Why should we use quantum theory?
The case of human sciences

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Introduction

Why is quantum theory so universal? Why does it apply to so many situations beyond the field of microphysics? To answer such questions, we can find inspiration from a remarkable reflection of the French philosopher of Science Jean Cavaillès about probabilities: "If any physical law is nothing else than a gamble for action, the scandal of probabilities ceases: far from being an inadequate substitute for our power to know, probabilities must be seen as the paradigm and the foundation of all scientific activity" [1]. Accordingly, if quantum laws are understood as nothing more than a gamble for action, the "scandal" of their probabilistic status ceases. For, under this hypothesis, the probabilistic status of quantum mechanics does not mean that one accepts that natural processes are intrinsically stochastic, but only that we cannot avoid the attitude of *gambling* when we wish to anticipate the outcomes of our measurements. We cannot do anything better than gambling, for the simple reason that we are unable in principle to control those outcomes and even to describe the detailed processes that yield them. Indeed, we partake of these outcomes by our own experimental activity.

This way of understanding the reason why probabilities are constitutive of quantum mechanics can help us to suspend the relationship of distrust (not to say of estrangement) that we have maintained with this theory since its creation, and to change it into a feeling of proximity and trust. It can help us see quantum mechanics, not as an anomaly in the space of physical theories, but rather as their deepest archetype.

From this decidedly probabilistic standpoint, the application of quantum theory to many cases in the human sciences is no longer a coincidence, but a necessity. That it is a necessity becomes clear as soon as one understands two things: (i) that quantum theory formalizes a broad class of activities of knowledge rather than the objects of such knowledge; and (ii) that there is an isomorphism between certain situations of knowledge typical of the human sciences, and most situations of knowledge in microphysics. To put things shortly, both the human sciences and microphysics deal with situations in which knowing is not tantamount to observing, but rather to intervening and participating. As soon as we realize that quantum theory is above all a generalized probabilistic valuation for situations of knowledge in which intervention and participation are insurmountable, its universality and its applicability to such cases as decision-making, case-sensitive categorization and behavior in situations of uncertainty, becomes almost trivial.

By contrast, the purely pragmatic justification that is usually provided for applying quantum theories to the human sciences looks shy and contrived. The standard name for this application is "quantum model": quantum model of decision, quantum model of perception, quantum model of meaning ascription etc. And the best reason one then finds for the ("surprising") validity of such models is that quantum theories are "rich" and that "A richer expression scheme comes with a greater modeling power" [2].

But is the status of "model" ascribed to quantum theoretical accounts of human processes, credible ? And, to start with, what about this word "model", that mostly refers to restrictive uses of a theory aiming at making sense of some particular experimental situations ? Remind that "model" is a word derived from the latin 'modulus', 'a small measure'. Its primary semantic content is therefore *a likeness made to scale.* But what if, as Heisenberg and several other creators of quantum mechanics suspected, quantum theory is no image, and no likeness, of anything ? What if quantum theory does not resemble its object in any way, but (as suggested above) only formalizes gambles about the reactions of any object whatsoever when it is put in a certain class of situations of knowledge [3] ? What if, as Richard Healey pointed out, "quantum theory makes a radical break with previous physics not because of the weirdness of the physical behavior it represents, but … (because) quantum theory is simply not in the business of representing what happens in the physical world" [4] ? In this case, the very idea of quantum models *representing* some human processes is deeply undermined. Conversely, the fact that quantum theory can indeed be applied to human sciences makes a non-representationalist interpretation of quantum mechanics much more compelling.

1-On the human science / natural science issue

There are some philosophical reasons to the persistent resistance to quantum theoretical approaches of the human sciences. Those who resist this approach sometimes fear that the desire to formulate quantum theories of human processes stems from an old thesis proposed by Otto Neurath around 1930 under the name of "Physicalism". The latter thesis amounts to a quest for the general unity of science under the exclusive authority of physics promoted "queen of sciences". But the search for the unity of the sciences by their absorption in physics understood as universal knowledge may well imply reductionism, with the basic assumption that only the things described by physics are real, and that all the rest, especially the individual and social processes studied by the human sciences, is only an epiphenomenon. John Searle expressed this conflation of physicalism and reductionism thus: "That," he said, "is the raw structure of our ontology. We live in a world made entirely of physical particles in fields of forces. Some of them are organized into systems (...). Now the question is: how can social facts be justified within this ontology?" [5] Here, physics reveals ontology; ontology holds the ultimate truth about the world; and every other science, including social and mental sciences, must conform to it.

This way of relating quantum mechanics to the human sciences certainly represents a possibility for thought, but it is not the only one, and not even the most interesting. Another philosophical approach may lead us to identify a deeper relationship between the two families of sciences. This is the approach, familiar to Bas Van Fraassen, which consists in giving the *methods* of scientific research an importance and scope greater than that of the contents of scientific representations. Scientific representations are historically shifting, ontologies replace one another, but the methods of science continuously become broader and more refined. It may be useful, as an exercise in self-consistency of the system of science, to articulate the representations associated to physics with thoses associated to the human sciences. But it is much more instructive to identify the common constraints that eventually lead to methodological prescriptions shared by advanced physical theories and the human sciences. On the basis of these shared methodological prescriptions, we can indeed arrive at unified forms of theorization, even though there is no reason to mix up the objects of the two sciences, and no reason either to believe in the possibility of reducing them to each other.

Let us then examine the methods of modern physics and the human sciences; Let's try to identify what they have in common, and above all what are the constraints that shaped them in so similar ways.

