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Quine’s Holism and Quantum Holism

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1. Introduction

Quine’s holism and holism in quantum physics are usually considered to be two different issues which merely have the name “holism” in common. My aim, by contrast, is to build a bridge between these two sorts of holism. This paper is an argument for three theses:

1) The discussion on holism and other options in the interpretation of quantum physics is one paradigmatic example of Quine’s confirmation holism in the philosophy of physics. In particular, taking Quine’s holism into account puts the claim of experimental metaphysics in the interpretation of quantum physics into perspective.
2) Quine’s criterion for changes to our system of knowledge enables a rational evaluation of the options in the interpretation of quantum theory. In particular, this criterion supports the option for quantum holism.
3) The meaning of “holism” in Quine’s thesis about statements and the meaning of “holism” in what quantum theory says about physical systems exhibit a far-reaching analogy.

According to Quine’s seminal paper “Two Dogmas of Empiricism” (first published as Quine (1951)), four features are central to his holism: [52]

a) There is no separation between science and philosophy in the sense of metaphysics.
b) Experience confirms or disconfirms a scientific hypothesis only together with a cluster of background assumptions that finally encompass the whole of science.
c) We always have a number of options to adapt our system of knowledge to new experience. It is rational to endorse that option which implies the lest overall change to the system as a whole.
d) Only a cluster of statements and ultimately only the whole of science has meaning.

My argument for my first thesis is that a) and b) can be applied to the interpretation of quantum physics. I argue for my second thesis by claiming that c) supports the option for quantum holism. To make a case for my third thesis, I compare the characterization of science which b) and d) imply with the characterization of nature at the microphysical level that quantum theory implies according to the option for quantum holism.

To begin with, I briefly recall Quine’s confirmation holism (section 2). I shall accept Quine’s holism for the sake of the argument of this paper and not consider its pros and cons. I then explain how the results of the debate about Einstein’s objections to quantum theory illustrate the thesis that there is no separation between science and metaphysics (section 3). I sketch the major options for integrating the results of the relevant experiments into our system of knowledge. Evaluating the consequences of these options, I argue that the option for quantum holism implies the lest overall change to our system of knowledge as a whole (section 4). Finally, I develop a far-reaching analogy between Quine’s holism and quantum holism as regards the meaning of “holism” (section 5).

2. *Quine's confirmation holism*

Quine's alternative to traditional logical empiricism in "Two Dogmas of Empiricism" starts from the claim "that our statements [53] about the external world face the tribunal of sense experience not individually but only as a corporate body" (p. 41; the page numbers refer to the edition in Quine (1980)). This is *confirmation holism*: a statement cannot be confirmed in isolation, but only together with other statements that finally encompass the whole system of our knowledge. As far as physical theories are concerned, a similar point is already made by the French scientist and philosopher of science Pierre Duhem at the beginning of this century (part 2, chapter 6 in Duhem (1981)). Therefore, confirmation holism is also known as the *Duhem–Quine thesis*.

From "Two Dogmas" on, Quine suggests regarding our system of knowledge as a web. This web touches experience at its edges. Empirical statements such as "There are brick houses on Elm Street" are on the periphery of this web. Statements of logic are located in its centre. This web is not determined by experience: if a conflict with experience occurs, we have several options for adjusting the web to experience (pp. 42–45). Quine proposes a pragmatic attitude: it is rational to opt for those changes which imply the slightest perturbation within our system of knowledge as a whole in order to accommodate this system to new experience (pp. 43–44, 46).

No statement is immune against revision. Even statements which are regarded as logical laws can be abrogated as a result of new experience. The demarcation between what counts as logic and what counts as empirical science can hence be subject to change in case of new experience. Quine's favourite example is that it can turn out to be reasonable to abrogate the law of the excluded middle subsequent to experiments in quantum physics (p. 43). Quine's position thus implies not only that experience cannot confirm any statement in isolation, but also that there is no separation between science and metaphysics. He says: "Ontological questions, under this view, are on a par with questions of natural science." (p. 45)

