Why do we need classical concepts? Reading Bohr through Darwin's glasses

In the long series of misunderstandings that have beset Niels Bohr's epistemology over time is the confusion of classical concepts and classical physics as identical. When Bohr talked about the indispensability of the use of classical concepts, or the use of terms associated with classical physics, for describing the experimental setting and the corresponding outcome, he wasn't thinking of the indispensability of classical physics. Classical physics is one thing, classical concepts is another. Classical physics consists of certain laws of motion which don't apply to the quantum world, not even to all parts of the measurement apparatus, whereas the classical concepts are necessary for any description of the experiments. The latter, he believed, are built into the way we perceive the world.

As a response to this particular misunderstanding I want to show why Bohr thought that we cannot understand our world of experience without the use of classical concepts. My suggestion is that Bohr's claim that the use of classical concepts is indispensable for describing even quantum phenomena is grounded in an assumption that these concepts reflect our cognitive adaptation to our physical environment. This means that we will not be able to know what Bohr meant unless we go back to see what Charles Darwin said about human evolution and what kind of scientific thinking Darwin theory of the origin of the human species engendered. In this paper, Darwin and Bohr take center stage as I read passages by Bohr about the source of the classical concepts and interpret them as a reflection of the evolution of the natural language.

Although Bohr insisted on the use of classical concepts, he also claimed that the use of classical concepts in quantum mechanics had to be different from what they were in classical physics. Their use had to be restricted, due to the quantum of action, so their application made sense only in relation to the context of specific experiments. A consequence he drew from that picture was that the quantum formalism does not represent the quantum world in itself but can be used only as a tool for calculation of experimental results. While this part of his philosophy was as important as the requirement of using classical concepts, I now turn to how we may understand Bohr's view concerning the description of our perceptual experience.

From Hominini to Homo sapiens

A Darwinian maintains that much of our cognitive capacity evolved during eons by natural selection and adaptation. Long before our ancestors separated from the Great Apes many conceptual schemes and dispositions seem to have been in place. So our basic cognitive mechanisms were already there when our predecessors split off from the common ancestors we share with the chimpanzees. For all we know the chimpanzees are our closest relatives among the present living species; our common descendants divided from one another around 5-7 million years ago. The capacity of perception, memory, imagination, concept-formation, and intentional action are some of the cognitive dispositions we and the chimpanzees have in common. More specifically it is the case that capacities such as colour vision, the ability to sense unities and differences, recognizing spatial and temporal relations, sensing movements, classifying various kinds, feeling empathy, and setting up strategies for action to gain imagined goals are all basic cognitive mechanisms that we find in human beings as well as in other higher animals.

The modern human being is not that old. Homo sapiens appeared approximately 200,000 years ago, but before and even after there were several more species of hominids. Apparently, the Neanderthals died out around 35.000 years ago, and most lately it has been established that a small species of hominids may have survived on Flores until 12,000 years ago. There is some evidence that non-Africans may have interbred with the Neanderthals after the Homo sapiens' exodus from Africa, and some indication that the Neanderthals may even, as a result of their evolution, have been able to speak.

Natural language use is sometimes estimated to have evolved between 350,000-150,000 years ago. If this is true that means that a common language evolved roughly during the period our forebears became Homo sapiens. Another estimate holds that language, as we know it, emerged with what is called behavioural modernity around 150,000-50.000 years ago. So the Homo sapiens may have evolved from being mute to be speaking around 100,000 years ago. Whether this is exactly true or not does not affect the point of my argument. What matters is that the capacity of language is innate and that language has gradually evolved from primates' conceptual thinking. In my opinion it makes sense to say that if an animal has a notion of a type, i.e. has an ability to see an individual object as belonging to a certain class of objects, then it has a concept of that object. Equipped with this functional definition of what a concept is I would argue that the capacity of being a concept user evolved much earlier than the the ability among apes to distinguish between different kinds of colours, kinds of fruits, and kinds of animals, as well as their ability to count small numbers. All these perceptual behaviours indicate that our capacity to form concepts had developed long before our non-linguistic forebears were set on the trail to become language users.