It should be noted, even before beginning the investigation, that the methodological similarity with the human sciences does not concern classical physics. As long as one sticks to classical physics and its epistemological paradigm, one can accept the strict dichotomy between natural sciences and human sciences that the hermeneutic tradition has constantly affirmed since Dilthey. According to this dichotomy, the natural sciences yield *explanations* of the processes they study, whereas the human sciences are based on the possibility for a human subject to *understand* her co-subjects, that is to say to *simulate* their inner states, to imagine what she would have done if she had been "in their shoes". The sciences of nature *explain* an environment which we are free to contemplate at a distance, while the human sciences explore our possible insertions in the situation and in the (instrumental and linguistic) practices of our fellow human beings. Habermas reformulated this difference as follows: "The theories of the natural sciences are systems of statements about states of affairs, whereas, in the human sciences, the complex relation between statements and states of affairs is already present in the states of affairs under analysis" [6]. According to this version of the traditional distinction, the natural sciences manage to completely separate their object from their means of study and linguistic designation. On the contrary, the human sciences are condemned to maintain an inextricable link between what they aim to study (the "states of affairs") and their interpretative grid conveyed by language (the "statements"). Indeed, the human sciences have what some consider to be a disadvantage compared to the classical sciences of nature: their act of investigation is coextensive with the field investigated; their own personal, social, and linguistic processes partake of what they seek to know.

There is also a second distinction, stated by Von Kempski and endorsed by Habermas: "The studies of the social sciences (...) are essentially studies of *possible* action, whereas theoretical physics always refers to actual nature" [6]. In other words, the classical sciences of nature describe what happens, what is the case, whereas the human sciences content themselves with identifying what holds potentialities for events to come. The reason is that the human sciences are not so much concerned with the present *causes* as with the *reasons* for acting in the future; not so much on facts as on norms. As Jean Piaget writes, "The three fundamental notions to which social structures are reduced are those of rules, of values and of signs; and at first sight they seem irreducible to the concepts used in the natural sciences" [7]. A widespread tendency to mix up the two approaches, could even be considered as the root of many false riddles about the mind and body: it is this kind of confusion that Gilbert Ryle called a "category mistake" [8].

However, the two major epistemological differences that have just been identified between the science of nature and the human sciences are partially canceled when the natural sciences adopt the paradigm of quantum physics instead of the paradigm of classical physics.

Firstly, we know that quantum physics is working on an experimental material in which the separation between what is explored and the means of exploration, meets fundamental limits. Like the human sciences, quantum physics must take into account the involvement of practices of knowledge in the phenomenon to be known. Like the human sciences, quantum physics deals with a situation where the epistemic act is coextensive with its field of study.

Secondly, because of the limits to the separation between the domain explored and the means of exploration, quantum physics can no longer claim to describe the properties of entities, as if it were from outside. All it can specify is the evolution of a pre-probabilistic symbol (the state vector) that can be used as an internal guideline for experimental and technological research. Just as the human sciences, quantum physics concentrates its theoretical activity on identifying potentialities for guiding effective operations, and no longer on highlighting actual events that are supposed to be independent of any intervention. The human sciences and quantum physics thus have in common a crucial constraint which they must take into account, and which is likely to be reflected in their methods as well as in the structure of their theoretical products.

2- **The human roots of quantum science**

The analogy with the human sciences was first noticed by Bohr, and it seems to have guided his research in physics. Testimonies show that his early familiarity with the psychology and philosophy of knowledge of the Danish thinker Harald Höffding determined his interpretation of quantum theory [9]. Instead of quantum theory playing the role of ontological "foundation" for the sciences, including human sciences, it is the human sciences that, through the voice of Höffding, offered to the nascent quantum theory a model of non-standard epistemological positioning.

Let's now examine this alternative model. Höffding's psychology had among its most fundamental principles a "law of relations" stipulating that no mental state can be considered as existing in itself, regardless of the relations it has with other mental states. Very soon, this psychological "law of relations" was extended by Höffding to physical properties, giving Bohr an example of how to export thought patterns from one science to another. According to Höffding, in the same way as mental states are relational rather than monadic traits, "(the) 'things' (...) are only understood as their properties, and the properties are manifested as so many relations to other stuff" [10]. Molecules, atoms and electrons are still 'things', totalities; but they are only known and understood as relations. A particular interest of the "law of relations", according to Höffding, was that it manifested, with particular force in the mental domain, a universal fact of interdependence between the knowing and the known. In the mental domain, more than in any other, the relation of knowledge comes first, and the related terms (subject and object) are derived. Rather than admitting without discussion an object and a subject given in advance, one realizes that each act of knowledge relates “(...) an objectively determined subject with a subjectively determined object” [11]. In other terms, subject and object are correlative of each other in each act of knowledge; they help to define each other through a process of delimitation of one by the other. In a style that evokes Hegel’s dialectic, Höffding therefore asserts that the progress of knowledge is conditioned by a mutual revelation of the subjective part in the object, and of the objectivable part of the subject.

On careful examination, it is quite easy to see this dynamic at work in history. The most important advances of the sciences of nature have had as a prerequisite a revelation of the function fulfilled by the situation of the knowing subject in the phenomena that were previously supposed to be “objective” and therefore independent of knowledge. This was the case when Copernicus connected the apparent motion of the planets to their relation to an astronomical subject living on the planet Earth, or when Galileo connected the speed of material bodies to their relationship with an observer who is conventionally motionless. But this condition of subjectivation of the objective field is accompanied by its converse, which is the objectification of the subjective. Thus, all that Copernicus has retained from the subject is a terrestrial location, and all that Galileo has retained from the subject is an origin of the geometrical reference frame.

