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# The Constructive Interpretation of Probability

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【Abstract】This essay suggests a constructive interpretation of probabilities by diagnosing problems of the objective and the epistemic interpretations of probability. According to this interpretation, attributions of the mathematical structure of probability to a given system can be understood as positing constructive theoretical hypotheses showing the relationship among empirical data. The constructive interpretation is applied to comprehend probability claims in the explanation of temporal asymmetrical behaviour of our universe. A new approach interpreting probabilities as constructive theoretical terms enables us to circumvent shortcomings of both objective and subjective interpretation of probability, and appreciate why these interpretations nevertheless appear to be convincing in our case.

【Key Words】The Interpretation of Probabilities, The Objective Interpretation of probability, The Epistemic Interpretations of Probability, The Constructive Interpretation of Probabilities, Temporal Asymmetrical Behaviour of Our Universe

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## 1. Introduction

The objective (frequency and propensity) interpretations of probability, although necessary for understanding scientific theories, fail to provide non-circular understandings of probability. Although the frequency interpretation of probability can be based on the law of large number, the law itself is a probabilistic claim. So, it seems circular in a sense that the frequency interpretation of probability is based on a probability claim. (Skyrms 1980) And the propensity interpretation of probability has similar shortcomings. (Sober 1993) The epistemic interpretations, on the other hand, while solving the above problem, fall short of comprehending how we can extract specific information from the ignorance of a given system. (Fine 1973)

By employing the intuitions of Sklar (1992) and Sober (1993), I have attempted to show that these impasses could be resolved if we view probabilities as constructive theoretical terms that provide significant generalizations about the world. (Yang 2010) From this interpretive framework considering probabilities as constructive theoretical terms, the attributions of the mathematical structure of probability to a given system can be understood as positing theoretical hypotheses showing the relationship among empirical data. In other words, undefined probabilities as certain primitive features of some system gain their empirical meaning by upward rules which decide the way to infer from the observation of frequencies to attributed probabilities, or downward rules which determine how the outcome of frequencies, given attributed probabilities, can be inferred. Sklar maintains that "rather than identifying probability with some actual proportion or frequency, perhaps we ought to take it that such actual frequencies and proportions specify what probability is only by means of their connection to probabilities through these upward and downward rules of inference, rules that connect actual frequencies and proportions to attributed probabilities (Sklar 1992, p. 95)." Along the similar lines, Sober emphasizes the roles of probabilities as explanations within specific scientific theories. In other words, probabilities provide a shortcut explanation by substituting detailed information about causal factors that affect an event to happen. Sober writes: "[w]e possess further information about the idiosyncratic details concerning each [event]. These would be ⋯ not necessarily to the take of explanatory description." (Sober 1993, p. 65) By constructing a probability space for a given system, an explanation for a specific event could be provided. In this way, what provides the meaning of probability is the rule of inference which is decided within the complex network of scientific theories.

By employing this perspective, this essay will interpret the use of probability within the context of the explanation of temporal asymmetrical behaviour of our universe. By positing the specific distribution of probability which corresponds to the low-entropy condition of the early universe, the temporal asymmetrical behaviour can be explained. However, both objective and epistemic interpretations have their own limitations to comprehend the probability assigned in the initial state of universe. This essay will argue that a new approach interpreting probabilities as constructing theoretical terms enables us to circumvent shortcomings of both objective and subjective interpretation of probability, and appreciate why these interpretations nevertheless *appear* to be convincing in our case. The epistemological aspect of the constructive interpretation of probability will be discussed in the final section.