The cognitive development that took place in virtue of natural selection among hominids evolved towards an increasing capacity of abstract thinking in combination with proper language skills. For this process to be successful the rise of ordinary language had to adapt to the natural concepts by which our non-linguistic predecessors already grasped their experience. Hence, the perceptual and behavioural oriented part of the natural language comprises distinctions and classifications which our non-linguistic forefathers already possessed a long time ago.

Classical concepts

What we have said up to now fits nicely into Darwin's idea of how biological evolution is determined by variation, selection, and adaptation. Nature does her job by bringing random variations among organisms into play with the environment. Some of these variations functionally fit better into the environment than others, and the organisms with a better fit are more adapted to survive and reproduce than others. But let us not forget Bohr.

Why did Bohr believe that ordinary concepts such as unity, movement, velocity, the change of velocity, space, time, and causation – and their physical equivalences which he mentioned as the classical concepts – were indispensable for any description of physical experience including that of the quantum world? Was it because he believed (much like Kant) that human beings are restricted by a priori reasons to use certain basic categories whose existence act as a transcendental precondition for human experience, or did he had a more naturalistic view in mind? Bohr seems to think of the classical concepts as a kind of Kantian categories of understanding, which are necessary for human beings to have in order to organize their sense impressions and thereby making experience possible. I have once called Bohr a pragmatized Kantian, because I then thought, and still believe it for the matter, that the Danish philosopher Harald Høffding was Bohr's philosophical mentor, and that Høffding was definitely influenced both by Kant and by the American Pragmatists, especially William James. [1] However, there is more to the story.

Let me point to three different passages taken from Bohr's writings in which he indicated that we should pay attention to a broader naturalistic perspective on what he was up to while discussing classical concepts.

> "All account of physical experience is, of course, ultimately based on common language, *adapted to* orientation in our surroundings and to tracing relationship between cause and effect." [2]

> From a logical standpoint, we can by an objective description only understand a communication of experience to others by means of a language which does no admit ambiguity as regards the perception of such communications. In classical physics, this goal was secured by the circumstance that, apart from unessential conventions of terminology, the description is based on pictures and ideas embodied in common language, *adapted to* our orientation in daily-life events." [3]

> “The main point to realize is that all knowledge presents itself within a conceptual framework *adapted to* account for previous experience and that such frame may prove too narrow to comprehend new experiences.” [4]

As one can see from these three quotations in which I have highlighted his use of the word “adapted to”, Bohr believed that the classical concepts were not accidental to our common language but were part of the conceptual framework now embodied in this language. Originally this language evolved by being adapted to our perceptual experience.

We may give a more precise analysis of Bohr’s argument. First I want to lay out what I will call his indispensability thesis and his adaptation thesis, respectively.

> *Bohr’s indispensability thesis*: It states that the classical concepts are indispensable for any physical description since these concepts are already embodied in the ordinary language of perception before they receive a physical explication.

The classical concepts are indispensable because the ordinary language constitutes the only means by which we can unambiguously communicate about our perceptions and actions.

> *Bohr’s adaptation thesis*: It states that any description of physical experience must use a language that reflects those concepts and ideas that have been installed in human beings as a result of our cognitive adaptation to the physical environment.

What we can draw from those two theses is that Bohr was not a transcendentalist in his insistence on the use of classical concepts. Instead he had a naturalistic attitude to how common language came about.

Defending his indispensable thesis, Bohr did not take Kant’s line of thought that the categories of understanding are necessary for human experience because they act as the transcendental conditions for human empirical knowledge. According to Kant, the categories of understanding frame our sense impressions given in the intuition of space and time. However, Bohr argued quite the opposite. Human experience comes first, the categories come second. He seems to say that the categories of understanding stem from human experience, since our common language has been formed by being adapted to human experience.