It should be noted at this stage that the co-definition of the objective and subjective sides of knowledge, as a consequence of their origin in an inextricable epistemic relation, has as its correlate the incompleteness of their characterization, and their being in constant development. For each revision of the polarity of the subject-object link, a redefined object arises before a subject whose questioning is renewed accordingly.

Here again, the human sciences and especially psychology serve as an emblematic case, because they are confronted with the most extreme version of the knower’s inextricability in the process of knowledge. Höffding notices that, because it tries to objectify its field of study, the introspective psychology of his time misses a crucial aspect of mental activity: the possibility of being so immersed in it, that no reflection on it is allowed. It is impossible to have desire, and to analyze one's own motivations at the same time. It is impossible to be attentive, and to be attentive to this attention at the same time. The object of attention is constantly redefined as the attentive subject reorients herself. Another way to express this is the following: when the subject of attention is not really distinct from its object, the act of observation can only alter the latter. This is true in introspective psychology, since when I attempt to observe the subject that I am, I transform myself into another subject capable of positing this very attempt as a new object of my attention. And this is also true in experimental psychology, since the subject being studied is likely to reshape itself according to the experimenter's expectations. What should we do, faced to this dilemma? What should we choose, between a continuous absorption into one's own subjective experience, and the systematic objectifying distance advocated by scientific psychology? In the wake of his understanding of subject and object through a dynamic of reciprocal definition, Höffding advises not to priviledge one of these two mutually exclusive attitudes; he advises not to remain stuck in either commitment or distancing. Both attitudes are indispensable in some ways. Their incompatibility does not exclude their alternative use.

Here, it is not difficult to recognize the conceptual structure that Bohr named "complementarity". Complementarity in Bohr's sense refers to the joint use of two mutually exclusive characterizations of the same object.

In quantum physics, Bohr identified a reason for the relevance of the concept of complementarity: it is the finite character of the quantum of action, which comes into play at the moment of the measurement process. The indivisibility of the elementary quantum exchanged at the moment of the interaction between a microscopic system and a measuring device does not allow to separate, in the phenomenon, the contribution of the system from the contribution of the apparatus. But if phenomena cannot be decomposed into a contribution of the object and a contribution of the apparatus, no inference from them to an "independent" object can be done. The microscopic phenomenon is nothing more than the expression of a global experimental situation; it is not the revelation of an intrinsic property of some object.

Bohr also notes that it remains necessary to describe part of the measuring instruments by means of current language appropriately refined by the terminology of classical physics. Indeed, this immediately significant part of measuring instruments must be interpreted in terms of objects with definite “properties”, if its indications are to be communicated in an unambiguous way to all experimenters by means of propositions containing a grammatical subject (the object “dial of the measuring instrument”) and a predicate (the value displayed by this dial). Projecting this constraint of classicity from the mesoscopic domain onto the microscopic domain, Bohr emphasizes that each characterization relating to the microscopic domain is not that of a microscopic object, but that of a semiclassical interpretation of such object, supported by a classical interpretation of the measuring process.

It then becomes possible to account for both the mutual exclusivity of microscopic characterizations and their joint necessity, that are the two definitional components of Bohr’s concept of “complementarity”. The mutual exclusivity of the microscopic characterizations is explained by their “holistic” indissociability with the corresponding experimental procedures, and by the incompatibility of these experimental procedures. The joint need for several incompatible characterizations is justified by the desire to continue to consider that certain experiences, including when they are incompatible, “relate to” the same object; that is to say, by the wish to admit that, even if they do not reveal what an object is in itself, the experimental characterizations offer sketches of it.

Inspired by Höffding, Bohr considered the complementarity of characterizations in the human sciences as the expression of a similar tension. On the one hand, the mental and social processes are so integrated, so participatory, so “holistic”, that one can manifest one of their aspects only by cutting them off from conditions that would manifest another aspect. On the other hand, if, in order to conform to the norms of the theory of knowledge, we still wish to subdivide these integrated-holistic processes so as to act as if an object were distinguishable from its subject, we come to the conclusion that this artificially posited object, having only “symbolic” consistency, can only be approached through several of these mutually exclusive aspects. One of Bohr's best-known examples of complementary structures is introspective psychology (just as Höffding). Better still, Bohr does not present introspective psychology as a mere illustration, but as the paradigmatic description of the epistemological limitation facing modern physics. In this example, the subject, being at the same time the object of its self-examination, must use several mutually exclusive approaches to explore herself. Thus, when the subject wants to analyze her own use of a concept, she must adopt a posture which excludes the unreflected application of this concept. The subject cannot be simultaneously actor and spectator of her own conceptual elaboration. Bohr also gave examples of complementary structures in the social sciences. For example, he wrote, benevolence is complementary to justice, since the first point of view requires personal commitment while the second point of view is a social norm.

In his fundamental philosophical text written in 1942, Heisenberg [12] transformed Bohr's thesis into a general theory of concrete human knowledge. According to Heisenberg, there exist at least three regions of knowledge that are distinguished by the degree of dissociation which can be achieved between the process of knowledge and its object.

• The first region is such that the states of things are completely separable, by a technique of search for invariants, from the process of their study. This is the region of classical physics and chemistry.