[54] *3. Physics and metaphysics in the interpretation of quantum theory*

The discussion on holism in the interpretation of quantum physics is one example from the philosophy of physics which illustrates Quine's thesis that there is no separation between science and metaphysics. This discussion goes back to a paper by Einstein, Podolsky and Rosen (1935) (EPR). Einstein and his collaborators consider two elementary physical systems which are emitted together from a source and which are in one-dimensional motion. According to quantum theory, as long as there is no measurement, the states of these systems are in a superposition with each other as far as position and momentum are concerned. That is to say: neither system has a definite numerical value of position or momentum. But the two systems taken together have a definite numerical value of relative distance and total momentum. The value of the relative distance increases in time; the value of the total momentum is zero. These properties of the whole of the two systems taken together determine correlations between the possible values of position or momentum that each system can acquire in measurement. Owing to these correlations, if a measurement of position or momentum of one of these systems is carried out, the outcome of a measurement of the respective observable of the other system can be predicted with certainty. These measurements can be separated by a space-like interval. (As to relativistic qualifications, see

Smith and Weingard (1987). Furthermore, I skip all the qualifications which relate to the fact that position and momentum have a continuous spectrum of values).

Bohm (1951), pp. 611–622, introduces a similar example with respect to spin. There are systems of spin 1/2 such as electrons and neutrons. In this case, the spin in any of the three orthogonal spatial directions can take only two definite numerical values. These values are called “spin up” and “spin down”. Bohm considers two systems of spin 1/2 which are emitted together from a source. After the emission, their interaction ends, because they fly apart in opposite directions. Nonetheless, however [55] far apart in space these two systems are removed, the spin state of the whole, i.e., the joint spin state of these two systems taken together, is a superposition of the first system having spin up and the second system having spin down with the first system having spin down and the second system having spin up in any direction. This state is known as the *singlet state*. If we measure the spin of one of these systems in an arbitrary direction, given the direction measured and the outcome of this measurement, the probabilities for the outcome of a spin measurement on the other system are changed (unless the spin is measured on both systems in orthogonal directions). As regards a spin measurement on the other system in the same direction, it is even possible to predict the outcome with certainty, i.e., either “spin up” or “spin down” has probability one.

The crucial point in these examples is that, according to quantum theory, neither of the two systems is in a state in which it has a definite numerical value of the local observables of position or momentum (EPR) or spin (Bohm). A *local observable* is an observable that relates only to one of the two systems. But the whole, which consists of these two systems, has a definite numerical value of the global observables relative distance and total momentum (EPR) or total spin (Bohm). These global observables determine correlations between the possible values of the respective local observables. A *global observable* is an observable that relates to the whole. The properties of a quantum system are commonly referred to as *observables*. In the Schroedinger representation, the *state* of a system at a given time determines the probability distributions of the values of those properties of the system at this time whose value can change during the existence of the system (such as position, momentum, or spin in any direction). These properties can therefore be considered as *state-dependent properties*. By contrast, properties such as mass and charge are state-independent; their value does not change during the existence of the system.

Following Schrödinger (1935), p. 555, cases such as the mentioned ones are known as *entanglement*. If there is entanglement, the states of two or more systems are entangled in such a way [56] that only the whole, i.e., these systems taken together, is in what is known as a *pure state*. Nonetheless, it is possible to give a description of each of these systems considered independently of the other system(s). One may regard this description as a sort of state description. In this case one has to work with the notion of a mixed state in the sense of what is known as an improper mixture (d’Espagnat (1971), chapter 6.3). However, this description ignores the correlations between the possible values of the local observables of these systems which can be acquired in measurement.

Consequently, *in the case of entanglement, the description which relates to each of the systems in question does not completely specify the local observables of this system*. Furthermore, this description does not specify the state of the whole, i.e., the state of these systems taken together. It is possible that two systems can be described in terms of the same mixed states as in the mentioned cases without being in the EPR state or in the singlet state. Hence, *in the case of entanglement, it is only the pure state of the whole which completely determines the local properties of the parts and their relations* (to the extent that these properties and relations are determined at all in quantum physics). That is the core of holism in quantum physics.

However, Einstein does not accept quantum holism. By means of the example which he introduces in the EPR paper, he intends to show that quantum theory is incomplete: in order to explain the correlations which are revealed in measurement, we have to assume that in fact each of the two systems has a definite numerical value of all the observables that can be measured on it ever since its emission from the source. The predictions of quantum theory are correct; but quantum theory is an incomplete description of physical reality at the level of microphysical systems.

In this argument, Einstein presupposes two principles which can be called "separability" and "local action". (The clearest statement of these principles is Einstein (1948), pp. 321–322). Starting from Einstein's work, Howard (1989) formulates separability as the claim that (1) spatially separated systems possess [57] their own, distinct physical state each and that (2) the joint state of two or more spatially separated systems is wholly determined by their separate states (pp. 225–227). Taking up Howard's work, I propose the following characterization of separability:

Principle of separability

> Physical systems have a state each in the sense that (1) this state completely determines the state-dependent, local properties of the system and (2) the joint state of two or more systems supervenes on the states which each of these systems has.

