Chapter 10

Can quantum analogies help us to understand the process of thought?

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A number of researchers today make an appeal to quantum physics when trying to develop a satisfactory account of the mind, an appeal still felt to be controversial by many. Often these "quantum approaches" try to explain some well-known features of conscious experience (or mental processes more generally), thus using quantum physics to enrich the explanatory framework or *explanans* used in consciousness studies and cognitive science. This paper considers the less studied question of whether quantum physical intuitions could help us to draw attention to new or neglected aspects of the mind in introspection, and in this way change our view about what needs explanation in the first place. Although *prima facie* implausible, it is suggested that this could happen, for example, if there were *analogies* between quantum processes and mental processes (e.g. the process of thinking). The naïve idea is that such analogies would help us to see mental processes and conscious experience in a new way. It has indeed been proposed long ago that such analogies exist, and this paper first focuses at some length on Bohm's (1951) formulation of them. It then briefly considers these analogies in relation to Smolensky's (1988) analogies between cognitive science and physics, and Pylkkö's (1998) aconceptual view of the mind. Finally, Bohm's early analogies will be briefly considered in relation to the later analogies between quantum processes and the mind he went on to propose in his later work.[1]

1. Introduction

There are by now many approaches that seek to explain conscious experience, and mental processes more generally, in terms of a conceptual framework involving ideas from quantum and relativity physics (see e.g. Van Loocke (Ed.) 1999 and Vitiello 2001, and the references therein). In this paper I will explore another, less studied possibility, namely that quantum physics might not only

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help us to explain commonly acknowledged features of the mind, but also to draw attention to neglected but important aspects of our inner experience. In other words, I am interested in the question of whether the consideration of quantum physics can change our view of what there is to be explained about the mind in the first place (the *explanandum*), over and above the more obvious role it might play as affecting the *explanans* or the conceptual framework we are using when trying to explain some well-known features of conscious experience and mental processes (cf. Van Gulick 1995).

Insofar as it is a quantum physical framework as the *explanans* that helps us to see mind/consciousness as the *explanandum* in a new way, we could say that "*explanandum* is *explanans*-laden". Robert Van Gulick (1995) does not consider this possibility in his interesting paper "What would count as explaining consciousness?", although he makes otherwise a very useful attempt to "divide and conquer" the problem of consciousness. But if we want to acknowledge at the outset any possible bias in our attempts to explain conscious experience and mental processes, then we ought to consider not only how our *explanans* deals with the *explanandum*, but also the more difficult issue of whether the *explanans* we always *already* have affects the way we perceive and define the *explanandum* in the first place.

In consciousness studies, introspection plays a central role as a method. But when studying conscious experience in introspection, how much is what we "see" affected by the scientific theory, and more generally, the world-view or paradigm we happen to hold? To what extent is introspection theory- or paradigm-laden?

To unpack the idea of "paradigm-ladeness of introspection", the first point to note is that in the philosophy of science it is a household fact that "observation is theory-laden", that what we observe in general and also in our scientific experiments is affected by the theory we are using, and other assumptions, and our (more or less unconsciously held) *Weltanschaung* or paradigm (see e.g. Hanson 1958; Kuhn 1962/1970; and Feyerabend 1975/1993; see also Suppe (Ed.) 1977). A nice summary of the Feyerabend-Kuhn view of theory-ladeness is given by Suppe (1977: 689):

> [Shapere] finds that the Feyerabend-Kuhn view makes the following chain of inferences:
>
> i. Observation, if it is to be relevant, must be interpreted.
> ii. That in terms of which interpretation is made is always theory.
> iii. The theory that interprets is the theory to be tested.
> iv. The theory to be tested is "the whole of science" (or a branch thereof).

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v. This whole forms a unity ("paradigm" or "high-level background theory").
vi. This unified whole not only serves as a basis of interpretation, but also determines ("defines") what counts as an observation, problem, method, solution, and so forth.

For the purposes of this paper the question is whether it makes a difference to consciousness studies (and introspection in particular) whether "the whole of science" includes quantum physics. In other words, can the radically different "whole of science" we get as a result of quantum physics affect the way we interpret our observations in introspection? Can it affect it so that we can obtain in some ways a more complete and accurate explanation of conscious experience and mental processes?

Note that the Feyerabend-Kuhn approach raises the issues of *relativism* and *circularity* in a powerful way. If the theory we are allegedly testing is also the one we use to interpret the results, and the one which defines what counts as observation, problem, method and solution, how objective, neutral and impartial can such testing be judged to be? There is a risk of a deep circularity that arises if we take seriously the idea that observation – including introspection – is theory- and paradigm-laden. In this paper, however, I will not try tackle the difficulties raised by this circularity and relativism. For the sake of the argument, I will assume that there is a sense in which a given theory or paradigm can give us a more complete and more accurate description and explanation of a given phenomenon or domain. And thus, I assume that it is at least in principle possible that, for example, a scientific world-view that takes into account the results of new quantum and relativity physics could help us to describe and explain the mind in a better way. Let us now proceed to explore in more detail how this might be possible.

It seems fairly obvious that people who are familiar with quantum physics develop a whole new set of intuitions or a new "paradigm" about, for example, what it can mean for a phenomenon to be physical, or about general principles that prevail in phenomena. The possibility to be explored here then is that when studying conscious experience in introspection these people might well make use of these new intuitions and see new aspects of the mind, or give importance to aspects that others in a sense see but tend to neglect.

If introspection is theory- or paradigm-laden, then people who hold the classical, mechanistic worldview as the only relevant truth in this context might well tend to see and emphasize only the classical and mechanistic aspects of conscious experience and mental processes, while people equipped with clas-

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sical *as well as* quantum intuitions might see broader aspects. What are such "classical and mechanistic" aspects? The sorts of thing I have in mind are the dominance of separable objects in experience, causal relations between them, the idea that (more or less) Euclidian/Newtonian space-time is the only arena where conscious experience takes place. In the domain of thought and language, some cognitive scientists emphasize that thinking is essentially mechanical symbol manipulation. Presumably they find such characterization introspectively accurate.

I do not claim that when we ordinarily and pre-theoretically introspect we would automatically find only such mechanistic features. The idea is more that much of contemporary cognitive science and philosophy of mind and cognitive neuroscience etc. involves strongly mechanistic assumptions ("paradigm") that help to draw attention to the mechanistic aspects of the mind, while making it more difficult to see other aspects. Someone once said: "when you have a hammer in your hand, everything in the world looks like a nail". Analogously, to an introspectionist equipped with the mechanistic conceptual tools of modern cognitive science and philosophy of mind, conscious experience and mental processes may well look more mechanistic than to someone with a different, less mechanistic paradigm. This does not, of course, mean that the mind has no mechanistic aspects. But it should make us more open to the possibility that the mind has also other kinds of aspects that might be better seen with a different theory.

The above, if correct, suggests an interesting way in which "quantum approaches" to consciousness and mental processes can be relevant. For they might draw attention to important aspects of mind that tend to be neglected (or simply "not seen") by the more mechanistic prevalent approaches to the mind. The above suggestion may, of course, sound *prima facie* very implausible. How on earth could quantum physics which deals with atomic phenomena help us to more accurately introspect conscious experience and mental processes, which appear to be completely different phenomena at a different, higher, perhaps neurobiological level of organization? One way in which this could happen is if there were *analogies* between quantum phenomena and mental phenomena.[2] Suppose, for the sake of the argument, that quantum phenomena and some features of our inner experiences resembled each other in some important respects. For example, let us assume that the way conscious thought typically "proceeds", or changes its state from moment to moment, would resemble the way a quantum system typically moves. Then suppose that someone familiar with quantum processes would begin to systematically consider the nature of inner experience and thought processes. The seeing of the

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resemblances between the two domains might well constitute a non-trivial, exciting discovery.