## 2. Probability as an Explanation of the Temporal Asymmetry of Our Universe

The probability within this context plays a role of the statistical explanation of the second law of thermodynamics; the statistical explanation of the law answers to the question of why physical systems tend to approach to equilibrium by stating that the entropies of the closed system is always increasing. (Callender 2003)

The second law of thermodynamics provides the description of phenomenological aspect of all thermal system, rather than presenting a specific causal mechanism which shows the process of the way the entropies of closed systems tend to increase. We can then inquire into why the phenomenological law is the way it is. The answer for this question does not originate from other fundamental laws, but from a probability claim; thermal systems approach to their equilibrium because they are *probable* to do so. The temporal asymmetry of thermodynamics is explained by the uniform probability distribution that is assigned to the microstates compatible with the initial macro-state of the universe. By positing the specific distribution of probability that corresponds to the low-entropy condition of our early universe, the temporal asymmetric behaviours can be explained.

In a more technical detail, suppose our universe as being modelled by an n particle system within a box isolated from the external environment. Given that the state of a single particle is fully specified by six degrees of freedom (three dimensional position and three dimensional momentum), one can describe this system by means of a 6n dimensional phase space that is the function of position and momentum of individual particles. Within this scheme, one macrostate of a given system is compatible with its numerous distinct microstates. The macrostate is specified by the volume which occupies the phase space of microscopic state corresponding to specific macroscopic states. The explanation of the second law of thermodynamics, then, goes as follows. Given that the volume of the states of high entropies is much larger than the volume of the states of low entropies, it is more likely that the entropy of the universe increases rather than it decreases. What is worth noting here is that individual microstates which consist of phase space are assigned with *identical* probabilities. This is the standard probability distribution that explains and predicts asymmetrical macroscopic thermal phenomena approaching to equilibrium states which we observe. And extremely low entropy is posited to the standard measure of the initial states of our universe in order to provide an explanation of the second law of thermodynamics. (Reichenbach 1952)

## 3. Shortcomings of the Objective (Frequency and Propensity) Interpretation

How the probability posited in this context can then be interpreted? It seems that we cannot characterize the probability assigned in the initial states of the universe under the frequency interpretation. The intuition of the frequency interpretation originates from attempts to understand how often a specific event occurs among a certain population of events. Thus, if the probability is about whether a specific type of system among a population of events will demonstrate the temporal asymmetric behaviour approaching to equilibrium states, we can understand the probability claim under the frequency interpretation. But we can specify neither a specific type of event nor a population of events. For, the probability is concerned with a unique event of the whole universe, rather than a specific type of a system where its entropy increases. It is a typical example of assigning a single case probability, which is not founded on repeated observations.

Aside from this problem of assigning probability to a single case, there is another problem to understand this case under the frequency interpretation. Given that since what we are interested in is the initial state of the whole universe, it is not possible to carry out repeated observations. So, the probability in this case is not assigned as a result of series of the observation of a specific type of systems. It is only possible for us to figure out the initial state of our universe by indirect clues, which are achieved by means of theoretical considerations. The uniform probability distribution needs to be assigned by considering the theory of thermodynamics, which go beyond direct empirical results. Given that the frequency interpretation is based on repeated observations, we can say that the frequency interpretation cannot provide an answer to the question of how probabilities can be understood in this context.

Can we then understand the probability which is assigned to the initial state of the universe by using the propensity interpretation? The propensity can be unambiguously captured by presenting the causal mechanism of how a given event is likely to happen. One way to understand this case under the propensity interpretation is by providing a mechanism which explains how the initial state is the way it is. Albert (2000) maintains that GRW theories can provide a causal mechanism that grounds probability distribution of the initial state of the universe. His idea is that we can derive statistical mechanical probability from the quantum dynamics of the collapse of the wave function. The probability distribution of the initial state of the universe can then be obtained from the fundamental dynamics. Hence, if GRW theory is correct, a probability measure over the initial state of the universe can be substituted by the fundamental dynamics.

