of Indifference" by John Maynard Keynes in the 1920s, and the "Principle of Insufficient Reason" by Laplace in the early 1800s, it has its origins as far back as Leibniz in the 1600s (ref. 2). Among other counterintuitive results, this principle can be used to justify the prediction that after flipping a coin and finding a head, the probability of a head on the next toss is 2/3 (ref. 3). It has been the source of many an apparent paradox and controversy, as alluded to by Keynes, "No other formula in the alchemy of logic has exerted more astonishing powers. For it has established the existence of God from total ignorance, and it has measured with numerical precision the probability that the sun will rise tomorrow"[4]. Perhaps more to the point, Kyburg, a philosopher of statistical inference, has been quoted as describing it as "the most notorious principle in the whole history of probability theory"[5].

Simply put, the principle of indifference says that if you know nothing about a specified number of possible outcomes, you can assign them equal probability. This is exactly what Gott does when he assigns a probability of 2.5% to each of the 40 segments of a hypothetical lifetime. There are many problems with this seductively simple logic. The most fundamental one is that, as Keynes said, this procedure creates knowledge (specific probability statements) out of complete ignorance. The practical problem is that when applied in the problems that Gott addresses, it can justify virtually any answer. Take the *Nature* projection. If we are completely uncertain about the future length of publication, T, then we are equally uncertain about the cube of that duration T^3. Using Gott's logic, we can predict the 95% probability interval for T^3 as $T^3/39$ to $39T^3$. But that translates into a 95% probability interval for the future length of publication to be $T/3.4$ to $3.4T$ ($3.4=\sqrt[3]{39}$), or 42 to 483 years, not 3 to 4,800. By increasing the exponent, we can conclude that we are 95% sure that the future length of anything will be exactly equal to the duration of its past existence, T. Similarly, if we are ignorant about successively increasing roots of T, we can conclude that we are 95% sure that the future duration of anything will be somewhere between zero and infinity. These kinds of problems are inherent in any argument based on the principle of indifference.

On the positive side, we should all be encouraged to learn that there can be no meaningful conclusions where there is no information, and that the labours of scientists to predict such things as the survival of the human species cannot be supplanted by statistical arguments.

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SIR — At a lecture in Cambridge, Steven Wolfram was asked whether he could supply a meter which would indicate how near a Mathematica computer program was to finishing. Wolfram explained that there were serious philosophical problems preventing this very desirable facility. Now J. R. Gott III (*Nature* **363**, 315–319; 1993) has used the Copernican principle (that we do not occupy a privileged position in the Universe) to estimate when human life might come to an end. Bearing in mind E. Fredkin's view that the Universe is itself a computer, Gott's method can be applied directly to the computer case.

We start an unfamiliar computer program and it has not halted after one unit of time (minute, hour or day according to our patience). On the assumption that *time* (*now*) is uniformly distributed in the range *time* (*begin*) to *time* (*end*), then at the 50% confidence level, Gott finds that *time* (*future*) < 3 *time* (*past*), or at the 95% confidence level, *time* (*future*) < 39 *time* (*past*). This gives a good working rule. If your program has not finished in 1 hour there is an even chance that it will still not have finished in three further hours.

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SIR — In his Hypothesis (*Nature* **363**, 315–319; 1993), J. R. Gott III defines an intelligent observer as a being capable of understanding and applying his "delta t argument". In this sense I am not such a being. I think the delta t argument is wrong.

Gott claims to have derived some equations that allow him to calculate an estimate for the future longevity of any system just from the knowledge of its past duration. He applies them, with hindsight, to Stonehenge, the Berlin Wall and the Soviet Union. In these selected examples his theory turns out to be correct. From a present point of view, he predicts the future publication of *Nature* and the longevity of mankind. His results were surprising, almost unbelievable.

Let us rewrite Gott's argument in the strict terms of probability theory. Consider that the observation of a system is possible in a time interval of length T. We do not know T, and we can only speculate about its probability distribution $P(T)$. The time of observation divides the interval into two parts of length T_{past} and T_{future}, respectively. It is random in the sense that (for a given T) the values for T_{past} are equally distributed in the interval $[0,T]$. That is,

$$P(T_{\text{past}}=t_p|T=t)\,dt_p = \begin{cases} (1/t)\,dt_p, & 0<t_p<t \\ 0 & \text{else} \end{cases} \quad (1)$$

Here, the left-hand side of equation (1) is the symbolic notation of the condition probability distribution of the variable T_{past} for T having the value t.

For the future-to-past ratio R, $R = T_{\text{future}}/T_{\text{past}}$, we find

$$P(R=r|T=t)\,dr = P(T_{\text{past}}=t_p|T=t)\,|dt_p/dr|\,dr = (r+1)^{-2}\,dr,\ r>0 \quad (2)$$

and

$$P(R>r|T=t) = \int_r^\infty P(R=r'|T=t)\,dr' = (r+1)^{-1},\ r>0 \quad (3)$$

This is the result of Gott's equation (6). In this notation, Gott's equation (1) reads

$$P(1/39<R<39|T=t) = (1/39+1)^{-1} - (39+1)^{-1} = 0.95 \quad (4)$$

This equation means that for a given total time T (in a sample of systems with an arbitrary, but common and fixed T) the future duration of a system is between 1/39 and 39 times its past duration in 95% of all cases, which is obviously true. Although the right-hand sides of equations (2)–(4) do not depend on t, there is no way to omit the condition $|T=t$ on the left-hand sides.

Alas, the equations above do not apply to the intelligent observer's situation. He does not know T, but he knows T_{past}. So we have to calculate

$$P(R=r|T_{\text{past}}=t_p) = \int_0^\infty P(R=r|T=t \text{ AND } T_{\text{past}}=t_p)\,P(T=t|T_{\text{past}}=t_p)\,dt \quad (5)$$

The additional condition AND $T_{\text{past}}=t_p$ must not be omitted.

Using

$$P(R=r|T=t \text{ AND } T_{\text{past}}=t_p) = \delta(r-(t-t_p)/t_p)$$

and Bayes' theorem

Scientific Correspondence

Scientific Correspondence is intended to provide a forum in which readers may raise points of a scientific character. They need not arise out of anything published in *Nature*. In any case, priority will be given to letters of fewer than 500 words and five references.