A naturalistic explanation of the inevitability of classical concepts is then that these concepts are already embedded in our ordinary language as reflecting our innate categories by which our thinking is organized. Hence physics, as an exact empirical discipline about our physical environment, has to adjust its descriptive capacity according to the way we are innately disposed to experiencing the world. Therefore, as long as physics is an empirical discipline, it cannot but be confined to describing the world in terms of those concepts which we are adapted to use and by which we are genetically enforced to convey perceptual information.

In the light of what science knows about genetics and human cognitive evolution Bohr's adaptation thesis makes a lot of sense. Ordinary language is adapted to report about human experience, and similarly human sensory experience is the cognitive disposition to respond to information we receive from the external world through our sense organs. Again such a disposition is based on our biological adaptation to the physical environment in which our non-linguistic predecessors lived. The evolution of Homo sapiens also gave rise to a proliferation of abstract and reflective thinking from which both mathematics and physics have benefitted. A feature strongly connected to human thinking is this thinking's ability to operate consciously and to become the content of its own reflection. Most of our experiential understanding inherited from our non-human forefather takes place without reflective thinking, but when we by evolution gained the disposition to form this kind of thinking, the road opened for more and more sophisticated reasoning. Abstract thinking goes beyond our sensory experience and creates concepts which may or may not have a real origin in perception. But without an unambiguous connection to human experience which traces it back to perceptual categories, such abstract thinking has a tendency to fool its thinkers to believe that it objectively represents something separated from our experience. This is what happens, say, whenever scientists and philosophers believe that numbers are real abstract entities, and not abstracted entities, or believe that universals are real abstract entities which have not been constructed by us. Numbers and abstract concepts are constructed for a purpose. They help us to organize our experiential understanding and provide tools for improving rational thinking.

The correspondence principle

Assuming that the basic categories and schemes for perception and reasoning were already in place long before our common language evolved has far reaching significance for our understanding of the development of knowledge. Since physics as an empirical discipline is grounded in experience it has to be in accordance with the way we perceptually grasp the world around us. In my opinion that was one of the main insights Bohr had when he formulated his principle of correspondence. Very early he realized that even though the world of microscopic objects required a new theory that incorporates the quantum of action, and therefore deviates from classical physics, such a theory needs to have the same empirical consequences as classical physics. For Bohr as well as Heisenberg it became a guiding principle of theory construction that classical physics and the new theory had an empirical overlap. This guiding principle he called the principle of correspondence. Technically speaking one formulation of the principle maintains that the frequencies, associated with the transition between two states, "in the limit where the motions in successive stationary states comparatively differ very little from each other, will tend to coincide with the frequencies to be expected on the ordinary theory of radiation from the motion of the system in the stationary states." [5] But this requirement makes sense only if we can compare predictions made by the two theories with the similar empirical observations. And this is possible only if the concepts in terms of which we describe our experience are the same. These concepts are the classical terms.

Indeed, Bohr's view on correspondence and the indispensability of classical concepts upholds a very anti-Kuhnian perspective on scientific revolutions. But it is definitely a Darwinian perspective. Had Kuhn not been under such a strong influence of Quine's anti-Darwinistic claim that the meaning of words – even the basic terms of experience – are entirely determined by their place in the linguistic system, he would perhaps never have argued that two succeeding paradigms are incommensurable and that observation connected with these paradigms cannot appeal to a common set of perceptual descriptions. Bohr saw the situation quite differently. We can understand a theory in relation to its empirical content, but this content has to be expressed in terms of concepts that are embodied in our common language as adapted to our experience. Thus we can compare the two theories with respect to how successfully they allow us to communicate our physical observation. Whatever theory science invents in its search for understanding nature, it must always account for its observation in terms that connect it to observations that have been accounted for by earlier theories.