However, according to North (2003), it is doubtful that the propensity interpretation could achieve what the objective interpretation attempts to accomplish, that is, to interpret probability in terms of empirical means. For GRW theory depends on empirical evidence that is not yet available to us. Given that GRW theory still remains hypothetical, it is too quick to say that the mechanism supported by the theory provides empirical means to make sense of probability. There are other attempts to explain how initial state is the way it is. For example, Penrose (2004) offers a non-collapse theory of quantum mechanics based on the Weyl Curvature Conjecture which posits very unique space-time structure to the beginning of universe. Smolin (2006) suggests evolutionary cosmology in order to explain the unique status of our universe. Given that these approaches are based on highly speculative cosmological theories, they have still too weak empirical support to base the objective interpretation that the propensity interpretation aims to be. So, whether the propensity interpretation based on these theories will be successful is still inconclusive.

## 4. Shortcomings of the Epistemic Interpretation

It has been argued that the both frequency and propensity interpretation is not sufficient to understand the probability in the initial state of the universe. We can then ask whether the epistemic interpretation enables us make sense of probabilities within our case. The epistemic interpretation maintains that placing the uniform probability distribution over the system is due to our ignorance of which microstate the system happen to be in. (Laplace 1814) In other words, since there exists no reason for the system to be one specific microstate rather than another, equal probability should be assigned to each microstates. Probabilities in the initial state of the universe are assigned through the Principle of Indifference. (Keynes 1921) Price is one who holds this view. (Price 1996)

The epistemic interpretation in itself, however, fails to provide the meaning of probabilities posited to each microstate. Since the second law of thermodynamics is explained by the imposition of the uniform probability distribution, the interpretation of probability is supposed to clarify the way explanation occurs in this context. But the fact is that the epistemic interpretation based on the Principle of Indifference does not itself provide any plausible understanding of how explanation works in our case. The problem of the epistemic interpretation is related with the burden of explaining how our ignorance of a given system can be transformed to specific information. According to Fine, "[if] we are truly ignorant about a set of alternatives, then we are also ignorant about combinations of alternatives and subdivisions of alternatives." (Fine 1973, p. 170) When we assert that probability stems from our ignorance of the system in which we are interested, it is equivalent to saying that the second law of thermodynamics can be explained by our absence of knowledge of the system.

It seems that the theories of explanation in the market now, which are the nomological deductive or inductive views (Hempel 1965), the causal mechanical view (Salmon 1984), the unification view (Friedman 1983), and the pragmatic view (van Fraassen 1984), conflict with the contention that our epistemic ignorance could contribute to our understanding of a specific system. For the first three explanation schemes start from something fundamental to our knowledge which is definitely what we are supposed to be already aware of, such as nomic contents and causal structures of the given system. Therefore, these explanation schemes certainly do not come from our ignorance of the system. The pragmatic view asserts that we may neglect specific knowledge irrelevant to a given context, but it does not mean that explanations depend on our ignorance of the system. At this point, we may say that it is still possible that we can construct a new model of explanation which makes sense of the epistemic interpretation of probability in the initial state of the universe. Yet, the basic intuition of explanation, which is to make certain events understandable (Salmon 1984), seems to be at odds with the fact that explanation originates from our ignorance of a given system.

Thus, we need more than our ignorance in order to understand probabilities from the perspective of explanation. For, our understanding of a given system is not due to our ignorance by itself, but comes from certain additive elements which manage our ignorance. Hence, when we attempt to understand the application of probabilities in physical system, it seems inappropriate to adopt the epistemic interpretation in its original form.

## 5. Lessons from Intuitions under Traditional Interpretations of Probability

In spite of the shortcomings of these two approaches, we cannot say that the intuitions under both objective and epistemic interpretations are completely wrong. If we can pin down the plausible aspects of intuitions under the two interpretations, we can learn something that will help us construct a more plausible interpretive scheme. To do so, we need to distinguish the strength of each interpretation from its weakness.

As argued above, we can say that it is difficult to define probability by direct empirical means, such as the frequency of the occurrence of a specific event. This is especially true in the case of probabilities assigned in the initial state of the universe. However, given its successes in explaining empirical phenomena, we cannot also say that probabilities assigned to the initial state of the universe are irrelevant to our experience. Although probabilities do not come from our *direct* observations, we can admit certain *indirect* empirical basis of early universe to understand probabilities. In this way, we can maintain that the objective interpretation can be established on a broader empirical basis, which is not restricted to the direct observation of frequencies. In this way, we can recover indirect empirical aspects of the objective interpretation without loosing the vision of empiricism. With this objective feature, we can extract a clue of modifying the interpretation of probability underlying constructive intuition.

