

Interpretation in the Natural Sciences

Jan Faye
University of Copenhagen
Njalsgade 80. DK-2500 Copenhagen S.
faye@hum.ku.dk

The distinction between the natural sciences and the liberal arts is usually regarded as significant. Not only do they deal with ontologically distinct objects, but the ways they come to terms with these objects are very different. In philosophy of science there has been a focus on explanation, in contrast to interpretation, because providing explanation was thought to be a key issue in the natural sciences. Since Carl Hempel's seminal works on explanation, the world of philosophy has seen a growing body of literature devoted to explanation. The results have been prolific. Elsewhere I have argue in favour of a pragmatic-rhetorical theory of explanation, and it is in light of this theory that I suggest we can understand interpretation in the natural sciences [5], [8].

Although philosophers of science refer to both scientists' understanding and the interpretation of data, measurements, and theories in their accounts of the natural sciences, they make little attempt to develop philosophical theories of understanding and interpretation to grasp this side of the formation of scientific knowledge. This is undoubtedly due to the old, but long standing, positivistic distinction between the *context of discovery* and the *context of justification*. The context of discovery, where interpretation is thought to belong, is regarded as part of psychology, whereas the context of

justification, including explanation, is seen as an object to which logical and philosophical methods apply. After Thomas S. Kuhn, modern philosophers of science tend to be more sceptical about the possibility of drawing such a sharp distinction.

In the present paper it will be argued that the natural sciences involve interpretation as much as the human sciences. I distinguish between two notions of interpretation which are rarely set apart. One is concerned with the question what X represents; the other deals with the question of how to represent Y . In the first sense interpretation can be regarded as a form of explanation by which one explains a representational problem.

The Standard Wisdom of Interpretation

In recent years there has been a growing philosophical interest in interpretation. Most of the work on interpretation is still done within the narrow perspective of making sense out of meaning. The problem is, however, that interpretation is not only restricted to meaning within humanities. Interpretation is used within the natural sciences as well.

It is common wisdom that interpretation is associated with the understanding of meaning. The objects of interpretation are considered to be intentional objects or objects having intentional properties. Therefore, interpretation is seen as a process that leads us to an understanding of persons, actions, or products of these actions, such as linguistic expressions, texts, paintings, sculptures, music, film, dance, plays and social institutions. What we understand is the meaning being expressed by these products and an interpreting activity is what shows the way to this meaning. So an interpretation is

a response to a question like “What is the meaning of X?” An interpretation states or formulates some meaning, significance, character, etc., and often interpretation is characterized in semantic terms. But this view is too narrow and simplistic.

In one of his many studies of interpretation, Jerrold Levinson ([10]:3) characterizes the received wisdom of semantic interpretation in three points:

- 1) “Interpretation standardly involves the formation and entertaining of hypotheses, the weighing of possibilities of meaning, significance, role, or function in regard to a given phenomenon or thing.”
- 2) “Interpretation standardly involves conscious, deliberate reflection, explicit reasoning, or the like. Not all perception or understanding or apprehension is properly viewed as interpretative, some such is clearly preinterpretative, and serves as that on which interpretation rests, or that from which it departs.”
- 3) “Interpretation standardly presupposes the nonobviousness of what is being interpreted; if one simply and securely sees that X is F, if there is no question of choosing or deciding to do so, then remarking that X is F is not a matter of interpreting it.”

The received wisdom has been called into question by so-called post-modern philosophers who argue that every belief, idea, or opinion is acquired in virtue of an interpretation. There is, however, very little that supports such an extreme view [7].

Levinson is no post-modern philosopher. He more or less accepts “these three features as definitive of any activity worth labelling interpretative.” I very much agree.

