lit candle (Fig. 3.4). Again, there exists a well-defined path for the motion of the butterfly, this time through a very complex interaction mechanism. The butterfly's motions of the wings determine the path. In this case, contrary to the case of the interaction between the planet and the moon, the energy needed for the movement of the wings comes from the relatively unformed energy provided by butterfly's metabolism,

not from the electromagnetic energy emitted by the candle. However, the pattern of the electromagnetic waves emitted by candle plays its role as a kind of *pilot wave* resulting in the regulation of the force of the wings of the butterfly. This is the pattern of the light emitted by the candle, not its energy, which is considered a controlling factor. The purpose in this case does not lie in the lit candle as the original pattern, but in the mechanism of the perception in the butterfly itself. However, if one still insists on the role of the candle as the sender, it can be said that in this case, both purpose and meaning lie at the recipient's side. In other words, "purpose is not given by the symbols in the input [...], rather it is given by the physiological and neural mechanisms that are seeking out certain input patterns [...]. This is a prototype of the interactions that involve *information extraction*: it is a fundamental aspect of the interaction of any organism with the environment" (Roederer, 2005). According to Roederer, the most fundamental purpose of any measurement process in physics is information extraction (ibid).

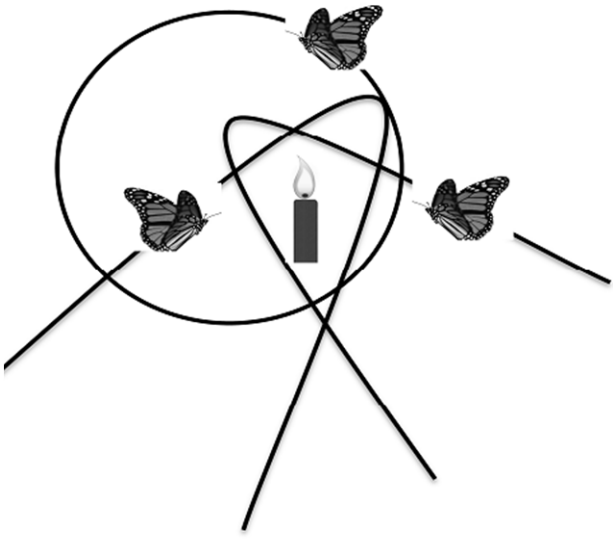

Figure 3.4. A butterfly in orbit around a lit candle

Another important difference between the latter and the case of planet/moon system is that the configuration of the butterfly's orbits around the candle depends very little on the injection point. Knowing the initial conditions at the starting point of the butterfly's motion at time t_o would not help in knowing its position and velocity at any later time.

What are the implications of all this concerning the relation between the key elements of active information (or quantum potential) and information-driven interactions (or pragmatic information)? It seems that at macroscopic level they are the same. Let us have a closer look at Bohm's examples at macroscopic level: an auto-piloted ship/radar waves and radio waves/radio are two tokens of information-driven interactions in artifacts. They will not happen in nature or would just happen by chance. In the latter case, they would not count as information-processing systems at all. We call such systems 'derived information processing systems' as they must be purposefully designed to fulfill a certain goal by 'original information processing systems', that is, natural living systems such as human beings. Indeed, it is not hard to examine that the conditions of the occurrence of information-driven interactions (and now active information) are *only* fulfilled in the realms of natural living and unnatural non-living systems. The Bohm's example of DNA/proteins interaction falls under the former case.

Interactions happening in nature *irrespective* and *independent* of biological systems count as force-field driven interactions as we mentioned in the moon/planet example. As information-driven interactions are *fundamentally* different from force-field driven interactions, the extension of Bohm's examples to the whole universe would be an ill generalization. But what about the extension of Bohm's examples to quantum domain? This is an important question. For as already mentioned, from interactions in the ordinary life (such as radio waves/radio), Bohm shifts to the quantum world projecting the notion of quantum potential and then extends the

notion to the whole universe. Bohm's notion of active information in quantum domain is dealt with in the next section by means of explaining double-slit experiment.

4. Bohm's Interpretation of Double-Slit Experiment

We already saw that Bohm defends a version of holism which embraces the non-separation of mind and matter, the observer from the observed, and the subject from the object (Bohm, 1990), using the notion of implicate order. To reach the goal of this paper, that is, to show Bohm's ill induction with regard to the notion of active information and to modify his thesis through a new holistic theory of mind, we still need to know Bohm's ideas on some other key notions such as wave-particle duality and non-locality. This task will be fulfilled via Bohm's account of double-slit experiment. In such experiment, a weak beam of electrons is shined to a plate with two parallel slits, leading to the interference pattern on the screen behind the plate.

