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Letters to the Editor

THE DATA-ENRICHMENT METHOD

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THE FOLLOWING remarks are intended as a nontechnical exposition of an interesting method which has been proposed (not by the present author) to improve the quality of inferences drawn from a set of experimentally obtained data. The power of the method lies in its breadth of applicability and in the promise it holds of obtaining more reliable results *without recourse to the expense and trouble of increasing the size of the sample of data.* The method is best illustrated by example. Two such examples are outlined below; the first is somewhat routine, but the second is a striking illustration of what 'data enrichment' can achieve.

Consider an experiment performed to test the ability of a specific sound receiver to detect an audio signal. The experiment is performed in such a way that in each of a series of trials one learns either that detection was accomplished or that it was not accomplished. Suppose, moreover, that the sound source and the receiver are fixed in space and trials are made with the source intensity set at six different levels. At each of the six source intensity levels a number of tests are made and the result, detection or no detection, is recorded. The data from such an experiment are summarized in Table I.

It is desirable, of course, to increase the amount of data available at each source level. It is reasonable to assume that detectability is a function of source level and that, if all other parameters are held constant, a loud sound is easier to detect than one of smaller intensity. Thus it is safe to assume that if a signal was detected at a given level, it would have been detected at all higher source intensity levels. (The electronics are not such that overloading of the receiver will prevent detection.) Moreover, if a signal was not detected at a given level, it would not have been detected at any lower level of source intensity. Using these simple facts, the data collected at one source level can be used to add to the data available for other levels. For example, looking at Table I we see that three of the trials made at a source level of 77 db resulted in no detection. These trials would also have led to no detection had the source level been 62 db. Consequently, we can add the results of these experiments to our body of knowledge about 62 db *since we know how these experiments would have come out had we performed them.* Similarly, the five trials made at 62 db and resulting in detection would certainly have resulted in detection had the signal level been as high as 77 db at the source. Thus five more trials resulting in detection can be added to those actually made at 77 db. Treating all the data in this fashion, Table II can be compiled.

Two things are apparent at once: the probabilities of detection given in Table II are quite different from those which might have been deduced crudely and directly

from Table I; in addition the number of 'virtual' trials at each level of source intensity is much larger than the actual number of trials. Hence one may be more confident of the results of Table II than of any results one might get directly from Table I.

A second example, even simpler than the first, should make the advantages of this method of analysis quite clear now that the details are fixed in the reader's mind. It has long been known to those interested in psycho-physical phenomena

TABLE I

RAW DATA

Source level (db)	Number of detections	Number of failures to detect
62	5	40
65	10	30
68	15	20
71	20	10
74	25	5
77	30	3

TABLE II

'ENRICHED' DATA

Source level (db)	Number of virtual detections	Number of virtual failures	Probability of detection
62	5	108	5/113
65	15	68	15/83
68	30	38	30/68
71	50	18	50/68
74	75	8	75/83
77	105	3	105/108

that a man's tendency to flip a coin in such a way that when it lands he will be faced by an Indian's head rather than by a buffalo's tail increases with the altitude at which the experiment is performed. The effect is small but a vast number of trials conducted on Mount Everest, from base to summit, have shown that the effect indeed exists. With due respect to the hardy band of men who invested so many years and Sherpas in this effort, it is of interest to show how the same result can be obtained by one man with no more athletic ability than that required to climb a flight of stairs and no more equipment than an unbiased nickel. Our advantage over the pioneers in this field lies, of course, in our knowledge of the 'enriched-data' method.

Consider a set of stairs with ten levels and number them in the order of their increasing altitude. The experimenter climbs the stairs, slowly, and at each level flips a coin ten times and records a head as a success and a tail as a failure. The results of an actual test are recorded in Table III.

The results of Table III are not conclusive. The altitude effect may be present but it is not evident, at least to a naive observer. Suppose we now attempt to increase the data available by recourse to logic in the manner already illustrated in the first example. The altitude principle tells us that if a trial on the first step resulted in a head, then it would certainly have resulted in a head if the trial had

TABLE III

RAW DATA: COIN EXPERIMENT

Step number	Number of successes	Number of failures
1	4	6
2	5	5
3	7	3
4	4	6
5	6	4
6	5	5
7	6	4
8	6	4
9	3	7
10	4	6

TABLE IV

ENRICHED DATA: COIN EXPERIMENT

Step number	Number of virtual successes	Number of virtual failures	Probability of throwing a 'head'
1	4	50	4/54
2	9	44	9/53
3	16	39	16/55
4	20	36	20/56
5	26	30	26/56
6	31	26	31/57
7	37	21	37/58
8	43	17	43/60
9	46	13	46/59
10	50	6	50/56

been made at the loftier tenth step. Similarly, if despite the height of the tenth step a trial made there resulted in a failure to throw a head, then the same trial would surely have been a failure on the lower steps. Using this added insight, the data can be enriched by a large number of virtual trials as is shown in Table IV.

A glance at Table IV shows that the altitude principle, which was skulking almost unnoticed in the raw data of Table III, has been fully brought forth by the

data-enrichment method. The probabilities in Table IV are shown in Fig. 1 to further emphasize the point. It might be mentioned in passing that the altitude effect in the Pentagon appears to be 10^5 times as large as that found in the Himalayas. Whether this is a temperature effect, a geographical effect, or the result of psychical factors as yet unknown should be the object of further study.

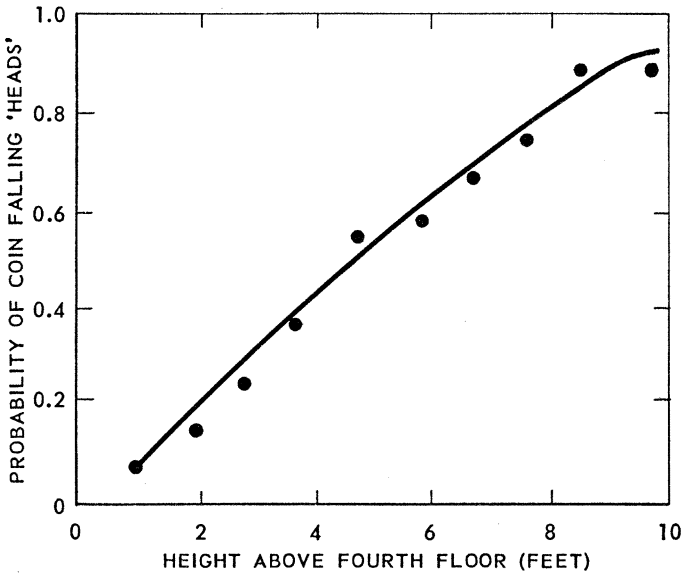

Fig. 1. Altitude effect in the Pentagon.

A final remark on the strength and weakness of the method is in order. As mentioned earlier, its strength lies in its breadth of applicability, and the method is as pertinent to experiments in classical physics as it is to experiments in psychical phenomena. In short, the method will give new meaning to data quite without regard to the status of the hypothesis used to increase the sample size. Despite its evident power, however, the method requires further study. Its principal shortcoming is that before the enrichment process can be started, some data must be collected. It is quite true that a great deal is done with very little information, but this should not blind one to the fact that the method still embodies the 'raw-data flaw.' The ultimate objective, complete freedom from the inconvenience and embarrassment of experimental results, still lies unattained before us.