In this characterization of separability, I have left out the condition of spatial separation. There are cases of entanglement where there is no question of a spatial separation. For instance, the joint spin state of the two electrons of a helium atom in the groundstate is the singlet state too, and these electrons are not spatially separated. Furthermore, in quantum computation, one considers the entanglement of the states of many systems which are usually not localized in such a way that they are separated in space. It is reasonable to treat such cases as cases of quantum non-separability too. Quantum entanglement violates separability, as the above mentioned examples show. Even if we regard the description of each of the two systems in terms of a mixed state in the sense of an improper mixture as a state description, this state description does not completely specify the state-dependent, local properties of the system.

The second principle which Einstein presupposes is a locality requirement. I suggest speaking of the principle of local action. Local action imposes a restriction on the way in which the states of physical systems can change by interaction. It thereby presupposes separability: the systems in question have states each which completely determine their local properties. The idea is that interactions propagate contiguously from point to neighbouring point with a finite velocity. Having the discussion on whether or not quantum theory is compatible with special relativity in mind, I propose to characterize local action in relativistic terms:

[58] *Principle of local action*

> Every interaction (force) propagates contiguously with a finite velocity, i.e. – in relativistic terms – a velocity that is not higher than the velocity of light in vacuum.

In the discussion on holism in quantum physics, the conjunction of separability and local action is often referred to as locality without further qualification.

Separability and local action are metaphysical principles in the sense that they are a precise formulation of assumptions which are at the centre of our common sense view of nature. We take it for granted that physical systems have a state each that completely determines their local properties and that interactions propagate with some finite velocity. The answer to the question whether quantum theory is complete therefore seems to be a purely metaphysical matter. It depends on whether we lay stress upon separability and local action as metaphysical principles which are at the very foundation of empirical science or whether we base ourselves on quantum physics and claim that separability or local action are to be abrogated consequent upon new experimental evidence. The predictions of quantum theory and their empirical confirmation are not in dispute.

Einstein's argument for quantum theory being incomplete triggered a debate about hidden variables which are not taken into account in quantum theory. The most important result of this debate is the famous theorem of Bell (1964). Based on the principles of separability and local action, Bell's theorem sets an upper limit upon correlations between the measurement outcomes in cases of entangled states of two or more systems. Quantum theory, however, predicts higher correlations than those ones which Bell's theorem permits. Bell's theorem thereby proves, to put it in a nutshell, that in a case like the singlet state and the EPR state, the emission of the two systems from the source cannot be a common cause that accounts for the correlations between the measurement outcomes. (A precise formulation of the assumptions that are presupposed in Bell's theorem is achieved by Jarrett (1984)).

[59] Subsequent to Bell's theorem, a number of experiments have been carried out. All these experiments are known as *Bell experiments*. Most of them consist in correlation measurements of the polarization of two photons which are emitted together from a source and then fly apart in opposite directions. Although photons are not systems of spin 1/2, the polarization state of such pairs of photons is the singlet state. Correlations which violate Bell's theorem and confirm the predictions of quantum theory are even established by measurements on two such systems at a space-like distance. The first such experiment is Aspect, Dalibard and Roger (1982).

As a result of Bell's theorem and the Bell experiments, the apparently clear distinction between physics and metaphysics in the interpretation of quantum theory has become blurred. Physics – the predictions of quantum theory – challenges a metaphysics that bases itself on separability and local action as principles for the very possibility of empiriccal science. We cannot simply accept the predictions of quantum theory and claim when it comes to metaphysics that all physical systems nevertheless conform to separability and local action, taking quantum theory to be incomplete. Metaphysics – Einstein's realism – has been shown to have exactly computable, empirical consequences which can be put to the test in experiments.

To describe this situation, Shimony (1989), p. 27, uses the term "*experimental metaphysics*" (see also Jarrett (1989) and Redhead (1995), in particular lecture 3 and p. 87). This term has not been created by Shimony. To my knowledge, it has been introduced by Michele Besso (1948), a friend of Einstein in his Swiss years, in the context of Ferdinand Gonseth's philosophy; Gonseth's position is similar to Quine's, at least insofar as Gonseth (1948), pp. 123–124, also rejects a separation between mathematics, science and philosophy and considers every part of our knowledge to be revisable. (As to the analogy with Quine, see Gochet (1977), p. 121). But the term "experimental metaphysics" is not yet applied to the interpretation of quantum theory there.