As for the epistemic interpretation, we can also find its weakness and strength. The weakness of the epistemic interpretation comes from the difficulty to comprehend how our ignorance can be transformed into specific information about the physical system. The Principle of Indifference is criticized due to its lack of capacity to generate specific empirical information. Its *a priori* nature makes the Principle of Indifference difficult to make sense of how we can retrieve empirical information. To comprehend how probability claims capture the reality, certain empirical aspects in understanding how probabilities work, although not directly empirical, should be indispensable within our context. This is what the epistemic interpretation fails to provide. On the other hand, we cannot neglect the intuition of scientists' contention that supports the epistemic interpretation. Tolmin claims that there is "no justification for proceeding in any manner other than that of assigning equal probabilities for a system to be in different equal regions of the phase space that correspond … with what knowledge we do have as to the actual state of the system (Tolmin 1979, p. 61)." Given common claims of scientists, we can expect a certain plausible feature within the epistemic interpretation.

The epistemic interpretation is in fact related with *constructing* specific information over and above our ignorance of the physical system being this state rather than the other states. Given this intuition, we can think that the epistemic interpretation shows how to assign probability distribution *in spite of* ignorance. In other words, following Kant's intuition, the epistemic interpretation attempts to show how we can manage ignorance. Deciding how to divide partition and positing identical probabilities to alternative partitions can be understood as an epistemic construction. In contrast, this epistemic construction, unlike Kant's one, by no means originates merely from *a priori* consideration. It comes also from its success to explain and predict empirical phenomena. In our case, the symmetric probability distribution of the initial state of universe stems from its empirical success with respect to explanation and prediction of temporal symmetric behaviours of a given systems. In this way, while maintaining the intuition of the epistemic interpretation, we can retrieve empirical aspects from which we can connect the link between probabilities and the world.

## 6. A Constructive Interpretation of Probability from the Lessons

We have seen that both strengths and weaknesses of the objective and the epistemic interpretation. Lessons from the above discussions lead us to consider the strengths of both empirical and epistemic aspects. Although each traditional interpretation has its own problems, it would be a legitimate starting point to take the strengths of each interpretation into account to build a more plausible interpretation of probability. In this context, we need to retrieve empirical basis by modifying both objective and epistemic interpretations in order to make probabilities relevant to the real world. It seems that we can recover empirical basis from both interpretations by considering probabilities as posting a certain posited generalizations rather than providing a specific causal mechanisms, which are sometimes immaterial to the explanation and the prediction of the phenomena. The generalization in our context is made by considering empirical elements which are obtained by astronomical observations. The imposition of probability in the initial state is established partly by the generalization of our observations, which is involved in theories of our universe, i.e., cosmology.

However, it is merely a partial story for interpreting probability given that our epistemic construction also plays an important role. Goldstein writes that “for classical mechanics, for which symplectic or canonical structure plays crucial role in the dynamics, the most natural measure is the volume measure defined by the symplectic coordinates (Goldstein 2001, p. 15).” The symplectic coordinates within classical mechanics are employed to posit equal probabilities to all individual state of the universe. But this posit does not originate from our ignorance of the physical system, but is due to the symmetric construction of our physical system. In this spirit, Bricmont claims that “symmetry considerations show that the uniform measure is the most natural one and since the distribution is the *empirical distribution* corresponding to most phase point, it is exactly what we would expect if we know nothing more about the system (Bricmont 1996, p. 9).” The symmetric consideration is epistemic one in that it is used as a heuristic that provides a significant generalization to construct reference system for the representation of complex structure. We impose symmetries that provide a significant generalization in construct reference classes by emphasizing information relevant to explanations and predictions. Rather than employing far-fetched causal mechanical theories with weak empirical supports, we can start our explanation from a well-confirmed heuristics using the symmetry principle. In this sense, Maudlin claims that "[t]here are certain e.g. symmetries to space itself (this is not, of course, a priori) and one might reasonable expect, or employ, a distribution over initial states that respects those symmetries. Since the symmetry of space can be verified by the microdynamics, without regard to statistics, this looks like a sort of (empirical) input that is still distinct from checking the distribution directly." (quoted from North 2003) Hence, asymmetric thermal behaviour is properly explained and predicted by positing the probability distribution within the initial state of the universe. For, explanations and predictions are based on relevant astronomical observations and empirically sound symmetric principle. So, we can find out how both empirical and epistemic aspects can contribute to the imposition of probability within our context.