Contextualism

So Bohr had his naturalistic reasons to argue that the classical concepts are indispensable for our description of nature. Now Bohr argued: Since the quantum of action constitutes the foundational basis for quantum mechanics, the conditions under which we may use the classical concepts have changed. This leads to his definability thesis:

> *The definability thesis*: It specifies the conditions under which it is meaningful to apply classical concepts to a quantum system by restricting the application of classical concepts in quantum mechanics to a specific setting with a definite outcome.

Discussing the distinct outcomes under the variation of the double-slit experiments Bohr said: "Obviously, "these [kinds of] facts not only set a limit to the extent the information is obtainable by measurements, but they also set the limit to the *meaning* which we may attribute to such information." [6]

An obvious reaction is to ask: "Why?" Apparently, the answer lies in the scope of *the adaptation thesis*. Natural, experience-based, concepts, like the classical concepts, apply meaningfully only to physical states of a system that are directly accessible to our experience. We can use them for grasping experience and nothing else. Thus Bohr argued that the classical concepts did not apply to the objects themselves but to what could become the direct object of our experience such as the experimental apparatus and the effect the quantum object may have on the apparatus whenever a measurement is performed and a certain outcome is observed. One could say that it is the experimental context which determines whether or not the right conditions are being fulfilled under which it makes sense to assign a classical property to the system. Thus the meaning of the classical terms becomes context dependent.

In general, contextualism about meaning can be defined as the position that sees the meaning of a term or a concept to be dependent on the situation in which it is applied, stated, uttered, used, etc., which may include a direct or an indirect reference to the speaker. If somebody says “I plan to go to Nice” then, of course, there is a direct reference to the speaker. It depends on who the speaker is whether the utterance is true or not. The context of utterance, including a reference to the speaker, determines the meaning of the sentence. But also sentences with an indirect reference to the speaker are context dependent. If somebody claims, “Here is no one”, it means that there is nobody other than me, whoever “me” refers to. Such sentences are also context-dependent. But is it possible for sentences to have a context-dependent meaning and the context is not being determined directly or indirectly by the speaker? Can the meaning of an utterance depend on context that is objective?

Some authors, like John Searle, have argued that the meaning of all statements has a contextual part. [7] If someone says “The cat is on the doormat”, such an utterance is true, claims Searle, in a situation in which the cat and the mat is placed in an earthly environment where gravitation holds the doormat and the cat to the ground, where the cat is not suspended in a wire over the doormat, etc. If the cat and the doormat are in a spaceship and are touching one another, we would not say that the statement “The cat is on the doormat” is true. The problem with Searle’s suggestion is not that he may or may not be correct, I think, but that it takes away the motivation for declaring a particular interpretation to be contextualistic in quantum mechanics. If Searle is correct, and in fact I think he is, the consequence would be that all interpretations would be more or less contextual. So the question is whether we can find a way to distinguish between statements like “The cat is on the doormat” and “The electron in the left wing of the experiment has a spin up”.

I take that such a distinction is possible. It is the cat that has decided by itself to be on the doormat; but it is we who decide to measure the atomic object in a certain way. Bohr emphasized more than once that the experimenter makes the decision by selecting which kind of experiment he wants to perform. But when the decision has been made, the experiment would be operating by itself, and the agent would be completely detached from the result produced. From that moment he has determined the experimental context and the experiment is running he would have no influence on his own later observation. To put it in this way: According to Bohr, any context which the agent may select is an objective one, but what he or she selects is actually becoming a context for the use of a specific classical concept, because the agent has selected what kind of measurement the system is supposed to undergo. By making his or her choice of the experimental context the agent has chosen the conditions under which it makes sense to apply a specific concept.

Bohr seems to subscribe to two types of contextualism with respect to the use of classical concepts which we respectively may call 1) *setting contextualism*, and 2) *shifting cut contextualism*. Setting contextualism follows from the definability thesis which states that the context, in which the measurement takes place, i.e. the setting, has to be included in the specification of the conditions under which the use of a classical concept is well-defined. Thus Bohr is a contextualist in the sense that the ascription of classical concepts to a quantum system makes sense only in relation to an experimental context. His argument for setting conceptualism may be developed a bit more.