Now, it so happens that many physicists have in fact proposed that there are strong resemblances between quantum processes and our inner experiences and thought processes. Such analogies were proposed to exist early on by the "founding fathers" of quantum theory, for example by Niels Bohr (1934). In contemporary research similar analogies still play an important role. Consider, for example, Globus' (2003) interesting suggestion that Vitiello's dual mode quantum brain dynamics resembles Heidegger's dynamical *der Ereignis* whose modes are Being and time. In this paper we will focus upon a fairly detailed early discussion of analogies between quantum processes and thought presented by David Bohm (1951). Interestingly in view of the questions we started off with, Bohm's analogies seem to draw attention to certain aspects of the mind that, although at least potentially fundamental and important when noticed and considered, nevertheless tend to be neglected in many contemporary academic studies of the mind.

In this paper my aim is thus, via considering Bohm's analogies, to explore whether "quantum intuitions" can help us to understand conscious experience and mental processes in a new and better way – better in the sense that quantum intuitions would draw attention to and help to explain certain important but neglected characteristics of the mind. In order to realize that aim I will first describe and discuss at some length Bohm's analogies between quantum processes and thought processes; I will then consider these in relation to Smolensky's (1988) analogies between physics and cognitive science; I next interpret Bohm's analogies in terms of Pylkkö's (1998) aconceptual view of the mind; and in concluding reflections I briefly consider some of Bohm's later interpretations of quantum theory and the way he used them to develop new analogies to understand the mind.

2. Analogies between quantum processes and thought processes

As mentioned above, already the "founding fathers" of quantum theory, in particular Niels Bohr, drew attention to the possible relevance of quantum physics to our understanding of the mind (see e.g. Bohr 1934). A particularly clear early statement about certain close resemblances between quantum processes and thought processes, influenced by Bohr's ideas, can also be found in the physicist-philosopher David Bohm's (1951) text-book *Quantum theory*. That book, written when Bohm was still an advocate of the so called "orthodox" or

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"Copenhagen" interpretation of quantum theory, puts a strong emphasis on making clear the *physical meaning* of quantum theory, as opposed to focusing on the mathematical formalism, which tends to be the case in many textbooks. When writing this 646-page book Bohm thus certainly had the more general physical and philosophical significance of quantum physics strongly in his mind (see especially Chapter 8, "An attempt to build a physical picture of the quantum nature of matter", pp. 144–172). This put him into a good position to consider "wide ranges of experience in which occur phenomena possessing striking resemblances to quantum phenomena". Bohm's basic claim in this regard was that there is a *close analogy between quantum processes and our inner experiences and thought processes*. After discussing such analogies he also provided some speculations of the underlying reasons for the existence of the analogies (pp. 168–172). Let us now consider Bohm's discussion in some detail. I have included fairly long quotations from Bohm and added explanatory comments in order to make the paper more accessible to those without a strong background in quantum physics. Also, I have let Bohm speak on the physics issues whenever this has seemed reasonable. A closer examination of Bohm's (1951) analogies is also useful from the point of view of understanding the historical roots of the idea that quantum physics might play an important role in the study of the mind.

2.1 An uncertainty principle for the process of thought

Bohm starts off by considering the uncertainty principle of quantum theory and certain aspects of our thought processes:

> If a person tries to observe what he is thinking about at the very moment that he is reflecting on a particular subject, it is generally agreed that he introduces unpredictable and uncontrollable changes in the way his thoughts proceed thereafter. Why this happens is not definitely known at present … If we compare (1) the instantaneous state of a thought with the position of a particle and (2) the general direction of change of that thought with the particle's momentum, we have a strong analogy. (1951: 169)

In classical, Newtonian physics one can, in principle, measure momentum and position of a particle accurately at the same time – a special case of that is when we look at a stationary object where momentum equals zero and the position is where we see and measure it to be located. At the quantum level of accuracy it is not possible to measure position and momentum accurately simultaneously, not beyond the limits set by the uncertainty principle. Bohm

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implies that in this respect thought is more quantum-like than classical-like. Given that the uncertainty principle is one of the most characteristic features of quantum physics (and underlies Bohr's principle of "complementarity", see e.g. Plotnitsky 1994 and 2002), it is of course at least *prima facie* interesting if a kind of uncertainty principle (and thus complementarity) also applies to aspects of our thought process.

Bohm continues:

> . . . however, . . . a person can always describe approximately what he is thinking about without introducing significant disturbances in his train of thought. But as he tries to make the description precise, he discovers that either the subject of his thoughts or their trend or sometimes both become very different from what they were before he tried to observe them. Thus, the actions involved in making any single aspect of the thought process definite appear to introduce unpredictable and uncontrollable changes in other equally significant aspects. (Bohm 1951: 169)

This, again, is reminiscent of quantum physics. It is possible to make "unsharp measurements" where one obtains an approximate idea of the position of a particle, without making the momentum completely unknown. But should one want to measure the position accurately, the momentum becomes undefined. Thus, even if we were able to make "unsharp measurements" of both the direction and content of our thought process at a given instant, this would still be analogous to measurements in quantum physics.

2.2 Holistic features of thought and quantum processes

Bohm further develops the above analogy by suggesting that the "significance of thought processes" appears to have *indivisibility* of a sort:

> . . . if a person attempts to apply to his thinking more and more precisely defined elements, he eventually reaches a stage where further analysis cannot even be given a meaning. Part of the significance of each element of a thought process appears, therefore, to originate in its indivisible and incompletely controllable connections with other elements. (1951: 169)

In a footnote, he adds:

> Similarly, part of the connotation of a word depends on the words it is associated with, and in a way that is not, in practice, completely predictable or controllable (especially in speech). In fact, the analysis of language, *as actually used*, into distinct elements with precisely defined relations between them is probably impossible.

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Bohm is here concerned with the nature of meaning. We may customarily think that elements of our thought and language, such as sentences or words, carry their meanings autonomously. Just as classical physics assumed that the physical world consists of some basic elements (particles and fields), whose "intrinsic nature" is not affected by the relationships they enter, so we might assume that thought and language can be analyzed to some basic elements which have determinate and well-defined meanings, independently of the relations that such elements have to other such basic elements or the surrounding context. The idea of "elementary propositions" and "names" in Wittgenstein's *Tractatus* can perhaps be seen as an attempt to conceive language in such a way. Wittgenstein writes (4.221 in *Tractatus*, quoted in Jones 1975: 204): "It is obvious that the analysis of propositions must bring us to elementary propositions which consist of names in immediate combination". Jones further describes Wittgensteins's view as follows: "… unless a sentence can be analyzed into a series of simple symbols ("primitive names"), each of which refers to a simple object that can be "elucidated" by primitive propositions, the sentence is meaningless" (1975: 204).

As is well known, the later Wittgenstein gives up such an atomistic view of meaning and emphasizes, for example, that when in search of a meaning of a term we ought to consider how the term is *used*. It is also obvious that Bohm did not think that the structure of thought and language is atomistic. Instead, he emphasized the holistic nature of meaning. Elements of our thought process and language do not have their meanings completely autonomously, but instead the meanings originate in the connections with other elements. And, Bohm suggests, these connections are both indivisible and incompletely controllable. For him this implies that it is not possible to analyze language beyond a certain stage and expect to find elements with well-defined significance.