• The second region corresponds to the case where the states of things that one seeks to characterize are fundamentally inseparable from the approach adopted for the characterization. This is the region of quantum physics. But this is also, according to Heisenberg, the region of psychology and biology. Psychology is indeed marked by the fact that "(...) an essential part of what happens in the soul escapes any objective fixation because the act of fixation intervenes itself decisively in the processes". In other words, it is impossible to dissociate an object "soul" from the very act that the "soul" accomplishes. As for biology, it must take into account the incompatibility of analytical approaches (such as physicochemical examination of cellular components), and global approaches, such as those concerned with homeostasis, behavior and intentions. If these two approaches are incompatible, then it becomes absurd to pretend to absorb one of the objects into the other, as reductionism seeks to do by excluding the categories of homeostasis and intentionality in favor of molecular concepts alone.

• The third region, finally, is one where one is interested in symbols capable of guiding not only the process of knowledge, but also life in general. This is the region of art with its formative figurations, of religion with its representations and archetypal narratives, but also of the many social practices in which an institutional symbol (fiduciary money, constitution, bill of rights) is treated as if it were an autonomous reality.

At a higher level of reflection, however, the very existence of a multiplicity of regions of knowledge is sufficient to express the impossibility to separate knowledge from the processes it uses. Heisenberg thus pointed out that "It may not be possible, in a complete description of the connections of a region, to disregard the fact that we ourselves are part of these connections." It is true that the examples of this impossibility of ignoring our commitment in the (law-like) connections which constitute a region of knowledge are found by Heisenberg in atomic physics and psychology (in his second region of knowledge). But the wording of his sentence implies than our commitment can no longer be ignored when we seek the completeness of any description whatsoever. Our commitment becomes obvious as soon as we strive to reach the boundaries of a region of knowledge, no matter which region we explore.

Many historical cases illustrate this self-revealing power of the exploration of confines. Thus, a search for completeness of the classical description of atoms and light, at the turn of the nineteenth century and the twentieth century, has led us to run up against a fundamental limitation of objectification (in the sense of complete “detachment” of an object with intrinsic properties) : the limitation manifested in quantum theory. Earlier in history, a search for completeness in classical science, a science elaborated from the point of view of a detached spectator, made us stumble on the enigma of free will. As suggested by Kant, this enigma that is formulated from the point of view of the spectator could be sorted out only from the point of view of the agent.

This repeated figure of human beings meeting their own limitations at the end of a quest of knowledge has been expressed by Eddington in a celebrated sentence : “ We have found a strange footprint on the shores of the unknown. We have devised profound theories, one after another, to account for its origins. At last, we have succeeded in reconstructing the creature that made the footprint. And lo! It is our own” [13].

Heisenberg made another suggestion that may help the development of a detailed relationship between quantum mechanics and the human sciences. His additional suggestion is that the impossibility of completely ignoring our own contribution can be recognized in the mathematical formalism of quantum physics itself. To understand how this is possible, we must first clarify the process by which the search for objectification overcomes obstacles. This is usually done by incorporating this obstacle into the newly defined objects and turning it into an advantage. As Heisenberg pointed out, "(...) even if a state of affairs can not be objectified in the standard sense, it remains that this fact itself can (...) be objectified in its turn and explored in its connection with other facts" [12]. In other terms, the limits of objectification are (reflectively) objectifiable. This remark illuminates the status of the mathematical formalism of quantum theory. The mathematical formalism of quantum theory is a second-order objectification of the impossibility of any first-order objectification. The first-order objectification consists in extracting spatio-temporal invariants such as classical material corpuscles with a trajectory in space and in time. It thus directly organizes the *individual* experimental phenomena observed in the space and time of the laboratory. But the second-order objectification is elaborated out of the *statistical distributions* of these experimental phenomena. It extracts an invariant predictive tool such as the state vector in a Hilbert space, thus organizing phenomena indirectly.

What is connected through the basic law of quantum mechanics, namely the Schrödinger equation, is then the state vector, rather than the individual experimental phenomena. This further expresses: (i) the impossibility of a first-order objectification (that is to say the impossibility to detach experimental phenomena from their experimental context), and (ii) the effectiveness of the second-order objectification of an invariant generator of statistical distributions. We thus realize that a considerable part of the quantum formalism has a deep meaning that extends far beyond microphysics. This formalism actually expresses a universal general epistemological situation : a stepping up of objectification in the face of the fundamental obstacles that it encounters.

Subsequently, several philosophers have taken advantage of these pioneering analyzes of the creators of quantum mechanics and elaborated a new conception of knowledge on that basis. This is the case of Karl-Otto Apel, who devoted a book to this endeavor. Starting from the two differences between natural sciences and human sciences mentioned by Habermas, Apel shows that they vanish in the quantum paradigm. The first opposition, between the (natural) sciences of detachment and the (human) sciences of commitment, collapses from the outset: "In the [sciences of nature as in the human sciences], writes Apel, it is necessary to give up the representation of an objective external world of which a multiplicity of perspectives falls, in principle, under (...) theoretical control. Instead, there are aspects of the world that are incompatible, complementary, [because they are indissolubly linked to each perspective, to each mode of intervention]" [14]. The aspects of nature seen in microphysics, "(...) are objectively incompatible and, for this reason, comparable to the mutually exclusive worldviews of the (human) sciences (*Geisteswissenschaften*)".

