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Objective vs Subjective probability.

Since the root of the controversy over the interpretation of the formalism of quantum mechanics lies in the interpretation of the probabilities given by the formalism, we must devote some time to discussing these interpretations. There are basically two types of probabilities, which may be called subjective and objective probabilities, respectively. A subjective probability refers to an estimate by a particular observer which is based upon incomplete information, and as such is not a property of the system being observed, but only of the state of information of the observer. An objective probability on the other hand is regarded as an intrinsic property of a system, i.e. to what might be called "really" random processes. To illustrate, we consider the following experiment: A deck of cards is shuffled, and one card is selected and placed face down upon the top of a table. An observer, A, is asked whether or not that card is the ace of spades, whereupon he would probably reply that the "probability" that it is the ace of spades is $1/52$. This probability would be a subjective probability, because it clearly refers to the state of information of the observer, and not to the system, namely the card, which is in actuality either the ace, or not the ace, and not a probability mixture. Nevertheless, A's statement that the probability is $1/52$ has meaning, since if the experiment were to be repeated a large number of times, and he were to state each time that the card on the table is the ace of spades, then he would be correct roughly $1/52$ of the time. However, if there were another observer, B, present, who is informed each time of the color of the card, he would answer differently, either 0 or $1/26$ depending upon the color, and he would also be correct in the same sense that A was. Still another observer, who caught a glimpse of the card each time it was placed on the table would have yet another answer, in which no probability was present at all. This illustrates that subjective probabilities are not invariant from observer to observer, due to differing states of information.

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Observation

Since an objective probability is conceived to be a property of a system, and hence independent of states of information, it must be invariant from one observer to the next. That is if two observers ascribe different probabilities to some aspect of the same system, then at least one of these probabilities is subjective! One possible method of arriving at a probability which satisfies this criterion of invariance is as a limit of subjective probabilities as information becomes more and more perfect. This obviously satisfies the criterion, but can never be verified in practice. We cannot go further towards a positive definition of objective probabilities, but we can investigate the consistency of ascribing objective probabilities to events in certain situations, with regard to the above negative criterion. In particular we wish to investigate the limitations of interpreting the probabilities of quantum mechanics as objective probabilities, which are imposed by this criterion. We shall refer to this view as the objective interpretation of quantum mechanics.

As a starting point we might investigate the consequences of the following set of postulates:

1. Every physical system ^s possesses a state function, ψ_s , which gives the objective probabilities of the results of any measurement which might be performed upon the system.
2. The state function ψ_s of an isolated system changes causally with time as long as the system remains isolated.

We shall now show that the above postulates are inconsistent by consideration of the following situation: We suppose that we have a system, S_1 , and a measuring device M_1 , for measuring some property of S_1 , which is connected to a recording device which will record the results of the measurement at a classical level, such as the position of a relay arm, and we assume that the measuring device is arranged to make the measurement automatically at some time. We further assume that the entire system, S_2 , consisting of S_1 , M_1 ,

and the recording device, is isolated from any external interactions.

Now, the system S_1 possesses a state function ψ_1 which gives the objective probability of the results of the measurement. (we shall also assume that ψ_1 is not an eigenstate of the measurement, so that we shall have a probability which is neither 0 nor 1. But if we now consider the total system S_2 , before the measurement, it also possesses a state function ψ_2 . Furthermore, ψ_2 at any later time is strictly determined by our initial ψ_2 so long as there are no outside interactions, so that in particular ψ_2 for some time after the measurement has taken place is strictly determined by its value before the measurement. We now consider what this later ψ_2 may say about the configuration of the recording device. If it gives a probability mixture over the configurations, then clearly these probabilities are of the subjective type, since they refer to something which actually exists in a pure state, because in reality the configuration of the recording device has already been determined. (Just as in the case of the man and the card.) On the other hand If this later ψ_2 gives the exact configuration of the recording device, then clearly the outcome of the measurement was determined before it took place, since the later ψ_2 was strictly determined by the earlier, in which case the probability given by ψ_1 was not objective. So that we see that in any case at least one of the probabilities was subjective, and the postulates are untenable.

There are several ways of removing this inconsistency, such as the following modifications:

1. Not every physical system possesses a state function.i.e. that even in principle quantum mechanics cannot describe the process of measurement itself. This is somewhat repugnant, since it leads to an artificial dichotomy of the universe into ordinary phenomena, and measurements.

2. The wave function of an isolated system is not always causally determined, but may suffer abrupt discontinuities from mixed states into probability mixtures of pure states, corresponding to an internal phenomenon which is regarded as a measurement. This is quite tenable, but leaves entirely unknown what is to be regarded as such a measurement, so that for this interpretation no formalism has been developed to give the points of discontinuity.

3. The probabilities occurring in quantum mechanics are not objective. That is, they correspond to our ignorance of some hidden parameters. Under such an interpretation the inconsistency resolves easily, since the outside wave function possesses more information than the internal one, such as phase factors, etc. for the interaction, so that it leads to a causal description.