The first feature, mentioned by Levinson, is that interpretation consists of ‘formation and entertaining of hypotheses’. If we include the hypothetical character as a necessary feature of interpretation, we may define interpretation as

- (I) The connection between X and Y constitutes an interpretation for some person P , if and only if (i) P believes that X represents Y because X is in some manner attached to Y , and (ii) P 's belief as expressed in (i) is presented as the result of a hypothesis. (Cf. [6]:56)

How X is attached to Y is determined by the kind of objects being interpreted. If X and Y stand for physical phenomena it may be a case of cause and effect, but if they stand for items relating to human thought and agency, the connection may be intentional or conventional. Thus, there are two kinds of “representing”: causal, as when effects “represent” their causes and therefore act as the evidence for holding certain causes occurred, and non-causal, intentional, or conventional as in what a work of art “represents”.

Levinson believes that interpretation is concerned with meaning, significance, purpose, or role which he associates with semantic issues in a broad sense. For instance, he assumes that interpreting whether or not a rock is a meteorite, an unexpected natural event, readings or measurements are all examples of semantic interpreting, admitting that ‘semantic’ should be understood broadly. As far as interpreting

aims at finding out which conceptual category covers a particular specimen or a natural event, it is certainly justified to call it “semantic.” I think, however, that there are other forms of interpretation that depend on the kind of object under consideration and the epistemic character of one’s representational problem. Hence, I suggest a distinction between proper semantic interpretation as an activity directed towards linguistic or symbolic meaning from other kinds of interpretation such as causal, structural, functional or intentional interpretation.

The third feature of those mentioned above indicates that we make use of an interpreting activity in case we are facing something which we cannot immediately recognize or understand. But, then, how do we differentiate between explanation and interpretation? If both supply the explainees and interpretees with understanding, an obvious answer seems to be that explanation provides understanding in virtue of causation whereas interpretation is occupied with understanding in virtue of meaning. We carry out explanation whenever there is something we don’t understand, and we engage ourselves in interpretation for similar reasons whenever we are facing a representational problem or a representational exigency.

Interpretations in Science

We do talk about interpretation in the natural sciences. Think of interpretation of visual phenomena, experiments, measuring effects, data, formalisms, mathematical models and theories. Interpretation takes place in cases where we want to understand what is going on in astronomy, physics, chemistry, and biology. If this is true, then the

objects of interpretation need not be intentional objects. Interpretation is not merely oriented towards objects that carry linguistic or symbolic meaning like languages, actions, and social institutions, but just as well towards the unanimated and meaningless nature. Interpretation should not be characterized as a cognitive activity which involves understanding meaning. Being a cognitive activity it should be characterized with respect to what it does with the interpreter. The functional role of interpretation is to make a conventional sign or a natural phenomenon *meaningful* for the interpreter; that is its role is to provide him or her with a further understanding of the object in question.

In science what makes a phenomenon meaningful is our ability to place that phenomenon into a causal story or to subsume it under a general law. Looking for applications of the notion of natural law or the notion of causation seems to be the way we attempt to understand things in science. As in other areas, the state of understanding is reached when a badly understood phenomenon is connected with some other phenomenon according to our background assumptions. So a question like "What does X mean?" may in the right context be equivalent to posing the question "What causes X?" or "What is X evidence of?"

So whereas the objects of interpretation may differ, it also seems to be the case, regardless of the nature of the object under investigation, that the cognitive act of interpreting within science and humanities have something in common. What turns a question into one about interpretation is not the kind of object that is subject of the question but the kind of epistemic context in which this question appears. Such an interpretation-seeking question arises, so it seems, in

an epistemic context in which the interpreter faces a representational problem.

A person may be presented with an interpretation by another person as an appropriate reply to her interpretation-seeking question. But if nobody (to her knowledge) is able to answer her, she has to respond herself. Whenever a person comes up with a hypothetical answer as a reply to questions like “What does *X* mean?” etc., she is involved in an act of interpretation. We are engaged in an interpretive process in situations where we try to understand (or improve our understanding of) a particular phenomenon – whether it is verbal meaning, visual signs or unknown or unexpected natural events – and whenever we can get no help from other people who may understand what we actually don’t understand. We interpret by asking interpretation-seeking questions and then go on by answering them in terms of positing a hypothesis. In situations, which produce an underdetermined answer, a more provisional hypothesis is formed. But interpretation need not be more tentative than explanation; it simply depends on the consensus of the interpretive community.