The second epistemological difference mentioned by Habermas between the natural sciences (supposed to describe actual properties) and the human sciences (supposed to focus on potentialities) is also analyzed and criticized by Apel. Indeed, this difference was canceled out by the advent of quantum physics. Just as the human sciences, quantum theory manipulates symbols (the state vectors) that describe a potentiality rather than some actual event. It serves to anticipate what can happen in the future in various experimental contexts, rather than context-independent present findings. Apel attempts to identify the reason for this shift from classical physics to quantum mechanics: "(Quantum mechanics), he writes, succeeds in separating the subject from the object in the statistical explanation of the behavior of sets of particles, but it fails at the level of the individual particles". In other words, the use of probabilities in quantum physics is the mark left on the limit of first-order objectification, and the expression a second-order objectification: the indirect objectification of statistical distributions of spatio-temporal phenomena, rather than the direct objectification of a set of spatio-temporal entities.

This being granted, the modalities of the connection between quantum physics and the human sciences are of two quite distinct types. On the one hand, we can qualitatively develop the similarity of the epistemological situation between microscopic physics and each human science considered separately. On the other hand, we can seek to state the quantitative or at least formal consequences of this type of epistemological situations.

3-Qualitative parallels between quantum theory and the human sciences

As we have just seen, qualitative parallels between quantum theory and the human sciences can be based on the Bohrian concept of complementarity. However, complementarity being a "broad-spectrum concept" (Putnam), its modalities of applications can vary a lot. Already, in quantum mechanics, several variants of this concept have been listed by Bohr.

Taken in the broadest sense, Bohr's complementarity expresses the impossibility of getting rid of the holistic features of experimentation. But these holistic features manifest in three different ways:

- The mutual exclusivity of two variables that are inseparable from experimental contexts. An exemple of such pairs of conjugate variables is position and momentum.

- The mutual exclusivity of two pictures, respectively associated with partial experimental contexts and a global experimental context. This is the case of the corpuscular and wave pictures in the double slit experiment. The corpuscular picture is associated with the partial context of detection of the passage of an object through one slit ; and the wave picture is associated with the global context of indistinguishability of the paths corresponding to the two slits.

- The mutual exclusivity of potentiality and actuality. They correspond respectively to: (i) the context of forecasting future measurement results after the initial preparation, and (ii) the context of the final measurement. This latter pair is represented in quantum theory by the continuous and discontinuous modes of evolution of the state vector. The "causal" mode of evolution by the Schrödinger equation excludes the "acausal" mode of evolution associated with an act of experimental localization in space-time.

Two examples of qualitative use of the Bohrian concept of complementarity in the human sciences will now be developed. They manifest the same amplitude of variation around the common theme of the holistic character of knowledge, as in quantum physics.

Klaus Meyer-Abich [15] developed a psychological variety of complementarity, in the spirit of Bohr and Höffding. According to Meyer-Abich, this kind of complementarity reflects an incompatibility between the act of aiming at objects and the act of reflecting on objectification. This incompatibility was especially highlighted by Kurt Goldstein in his empathic observations of patients who suffered brain damage during the First World War. For such patients, the psychical attitudes of intentionality and reflexivity are so dissociated that even their succession becomes impossible. Surprising as it may seem, this alteration observed by Goldstein is not a consequence of certain focused lesions, but is found in virtually all patients with extensive lesions of the cerebral cortex. In every patient of this kind, "everything that forces him to go beyond the sphere of 'actual reality' to reach what is 'simply possible', brings a failure" [16]. Patients adhere to what is immediately experienced, without being able to distantiate from it and without being capable of embedding it into a representation. They remain bound to intentional directedness towards objects without being able to step back and acquire a reflective knowledge of themselves. In a later reflection, Goldstein characterizes this deficit of patients having cortical lesions with words that were also used by Bohr: patients "act in the world instead of thinking of it or talking about it"; in other words, they become pure actors because they have lost the degrees of freedom that would have allowed them to behave as spectators of themselves as well. From this, one may infer that in organisms, the actor-stance, the stance of self-adherence to oneself, is fundamental. By contrast, the complementary stance of a detached spectator: (a) can only be incomplete, and (b) requires resources in excess of that of the actor. Holistic integration imposes the actor-stance. It allows only incidentally and fragmentarily the stance of a detached spectator, which supposes that one suspends for a time the fundamental actor-stance.

The analogy between this cognitive pathology and the complementarity of corpuscular and wave representations is striking. In the latter type of complementarity, the corpuscular representation prevails in the context of a local detection on one branch of the interferometer, whereas the wave representation is relevant in the context of an evaluation of the effects produced by the interferometer as a whole. The corpuscular representation prevails when only one path is available, while the wave representation prevails when all possible paths have been left open. Similarly, Goldstein's pathological configuration highlights a type of complementarity wherein the local approach of an act is exclusive of a global approach of action. It also corresponds to a duality of attitudes between adherence to a certain act, and the reflective distancing that allows every possibility of acting to be displayed before the eyes.

A different variety of complementarity, that still manifests the holistic nature of knowledge, is mobilized by Michael Rasmussen's reflection on linguistics [17]. Rasmussen confronts Bohr with another great Danish thinker who is almost contemporary with him: the linguist Louis Hjelmslev. However, his comparison of linguistics with the epistemological configuration of quantum physics is not limited to one author; it extends to any structuralist conception of language, such as Saussure's. The comparison is established in two steps.

The first step is a definition of observation: observing means restricting the initial conditions on the basis of which a prediction can be made. The question of the impact of the observation on the observed domain can then be replaced with a request concerning the impact of the forecast on the forecasted events. But, says Rasmussen, in linguistics, this impact is by construction considerable. When a linguist tries to predict the future evolution of her own language, she modifies it by her very act of forecasting. For, as a speaker of her language, the linguist is bound to give a normative or prescriptive value to her prediction. When she foresees the future state of her language, she prescribes a condition of identity (this future language must still be "English", despite all its transformation). And since her speech is guided by such prescription, she influences the evolution of her own language. To sum up, the prediction "disturbs" the language. The work of the linguist influences the evolutionary dynamics of her own language. Linguistic analysis cannot be detached from the metabolism of language.