Quine has also emphasized the holistic nature of language. He holds that we cannot define concepts and words individually, for language is a holistic system. Quine has, following Duhem, famously analyzed the implications of this holism for the empirical verification of propositions:

> … our statements about the external world face the tribunal of sense experience not individually but only as a corporate body (1961/1951: 41)

> The idea of defining a symbol in use was … an advance over the impossible term-by-term empiricism of Locke and Hume. The statement, rather than the term, came with Bentham to be recognized as the unit accountable to an empiricist critique. But what I am now urging is that even in taking the statement

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> as unit we have drawn our grid too finely. The unit of empirical significance is the whole of science. (1961/1951:42)

> Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system. (1961/1951:43)

These brief quotations provide some broader context for Bohm's ideas about indivisibly of meaning. Interestingly, Bohm's remarks were published at the very same year, 1951, when Quine published his famous article "Two dogmas of empiricism", from which the above quotations are taken. Of course, Bohm is not specifically concerned with propositional thought or truth conditions, but more with meaning as we encounter it with actual thought processes and actual language use. Bohm's way of looking at meaning and thought as psychological phenomena seems more similar to, for example, *Gestalt* psychology, (see e.g. Sundqvist 2003:177–181) than to analytical philosophy of language which latter is more concerned with logical and semantic properties of language. It is an interesting question whether the holism of thought and language when seen as an actual psychological phenomenon is connected with the holism of the semantic properties of propositions (which some see as mind-independent). This question, however, will not be pursued here. Instead, let us go on to consider in what way Bohm thinks that there is an analogy between the holistic features of thought/language and quantum processes:

> Similarly, some of the characteristic properties of a quantum system (for example, wave or particle nature) depend on indivisible and incompletely controllable quantum connections with surrounding objects. Thus, thought processes and quantum systems are analogous in that they cannot be analyzed too much in terms of distinct elements, because the "intrinsic" nature of each element is not a property existing separately from and independently of other elements but is, instead, a property that arises partially from its relation with other elements. In both cases, an analysis into distinct elements is correct only if it is so approximate that no significant alteration of the various indivisibly connected parts would result from it. (1951:169)

To get a better idea of the quantum physical side of the analogy, it is useful to consider another description of the indivisible quantum connections that Bohm gives. At the quantum level of accuracy, he says,

> [t]he quanta connecting object and environment constitute irreducible links that belong, at all times, as much to one part as to the other. Since the behaviour of each part depends as much on these quanta as on its "own" properties, it is clear that no part of the system can be thought of as separate.

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> If, in a classical experiment, we discovered the presence of irreducible "links" between objects, we should then postulate a third object, the link, and thus re-establish the old type of description [analysis into parts], this time in terms of *three* parts to the system. In quantum theory, however, these quanta do not constitute separate objects, but are only a way of talking about indivisible transitions of the objects already in existence. (1951: 166)

Consider, for example a situation in which a hydrogen atom in the ground state absorbs a quantum of energy from an electromagnetic field: "[d]uring the process of transition, both systems are coupled because they are exchanging an indivisible quantum of energy belonging as much to the electron as to the electromagnetic field" (1951: 166–167). More generally, because strictly speaking all physical "parts" that interact with each other are connected by such indivisible quanta to other "parts", quantum theory implies a fundamentally holistic view of the physical universe. Bohm concludes that

> [t]he entire universe must, on a very accurate level, be regarded as a single indivisible unit in which separate parts appear as idealizations permissible only on a classical level of accuracy of description. This means that the view of the world as being analogous to a huge machine, the predominant view from the sixteenth to nineteenth centuries, is now shown to be only approximately correct. The underlying structure of matter, however, is not mechanical. (1951: 167)

Bohm thus suggests that thought processes and quantum systems have in common a certain *ontological holism*, which means that they cannot be analyzed too much in terms of distinct elements. This is so, he suggests, because an analysis beyond a certain point changes the "intrinsic" nature of the element in question. Elements can have certain characteristic properties (e.g. individual words have meaning; an individual electron exhibits either a wave or a particle nature), but they have such properties partly in virtue of the relations they have with other elements. Change those relations, and you may profoundly change the characteristic properties. For example, an electron that just exhibited a wave-like property may suddenly exhibit a particle-like property, if it is made to interact with an apparatus that measures its position. Analogously, in the spirit of Quine's "meaning holism", a statement that previously seemed false may suddenly seem true if we make drastic enough adjustments elsewhere in the theoretical system it belongs to.

Bohm implies that the context-dependence of properties is no anomaly in a quantum universe. On the contrary, the context-dependence of properties seems to be a very fundamental feature of our physical universe. Although the

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context-dependence we find with e.g. meanings of words or statements is not necessarily the same type of context-dependence that we with the properties of quantum systems, I would say that the similarities between thought/language and quantum systems in this respect are at least *prima facie* interesting and worth further exploration (see also Maxim Stamenov's discussion of language and Bohm's "rheomode" this volume).

2.3 The classical limit of quantum theory and the logical aspect of thought processes

Bohm next points out yet another analogy, namely that there is also a similarity between the thought process and the classical limit of the quantum theory. Before discussing this analogy, let us briefly consider the physics side of the issue.

When we say that the quantum theory has a classical limit, we acknowledge that although at the fundamental quantum level movement seems discontinuous, there is a domain of physical phenomena where Newton's laws of motion that are continuous and deterministic provide an approximately correct description. Similarly, although quantum theory emphasizes the indivisible unity of the world, it seems that in our everyday experience we encounter a world that can, for all practical purposes, be analyzed into distinct elements. But how to reconcile the classical and quantum "worlds" – after all it seems that the world in which we live has *both* aspects. This question is connected with the *correspondence principle* that Bohr developed, described by Bohm as follows:

> [t]his principle states that the laws of quantum physics must be so chosen that in the classical limit, where many quanta are involved, the quantum laws lead to the classical equations as an average. The problem of satisfying the correspondence principle is by no means trivial. In fact, the requirement of satisfying the correspondence principle, combined with indivisibility, the wave-particle duality, and incomplete determinism . . . define[s] the quantum theory in an almost unique manner. (1951: 31)

The discontinuous, indeterminate quantum level and the continuous, determinate classical level are reconciled by noting that

> . . . first, the discontinuities are too small to be seen on a classical level and, second, that so many quantum processes take place in any classical process that the deviation of the actual results from the statistical average is negligible. (1951: 142)

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Yet another quotation illustrates how to reconcile the unpredictability of an individual quantum with the causal laws on a macroscopic scale involving many such quanta:

> As for the appearance of apparently exact causal laws on a macroscopic scale, when only the probability of each elementary quantum transfer is determined, we merely note that, where many quanta are involved, the probability becomes *almost* a certainty (but not quite). This is very similar to the exact prediction, by insurance statistics, of the *mean* lifetime of a person within a large group, even though an *exact* prediction of the lifetime of a single individual in the group is not possible. (1951:30)

Having now a better idea of what is meant by the classical limit of the quantum theory, let us move on to explore what Bohm means when he says that there is "…a similarity between the thought process and the classical limit". His basic idea is that "[t]he logical process corresponds to the most general type of thought process as the classical limit corresponds to the most general quantum process" (1951:169–170). This implies that the general structure of thought is analogous to the general structure of physical reality. In physical reality, as seen via the quantum theory, there is the level of general quantum processes with characteristic properties (indivisibility, wave-particle duality, uncontrollability, unpredictability etc.). Also, there is the classical limit where analysis into distinct elements is possible, as well as the mathematical description of the movement and interaction of these elements in terms of the causal laws of classical physics. Bohm suggests that the *relation* between the logical process to the most general type of thought process is analogous to the *relation* between the classical limit and the most general quantum process. How does this analogy work?