Strangely enough, philosophers of science who have been occupied with explanation have paid little interest in characterizing interpretation in spite of the fact that they themselves speak of interpretation.¹ This lack of interest is partly due to the fact, I think, that they intuitively assume that these two concepts belong to each side of Reichenbach’s famous distinction between the context of discovery and the context of justification. Thus, interpretation has to do with the context of discovery, whereas explanation belongs to the

¹ An exception is [12] in which Bas van Fraassen and Jill Sigman write about interpretation in the natural sciences and the fine arts. But van Fraassen does not attempt to relate their discussion of interpretation to his pragmatic theory of explanation.

context of justification. They simply didn't take the notion of interpretation serious because they considered it to be too psychological with its close ties to meaning and understanding; tacitly, they seem to have accepted the hermeneutic division between explanation and understanding as important for a characterization of the difference between the natural sciences and the humanities. In contrast, hermeneutic philosophers have dealt with understanding and interpretation, but paid no attention to explanation. An important consequence is that the rigorousness of the various accounts of explanation is missing with respect to the accounts of interpretation. Explanation was the object of a logical analysis, interpretation involved a psychological specification.

Two Forms of Interpretation

But there is more to interpretation than the fact that the natural sciences also make use of it. There is a general ambiguity in the way we think of interpretation which seems to have gone unnoticed. Sometimes the object of an interpretation is what is considered to represent something such as signs, symbols, and symptoms. The interpretation-seeking question is then questions like "What does X mean?", "What does X stand for?", "What is X evidence for?", "What kind of role does X have?", or "What causes X?" We shall call a response to any such questions, for the lack of anything better, a *determinative* interpretation.²

² Levinson isolates two notions of interpretation which he calls the 'determinative mode of interpretation' and the 'exploratory modes of interpretation'. The first is concerned with the question "What *does* it means"; the second is dealing with "What could it mean?" Even though the first notion is similar to the one suggested here, the second is not.

In science these kinds of questions are posed in connection with data, observation, mathematical models, and theories. The industry around concocting interpretations of quantum mechanics reveals better than anything that determinative interpretation in science takes place on the scale of metaphysics. But the separation of mathematical models and physical reality is also a place for determinative interpretation. This is so because there is no blank inference from a statement that X is mathematically well-defined or X figures in a mathematical structure to a claim that X has physical meaning, or X is physically real. A mathematical model may have a surplus structure which has no real counterpart. Take, for instance, the existence of advanced solutions to the Maxwell equations or the negative energy solutions of the relativistic four-momentum vector. From these solutions we cannot automatically deduce the existence of backward causation of some sort.

Finally, on the level of discovery of new data or measurement results, a great amount of determinative interpretation is present all the time. For instance, the observation of type 1a supernovas by Perlmutter et al. and Smith et al. in the last 7 years has shown that the light is dimmer when comparing light curves with redshifts than would be expected if the Universe were expanding or slowing down at a constant rate. This observation is then interpreted as a sign that the expansion of the Universe is increasing, but also the experimental data, which define the actual light curve and redshift, are constructed based on determinative interpretations.³

³ See Saul Perlmutter's review article [11], in which he talks about "Such a supernova CAT-scan is difficult to interpret" p.53. A supernova CAT-scan is the measurement of the atmosphere of the exploding type 1a supernova. When the outer layer of atmosphere is

Sometimes, however, interpretation cannot be considered a cognitive response to a question like “What does X mean?” or similar questions. In these cases the object of interpretation is a phenomenon Y that lacks a proper conceptual or mathematical representation. Facing this kind of epistemic problem the interpretative questions are like “What is Y ?” or “How can Y be represented?” We shall call a proper response to such a question an *investigative* interpretation. Clearly, there is a difference here between the two types of interpretation. The distinction is between whether or not it is the representation or the would-be represented that is the object of one’s curiosity and attempts of understanding.

A determinative interpretation suggesting whether or not X represents Y is a form of explanations, whereas an investigative interpretation telling us how Y may be represented can be seen as a conceptual or theoretical presentation of Y which may then be used for explanatory purposes. Determinative interpretations act as explanations of meaning in a broad sense. It is not the degree of certainty being associated with the response which determines whether it should be considered as an interpretation or an explanation.

