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On certainty in empirical sciences

“Eigentliche Wissenschaft kann nur diejenige genannt werden, deren Gewissheit apodictisch ist” (“That only can be called science proper whose certainty is apodictic”) is this statement by Kant (*Metaph. Anfangsgründe der Naturwiss.*, 1786, Vorrede, S. V.) valid from today’s perspective? Half a century earlier, Hume had already stated that judgements about facts are not certain, and that those judgements which are certain do not concern facts, but rather the relationships between ideas. Kant, on the other hand, followed in the footsteps of Plato and Descartes – just as Descartes believed that the *a priori* propositions of mathematics also constitute the laws of nature, and to defend this position he created his Copernican conception of the world of experience. The course of scientific development took the path indicated by Hume against Kant. It turned out that *a priori* propositions cannot be applied without reservation in the empirical world, as they concern the meanings of terms, not objects or facts; natural laws and hypotheses are not certain and can be refuted by experience.

The role of such uncertain elements of science presents numerous difficulties for methodologists. They are commonly assigned a supporting role in scientific theories. They are said to be a tool for organizing and recording observational statements, or that they should be understood as guidelines for predicting unknown facts. However, this understanding does not take into account the fact that they are essential components of scientific theories, linked by logical relationships into a whole with other elements of these theories.

In order to define the position of these uncertain elements within a theory, it is essential to consider how they are introduced into the theory, i.e. how they are justified. This is done using methods of probabilistic reasoning. A typical method of this kind is to verify scientific laws and hypotheses by means of observational statements, which we will refer to as verification premises. This method of verification allows us to compare the degrees of probability of the verified statement in terms of different verification premises, or the degrees of probability of different statements in terms of the same premises. Verification methods make it possible to choose from a range of possible laws or hypotheses those whose degree of probability is greatest in terms of given verification premises. There is no verification method that would allow the probability of a certain statement to be determined absolutely, i.e. without referring to circumstantial premises, as the implication of the probability 'if p , then probably q to the degree of u ' differs from the material implication 'if p , then q ', in that it does not allow the use of the cut rule and the conclusion that q is probable to some degree, as is the case in ordinary reasoning by *modus ponens*. In probabilistic reasoning, the cut rule is used only between individual probability relations that are linked by a material implication; suppose that the probability relation 'if p , then q is probable to degree u ' (a) implies 'if p_1 , then q_1 is probable to degree u_1 ' (b) – if (a) is true, then we have the right, as in any inference, to also conclude (b).

The premises for testing laws and hypotheses in empirical sciences are observational statements. They also require testing, where the premises are other observational statements. If, in a given case, an observational statement used as a premise for verification proves to be false, the degree of probability of the statement being verified on the basis of this premise becomes indeterminate.

Theories of empirical sciences are structured around scientific laws, hypotheses, and observational statements (other components of theories can be omitted in these considerations). The elements of a theory are not individual laws, hypotheses, or observational statements, but systems of statements linked together in probabilistic implications, consisting of a statement being tested and the premises for testing it. This is because, as mentioned above, methods of probabilistic reasoning only allow us to establish probabilistic relationships (implications), rather than individual probable statements. Let us express this differently, distinguishing between independent and dependent statements within the theory. Independent statements are those that can be preceded by an assertion sign, i.e. those that we consider to be theory propositions –

dependent statements in theory, on the other hand, are statements that do not appear in it as propositions, but only as elements of functions of truth (implications, alternatives, etc.) or implications of probability. In empirical theories, it is not individual laws, hypotheses, or observational statements that are independent, but only the probability relations that connect them.

Laws and hypotheses are matched to observational statements in such a way that they explain them and allow us to predict the results of subsequent observations; they are, in fact, reasons for observational statements. Every probability relation between the premise p and the law or hypothesis q , which we express in the form of a probabilistic implication 'if p , then q is probable to a degree u ', can be reversed into a material implication 'if q , then p '. Therefore, an empirical theory can be presented either as a system of probabilistic implications between observational statements and laws or hypotheses, or as a system of material implications, which have laws and hypotheses in their antecedents and observational statements in their consequents; we use the latter method when we wish to present the theory in the form of a deductive system.

If a new observation refutes a law or hypothesis, all implications containing that law or hypothesis remain true as implications with a false antecedent; all previously established probability relationships between observational statements as premises for verification and a given law or hypothesis also remain in force, although the conjunction of the new (negative) observation with the previous observations reduces its probability to zero. In other words, statements asserting the degree of probability of a law or hypothesis based on specific premises do not become false, even though the law or hypothesis is refuted by the new observation. In this sense, therefore, they can be considered certain, and a theory composed of statements of this kind satisfies Kant's postulate mentioned at the introduction to these considerations.

But why do such statements not remain within the realm of scientific theory, but are replaced by others containing laws or hypotheses that are as highly probable? When considering this question, it must first be noted that this is not always the case. Clearly false hypotheses are preserved in various theories as conscious fictions if they satisfy certain needs of scientific practice. However, they bring with them a fundamental limitation, namely that, as false, they cannot be further generalized, since every reason for such a false hypothesis would again have to be false. Thus, even if it is preserved as a fiction, it remains, in a sense, on the sidelines and does not become a starting point for further development of the theory. We can ignore this case in further considerations, as

it will not affect the course of our arguments. There is no doubt that scientific theories change and that the postulate of certainty – even though it is preserved in a sense – cannot guarantee them the stability that is usually considered a consequence of certainty.

Laws and hypotheses, which are dependent elements of theory, are not subject to the postulate of certainty, but are nevertheless selected according to the postulate of maximum probability; laws and hypotheses that are most probable on the basis of given verification premises best fulfil their respective tasks, because they explain and allow for the most accurate predictions. Each theory, when considered statically in a specific era of development of knowledge, is a system of probabilistic implications that contain the laws and hypotheses that are most probable due to the resource of observational statements as premises for verification, i.e. based on the extent of experience characterizing that era. The changeability of theories stems from the changeability of the scope of experience, which is constantly expanding and providing new premises for testing laws and hypotheses. These premises give rise to new probabilistic implications, in which laws and hypotheses are assigned changed probabilities. Implications from the previous era of development are superseded by implications from the new era, as they are based on richer empirical material. The volatility of theories is governed by the law of actualization. Theories of the empirical sciences must be rejuvenated in line with the constant enrichment of the world of experience, revealing ever new areas of reality.