> In the logical process, we deal with classifications. These classifications are conceived as being completely separate but related by the rules of logic, which may be regarded as the analogue of the causal laws of classical physics. In any thought process, the component ideas are not separate but flow steadily and indivisibly. An attempt to analyze them into separate parts destroys or changes their meanings. Yet there are certain types of concepts, among which are those involving the classification of objects, in which we can, without producing any essential changes, neglect the indivisible and incompletely controllable connection with other ideas. Instead, the connection can be regarded as causal and following the rules of logic. (1951:170)

Bohm implies that there is a general type of thought process in which wholeness prevails. The component ideas are not separately existing elements with

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well-defined meanings. These ideas do not necessarily transform according to the rules of logic, but instead they "flow steadily and indivisibly". This general thought is a process, but not necessarily a process having an order and necessity characteristic of logical thought.

However, just as the physical world has a classically describable domain, so the process of thought includes the domain of logical thought process. In this "classical limit of thought" the indivisibility and uncontrollability between ideas that typically prevail in the general thought process have such a small effect that they can be *neglected* for all practical purposes. This makes it possible for relatively autonomous elements, for example concepts that classify objects, to arise. And it also makes possible for such elements to have causal relationships with each other, for example those causal relationships required for an actual thinking process to proceed according to the rules of logic. In this way the "classical limit of thought", or the emergence of separate concepts and causal connections between them, makes logical thinking process possible.

Of course, the classical limit is fundamentally important for both the physical world *as we know it* and for the very thought process that tries to have knowledge about the physical world. Bohm describes the role of the classical limit of both thought and quantum theory as follows:

> Logically definable concepts play the same fundamental role in abstract and precise thinking as do separable objects and phenomena in our customary description of the world. Without the development of logical thinking, we would have no clear way to express the results of our thinking, and no way to check its validity. Thus, just as life as we know it would be impossible if quantum theory did not have its present classical limit, thought as we know it would be impossible unless we could express its results in logical terms.
>
> (1951: 170)

It is important to note that Bohm does not deny the importance of the "classical limit of thought", any more than he would deny the importance of the classical limit of quantum theory. On the contrary, he emphasizes that logical thinking is fundamental for the enterprise of science, and for thought in general. But his approach implies that it would be a mistake to assume that logical thinking is the most general essence of the thought process, just as it would be a mistake to assume that classical physics reflects the essential nature of the physical world. He writes:

> Yet, the basic thinking process probably cannot be described as logical. For instance, many people have noted that a new idea often comes suddenly, after a long and unsuccessful search and without any apparent direct cause. We

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> suggest that if the intermediate indivisible nonlogical steps occurring in an actual thought process are ignored, and if we restrict ourselves to a logical terminology, then the production of new ideas presents a strong analogy to a quantum jump. In a similar way, the actual concept of a quantum jump seems necessary in our procedure of describing a quantum system that is actually an indivisible whole in terms of words and concepts implying that it can be analyzed into distinct parts. (1951:170)

Bohm thus implies that the basic thinking process is non-logical. Logical thinking then emerges out of such a process in certain conditions, analogously to the way causal physical processes emerge out of the general quantum process at the classical limit. Interestingly, he suggests above that the production of new ideas involves the more quantum-like thought process that essentially involves indivisible, non-logical steps. Galileo Galilei famously said that the path of discovery is different from the path of proof. Bohm gives a new expression to this old idea when he implies above that the discovery of new ideas may require a quantum-like, general thinking process, while their justification has to take place in the "classical limit of thought" and make use of the logical thinking process.

Notice also that Bohm's above quote implies that there is yet another feature which quantum processes and the general thought process have in common: it is difficult to talk about both of them when using the logical thinking process which employs well-defined concepts. Bohm emphasizes that the notion of "quantum jump" is an example of a notion that we have to use in quantum physics when we try to talk about something indivisible in terms of words and concepts implying that it can be analyzed into distinct parts.

The new proposal that comes out of Bohm's analogies is the idea that our thought process has a "quantum-like" aspect, and even more strongly, that the *basic*, most *general* type of thinking process is quantum-like. This basic thinking process is characteristic of quantum-like complementarity, in the sense that making one aspect of the process definite inevitably changes other equally significant aspects. It is also characteristic of quantum-like wholeness, in the sense that the characteristic properties (e.g. meaning) of elements of thought depend on indivisible connections with other elements. Further, the suggestion is that the way the general thought process changes from moment to moment is also quantum-like, for it involves indivisible non-logical steps. The component ideas in such a process are not separate but flow steadily and indivisibly. Finally, the basic thinking process seems to have a "classical limit", namely thinking in terms of well-defined concepts, including the logical thinking process.

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Suppose, for the sake of the argument, that Bohm is correct when suggesting that the most general type of thinking process is quantum-like. We can then ask *why* this is so. One possibility is that it is a mere co-incidence. But it seems also natural to ask whether the quantum-like features of the basic thinking process could be an indication that the physical aspect of the basic thinking process literally involves quantum processes. When considering this question, Bohm refers to Bohr's (1934) suggestion that "... thought involves such small amounts of energy that quantum-theoretical limitations play an essential role in determining its character". Bohm further writes:

> There is no question that observations show the presence of an enormous amount of mechanism in the brain, and that much of this mechanism must probably be regarded as operating on a classically describable level. In fact, nerve connections found thus far suggest combinations of telephone exchanges and calculating machines of a complexity that has probably never been dreamed of before. (1951: 170–171)

Bohm thus acknowledges that a great deal of neural mechanisms is classically describable. But unlike contemporary cognitive neuroscientists who tend to assume that *all* neural mechanisms relevant to understanding cognition and conscious are classically describable, Bohm, following Bohr, was looking for a role for quantum processes in neural functioning:

> In addition to such classically describable mechanism that seems to act like a general system of communications, Bohr's suggestion involves the idea that certain key points controlling this mechanism (which are, in turn, affected by the actions of this mechanism) are so sensitive and delicately balanced that they must be described in an essentially quantum-mechanical way. (We might, for example, imagine that such key points exist at certain types of nerve junctions.) It cannot be stated too strongly that we are now on exceedingly speculative grounds. (1951: 171)

There are by now a number of different and much more detailed suggestions about where such "quantum sites" could be located in the brain (see e.g. Loocke (Ed.) 2001; Penrose 1994; Hameroff & Penrose 1996). What is important in Bohm's suggestion, however, is the general scheme. We are to envision two different kind of levels of physical activity in the brain, one of them classically describable, while the other one needs to described in a quantum theoretical way. This leads naturally to the assumption that the physical correlate of the logical thinking process is at the classically describable level of the brain, while the basic thinking process is at the quantum-theoretically describable level. Bohm also implies above that there is a two-way traffic between these

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two levels. A typical state of mind then includes both levels. It is also interesting to speculate that different types of states of mind could correspond to physiological states that differ with respect to the relative contribution made by "classical" and "quantum" neural processes. In some altered states of consciousness, for example, the classically describable neural processes might make a relatively small contribution to the content of experience, and as a result the holistic features typical of the quantum-theoretically describable neural processes would dominate.

Although Bohm emphasizes that these ideas are speculative, he does not think that they are therefore not worth pursuing further:

> Bohr's hypothesis is not, however, in disagreement with anything that is now known. And the remarkable point-by-point analogy between the thought processes and quantum processes would suggest that a hypothesis relating these two may well turn out to be fruitful. If such a hypothesis could ever be verified, it would explain in a natural way a great many features of our thinking.
> (1951: 171)

This illustrates what is at stake here. The idea is that our thinking process has many features that are difficult to explain. Of course, in the end we use the thinking process to explain the thinking process, so there is a circularity to begin with. But the sort of thinking process that we commonly use in science is the logical thinking process. Thus we are using the logical thinking process when trying to describe the most general thinking process. The logical thinking process works best when we use it to describe the "classical limit" – whether the classical physical domain, or the logical aspect of the thinking process. It is more difficult to describe quantum processes with the help of the logical thinking process – just as it is difficult to describe the general thinking process with it. But we have already a fair amount of experience of dealing with quantum processes, both mathematically and conceptually. Now, if the general thinking process is analogous to quantum processes, we could make use of our experience with the quantum domain when trying to explain the general thinking process. For example, we saw above how Bohm characterized the production of new ideas as being analogous to a quantum jump.