The second step in this parallel between quantum mechanics and linguistic analysis consists in describing a form of complementarity. There are two mutually exclusive approaches to language: the synchronic approach and the diachronic approach. The synchronic approach tends to immobilize the language in its present form, namely in a present system of differences between signs. The diachronic approach, instead, follows in the short term the developments of the practice of speech, and it tends to identify in the long term the drifts of the system of semantic differences. Clearly, extracting a synchronic structure (from a snapshot of language), and making a diachronic analysis (of the history of language), are mutually exclusive operations. We find in Louis Hjelmslev's work a detailed description of this difference [18]. As a preliminary, Hjelmslev points out that while signs follow each other in speech, they coexist in the text that transcribes it. Their succession constitutes speech, and their coexistence constitutes texts. Both speech and texts involve a conjunction of signs. In both cases one sign comes, *and* then another, *and* then another etc. But this conjunction unfolds in time for speech, and it unfolds in space for texts.

Now, according to structuralism, each sign has a unique position which defines it by its differences with respect to the others. No other sign can *really* replace it, since to take its place would be tantamount to endorse the same pattern of differences and therefore to identify with its unique function. In this case, the signs form a disjunction: at each given position, one sign may be used *or* another, *or* another one etc. ; and this substitution changes nothing since what counts is the local pattern of differences. Hjelmslev called "relation" the conjunction typical of the textual process, and "correlation" the disjunction typical of the whole system of language. The relations between the signs of a text acquire meaning according to their positions in the system of correlations which constitutes language.

At this point, the difference in the modes of observational access becomes quite obvious. The observational access to a text is immediate, since it just consists in reading a sequence of signs. But access to the system of language is quite complex: it arises from the analysis of an immense (*a priori* unlimited) corpus of speeches and texts. Yet both types of access have a predictive value. Understanding of a text makes it possible to foresee to a certain extent what follows it, by constraining the field of future possibilities. As for knowledge of the system of language, it constrains any text and speech to fit with "grammatical" rules.

The reason for the "complementary" nature of synchronic and diachronic approaches to language is easily identifiable from there. The observation of a speech or a text forces us to accept a certain creative freedom, and consequently opens the way to a future destruction of the system that presently constrains it. The observation of the language system, on the other hand, makes it necessary to declare outlaw any deviation from it, and to set strict boundaries of what can be said without a time limit.

The most tempting analogy, although arguably a partial one, is with the third variety of Bohrian complementarity: the complementarity between actuality and potentiality. Here, the actuality is that of the text, while the potentiality is that of the system of the language, capable of generating all the texts that follow its rules and also capable of carrying a sentence of banishment against the texts which deviate from such rules.

4-Early quantitative applications of quantum theory to the human sciences

We must now examine the quantitative aspects of the epistemological analogy between quantum theory and the human sciences. Giving this analogy a formal translation is a decisive test for its relevance. The most delicate question for researchers in this field was how to collect in a formalism the constraints of the common epistemological configuration, while leaving aside the peculiarities of the various domains to which it extends. Let us admit, as we have said before, that the quantum formalism translates above all the limits of the activity of objectification. Does this mean that every symbol of the quantum formalism can be related to this epistemological constraint? And should we infer that the quantum theory formulated by physicists from 1925 can be transposed immediately to a number of problems of psychology, sociology, or economics? The answer to these questions is “no”. Indeed, several features of the quantum formalism are derived from specific domains of the physical science, from mechanics to electrodynamics. An exemple is the structure of the Hamiltonian operator in the Schrödinger equation: its form is identical to that of the Hamiltonian function of classical mechanics, and it unambiguously expresses the connection of quantum formalism with this domain of physics. One must therefore go further up the scale of generality, and identify the epistemological core of quantum formalism after having put aside its "physical" envelope. Where do we find this nucleus: in the probabilistic algorithm of quantum theory, in its Hilbert space structure, or in the underlying structure of "orthocomplemented lattices", which was extracted by Birkhoff and Von Neumann and formulated as "quantum logic"? Each of these options has been explored (albeit sporadically) during the twentieth century. I will mention three of them.

According to Jean-Louis Destouches (1909-1980), it is the structure of the probabilistic algorithm that expresses what quantum formalism owes to the epistemological situation confronting microscopic physics [19]. Destouches thus tried to build what he called a "general theory of predictions" capable of providing probabilistic evaluations ; and he identified in it the particular features that make it possible to arrive at quantum or classical versions of this kind of theory. During his research, worked out jointly with Paulette Destouches-Février, he obtained an important result that retrospectively justified his initial program. This result is stated in the following theorem: "If a theory (of predictions) is objectivist, it is in principle deterministic and one can thus define an intrinsic state of the observed system ... Conversely, if a theory (of of predictions) cannot be considered as objectivist, that is to say if it is irreducibly subjectivist, then it is not deterministic in principle; as a consequence, such theory is essentially indeterministic" [20]. In the latter case, the theory is bound to be probabilistic, whereas in the former case the use of probabilities is only due to the ignorance of the intrinsic state of the system. The result is remarkable, but the sentences by which it is expressed involve a vocabulary that may trigger misunderstandings. To begin with, the couple of terms "objectivist-subjectivist" expresses the opposition between an epistemological situation where the work of objectification can be carried out, that is to say, where it leads to object-specific autonomous determinations, and another situation (typical of quantum physics) where the phenomena are inseparable from the instrumental context that allows them to manifest. This translation of the term "subjectivist", with its inappropriate connotations, by a more neutral term as "contextualist", is justified by the definition given by Paulette Destouches-Fevrier herself: "(We call) ‘objectivist theory’ a theory in which measurement results can be considered as intrinsic properties of observed systems, and ‘subjectivist theory’ a theory in which the measurement results cannot be ascribed to the observed system as intrinsic properties, but only to the complex apparatus-system, with no possible analysis that would ascribe part of the result to each one (...)". Taking into account these definitions, the heart of the theorem can be stated as follows: a theory allowing to predict phenomena indissociable from their mode of access is "essentially indeterministic". The ineliminable use of probabilities is therefore, according to Jean-Louis Destouches and Paulette Destouches-February, the generic mark of the epistemological situation of microscopic physics.