This historical background puts the talk of experimental [60] metaphysics in the interpretation of quantum physics into perspective: it makes clear that speaking of experimental metaphysics does not at all imply that metaphysical issues are settled by experiment (Jones and Clifton (1993) raise such an objection). On the contrary, *speaking of experimental metaphysics emphasizes that the discussion on Einstein's misgivings about quantum theory can be comprehended along the lines of Quine's holism*: this discussion shows that there is no separation between physics and metaphysics in the interpretation of quantum theory. What the Bell experiments are taken to confirm or to disconfirm depends on which background assumptions we base ourselves. In an interview, Bell himself describes the experiment of Aspect in terms of Quine's confirmation holism:

> I think that it is very difficult to say that any one experiment tells you about any isolated concept. I think that it's a whole world view which is tested by an experiment, and if the experiment does not verify that world view, it is not so easy to identify just which part is suspect and has to be revised. Certainly the experiment says that Einstein's world view is not tenable. (Interview in Davies and Brown (1986), pp. 46–47)

According to the scholarly work of Howard (1990), Einstein did not know Quine's "Two Dogmas", but he knew Duhem's holism and endorsed it (see also Fine (1986), pp. 86–90). Unfortunately, Einstein did not live to see the publication of Bell's theorem and the options which we have consequent upon this theorem.

4. Holism and other options in view of Bell's theorem and the Bell experiments

Mathematical calculations and experimental evidence do not determine the interpretation of quantum theory. In accordance with Quine's confirmation holism, there is indeterminacy in the sense that we have several options for integrating the results of quantum physics into our system of knowledge. However, there is no indeterminacy in the sense that there are no rational criteria [61] for distinguishing some options as being more plausible than others. My thesis is: *The dovetailing between science and metaphysics in the interpretation of quantum theory enables a rational evaluation of the different options*. For lack of space, I can give only a rough sketch of what an argument for this thesis can look like in this paper. I do so by arguing that the option for quantum holism can be supported by Quine's criterion for changes to our system of knowledge according to which it is rational to opt for those changes which imply the slightest disturbance of our system of knowledge as a whole. This pragmatism is not a logical part of confirmation holism; but it is a plausible strategy to cope with the fact that, according to this holism, there always are several options for adapting a system of knowledge to new experience.

The option for quantum holism is tied to an ontological or realistic interpretation of quantum theory in the following sense: quantum theory refers to the states of physical systems, and it gives a complete description of these states. If we base ourselves on Quine's confirmation holism, suppositions such as separability are not a metaphysical sanctuary, but belong to our assumptions about the way the world is. They can hence be changed consequent upon experience. *My first claim is: It is more reasonable in Quine's sense to abrogate suppositions such as separability than to refuse to endorse ontological commitments of quantum theory at all on the basis of such suppositions.*

The Copenhagen interpretation of Bohr, Heisenberg among others as well as an instrumentalistic interpretation of quantum theory endorse a commitment to a classically describable world including experimental arrangements; but they resist an ontological interpretation of quantum theory. If statements that refer to quantum systems are countenanced at all, they are accepted only as descriptions of measurement outcomes (compare what Scheibe (1964), pp. 21–22, describes as an epistemic interpretation). The formalism of quantum theory is not regarded as referring to something in nature, but as an instrument to calculate probabilities for measurement outcomes. (Cushing (1997) claims that there is underdetermination in the sense of Quine between the Copenhagen interpretation and the interpretation [62] of Bohm and Hiley (1993) which proposes hidden variables).

From a Quinean point of view one can object that quantum theory thus interpreted does not fit into our system of knowledge. The Copenhagen interpretation and an instrumentalistic interpretation remove that sort of description of the microphysical level of nature that higher level theories presuppose. Taking the statements of the theory of the quantum level to require the reference to experimental arrangements which are set up by humans is incompatible with endorsing a commitment to higher level theories that intend to explain the evolution of life and human beings: these theories presuppose the quantum level; quantum events have been important in the evolution. This incompatibility shows up in physics itself when it comes to applying quantum theory to cosmology. Hence, although the Copenhagen interpretation and an instrumentalistic interpretation start from endorsing the ontological commitments of common sense including classical theories, these interpretations do not succeed in making quantum theory cohere with these theories.