In the constellation Norma, 10,000 light years away, astronomers recently discovered a strange object in the centre of a supernova remnant [4]. At first sight it looks like a neutron star. It is estimated to be about 20 km across like other neutron stars. But a closer study shows that its X-ray outburst is tens of thousands of times longer than expected from newly created neutron stars. And 1E161348-5055, as the object is called, is still young, approximately 2,000 years. So we have a

thinning it allows us to observe the inner layers and the changing luminosity of the energy spectrum.

situation which calls for interpretation: What does this mean? In the actual context this question is identical to "What causes the abnormal behaviour of 1E?" One answer is that the object is a magnetar, i.e. an unusual subclass of neutrons that is highly magnetized. However, these spin several times faster than this object. The suggestion is then that the object is surrounded by a debris disk slowing down the rotation of the star. Nothing like this has ever been observed before. Another answer might be that 1E is a part of a binary system where the other half is a low mass object smaller than our sun. Similar systems are known but in general they are millions of times older. Thus, scientists do not yet know how to explain the unusual behaviour of this, object and until one of these speculations is confirmed, they all count as possible interpretations of data.

On the other hand, every proposal of classifying and representing an object or a class of objects, a structure or a class of structures, a relation or a class of relations in a non-obvious and unexpected way is an example of investigative interpretation. Famous examples are Copernicus' heliocentric model, Newton's three laws, Bohr's semi-classical model of the atom, or Einstein's field equations around the time when these constructions were presented to the scientific world. It was not until later that these conceptual constructions lost their hypothetical and tentative character and gained their emblematic nature. This happened at the very moment the scientific community accepted them, at least for a while, as being empirically successful and therefore correctly representing the observable fact.

The above example of 1E161348-5055 is not a case of investigative interpretation. Based on models of star evolutions and

the data of observation, astronomers still believe that the object left behind is a neutron star. It is only the X-ray outburst data that does not fit neutron stars seen so far. The astronomers do not even question what these data are evidence of. They agree about their interpretation. They merely want to know what causes them to stand out from similar data from other neutron stars.

Investigative interpretations are concerned with classification and categorization. A realist concerning natural kinds might argue that this kind of interpretation is explanatory because classifications by theories are literally true. But a more pragmatic view on natural kinds and theories may take them to be vocabularies or conceptual tools for the construction of models which then can be used to give explanation. Thus, investigative interpretations are necessary presuppositions for generating explanations.

Interpretation and what-questions

Often explanations are associated with responses to why-questions. So a possible way of trying to separate explanation from interpretation would be to suggest that an explanation-seeking question is a why-question whereas an interpretation-seeking question is a what-question. The idea is that we ask what-questions as long as we have very little or no knowledge of the subject being asked about. But as soon as we acquire more information about the subject we begin to formulate how-questions and finally we pose why-questions to get the ultimate information. A typical example would be one in which we start out with "What is it?" Depending on the context that gives rise to

the question, the requested information seems to require either a determinative or an investigative interpretation.

Assume you are looking at a bright white spot on a starry sky. You know, as part of your background knowledge, that what you see is not a planet or a comet, but a hitherto unobserved big and bright star. This was also Tycho's conclusion after he had argued, based on observation of no parallax, that the very bright spot he saw in the constellation Cassiopeia didn't belong to the spheres of the planets. The question "What is it?" then became equivalent to a question like "What does an unexpectedly appearing star mean?" The interpreting answer might then be "It's a newborn star." Tycho, believing that the star he saw shining bright in the sky year 1572 was a new star, was in fact wrong in his interpretation of the phenomenon. But not until last century did astronomers realize that the phenomenon witnessed by Tycho was a star dying of age. It was a supernova. Baade and Zwicky [1] were the first to interpret observational data of suddenly very bright objects by separating common novae from supernovae in terms of their brightness. Furthermore, based on the luminosity of observed supernovae and by using Einstein's mass-energy equation they calculated the amount of mass being dispersed into space. Their conclusion was "that the phenomenon of a super-nova represents the transition of an ordinary star into a body of considerably smaller mass." (p.258) But they did not account for the nature of this object.