Bohm also considers the alternative that the general thinking process does not literally involve quantum processes:

> Even if this hypothesis should be wrong, and even if we could describe the brain's functions in terms of classical theory alone, the analogy between thought and quantum processes would still have important consequences: we would have what amounts to a classical system that provides a good analogy to

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> quantum theory. At the least, this would be very instructive. It might, for example, give us a means for describing effects like those of the quantum theory in terms of hidden variables. (It would not, however, prove that such hidden variables exist). (1951: 171)

Suppose that the general thought process is classically describable, and suppose that it is closely analogous to quantum processes. This opens up the possibility that quantum processes might, after all be classically describable; or at least it might be possible to describe them more fully than what standard quantum theory allows.

Another reason why Bohm thinks the analogy could be helpful, even in the absence of experimental data, is that it can give us a better feeling for quantum theory:

> For instance, suppose that we ask for a detailed description of how an electron is moving in a hydrogen atom when it is in a definite energy level. We can say that this is analogous to asking for a detailed description of what we are thinking about while we are reflecting on some definite subject. As soon as we begin to give this detailed description, we are no longer thinking about the subject in question, but are instead thinking about giving a detailed description. In a similar way, when the electron is moving with a definable trajectory, it simply can no longer be an electron that has a definite energy. (1951: 171)

Here one is using the analogy between quantum processes and thought process as a tool that helps to understand quantum theory. The kind of example Bohm gives above (about asking someone to describe what they think) is, in principle, easily understandable to all of us. If such familiar features of the thought process are analogous to quantum processes, this makes it easier for us to understand quantum processes. Given that quantum theory is notoriously difficult to understand, this underlines the usefulness of the analogy.

The upshot is that not only might quantum physics help us to understand the mind (as was suggested at the outset of this paper), but we might also use our understanding of thought processes as a tool to understand quantum processes! Thus, if quantum processes are relevantly analogous to thought processes, our understanding and familiarity of quantum processes can help to understand thought processes and vice versa. We are intimately familiar with our thought processes, although our acquaintance of their more subtle features can be highly tacit. Insofar as our thought processes have quantum-like aspects and we are familiar with these aspects, this can make some aspects of the *prima facie* strange quantum processes easier to understand. At the same time we encounter in quantum processes certain important principles (e.g. com-

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plementarity and wholeness) in very elementary and prototypical form. This makes it easier to abstract such principles and conceptualize them theoretically. Such theoretical principles can then be useful when trying to understand the quantum-like features of thought processes which are typically much more complex than elementary quantum processes. So although we may all be in some tacit way familiar with the quantum-like features of our thought processes, quantum theory can help us to recognize them and to describe them explicitly and theoretically.

Let us next consider the possibility that it is the case that the thought process *literally* involves quantum processes. This would open up yet another possible way for us to understand quantum processes:

> If it should be true that the thought processes depend critically on quantum-mechanical elements in the brain, then we could say that the thought processes provide the same kind of direct experience of the effects of quantum theory that muscular forces provide for classical theory. Thus, for example, the pre-Galilean concepts of force, obtained from immediate experience with muscular forces, were correct, in general. … We suggest that, similarly, the behavior of our thought process may perhaps reflect in an indirect way some of the quantum-mechanical aspects of the matter of which we are composed.
> (1951: 171–172)

This is an extremely interesting possibility. Remember that quantum effects are often thought to lie in a domain that is not at all accessible to us in ordinary experience. As a consequence, it is assumed that we should not be surprised that it is difficult for us to understand the quantum domain – after all, we have no experience of it prior to the scientific experiments that probe the domain. Bohm's above suggestion turns this familiar scheme upside down. For it might be the case that all of us are, after all, directly familiar with some quantum-mechanical aspects of matter, in virtue of being familiar with an important part of ourselves, namely the behaviour of our thought processes! Quantum effects, which were supposed to lie in some mysterious domain that only physicists have access to, may lie much closer to home than we thought. If we are, psychologically, partly quantum-theoretical beings, then by being aware of ourselves we might, in principle, be aware of quantum effects. In philosophy, we sometimes speak about "maker's knowledge", implying that someone who has made or constructed something has a special kind of knowledge about it which others may lack. In a similar vein we might speak about "be-er's knowledge" – the knowledge someone has in virtue of *being* a certain kind of system (so I do not here mean to imply that a barley drink has knowledge!).[3] Thought is a part of our being, and if thought processes reflect in an indirect way some of

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the quantum-mechanical aspects of the matter of which we are composed, we might, in principle have or be able to obtain "be-er's knowledge" of quantum aspects of matter.

Something like the idea of "be-er's knowledge" figures prominently in philosophical discussions about conscious experience. For example, Thomas Nagel (1974) famously argued that there is something it is like to be a bat; and that we cannot find out what it is like just be studying the bat's brain and behaviour. Only the "be-er" has direct experience of what it is like to be that system. In the case of the bat, it cannot communicate what it is like to be a bat in terms of concepts and logical thought to us. For Nagel the example of the bat underlines the subjective nature of consciousness. But even in the case of humans, it is not at all clear that we can communicate in any exhaustive sense in terms of concepts and logical arguments *what it is like to be* a human being. The problem is not merely that a description of the objective, physiological correlates of conscious experience does not necessarily capture what it is like to be that system. There may be a part of our being that simply is so holistic, unpredictable etc. that it is difficult to capture in terms of conceptual and logical thought.

We can interpret Bohm's above suggestion as saying that part of what it is like to be a thinking human being is to have direct experience of the effects of quantum theory. Of course, this is not to say that we all thereby have conceptually organized knowledge about the effects of quantum theory. Bohm argues that the general thinking process is holistic and uncontrollable by its nature, and thus difficult to describe in terms of our usual scientific language that is organized in terms of separate concepts and logical arguments. Insofar as we are all familiar with the quantum-like general thinking process, our familiarity or understanding may be "pre-conceptual" and "pre-logical" (cf. Pylkkö 1998). We can, of course, try to improve this "pre-conceptual" familiarity and try to develop new concepts and principles to capture the holistic and uncontrollable aspects of our thought processes. We will return to the issue of pre-conceptual experience later when considering the relation of Bohm's suggestion to post-phenomenology.

In summary, we have seen above that Bohm's analogies emphasize that the process of thought can be easily disturbed by introspective observation; that there is a limit in the extent to which significance of elements of thoughts can be analyzed; and that besides this general incontrollable, unpredictable and indivisible character, the mind also has a domain of separable concepts which can be connected causally, e.g. following the rules of logic. Bohm further suggested that the analogies would get a natural explanation if it turned out that

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the neural processes that realize thought processes in the brain would involve quantum processes.

I hope that the above lengthy presentation and discussion of Bohm's analogies has also given the reader an example of what can be meant by the idea that was raised in the introduction of this paper, namely that a "paradigm" can draw attention to new aspects of the mind in introspection. The fairly new idea contained in Bohm's analogies is the suggestion that our general thinking process is quantum-like, whether or not this is a mere co-incidence or the result of underlying quantum-physical correlates of thought. Although the above discussion is admittedly sketchy and speculative, one should realize that the scientific and philosophical implications of this line of thought are potentially very significant. There is a possibility of a revolution in our understanding of the mind that might parallel the significance of the quantum revolution in physics.