It is of course possible to adopt an instrumentalistic attitude to science as a whole for philosophical reasons. One may even attribute such an attitude to Quine's "Two Dogmas" (see, in particular, pp. 44–45 in Quine (1980)), although Quine cannot be tied down to instrumentalism; he arguably is a naturalist in the first place. But in this case one regards the ontological commitments of the whole of science including the claim that there are common sense objects and experimental arrangements as a mere instrument to account for connections among sensory stimuli or the like. It is incompatible with this attitude to single out one physical theory and to adopt an instrumentalistic attitude only to this theory for physical reasons, as the Copenhagen interpretation does. This just is contrary to the simplification which the philosophical instrumentalist has in mind.

One can endorse an ontological or realistic interpretation of quantum theory without being committed to quantum holism: one can claim that quantum theory does not give a complete description of the states of microphysical systems. There are further, hidden variables which are not taken into account by quantum [63] theory as it stands. The options in terms of hidden variables rescue the principle of separability from the threat of quantum entanglement. But they require drastic changes to other central principles in our system of knowledge, notably the view of causality that is connoted with the principle of local action.

One can propose *a new kind of interaction* by means of which the two wings of a Bell experiment are connected (see e.g. Chang and Cartwright (1993), pp. 181–189). One may also group the theory of Bohm and Hiley (1993) with this option, if one regards the quantum potential, which Bohm proposes, as a new kind of interaction. Since the two measuring events in a Bell experiment can be separated by a space-like interval, this new kind of interaction has to propagate with a superluminal velocity. This option thereby violates the principle of local action. All the known kinds of interaction, by contrast, satisfy local action. The price for this option hence is that we have to admit a new kind of interaction which does not fit in with the known kinds of interaction.

Furthermore, it is even possible to retain both separability and local action. We can opt for a *common cause* of the correlations between the measurement outcomes in a Bell experiment. However, the violation of Bell's theorem implies that the preparation of the singlet state at the source in a Bell experiment cannot be a common cause which screens the one measurement outcome off from the other measurement outcome. If we opt for a common cause, we have to invoke a hidden variable in the common past of the two systems beyond the experimental arrangement. What is more, this hidden variable has to coordinate the behaviour of the two systems with the adjustment of the two parameters in such a way that the predictions of quantum theory are satisfied; for, in an experiment such as the one of Aspect, Dalibard and Roger (1982), the parameters are adjusted only after the two systems have been emitted from the source. Because of this point, Bell (1987), p. 154, objects that the option for a common cause amounts to conspiracy (see also Kronz (1990), pp. 424–431, and against this objection Shanks (1993)). Note that this conspiracy can include the decisions of experimenters [64], since we can imagine a Bell experiment in which not automatic switches, but experimenters arbitrarily adjust the parameters.

We can avoid being committed to such a conspiracy by assuming *backward causation*: if one maintains that events in the future light-cone such as measurements and the future choice of parameters that are to be measured contribute to determine a hidden state of the pair of photons at the source in a Bell experiment (Price (1996), chapter 9), one can explain these experiments without coming into conflict with separability or local action. Backward causation does not contradict local action, because it can be maintained that the effects of future events, like the effects of past events, propagate with a velocity that is not higher than the velocity of light. However, it would be preferable to have first firm evidence for backward causation independent of quantum theory and then examine whether the assumption of backward causation can be applied to quantum physics. What is more, both the option for a common cause and the option for backwards causation infringe upon a presupposition of experimental science: according to these options, the event of fixing the parameters which are to be measured on the system is connected with the state of the system that is prepared at the source of the experimental arrangement.

In sum, one can argue that all those options which assume hidden variables imply a greater disturbance of our system of knowledge as a whole than giving up separability and thus endorsing quantum holism. *My second claim therefore is: On the basis of Quine's criterion* *for changes to our system of knowledge, there is no reason for preferring hidden variables to renouncing separability*.

According to the option for quantum holism, it is an objective feature of nature that the states of quantum systems are entangled. Quantum theory gives a complete description of the states of quantum systems. Cases such as the EPR state and the singlet state are not at all rare. Whenever we consider a quantum whole which has two or more quantum systems as proper parts, quantum theory tells us that, apart from very exceptional cases, the states of these systems are entangled. This consideration applies [65] also to the whole of nature at the level of quantum systems. We can therefore say that all quantum systems taken together are a holistic system (see e.g. Scheibe (1991), p. 228).