According to Bohm, in front of the slits there is a quantum potential whose form, not energy, guides the electron through a predetermined trajectory. Such a feature makes the interaction non-local as we defined it earlier. After arriving many electrons at the screen behind the slits, a fringe-like pattern will appear.

In the double-slit experiment as depicted by Bohm, it is again seen that all conditions of pragmatic information are fulfilled. However, there are differences from, say, radio waves/radio interaction. The first difference is that quantum potential affects the particle non-locally. The second difference is that the interaction is non-mechanical meaning that the interaction between quantum potential and particle does not involve any matter and/or energy transfer. Both of these differences have to do with the difference between the nature of fields in quantum mechanics and classical mechanics. However, as far as the notion of pragmatic (active) information is concerned, such differences do not taint the whole argument.

According to Bohm, quantum potential is the same as mind, the idea whose extension leads to the superquantum potentials and their interaction with matter as seen in the whole universe as stated above.

Suppose that Bohm's description of the double-slit experiment is true. Why do we witness such correspondence between the quantum potential and the particle? It seems that the way *we* choose and conduct each setup changes the form of the corresponding quantum potential. Each setup corresponds to a certain quantum potential which in turn corresponds to certain trajectories for the correspondent particle leading to a different fringe-like pattern.

If the quantum potential in the laboratory shows mind-like properties, it is because of the presence of an original information-driven system (we humans and our minds) that has intentionally and purposefully configured the setup to fulfill a certain task. Otherwise, such a system would not happen or just happen by chance. In the latter case the system does not count as an information-driven. Compare a purposefully designed double-slit experiment in the laboratory with what may happen somewhere in the universe by chance. It is not hard to see that the former fulfills all conditions of pragmatic information while the interactions in the latter are fully force-field driven.

To have given the reader a clearer idea, compare two scenarios: the first is that you are reading a book where you see the term "Jesus Christ". Reading such words in the book gives you some information and has *meaning* for you. The second scenario is when *by chance* the combination of the smoke coming out of the exhaust of an aircraft with wind makes a pattern like 'Jesus Christ'. Do you consider any meaning for such a pattern?

There is no information processed concerning the meaning of such a shape. What are the differences?

In the first scenario there is a purposeful author who is aware of the correspondence of the pattern 'Jesus Christ' with your mental patterns. In other words, the pattern "Jesus Christ" has the purpose of eliciting its correspondent neural correlates in our mind. The intentionality of the pattern 'Jesus Christ' represents the author's intentionality and this is why it is meaningful and informational for us.

However, in the second scenario, we don't get any meaning or information out of the pattern as far as we know that it is done purely by chance. There may be people who get surprised by seeing such a pattern in the sky because for them the pattern has a meaning. This is because they might consider the pattern a sign from God (God's intentionality). There could be no meaning without the intentionality of the sender.

There are fundamental differences between a double-slit experiment in the laboratory and a similar event happening by chance somewhere in the universe. In the former the setup has intentionally been ordered to establish a correspondence between an input pattern (electrons, the two slits, quantum potential, etc.) and the fringe-like pattern on the screen behind the plate (change). The energy of system is provided from outside and the system is *open*. Any purposeful change in the input pattern will have meaning for the output pattern resulting in a corresponding change in the fringes. In the case of the event happening by chance, however, no purpose and information are included. There are just physical processes at work, not informational.

5. Conclusion

Information and information-processing are exclusive attributes of living systems and artifacts. The former systems are called original information-driven systems. They are the product of the course of evolution in which "[i]nformation, information-processing, purpose and meaning, structure and function, are thus tied together in one package: the process of information-based interaction" (Roederer, 2005).

Artifacts are the products of intentional original living systems in order to fulfill a certain task. Without such original systems they would not happen or just happen by chance. They represent the information that living systems purposefully put in them.

Other than the above mentioned systems, interactions in the world are force-field driven, not involving any purpose and meaning which are the key requirements of the informational interactions. This makes any extension from living and artificial systems to the natural abiotic world be an ill generalization. So, Bohm's generalization of the quantum potential is not valid. In other words, contrary to Bohm, mind is not part of the more subtle quantum potential, but any quantum potential represents the mind without which there would be no information and information processing in the world.

Revising Bohm's theory of mind and matter this way, the idea will come closer to the Copenhagen interpretation of quantum mechanics according to which observer and the setup provider play a crucial role in any experiment. Therefore, the modified version of Bohmian mechanics will find another commonality with Copenhagen school, that is, an agreement on the *empirical reality*. This adds to other commonalities between Bohmian philosophy and Copenhagen school, that is, holism and non-locality.

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