Let us now move on to compare Bohm's description with some other descriptions of inner experience and thought in contemporary philosophy of mind and cognitive science. I think it is interesting to do such brief comparisons in order to further evaluate the suggestion we made at the outset of this paper, namely that quantum intuitions might help us to see new or neglected features of the mind in introspection. To fully explore this suggestion would require a much more thorough study than is provided here, and the following ought to be thus taken as a very preliminary first attempt, which hopefully motivates a further consideration of this issue in other contexts.[4]

3. Cognitive science and quantum analogies

Traditional cognitive science was for a long time dominated by the so-called symbolic paradigm in which cognition was assumed to be mechanical symbol manipulation according to a set of rules or a "program". This resembles the domain of separable concepts in Bohm's description. Within cognitive science the symbolic paradigm was subjected to heavy criticisms, and as is well known, connectionist modelling was offered as an alternative way to describe cognition.[5] Yet the advocates of the symbolic paradigm, most notably Fodor and Pylyshyn (1988), argued that connectionism lacks certain important features of the symbolic paradigm. As an interesting attempt to reconcile the tension between connectionism and the symbolic paradigm, Smolensky (1988) proposed that the relation between them is analogous to the relation between quantum theory and classical mechanics. The idea is that a theory typically works in its proper domain, and that often a more general theory that applies in a fairly

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broad domain can give rise to another theory that applies in a narrower domain as a limiting case. According to Smolensky's proposal we ought to view connectionism as the more general theory, describing a subsymbolic level of the mind, while the symbolic paradigm can be seen as a special, limiting case, describing those aspects of the mind where rule following and symbol manipulation seem to take place.

Smolensky's analogy is in some ways similar to Bohm's above analogy. Both recognise that the mind has a "classical limit", as it were, a domain we can describe in terms of separable symbols, related in definite ways. And both agree that another, more general description is required to give a fuller description of the mind, and that the relation between the two descriptions is analogous to the relation between quantum theory and classical physics.

However, there are also differences between the analogies provided by Bohm and Smolensky. A particularly important difference is that Bohm's analogy suggests that cognition is more radically holistic, unpredictable and uncontrollable than what Smolensky's approach implies. The reason for this is that Bohm proposes that there is a close analogy between quantum processes and processes of thought more directly, whereas Smolensky makes a more methodological analogy between the relation of quantum and classical physics on the one hand, and of connectionism and the symbolic paradigm on the other.

Smolensky is proposing that important, general features of cognition can be captured by connectionist networks. Connectionist networks have some holistic properties, and the mathematical formalism of connectionism has similarities to the mathematical formalism of the quantum theory (see Perus 1995). However, it has been emphasized that traditional connectionist models do not go beyond the symbolic paradigm when it comes to mechanical computability. Pylkkö, for example, suggests that "…most probably, all existing artificial neural networks and artificial models of chaotic systems are Turing-computable and, therefore, *mechanical*, in the obvious sense of the word" (1998: 94). Thus the suggestion that cognition can be described in terms of connectionist models is not as different from the ideas of the symbolic paradigm as the proponents of connectionism, including Smolensky, seem to assume. In contrast, Bohm's claim that our inner experiences and thought processes are closely analogous to quantum processes constitutes a much more radical suggestion than connectionism. For it is implied that mental processes have radically uncontrollable, indeterministic and semantically holistic features, which cannot be adequately modelled by either the symbolic or the connectionist paradigms, in so far as these are embedded in the framework of classical physics which implies controllability, predictability and separabil-

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ity. Bohm's use of quantum analogies thus led him already in 1951 to propose an outline of a much more radical view of the mind than what cognitive science, inspired by computational models of the symbolic and connectionist type came up with during the 1980s.

Now, the fact that Bohm's view of the mind is more radically holistic than that of either symbolic or connectionist cognitive science does not, of course, mean that Bohm's view is correct. But how do we find out which view is correct? Perhaps we ought to listen what the introspectionists and the phenomenologists have to say about the mind, then combine this with relevant computational models and empirical research in cognitive neuroscience and then make our judgement. But this brings us back to our starting point. If introspection, including the introspection used in phenomenology, is theory- or paradigm- or intuition-laden, then there is a clear danger that introspection or phenomenology will, in a self-serving way, produce evidence to the view of the mind that the practitioner of introspection *already* had – consciously or unconsciously – before the introspection. For example, Pylkkö (1998: 80) writes:

> . . . classical phenomenology (say, as it is developed in Husserl's *Ideen* 1913/1976) is not free of the intellectualist bias of the scientific-technological attitude because classical phenomenology clearly sides with the conscious subject and its allegedly autonomous rationality and quite openly acknowledges the rational subject's right to dominate the rest of the mind.

In particular, introspectionists and phenomenologists not familiar with quantum physics are unlikely to suggest that the kind of unpredictability, uncontrollability and indivisibility they may encounter in introspection has the radical, non-classical character of quantum processes, simply because they may lack the conceptual tools to recognize such features, and to evaluate their difference from more classical-type features. Of course, this does not prove that mind has quantum-like aspects. Perhaps an introspectionist equipped with a "quantum paradigm", such as Bohm, will be likewise biased in their introspection so that they attribute quantum-like behaviour to aspects of mind that do not really call for it. But as I said in the beginning of the paper, I am assuming that it is at least in principle possible that, say, a quantum paradigm will provide a more adequate characterization of the mind than a mechanistic paradigm. In other words I am assuming that human inner experience and mental processes have certain features that are not completely determined by the "paradigm", and which the different paradigms manage to deal with in varying degree of success. What the paradigm does is then to focus our attention in a particular

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way – so that we "see" certain aspects of what is "there" (in some sense "given" in experience). So I am suggesting that it is better when doing phenomenology to have a "classical" *plus* "quantum" paradigm, instead of just a "classical" one. That way one can "see" more of the conscious experience and thought processes – especially their unpredictable and holistic features, the sorts of features that are difficult to conceptualize. And the idea is that a yet richer and more inclusive paradigm can reveal yet further features. I do not claim that my above assumption is unproblematic, but I will not attempt to argue for it here.

One might also note here that the connection between physics and the nature of human experience is an interesting theme in the history of philosophy. Most notably, Kant assumed that human experience necessarily has to exhibit certain features of Newtonian physics, such as spatiality, temporality and causality (see Kant 1787/1991; Strawson 1966). With his analogies Bohm is drawing attention to the non-Newtonian features of human experience, and in this sense broadening the Kantian notion of what kinds of human experience are conceivable and possible. Kant was not wrong in claiming that human experience has Newtonian features, but he was perhaps wrong in his estimation of what are the limits within which human experience can vary. Today, armed with the resources of post-Newtonian physics we are in a position to see new analogies between physics and human experience, and consequently encouraged to articulate our view of the limits within which human experience can vary in a new, broader way.

4. Post-phenomenology and quantum analogies

Bohm is, of course, not alone in suggesting that human inner experience, especially conscious thought has unpredictable, uncontrollable, indivisible and non-logical features. In particular, the philosophical movement called "post-phenomenology" emphasizes such features. Indeed, the connection between post-phenomenological ideas and quantum physics has been emphasized by e.g. Plotnitsky (1994, 2002), Pylkkö (1998) and by Globus (1995, 2003), who latter also emphasizes the role of quantum brain dynamics developed by e.g. Jibu and Yasue, as well as Vitiello, which is a major focus of this volume. I have found Pylkkö's views particularly helpful when trying to make sense of the relevance of Bohm's (1951) analogies to cognitive science and the philosophy of mind.