Nonetheless, there are many different ways for spelling out the option for quantum holism. Although this option is committed to a holism that encompasses in the last resort all quantum systems, the most important difference in elaborating on this option concerns the extension of quantum holism: Is quantum holism limited to more or less the microphysical level of nature? Or is quantum holism universal in the sense that it extends to all physical systems including macroscopic systems such as measuring instruments, trees, and cats? I refer to the latter as the option for universal quantum holism and to the former as the option for limited quantum holism. *My third claim is: Quine's criterion for changes to our system of knowledge supports the option for limited quantum holism*.

From the point of view of Quine's holism, quantum theory, higher level theories (such as biological theories), and our common sense ontology have the same ontological status in the following sense: to the extent that these theories are confirmed by experience, they are all justified in claiming to describe physical systems as they exist independently of our knowledge of them. The task of the philosopher is to give an interpretation of our best scientific theories which brings them together in a description of the world which is as coherent as achievable, given the state of our knowledge.

This task brings the option for universal quantum holism into conflict with Quine's position. This option denies that state reductions occur in measurement. Instead of dissolving entanglement in such a way that each of the two systems in a Bell experiment acquires a definite numerical value of the local spin observable in question, all that measurement achieves is that the states of the measurement devices become entangled with the states of the measured systems. Consequently, it only appears to us observers that there is a macroscopic level of the world which is not touched by entanglement. There are different conceptions of how this appearance can be accounted for (see, for instance, [66] Albert and Loewer (1988) and Lockwood (1989), chapters 12 to 13, as well as Landsman (1995)).

It may be possible to build a coherent system of knowledge on the basis of the option for universal quantum holism. However, the point is: this option implies that we have to revise not only our view of the microphysical realm, but our conception of any physical system consequent upon quantum theory. Higher level theories, such as theories of chemistry, biology, physiology, including common sense describe things not as they are, but only as they appear to us, because these theories acknowledge nothing like entanglement in their domain. Instead of integrating the new experience in quantum physics into our system of knowledge, the option for universal quantum holism commits us to rejecting the ontological claims of our higher level scientific theories as well as common sense. From a Quinean point of view it is questionable whether such a disturbance of our whole system of knowledge is plausible in order to accommodate the holism of quantum physics.

By contrast, the option for limited quantum holism sets out to integrate quantum theory into our system of knowledge by making quantum theory compatible with the ontological commitments of higher level theories including common sense as far as macroscopic systems are concerned. For, according to this option, state reductions, which dissolve entanglement, occur in the transition to higher level systems such as those ones described by chemistry, biology, physiology as well as common sense. The problem for this option is that we do not have an overall convincing account of the dynamics of state reduction at our disposal. The most elaborate proposal goes back to Ghiradi, Rimini and Weber (1986).

In addition, the task for this option is to explain the correlations between the space-like separated outcomes in a Bell experiment without contradicting the principle of local action. The most influential strategy is to say the following: since the two systems do not have a separate spin state each, a measurement interaction with the one system directly changes the state of the whole. Qua change of the state of the whole, this local interaction [67] is relevant to the probabilities for the outcome of a measurement on the other system. But this change of the state of the whole is not a local change in the other system. (For proposals along these lines, see, for instance, Shimony (1993), pp. 151–154, as well as Healey (1989), pp. 129–136; see also Fleming (1996)). In this paper, there is no space to go into these suggestions; I can only mention these problems for the option for limited quantum holism.

5. Analogies in content between Quine's holism and quantum holism

So far I have argued that Quine's confirmation holism can be applied to the interpretation of quantum physics and that the option for quantum holism can be supported by Quine's criterion for changes to our system of knowledge according to which it is reasonable to adopt that option which implies the slightest disturbance of the system as a whole. However, Quine's confirmation holism is intended to be applicable to all fields of knowledge; in particular, there are other areas in the philosophy of physics apart from quantum theory where it might be appropriate to speak of experimental metaphysics. Furthermore, positions in any field of knowledge can claim to be supported by Quine's pragmatic criterion, independently of whether or not these positions are themselves a sort of holism. Consequently, the points made up to now are not sufficient to build a bridge between Quine's holism and quantum holism. Building such a bridge depends on whether significant parallels in the content or the meaning of "holism" can be established.

When going into this point, I shift the focus of attention from epistemology to ontology – in the sense that I shall be concerned with the way in which certain systems are organized, be it systems of knowledge, be it physical systems. The question whether there are parallels between Quine's holism and quantum holism as regards the meaning of "holism" can only be tackled on a fairly abstract level; that is to say, we have to abstract [68] from the fact that the systems in question are in the one case physical, whereas in the other case we consider systems of knowledge. If one refused to grant such an abstraction, one would have to claim *a priori* that cases in different areas which are known as holism cannot have more in common than the mere name "holism".