In the consecutive paper published in the same issue, Baade and Zwicky [2] proposed that the object might be a neutron star. "With all reserve we advance the view that a super-nova represents the transition of an ordinary star into a neutron star, consisting mainly of neutrons." (p. 263). This suggestion was made just a year after James

Chadwick discovered the neutron. Thus, you may say that their supernova hypothesis was an example of a determinative interpretation, whereas the neutron star hypothesis may count as an example of an investigative interpretation. It was mainly due to theoretical reasons that they identified the leftover of a supernova explosion as a neutron star because such a star might “posses a very small radius and an extremely high density.” This, they noticed, is a result of the fact that neutrons can be packed much more closely than electrons and nuclei.

The next question might then be something like “How does a supernova develop?” A qualified response to this question would, assuming that light coming from a supernova contains information about this process, require an answer to the following question: “How does the light of a supernova vary over time?” Baade and Zwicky were not able to answer any of these questions in 1934. As they stated: “A more detailed discussion of the super-nova process must be postponed until accurate light-curves and high-dispersion spectra are available. Unfortunately, at the present time only a few underexposed spectra of super-novae are available, and it has not thus far been possible to interpret them.” (p. 259) An answer came in 1941 when Rudolph Minkowski suggested that supernova could be divided into type I and type II according to their different spectra and different light-curves.

The same year, an answer to the question “How does a supernova take place?” appeared. The idea was that a star becomes a supernova through an explosion and a mechanics was suggested for how such an explosion was possible. It was only thereafter that astronomers had reached a level of understanding where the stadium of explanation could be introduced. Astronomers could now hope to answer a

question like “Why does a supernova explosion happen?” However, it was not until 1960, after the standard theory of stellar nucleosynthesis had come to light [3], that Fred Hoyle and William Fowler [9] were able to set up a quantitative theory of supernovas. According to this theory, the explosion of type I supernovas is caused by the “ignition” of heavier nucleons, especially carbon, in the centre of the stars; whereas type II is generated by an implosion of non-degenerated matter to a neutron star in the core of very heavy stars. A reasonable theory of supernovas was available around 1970, although a revised and even better understanding arose around 1990. This was a result of the fact that the astronomers became aware of the explanatory advantage it had to make a finer distinction among supernovas (type Ia, Ib, Ic, IIP and IIL) and to combine nuclear physics with hydrodynamical models (describing shock waves.)

Unfortunately, the proposed distinction between explanation and interpretation does not work. There are four reasons for this: 1) we can rephrase some what-questions as why-questions, and vice versa. For instance, “What makes X happen?” is semantically equivalent to “Why does X happen?” The questioner may therefore possess as little or as much information about X when he or she puts forward a why-question or a what-question. 2) Likewise, some what-questions can be translated into how-questions, and vice versa. The question “What is the relationship between X and Y?” has the same semantic content as “How does X relate to Y?” 3) It is not every what-question that invites an interpretation. Take examples like “What time is it?” and “What is an electron?” Similarly, not all why-questions are requests for explanation. It depends on the actual context whether or not they are. 4) Finally, everyone will probably agree that a response to a question

such as “Who is the murder?” “When was the victim killed?” or “Where did the killing take place?” may be classified as an interpretation given the epistemic uncertainty by which the answer is produced. But it also seems to be the case that some questions formulated as why-questions or how-questions may only be addressed tentatively and answered with a great amount of doubt. Any such question addressed in terms of a hypothesis that is not testable, or even not tested, can rightly be called an interpretative inquiry. For instance, nobody knows why the universe began expanding around 14 billion years ago, and any proposal based on theoretical and experimental information has the character of an interpretation.