The indispensable thesis states that all physical experience has to be described in terms of the classical concepts, whereas *the adaptation thesis* claims that the classical concepts are properly used only within those areas of sensory experience from which they have evolved. The *indispensability thesis* and the *adaptation thesis,* together with the discovery of Planck's constant, imply that the definability thesis holds for those cases where we have determinate observational results. Hence the *definability thesis* states that experience-adapted notions are applicable in quantum mechanics only if the use of these notions corresponds to an experimental arrangement that actually brings about an appropriate observation or measurement.

The other version of contextualism, shifting cut contextualism, is much less recognized among scientists with little knowledge of what Bohr actually maintained. Bohr has often been accused of drawing a distinction between quantum and classical physics along the same line as the distinction between microscopic and macroscopic objects. The claim is that Bohr should have urged that microscopic objects were always treated by quantum physics, whereas microscopic objects, including the measuring apparatus, should be described in terms of classical physics. But there is little evidence for such a postulate. In fact he would not deny that one could use the quantum mechanical formalism on any possible macroscopic objects as long as some part of the object, or another macroscopic object, acting as a measuring instrument, is not included in the quantum mechanical description but instead to be accounted for in terms of classical physics. Indeed, the indispensability thesis demands such a requirement since all experience can be grasped in classical terms only.

Already in Bohr's reply to Einstein, Podolsky, and Rosen we find an expression which shows that he was a shifting cut contextualist.

> This necessity of discriminating in each experimental arrangement between those parts of the physical system considered which are to be treated as measuring instruments and those which constitute the objects under investigation may indeed be said to form a *principal distinction between classical and quantum-mechanical description of physical phenomena.* It is true that the place within each measuring procedure where this discrimination is made is in both cases largely a matter of convenience. [8]

The separation of the quantum system from the classical setting in an experimental setup – and therefore which parts of the setup should be treated quantum mechanically and which parts classically is not a distinction between microscopic and macroscopic properties but depends on what is convenient and therefore what we want to know. This means that sometimes parts of the instruments may be treated as parts of the object under investigation, sometimes as a measuring instrument depending on the chosen context. The cut between object and the setting hinges on the context of our epistemic interests; but that the cut has to be made somewhere is epistemically necessary for us to grasp those parts that give rise to our physical experience. Thus the shifting cut contextualism implies setting contextualism.

Relationalism

Finally I want to discuss whether or not Bohr's contextualism implies a form of relationism. What does it mean for a quantum object to have a relational property? Well, it seems to indicate that an object has a property only in virtue of its relation to another object. For instance, being a man or a woman is an *intrinsic property* of a person, whereas being a father or a mother is a *relational property* because a person possesses this property only if he or she is related to another person who is said to be his or her child. This is the way we have defined being a father or a mother. It is quite clear from the following quotation that Bohr did not think that the measurement of non-commuting variables give us information about intrinsic properties.

> "In this respect we must, on the one hand, realize that the aim of every physical experiment – to gain knowledge under reproducible and communicable conditions – leaves us no choice but to use everyday concepts, perhaps refined by the terminology of classical physics, not only in all accounts of the construction and manipulation of the measuring instruments but also in the description of the actual experimental results. On the other hand, it is equally important to understand that just this circumstance implies that no result of an experiment concerning a phenomenon which, in principle, lies outside the range of classical physics can be interpreted as giving information about independent properties of the objects, but is inherently connected with a definite situation in the description of which the measuring instruments interacting with the objects also enter essentially." [9]

But did he understand a measurement as giving information about a relational property? For some time I had doubts about what Bohr's view really was. However, my opinion is that he might have been thinking about relational properties in contrast to intrinsic properties.