Quine's holism is not limited to confirmation. In "Two Dogmas" he espouses not only confirmation holism, but also semantic holism: a statement does not have meaning in isolation; like confirmation, meaning requires a cluster of statements which ultimately include a whole system of knowledge. Quine says in "Two Dogmas": "The unit of empirical significance is the whole of science." (p. 42) The connection between Quine's confirmation holism and his semantic holism is widely taken to be this one (but see Fodor and Lepore (1992), chapter 2): Quine endorses a verification theory of meaning – the meaning of a statement are its conditions of verification. Since, according to confirmation holism, a statement cannot be verified in isolation, it does not have meaning in isolation.

Properties such as meaning and confirmation can be regarded as characteristic of statements (or beliefs) in the following sense: nothing can be a statement without having meaning in some sense and without having a degree of confirmation in some sense. If something is a statement, it is reasonable to ask about its meaning and its confirmation. We can sharpen up this concept of properties that are characteristic of something by introducing the following notion: For every system of a certain qualitative kind, there is a family of non-disjunctive, qualitative properties which make something a system of the kind in question. Such a family of properties can include both non-relational and relational properties. Something is a system of the kind *S* if and only if it has all – or by far most of all – the properties which make something an *S*. For instance, something is a grain of sand if and only if it has properties such as a certain molecular structure and a shape, seize, and mass within a certain margin. Properties such as these belong to the family of properties which make something a grain of sand. (I employ this notion of a family [69] of properties to develop a general conception of holism in Esfeld (1998)).

In this perspective, the point of Quine's holism is that statements have some of the properties which belong to the family of properties that make something a statement (such as meaning and confirmation) not in isolation, but only as a cluster – and in the last resort only as a whole system of knowledge. However, even in "Two Dogmas", Quine does not deny that there is a difference with respect to meaning and confirmation between statements such as "There are brick houses on Elm Street" and statements such as the law of the excluded middle. The web which Quine suggests as a model for a system of knowledge has an internal structure: statements such as "There are brick houses on Elm Street" are located at its periphery; statements such as the law of the excluded middle are located in its centre. This difference in location is possible only because of a difference with respect to meaning and confirmation.

We can therefore say the following: even if it is strictly speaking only a system of knowledge as a whole that has properties such as meaning and confirmation, these properties of the whole indicate a differentiation within the whole; they indicate the way in which its constituent parts, i.e., the single statements, are related with each other as regards meaning and confirmation. Consequently, under this perspective, the point of Quine's holism is: *Statements have some of the properties which belong to the family of properties that make something a statement* (such as meaning and confirmation) *only taken together in such a manner that the resulting properties of the whole system of statements indicate the way in which its parts are related with respect to the properties in question* (i.e., meaning and confirmation).

This point of Quine's holism also applies to quantum holism. There is a family of properties which are common to all kinds of quantum systems and which thus make something a quantum system. State-dependent properties such as position, momentum, and spin in any direction belong to this family of properties, as do mass and charge. These latter state-independent properties are sufficient to distinguish one kind of quantum systems from [70] other kinds of quantum systems. But for something to be a quantum system more properties are needed than the state-independent ones. Having mass or charge is tied to being spatio–temporal.

However, in case the state of the system is entangled with the state of another system such as in the paradigmatic examples of the EPR state as well as the singlet state, these systems fail to have a position, a momentum, or a spin in any direction separately. Nonetheless, these systems taken together have properties such as in the paradigmatic examples relative distance, total momentum, or total spin. These properties of the whole are not only represented as a certain combination of observables of the parts in the Hilbert space formalism of quantum theory. What is more, they are significant only insofar as they say something about the parts. Relative distance indicates the way in which the parts are related to each other with respect to position, although it is not the case that each of the parts has a position in distinction from the other one. Total momentum zero indicates the way in which the two systems are related with respect to momentum, although neither of them has a momentum in distinction from the other one. The same goes for total spin zero: this global observable indicates the way in which the local spin observables of the parts are related, although neither part has a value of spin in any direction in distinction from the other part. A similar consideration applies to any case of quantum entanglement. We can therefore set out this characterization of quantum holism: In the case of entanglement, *quantum systems have some of the properties which belong to the family of properties that make something a quantum system* (such as position, momentum, and spin in any direction) *only taken together in such a manner that the resulting properties of the whole indicate the way in which the parts are related with respect to the properties in question*. Hence, Quine's holism and quantum holism can be conceived in such a way that they have the same conceptual content as far as the meaning of "holism" is concerned.