Pylkkö developed a radical philosophical view that differs in some important ways from Bohm's philosophy of nature. In particular, Pylkkö advocates

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an *antirealist* view, in which one does not assume physical reality to exist in a well-defined way independently of human experience. What is primary for him is *aconceptual experience* in which there is no sharp division between concepts and objects. How do then concepts and objects emerge? Pylkkö's idea is that they arise simultaneously as aconceptual experience divides itself into two aspects, concepts and the corresponding objects. However, he does not want to give too strong an ontological status for either the objects or the concepts. In contrast, Bohm had a tendency to defend a realist viewpoint in his natural philosophy, although his realism got increasingly modified, weakened and problematized as he kept on developing the epistemic implications of his holistic and processual view of nature (see e.g. Bohm 1980: Ch. 3). Here is a more detailed characterization of aconceptual experience given by Pylkkö himself:

> Let us take immediate and unstructured primitive experience as our philosophical starting point. This unarticulated and prelogical experience which we call *aconceptual* is what mind and language primarily *is*. It is not yet organized by concepts. Because we associate subjectivity strongly with the conceptual organization of experience we say also that, in aconceptual experience, there is no such hierarchy and perspective which characterize the subject's presence. The experience is, so to speak, holistically everywhere, without center, or it has a center which is not yet fully organized. (1998: 13)

When viewed from the perspective of Pylkkö's post-phenomenology, Bohm's (1951) analogies clearly draw attention to some important aspects of the "aconceptual mind". For as we saw above, according to Bohm the general thinking process is non-logical, uncontrollable, unpredictable, and its semantic elements are indivisible in a sort of way that makes it difficult to analyze it in conceptual terms. It seems to me that this fits fairly well with the view of the mind a post-phenomenologist like Pylkkö advocates, as long as one bears in mind the difference between, say, Pylkkö and Bohm on the issue of realism. No doubt Pylkkö's view of the mind differs also in other important respects from that of Bohm, but I think it is fair to say that the use of quantum analogies helped Bohm to capture some important and neglected features of the mind, which are today described by the post-phenomenologist in a more sophisticated way.

5. Concluding reflections

The question underlying this paper was that if introspection is paradigm-laden and if quantum physics gives rise to a new paradigm, might then someone

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armed with this new paradigm see new features in introspection, and thus have new things to tell us about conscious experience and the mind more generally?

As an example, I considered some analogies which Bohm already 1951 proposed to hold between quantum processes and inner experiences, especially thought processes. These analogies draw attention to certain quantum-like features of the most general type of thought process, such as uncontrollability, unpredictability, semantic indivisibility, inseparability, non-logicality and non-conceptuality, while also doing justice to the more "classical" features of the thought process such as semantic separability, conceptuality, logicality and causality. The analogies acknowledge that these classical features are indispensable in many ways, but they also underline the fundamentality of the more quantum-like aspect, for example, for the production of new ideas.

We have seen that Bohm's analogies are in some important respects similar to Smolensky's analogy that tries to reconcile symbolic and connectionist paradigms in cognitive science, but we have also emphasized that Bohm's view of the mind, as a result of being guided by his quantum intuitions, is more radically holistic than that of Smolensky's hybrid cognitive science. We also pointed out that it is difficult to judge which view is correct. If introspection is indeed paradigm-laden, whose paradigm are we going to use when introspecting in order to decide which paradigm is correct? The possible paradigm-ladeness of introspection gives rise to a circularity that ought to make us careful in our judgements regarding the nature of human experience. However, my proposal is that it is worth further considering the idea that human inner experience, and the general type of thought process in particular, has some quantum-like features. This opens up the possibility of a less mechanical and in my view more accurate description of human experience than what cognitive science can currently offer. We also considered the view of mind implicit in Bohm's analogies in relation to Pylkkö's post-phenomenological view of the mind as aconceptual experience, and saw a fairly good fit between some aspects of these views.

What lessons can we draw from our brief study? I think the above discussion provides tentative evidence that quantum physical intuitions can in fact help to introspect human experience in a new, productive way. Introspection seems to be theory-laden, but this need not be seen merely as an epistemic limitation. It is clear that such theory-ladeness requires us to become much more cautious when making statements about the "nature of the mind". But it seems to be at least a reasonable possibility that new theories can help us to see the phenomena we are exploring in a new light. And a theory originally developed to deal with a particular domain may prove useful in a *prima facie* very different domain. I write *prima facie*, because there are currently a number of different

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hypotheses proposing that in one relevant way or the other, the physical correlates of mental processes literally involve quantum processes, which, if correct, would make it less of a puzzle if quantum physics turned out to be relevant to describing the mind. In other words, the two *prima facie* very different domains may turn out to be partly the *same* domain, as Bohm indeed speculated already in 1951.

I recognize that it sounds somewhat far-fetched to many researchers that the study of physics could help us to understand the mind. But note that such a possibility is implicit in the whole programme of philosophical atomism that underlies many of the successes of modern science. The traditional idea has been that physics studies the simple constituents of nature and the regularities in their behaviour. This understanding of the behaviour at the micro-level may then help to understand features of more complex, higher-level systems. It is important to note, however, that with quantum physics the whole scheme of philosophical atomism is challenged, and one is forced to consider some radically holistic basic principles. It is also those principles that Bohm is referring to when making the analogies between quantum processes and the mind. But surely, if the mind has such holistic features it has had them all along, so does it really take quantum physics to notice and theorize about them?

The mechanistic view of the mind that dominates contemporary cognitive science and philosophy of mind – which is basically still just a hypothesis about the mind – has got part of its legitimacy and plausibility from the successes of the mechanistic view in physics and biology. In a similar vein, a radically holistic basic physics raises the possibility of a holistic biology and a holistic psychology (cf. Gierer 2002). Bohm's analogies suggest that just as the physical world has two aspects – the general holistic "quantum world", and as a special case, the mechanistic "classical world", so the human mind has two analogous aspects, the holistic general thinking process, and the more mechanical, e.g. logical thinking process. Quantum physics can play an important role for psychology in suggesting a simple *prototype* of how a general holistic level and a special case of a mechanistic level can be reconciled. Thus, although the holistic aspects of the mind can no doubt be discovered without quantum physics (and indeed have been), I suggest that the quantum analogies can enrich both our introspective experience of the mind and the theories we construct in psychology.

Of course, Bohm's (1951) analogies are only a limited illustration of the way quantum physics can be useful when trying to understand the mind. For one thing, Bohm himself went on to interpret quantum physics in different ways, and not surprisingly tried to invent new analogies between these new

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interpretations of quantum physics and the mind. For example, Bohm and Hiley's "ontological interpretation" of quantum theory suggests that electrons are guided by a new type of field containing "active information" (Bohm & Hiley 1993). Bohm further suggested that the way such information acts is analogous to the way information acts in subjective human experience (see Bohm 1990; Pylkkänen 1992; Hiley & Pylkkänen 2001; Hiley 2004). His idea was that such active information could help us to understand what the mental and the physical sides of reality are and how they can affect each other, thus using the quantum theory to tackle both the general mind-body problem and the more specific problem of mental causation. In the context of his "implicate order" framework, Bohm (1980) likewise discussed the relation of mind and matter in a new way. The idea here is that mind and matter are analogous to non-locally connected quantum systems. They ought to be seen as *correlated projections* from a common multi-dimensional ground, rather than as separate substances in causal interaction. This is a radically new version of "neutral monism", which again makes use of the resources of quantum theory.

It is important to note that Bohm's analogies differ from each other in important ways, although they have in common that they all originate from quantum physics (cf. Guarini 2003). This means that it is not a trivial task to construct a unified view of mind and matter on the basis of his analogies between quantum physics and the mind. For example, the implicate order scheme underlines the discontinuity of movement and suggests that the basic mathematical algorithm needed to describe movement is an algebra rather than the differential calculus (Bohm 1980: Ch. 6). If we apply the implicate order scheme to describing cognition and conscious experience, then we give up the idea of cognition as a dynamically describable phenomenon as fundamental (insofar as dynamical modelling considers the differential calculus as fundamental). In contrast, Bohm and Hiley's ontological interpretation of quantum theory (which allows for the hypothesis of quantum particles moving continuously along trajectories) seems to fit much better with the spirit of dynamical systems theory.