Having claimed that probabilities function as a construction providing a generalization of the physical world, we can see how empirically weak theories fit in our approach to interpreting probability. GRW theory provides a theoretical hypothesis that explains why the probability distribution is assigned as a low entropy state in the initial state of the universe. In this way, the propensity interpretation becomes possible. It seems, however, that GRW theory is an epicycle on an epicycle, that is, a hypothesis over a hypothesis (the probability distribution of the initial state of universe), which does not come from either direct or indirect empirical considerations. Given that the symmetric probability distribution is unlikely to occur necessarily, it is a good reason to expect a certain dynamics that makes the unlikely initial condition happen. But what we can say is that in case of GRW theory, we have not yet enough empirical basis to ground this hypothesis. Since the propensity interpretation is based on objective information, probabilities cannot have its meaning through a theory with weak empirical basis.

Although the mechanism that generates the initial state does exist, it is not necessary to explain temporal asymmetric behaviours of thermal systems by this specific causal mechanism. Instead, the probability distribution of the initial state itself functions as a significant theoretical construction in explaining the second laws of thermodynamics. The postulation of probability distribution replaces the mechanism that is irrelevant to the explanation. The mathematical structure of probability provides a certain level of generalization without hitting on the bottom of causal mechanism that produces the initial condition. Although this generalization does not provide direct empirical aspect in interpreting probability, we can say that it still contain indirect empirical aspects with which the theoretical postulate provides us.

## 7. Reconsidering Traditional Interpretations of Probability with Shortcomings

What can we learn from the strengths and weaknesses of traditional interpretations? As for the objective interpretation, we have seen that direct links between frequencies and probabilities are weak. But it is possible that this direct empirical link can be replaced by indirect link based on probabilities as constructive theoretical terms. What is worth noting regarding the shortcomings of the epistemic approach is that the interpretation of probability is not only about our ignorance of a given system, but is also related with casting specific structures within the system by projecting the mathematical structure of probability to provide significant generalizations. Considering this way of modifying the interpretations of probability, we can see that probability claims are not solely concerned with a summary of empirical data, but with constructing certain structures that provide significant empirical generalizations. With this perspective of seeing probability in its constructive role, we have a way of providing a subjective aspect within the objective interpretation in a similar manner of Kantian synthesis.

By interpreting probabilities along these lines, one can see why the two traditional interpretations, while having their own limitations, still provide convincing intuition. It seems clear why empiricist approaches to the interpretation of probability do not work. Just as theoretical terms cannot be completely reduced to observational terms, so probabilities cannot be completely reduced to observational data. (Sober 1983) But the objective (frequency and propensity) interpretation appears convincing, because observational data still provides *evidence* despite the failure to provide the definition of probability. In viewing probability as theoretical terms, it can be identified where the objective and the epistemic interpretations diverge. In cases where probabilities as theoretical terms are supported by *true generalizations* of the world, it reveals the origin of the objective interpretation. The frequencies of certain events are considered objective when generated from their lawlike theoretical contents, which describe the objective nature of the world.