In this characterization of what "holism" means in both cases, I have tried to translate the formal structure of quantum entanglement or quantum non-separability into general philosophical [71] concepts and then apply the result to quantum holism as well as Quine's holism. There are other proposals in the literature which offer a characterization of quantum holism in slightly different terms. Before concluding my argument, let me briefly consider the two most prominent proposals and show that they apply to Quine's holism too.

Teller (1986) characterizes quantum holism in terms of non-supervenient relations: being in the singlet state or being in the EPR state is a relation between two systems which does not supervene on their intrinsic properties. This point also applies to Quine's holism: meaning and confirmation are not intrinsic properties of statements (or beliefs). There are only meaning and confirmation relations among statements in a system of statements. These relations do not supervene on whatever intrinsic properties statements may have.

According to Healey (1991), a whole that is composed of at least two quantum systems with entangled states has significant, intrinsic properties which its parts do not have and which do not supervene on the qualitative, intrinsic properties of the parts and some of their relations such as their spatial relations. For instance, in the example of the singlet state, the whole has a definite numerical value of the total spin, but none of the parts has a spin property on which this property of the whole supervenes. This proposal can also be applied to Quine's holism: according to Quine, in the last resort, it is only a whole system of knowledge which has properties such as meaning and confirmation. Single statements do not have intrinsic properties on which these properties of a whole system of knowledge supervene.

It is not within the scope of this paper to enter into a detailed examination of these proposals for a characterization of quantum holism as well as the question which one is the most plausible way to construe Quine's holism. I only intend to suggest that the most prominent proposals for a philosophical characterization of quantum holism can be applied to Quine's holism too. This corrobates my thesis of a common conceptual content of Quine's holism and quantum holism as far as the meaning of "holism" is concerned.

[72] Nonetheless, as to any analogy, there are limits to this analogy too. The most important limit is this one: If we subscribe to the option for limited quantum holism and thus acknowledge state reductions in measurement or other suitable interactions, we countenance cases of a dissolution of entanglement and thus cases of a dissolution of holism. For instance, as a result of measurement in a Bell experiment, each of the two systems has a separate spin state (or would have a separate spin state if it were not absorbed by the instrument). Such cases of a dissolution of holism have no parallel in confirmation holism and semantic holism. This disanalogy notwithstanding, the decisive point is that if we endorse quantum holism, we have to start in our ontology from quantum holism encompassing the microphysical level of nature; only on the basis of holism can subsequently state reductions occur. Therefore, in conclusion, I submit that not only can Quine's holism be used as a guideline in the discussion on holism and other options in the interpretation of quantum physics; but also what Quine says about science and what quantum theory says about the object of science in the microphysical realm has a significant common conceptual content as far as the meaning of "holism" is concerned.

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OLISMO QUINEANO E OLISMO QUANTISTICO

Riassunto

In questo articolo l'olismo di Quine viene utilizzato ai fini della discussione dell'olismo all'interno della fisica quantistica. Partendo dall'olismo della conferma sostenuto da Quine, si spiega come i risultati del dibattito sulle obiezioni di Einstein alla teoria dei quanti forniscano sostegno alla tesi quineana secondo cui non esiste alcuna separazione tra scienza e metafisica. Abbiamo a disposizione parechhie opzioni per integrare i risultati della fisica quantistica nel nostro sistema cognitivo. Nel saggio si afferma che possiamo usare il criterio adottato da Quine per introdurre cambiamenti nel nostro sistema cognitivo come supporto dell'olismo quantistico. Si dimostra infine che vi è una marcata analogia di contenuto tra ciò che l'olismo quineano dice a proposito della conferma e del significato degli enunciati, e quanto sostiene l'olismo quantistico circa le proprietà dei sistemi microfisici.

Abstract

This paper applies Quine's holism to the discussion on holism in the philosophy of quantum physics. Recalling Quine's confirmation holism, I explain how the results of the discussion on Einstein's objections to quantum theory illustrate Quine's thesis that there is no separation between science and metaphysics. We have a number of options for integrating the results of quantum physics into our system of knowledge. I argue that we can use Quine's criterion for changes to our system of knowledge to support the option for quantum holism. Finally and most importantly, I show that there is a far-reaching analogy in content between what Quine's holism says about the confirmation and meaning of statements and what quantum holism says about the properties of microphysical systems.