That being granted, is there a way to identify, among the features of the probabilistic formalism of quantum theory, something that is specifically expressive of this epistemological situation, after having set aside what belongs to the physical domain to which it applies? Doing that is precisely one of the goals that Destouches set for himself when he developed his general theory of previsions in the late 1930s. This general theory of previsions, he writes, makes it possible to "... separate hypotheses about predictions from the strictly physical assumptions" [21].

As a first step, Destouches defines the initial "prediction element" that is characteristic of a given experiment. A "prediction element" is a mathematical entity that can be used to associate a probability distribution to each measurement that can be made after some given experimental preparation.

The second step consists in calculating the evolution of the prediction element in time. This is done by using a unitary operator, which has the property of ensuring that the sum of probabilities evaluated from the prediction element remains equal to 1 at any time.

The third step consists in making a list of "eigen (or proper)" prediction elements, which provide a probability 1 for one of the values that the selected variable can take, and 0 for all other values of this variable.

At the fourth step, one determines the set of coefficients such that the final prediction element can be written as a linear combination of the proper prediction elements, weighted by these coefficients (we thus generate a vector space of prediction elements that may, if certain additional conditions are met, acquire the structure of a Hilbert space).

At the fifth step, finally, the probability of each value of the measured variable is calculated. This last stage is especially interesting because from it, one may bring out a characteristic imprint, on the form of the probabilistic evaluations, of the epistemological situation of inseparability of the phenomena vis-à-vis their experimental modes of access. When the predictions concern such inseparable phenomena, one can prove a theorem stating that the probabilities are the square modulus of the previous coefficients. This is the "Born rule", which generates probability distributions that are isomorphic to the intensities of a wave. Through this theorem demonstrated by Paulette Destouches-Février, Born's rule and the wave-like effects typical of quantum mechanics have both been shown to be direct consequences of the limit to objectification that characterizes microscopic physics.

Now, we are certain that there is indeed a feature of the quantum predictive formalism (the Born rule) which directly expresses the epistemological situation of indissociability of phenomena with respect to their modes of access. But what about other features ? What in the structure of the general theory of predictions is still connected to physics? Two things, essentially: (a) the definition of each variable, because it depends on the procedure used for its measurement; and (b) the structure of the unitary operator that is used to calculate the evolution of the prediction elements, because it expresses the dynamics of the process under consideration. In standard quantum mechanics, this evolution operator is inserted in the Schrödinger equation ; it involves a Hamiltonian operator derived from classical mechanics or electrodynamics. All the rest of the predictive formalism (including the vector space structure) is much more general than any physical theory. A momentous consequence of this generality was drawn by Destouches in the 1950s : the quantum-like theory of predictions applies to "many other domains" than physics. In particular, it was applied by Destouches to biology and to "questions of econometrics" [21], thus showing its relevance for some human sciences.

Two other authors (Satosi Watanabe and Patrick Heelan) sought the similarity between quantum physics and the human sciences in an even deeper structure, underlying the probabilistic formalism. They found it in the "orthocomplemented lattice algebra", which replaces in quantum theory the ordinary Boolean algebra of the empirical propositions of classical science. This structure is at once looser and more general than that of Boolean algebras; it can be considered as a non-Boolean network of Boolean subalgebras. As Watanabe pointed out [22], the use of an orthocomplemented lattice algebra instead of a Boolean algebra is a mark of a deep alteration of the epistemological situation. Indeed, the Boolean algebra of empirical propositions is underpinned by a postulate according to which "each predicate corresponds bi-univocally to a defined set of objects that satisfy the predicate". In other words, Boolean algebras apply to a corpus of propositions which define subsets of objects characterized by the intrinsic possession of a predicate. Things become very different when a measurement result can no longer be assigned to an object as its intrinsic attribute. If this is the case, if we must suspend the attribution of predicates to objects, if we cannot even set apart "primary qualities" belonging to objects from "secondary qualities (or predicates)" relating to experimental methods, then the former postulate is no longer valid, and Boolean algebra no longer governs all empirical propositions. What comes in the place of Boolean algebras is a non-distributive orthocomplemented lattice algebra which articulates Boolean subalgebras within a structure that is more universal than the latter.