Interpretation as a response to a representational question

A determinative interpretation is, I suggest, an explanation that intends to solve a cognitive problem concerning understanding a representational issue. It is a result of a cognitive activity by which one explains *the representational role* of some given phenomenon. Inquiries about the representational role appear in connection with the consideration of natural effects, data, measurements, objects, signs, symbols, texts, or actions where the inquirer does have an epistemic problem of not understanding *the representative task of what* she is seeing, hearing, reading, observing, etc. A determinative interpretation arises in contexts where a phenomenon is considered to represent something else, say a peak on a graph, but where there are doubts about what the phenomenon is a sign of.

Similarly, we can say that an investigative interpretation takes place whenever the inquirer has an epistemic problem of not

understanding *what* she is seeing, hearing, reading, observing, etc. She then attempts to solve her cognitive disability by looking for a possible candidate of an appropriate conceptual classification or theoretical construction. Such a cognitive description may then be used with the purpose of explanation.

Thus, we ask for an interpretation whenever we believe that we do not possess the right and/or necessary information to solve a representational problem but believe that we, or somebody else, may have the capacity to provide us with a suggestive clue. An appropriate response is generated by the interpreter based upon a certain understanding of the cognitive problem raised by the interpretation-seeking question. As we have seen from the supernova examples, what is considered a relevant response is constrained by our background assumptions. Tycho assumed that a bright object in the sky belonged to the stellar sphere in case it didn't show any parallax, an assumption that has never been put into doubt. Similarly, Baade and Zwicky presupposed that Einstein's mass-energy formula is correct and that Chadwick had discovered electrically neutral particles with no electrostatic forces between them and therefore densely packable. The relevant hypothesis in Tycho's understanding was that the sudden appearance of a star presented a birth whereas in the Baade and Zwicky's understanding, the same phenomenon pointed to a supernova, i.e. a star dying of age in transition from the stage of an ordinary star to the stage of a neutron star.

So if no acceptable explanation of a certain phenomenon is available, we must ask the right interpretation-seeking questions and answer them by proposing a relevant hypothesis that can be used for explanation. Promoting a particular answer is exactly what

interpretation is. In situations where we understand things straight away, where we have knowledge of the facts involved and of the representational conventions, no interpretation is needed, and any response to a representational question, which relies on these facts and conventions, does not involve an interpretation.

A pragmatic notion of interpretation sees it as a context-dependent response to an interpretation-seeking question, and because the role of interpretation is more or less the same as that of explanation we may apply a pragmatic-rhetorical theory of explanation to interpretation as well. According to this approach, an interpretation is a deliberately produced answer to an interpretation-seeking question. How the interpretation turns out depends in part on the process and therefore, among other things, on the aim and cognitive interest of those who do the interpretive work. My claim is that the type of interpretation is determined partly by the interpreter and partly by the object of the interpretation.

Indeed, the object plays an important role in the interpreter's selection of the relevant type of interpretation. The interpreter constrains her interpretation in accordance with her grasp of the object by choosing the type of interpretation accordingly. A natural phenomenon will give rise to a different kind of interpretation than a text or a painting. But the interpreter's knowledge of the situation, her goals and interests are also elements in determining the form of interpretation. Thus the person's background assumptions and his pre-understanding of the object influence the hypothesis she generates. This applies not only to the form of hypothesis, but to the content as well. The content of an interpretation is as much context-dependent as

its form. But, again, the object of interpretation imposes some constraints on any possible understanding of the content.

Conclusion

Interpretation issues an answer to a question about the representation of a phenomenon whose comprehension falls outside the inquirer's background knowledge. Whenever we interpret something it is because we can't explain it since we don't understand it. The answer transforms a phenomenon, now understood in terms of some theory, from being somehow unfamiliar to something less unknown. The phenomena, or rather beliefs about the phenomena, are thereby included among that person's background assumptions and connected to his or her background knowledge. Phenomena become intelligible and meaningful because *by attributing identity to them or providing a representational explanation of them, an interpretation brings them in connection with our theories or belief systems*. Thus, the aim of interpretation is to reach a proper understanding of a representational phenomenon regardless of whether the proposed explanatory hypothesis is concerned with traditional meaning, function, intention or causation. In the end an interpretation is a hypothesis which is presented against a background of accepted conventions and ontological assumptions.

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