My suggestion it that the different Bohmian schemes, when applied to cognition and consciousness, can be seen as different tools which each can provide a useful way of looking at some aspect of the mind (cf. Murphy 1998). The implicate order scheme, I suggest, ought to be seen as the more general and fundamental tool, but this need not exclude the use of the ontological interpretation scheme, as long as one remembers that the latter provides a more limited view. Whether or not these tools, and other similar tools developed by other researchers, help us to construct a more satisfactory theory of mind is

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currently an open question. But I hope that this brief study, which has focused on some of Bohm's very early ideas, has illustrated some ways in which the consideration of quantum physics when studying the mind can be fruitful and open up radically new possibilities.

Perhaps some ideas discussed in this paper can also be useful when evaluating the relevance of quantum brain dynamics to humanities. For example, it seems clear that Vitiello's (2001) focus on the "double" structure of the mind has been inspired by his consideration of dissipative quantum field theory. This, I think, constitutes yet another example of how quantum analogies can guide us in our search for a new and richer view of the mind. Notice also that Vitiello's approach builds upon a more sophisticated scheme than quantum mechanics, namely quantum field theory. This, when applied to biological systems, opens up the possibility of developing a more empirically accurate description of the physical aspect of the brain. At the same time, quantum field theory is often felt to be more difficult to understand than quantum mechanics, and as a consequence, it can be more difficult to understand the analogies one might draw between quantum field theory and mental processes. Hopefully our brief consideration of some more simple analogies between thought processes and quantum processes can be helpful when trying to understand the fascinating synthesis of quantum field theory, biology, neuroscience and (continental) philosophy of mind that is emerging from the work of Vitiello, Globus and others.

Notes

1. A part of this paper was written in October 2003 while I was a visiting scholar at the Department of Philosophy, Stanford University, based in the Metaphysics Research Lab at the Center for the Study of Language and Information. I would like to thank the director of the lab, Dr. Edward N. Zalta, for providing me a stimulating environment in which to work. I also thank the various people who have commented on this paper. In particular, my colleague at the University of Skövde, Dr. Stefan Berglund made some critical comments that prompted me to considerably develop an earlier draft. Of course, he is not to blame for any mistakes or unclarities that may remain! I am also grateful to Gordon Globus and Per Hansell for their comments.

2. For an interesting paper discussing analogies between modern physics and cognitive psychology, see Shanon (1991). For a defense of the role of analogy in scientific reasoning, see Campbell (1957) and Hesse (1966, 1974); see also Pickering (1984) and Cushing (1990), all quoted in Guarini (2003).

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3. The physicist John Bell came up with the term "beer" in this sense when in search for an ontological counterpart to the term "observable" in quantum theory. Bell famously opted for the term "beable".

4. In a recent paper on introspection Anthony Marcel makes some points similar to this paper, and develops them in more detail. Consider, for example, the following: "*Attention can influence its object*. Attending to one's experience, introspecting, changes the content, nature and form of the experience. It is also widely accepted that the content, nature and form of the experience that constitutes the content of awareness depends on the way that we attend" (2003: 179). In this recent article Marcel further provides an interesting discussion of the way (a) attention can be directed to components or to a whole; (b) how one's stance toward the object of attention can vary between immersion and detachment; (c) how attention can create its object; (d) how awareness distorts its object; and (e) how our theories can mask our experience. I think the way Marcel's ideas stand out as radical ideas is an indication that the sorts of features of the mind that Bohm's analogies raise are not that commonly noticed and acknowledged in contemporary psychology. For example, Marcel (2003: 179) writes: "John Lambie and I (2002) have recently emphasized what we call the mode of attention, the manner in which one attends at any time – an aspect of attention stressed by William James (1890) but largely ignored by most current psychology".

5. In recent years dynamical modelling of cognition has become important and can thus be seen as a third approach alongside symbolicism and connectionism. For an interesting recent discussion of these approaches, see Eliasmith (2003).

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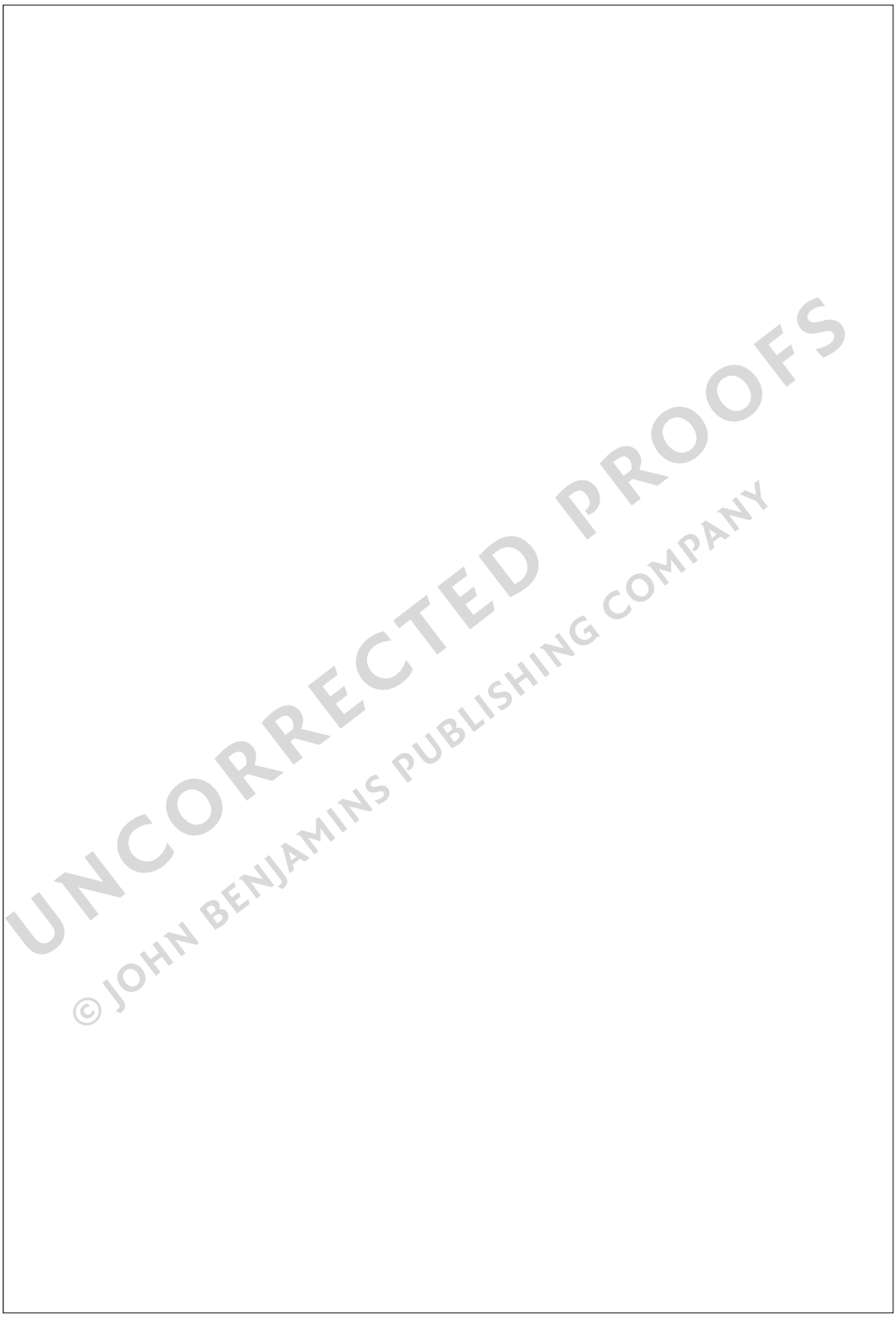

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