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WAS

# Some Comments on the Contribution of Statistics to Scientific Method

by

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Notes for informal discussion before study group of the American Statistical Association at Columbia University, January 10,1941
Teachers College

On the theory of errors of observation:

"It is a good thing to read up, and when you have done that, you may as well forget it."

Life of Lord Rayleigh by his son, New York, 1924, Longmans Green and Company, page 369.

"A so-called 100 percent sample from the viewpoint of scientific method is, as soon as taken, a sample of the past. The usefulness of such a sample is only as a basis for drawing an inference about the future and in this case the sample (even a 100 percent sample) is but a finite sample of a potentially infinite one that might result from the cause system existing at the time the sample was taken.*

Letter, WAS to WED, May 9, 1940

("In all scientific investigations the object is to find, not the situation that prevails at a particular moment, but the underlying tendencies and relations which, with chance modifications determine these situations approximately.) The chief object in sampling the population of Seattle is to find out something about the underlying relations that make that population what it is. The situation in the city fluctuates continually, and what is found today will not be exactly true tomorrow."

Letter, Harold Hotelling to Lester Frankel, July 30, 1938.

# SCIENTIFIC METHOD

| | |
|---|---|
| Hypothesis | Statistical hypothesis |
| Experiment | Statistically designed experiment |
| Test of hypothesis | Test of statistical hypothesis |

Hypothesis
1) Formal
2) Empirical



## Testimony

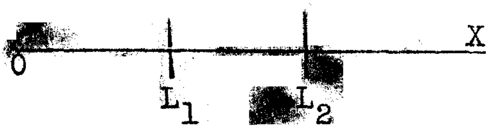
Certainly all applied scientists need to know something about statistical contributions of each step in scientific method. Even the layman should know something about the potential contribution of statistical method.

To me:

1. Formal mathematics (distribution theory) is guiding hand.
2. My experience does not justify use of some empirical rules of inference of the modern statistician.
3. However, same mathematics can be used in other rules to be established

FUNDAMENTAL OBJECT IN APPLIED SCIENCE

Set up and live economically within tolerance limits for each quality X for everything we eat, wear smoke, drink, or use in any other manner.

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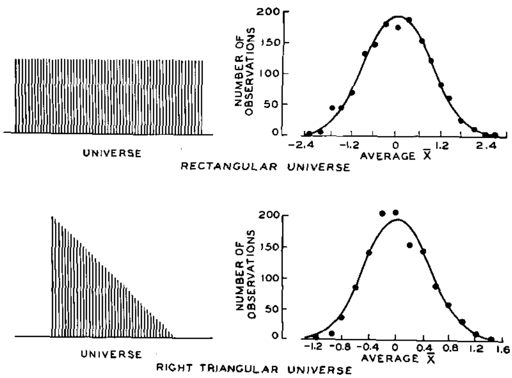
Valid prediction within limits: i.e., if such and such physical operation is carried out it will give X within previously specified limits,

$$L_1 \leq X \leq L_2.$$




UNIVERSES AND DISTRIBUTIONS OF AVERAGES FROM RECTANGULAR AND RIGHT TRIANGULAR UNIVERSES

| Length of Runs | Drawings from Bowl: Runs Above and Below Average: Observed Number | Drawings from Bowl: Runs Above and Below Average: Expected Number | Drawings from Bowl: Runs Up and Down: Observed Frequency | Drawings from Bowl: Runs Up and Down: Expected Frequency | Measurements of Inlay Thickness: Runs Above and Below Average: Observed Number | Measurements of Inlay Thickness: Runs Above and Below Average: Expected Number | Measurements of Inlay Thickness: Runs Up and Down: Observed Frequency | Measurements of Inlay Thickness: Runs Up and Down: Expected Frequency |
|---|---|---|---|---|---|---|---|---|
| 1 | 42 | 37 | | | 29 | 37 | | |
| 2 | 18 | 18 | 65 | 61 | 13 | 18 | 50 | 56 |
| 3 | 10 | 9 | 22 | 27 | 3 | 9 | 28 | 24 |
| 4 | 4 | 4 | 10 | 8 | 5 | 4 | 8 | 7 |
| 5 | 4 | 2 | 1 | 2 | 0 | 2 | 2 | 2 |
| 6 | 0 | 1 | 0 | 0 | 4 | 1 | 1 | 0 |
| 7 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

Prediction of Random

# I

## Fundamental Hypothesis 1

A. Formal - Distribution theory for what mathematician calls "random" but his results are independent of any connection with reality. They are operations with symbols.

B. There exist physical operations for which valid predictions can be made statistically. These operations are called random.

Example: Drawing chips from a bowl.