In many cases the context seems to allow us to ascribe relational properties to a system. Relational properties may not be permanent but temporary. I possess the property of driving a car, only when I am in the context of sitting in a car and steering it along the road. Apparently, the context defines my property as driving, and when I am in this context I automatically possess this property. To understand my argument in favour of such a view we should note that Bohr used the term "independent" properties. This seems to indicate that we may gain information about "non-independent" properties. Relational properties are non-independent properties. A father cannot be a father independently of his child. It also seems to be the case that when you measure something and get some information, what you then get information about allows you to assign a certain value to what you measure. A measurement is not a measurement if the information does not stem from the apparatus interacting with an object that is different from the apparatus. In combination these two arguments seem to show that Bohr believed that the instrument by its interaction with a quantum object establishes the conditions under which it makes sense to talk about a relational property. But this is not a view free of problems.

It is well known that Bohr thought that the quantum revolution required that the term "phenomenon" was not limited to the appearance of the object under investigation but that it referred to observation-cum-instrument. In 1948 he argued:

> Thus, phrases often found in the physical literature, as "disturbance of phenomena by observation" or "creation of physical attributes of objects by measurements" represent a use of words like "phenomena" and "observation" as well as "attribute" and "measurement" which is hardly compatible with common usage and practical definition and, therefore, apt to cause confusion. As a more appropriate way of expression one may strongly advocate limitation of the use of the word *phenomenon* to refer exclusively to observations obtained under specified circumstances, including an account of the whole experiment. [10]

One important point made in this passage is to my mind that Bohr denies that the agent creates the physical attribute he or she measures. But this does not rule out that agents may get information about a relational property. If I am taller than my wife it is fact about a property of me in relation to her which neither I nor she creates. What the agent may do, and probably does, is that he or she creates the physical conditions under which it is semantically meaningful to ascribe a classical property to the system. But this does not give us an answer about whether Bohr believed that the atomic object could have a property in relation to an experimental setting.

We are left with two options with respect to Bohr´s view of relational properties:

1. Classical concepts apply to quantum object-cum-setting-cum-outcome as one whole phenomenon, but certainly not to the object alone or the object in relation to a setting and an actual measurement. We would then seem to deny that classical concepts concern any relational properties between the object and the context.

2. Classical concepts apply to a quantum object in relation to a particular setting and a certain outcome, because the setting is a part of the truth/assertability conditions under which it only makes sense to ascribe such concepts to the object.

Only in case 2 do we have reason to believe that classical concepts are concerned with relational properties. I think it is difficult, merely based on the above quotation, to say whether Bohr considered classical concepts as assigned to relational properties or to the entire system. But if we can draw any ontological conclusion from Bohr's epistemology of experiments, I think it is reasonable to hold that Bohr would be open for a suggestion that when the agent registers a certain outcome in relation to an experiment, the agent is in a position where he or she can legitimately assign a property to the object under scrutiny.

One way or the other, Bohr was really not very interested in ontological questions. Objectivity for him what not to set the ontology straight. Objectivity had to do with unambiguous communication, and he had no intention of finding out about whether relational properties were real or not independently of the conditions for description as they have been redefined in quantum mechanics. If the experimental conditions were such that you could communicate unambiguously in terms of classical physics about the result of a measurement, we would be able to understand each other, and there would be no further problem of how the world really is.

Conclusion

Bohr insisted that the classical concepts were necessary for any form of communication about our physical experience. The reason seems to be that the classical concepts had their counterpart in ordinary language which had evolved in adaptation to our perceptual experience. Our cognition is not based on how we structure the world from sensual forms and categories that exist prior to all experience as Kant's transcendental philosophy maintains. It is largely, but not exclusively, of course, the experiential reality that have structured the natural language and forced its categories on us. But in order for the use of the classical concepts to be unambiguous, it is necessary, Bohr thought, to tie their use to the manifestation of certain outcomes in relation to certain instrumental arrangements. In this manner Bohr believed that we are able to keep a fair understanding of quantum phenomena which have played no role for human evolution.

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