Watanabe ascribes these results a generality that far exceeds physics alone. In order to test their generality, he applies them to the composite structure of everyday language. This language, he points out, combines effortlessly mentalist and physicalist elements in the same propositions. The option one adopts regarding the legitimacy or illegitimacy of such a combination partly determines the position one occupies in the debate on the mind-body problem. Considering that the mentalist predicates (about ‘inner’ states) should not be combined in the same sentence with physicalistic predicates (on the states of the body), but that both are legitimate, is to engage on a path that leads to dualism. Giving priority to physicalistic predicates (considering mentalist predicates as redundant) is to engage in the path of reductionism or even eliminativism. It remains to be seen what are the conditions of possibility of the curious association of the two kinds of predicates which is so common in ordinary language. Watanabe begins with emphasizing that this association is by no means obvious. The famous remark made by Gilbert Ryle, according to which the mentalist predicates are dispositional in nature, whereas the standard physicalist predicates are of a categorical nature, makes their juxtaposition in the same sentence almost baroque. This difference in nature also renders a strict correlation between mentalistic and physicalist predicates implausible: (a) a pure disposition may admit to being conditioned by a fairly wide range of physical states, and (b) information derived from complex mental states are probabilistic, whereas the physicalist propositions are of the assertoric type. In addition, the modes of access to the two types of predicates are profoundly different, not to say incompatible. Access to macroscopic physicalist predicates takes place through a single observation or measurement, whereas access to the dispositional traits of mentalist predicates can only be achieved through the study of an open-ended sequence of behaviors. Besides (as Bohr pointed out), access to the entirety of the alleged physical substratum of a dispositional mental predicate would destroy this substratum, and would thus be eminently disturbing for the mental state. The two languages, mentalist and physicalist, thus prove to be mutually exclusive in a sense very similar to that of the conjugated variables of quantum mechanics.

Therefore, if we want to understand how ordinary language is able to combine mentalist and physicalist propositions in one and the same discourse, it is necessary to aknowledge that this language can be underpinned by a non-classical logic. The latter logic is shown to be isomorphic to quantum logic, i.e. to a non-distributive orthocomplemented lattice. This is enough to see the mind-body problem under a new light. The mind-body problem stems from the wrong attempt to project on a single Boolean logic two classes of propositions and predicates that are mutually exclusive due to the incompatibility of the corresponding modes of access. The mind-body problem is then dissolved when one has accepted to take this duality of modes of access into account (yet without hypostatizing them into property dualism).

Patrick Heelan later extended Watanabe's cogent analysis to any context-dependent language that one purports to unify through a common meta- or trans-contextual language [23]. To illustrate this extension, Heelan applied the former analysis in ethno-linguistics. According to him, a meta-contextual language (namely a language that can be used by speakers of two linguistic subgroups who attempt to communicate with each other) is necessarily underpinned by a logic that is isomorphic to the quantum logic of Birkhoff and Von Neumann.

Epilogue

Perhaps, however, the most interesting lesson that can be drawn from these applications of quantum theory to the human sciences does not concern the latter sciences, but physics itself. In view of the successes obtained in perceptual psychology or in decision theory by applying a proto- or quasi-quantum formalism, it becomes difficult to deny the epistemological-reflective meaning of quantum mechanics. For the only plausible common feature of psychology, sociology, economics, decision-making, and quantum mechanics is the type of act of knowledge that these disciplines bring into play. Bohr's provocative statement (according to which "physics is to be regarded not so much as the study of something a priori given, but rather as the development of methods of ordering and surveying human experience" [24]) can now avail itself of its concretization in a multiplicity of domains whose isomorphism reveals a common epistemological approach towards what is still called, by habit, their "object".

The fact that quantum theory apply so well to many human sciences then lends credibility to recent non-representationalist and thoroughly probabilist interpretations of quantum mechanics. Two of them, that were already mentioned in the introduction, are Richard Healey's "pragmatic" interpretation and Christopher Fuchs' "QBism".

According to Richard Healey [4], quantum theory is a new kind of non-representational science ; it is fundamental but with no "beables" in it ; it is objective but its kind of objectivity consists in universal prescriptions to agents ; its symbols are purely predictive, not descriptive (therefore, famous features such as entanglement do not express a "real" entanglement of physical systems).

As for Christopher Fuchs [3], he considers that the symbols of quantum mechanics, such as state vectors, represent nothing more than a mathematical instrument used by agents in order to make optimal bets about the outcomes of future experiments. In Fuchs' own terms, the quantum symbolism is just a "user's manual" for each individual agent. If one wants to "explain" a phenomenon by quantum mechanics, the very meaning of the word explanation has to be changed : quantum mechanics explains why, in order to be coherent, an agent should assign probability p, not why a certain result has been obtained. Accordingly, standard paradoxes are dissolved by removing entirely the ontological import of symbols. A crucial example is the Einstein Podolsky Rosen paradox, that is dissolved by considering that predicting a future outcome with probability 1 does not imply the existence of Einstein's "element of reality", but only expresses the supreme confidence of agents.

In the wake of these deflationary intepretations of quantum mechanics, even the elementary presuppositions that measurement results are about "physical systems" has been challenged. The analysis of sequences of measurement outcomes, in the framework of the so-called "device-independent approaches" [25], has shown that their structure is generally incompatible with the concept of "permanent physical systems bearing properties". This puts an end to the implicit but pervasive idea that quantum mechanics describes the exceptional features of certain microphysical systems ; it rather reveals the collapse of standard ontological patterns at the micro-scale, and the emergence of a context-dependent kind of knowledge [26, 27, 28]. This is enough to give full legitimacy to a transposition of quantum theory to the human sciences. For, even though there can be no common ontological domain between microphysics and the human sciences, there is a common epistemological approach that determines the structure and meaning of both disciplines.

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