Furthermore, within this perspective, we can easily understand why the values of probabilities and the frequencies in certain cases are different. Although the probabilities of events are based on true generalizations, this occurrence of events is usually screened by *ceteris paribus* conditions, which show only *partial* aspects of the world. Hence, the gap between frequency and probabilities can also be understood as a result of theory construction. We can also understand why the propensity in the form of causal relations fails to capture all kinds of probabilities, since there are certainly different kinds of generalization without using causal structures, such as *lawlike* generalizations. In contrast, the generalizations within theories are *contingent* and *accidental*, probabilities based on such generalizations is closer to the subjective interpretation. From the point of view of probabilities as theoretical terms, we see why traditional interpretations have their shortcomings and strengths.

## 8. The Epistemology of Constructive Interpretation of Probabilities

What we can learn a philosophical lesson from the above perspective is that the mathematics of probabilities acquires their interpretation by being meditated by their theoretical construction, rather than by corresponding to the world directly. Rather than summing up information directly from the world, the mathematical structure of probability, as theoretical construction, filters significant information from what we observe the world. Accordingly, empirical data obtains its significance by means of mathematical structures, not the other way around. At this point, an alternative epistemological framework distinguished from the objective and the epistemic interpretation is necessary for the interpretation of probability. This new framework could be expected from the motive for our modification of interpretive scheme, which attempts to resolve the impasses that arise within traditional interpretations. In this context, in order to capture the epistemological status of the mathematical structure of probability, the epistemology of theoretical construction should be considered.

One of main lessens of demise of logical positivism is that the meaning of theoretical terms cannot be reduced to their empirical data. However, in offering meanings for theoretical terms, there must have empirical foundation. By means of probability as theoretical construct filtering some aspects of the world and deletes others, the world itself is altered into the phenomena. Rather than interpreting the mathematics of probability from an objective and an epistemic point of view, my approach provides a third way to the interpretation of probability; *By means of the projection* of the mathematical structure of probability, we can encapsulate significant information of the observed world. By projecting probability calculus into a given system, observed data becomes comprehensible. On the other hand, information that is not encapsulated by probability remains beyond our understanding.

In considering the uncertainties of events, for example, what is incorporated by probability calculus is transformed into measurable risks, whereas what is not remains as pure uncertainties. Accordingly, our understanding of a certain system is constrained by mathematics currently available. This framework has its origin from the Kantian epistemology, which focuses the role of categories through which our experience is constituted. The external world that cannot be capture by these categories, so called the thing as such, is then regarded as incomprehensible and meaningless to us. Kant's ambition is to get to the bottom of the deficiency of both rationalism and empiricism and to show why both school still seems to be convincing. Likewise, the aim of interpreting probability as constructive theoretical term is to disclose the deficiency of both objective and subjective interpretation. Furthermore, its aim is again to show why both approach still seems to be convincing. There also exists, yet, a clear difference between Kant's categories and probabilities as theoretical terms. While Kant's categories are *a priori*, the validity of meanings of theoretical terms could be refutable when confronted by falsifying empirical data. (Friedman 2001)

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# 구성주의 확률해석

양 경 은

본 논문은 확률의 객관적 해석과 주관적 해석이 가지는 문제점을 진단함으로써 이들을 극복할 수 있는 구성주의 확률해석을 제안한다. 이 확률해석에 의하면 확률의 수학적 구조는 경험적 자료들 사이에 연관성을 부여하는 구성적 이론적 가설을 제공하는 것으로 이해할 수 있다. 구성주의 확률해석을 위한 사례로 우주의 시간적 비대칭성에서의 확률구조를 분석했다. 본 사례의 확률을 구성적으로 해석할 경우 객관적 그리고 주관적으로 확률을 해석하는 문제들을 제거할 수 있다. 또한 구성적 확률해석은 고전적 확률해석이 그 문제점에도 불구하고 왜 표면적으로 신빙성 있는지에 대한 설명도 제공한다.

주요어: 확률해석, 객관적 확률해석, 인식적 확률해석, 구성적 확률해석, 우주의 시간적 비대칭성