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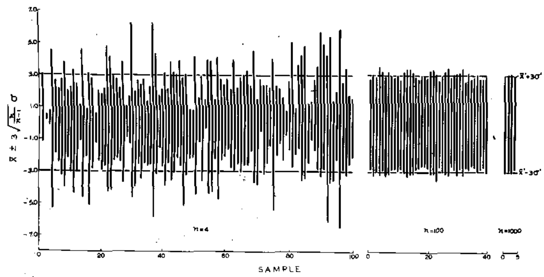
## Fundamental Hypothesis 2

Maximum control = random
= minimum tolerance
= maximum quality assuranc

## How Set Most Efficient Tolerance Limits

## if Random

How large a sample to set limits for which probability P of falling outside lies between $P_1 \leq P \leq P_2$ and $P \leq .01$.




PREDICTION – TYPE II

## Practical Significance

1. Management

2. Social

3. Need for dissemination to public

# II

## HOW ATTAIN A RANDOM STATE

Operation of Control S7 - 21179

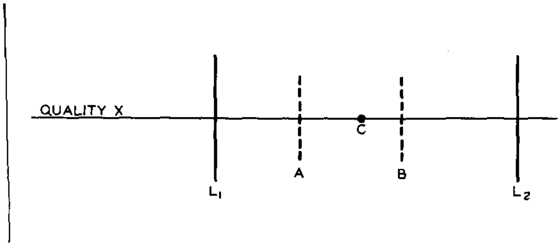
1. Specify in a general way how an observed sequence of n data is to be examined for clues as to the existence of assignable causes of variability.

2. Specify how the original data are to be taken and how they are to be broken up into subsamples upon the basis of human judgments about whether the conditions under which the data were taken were essentially the same or not.

3. Specify the criterion of control that is to be used, indicating what statistics are to be computed for each subsample and how these are to be used in computing action or control limits for each statistic for which the control criterion is to be constructed.

4. Specify the action that is to be taken when an observed statistic falls outside its control limits.

5. Specify the quantity of data that must be available and found to satisfy the criterion of control before the engineer is to act as though he had attained a state of statistical control.

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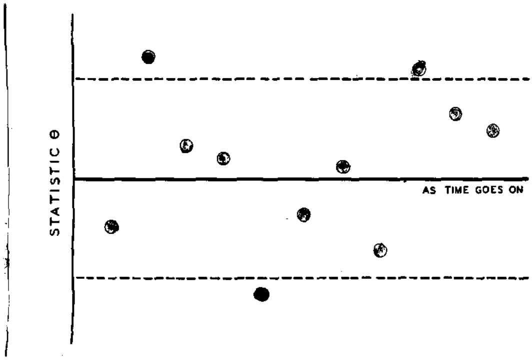
Historically $L_1$ and $L_2$ set for non-control

A, B, and C put in by statistics. Cannot be set a priori.

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1. Errors of two kinds    2. Running report

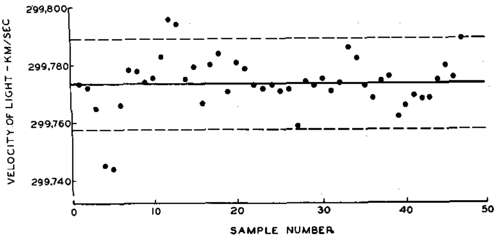
3. Sequence of small samples

4. Importance of order. (Even in stratified sampling)

Maximum control = random state

is empirical result.

a) Every example may be given by some random p
b) Some kind of samples are more likely to come from non random than from random. Trend.

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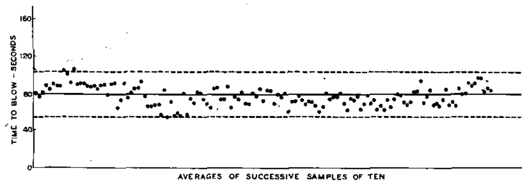
Such control does not exist even in measurement of velocity of light

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Shows that it can be attained by means of operation of control

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terion Using Runs

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there evidence of lack of control in
1-a?

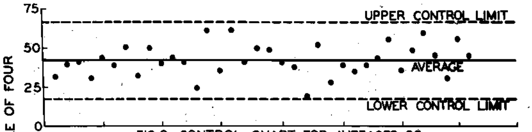



FIG. 2a CONTROL CHART FOR AVERAGES OF FOUR-RANDOM SEQUENCE OF FIG. 1a

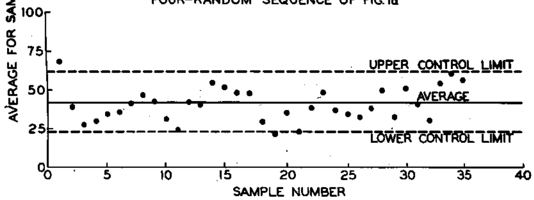



FIG. 2b CONTROL CHART FOR AVERAGES OF FOUR SEQUENCE OF THICKNESS OF FIG. 1b

## Some Comments

1. Statistical state of control requires a long sequence of small samples.
2. Need for at least 25 samples of 4 within limits.
3. Broad use. Measurement of [illegible] "individual".

# III

## TESTS OF SIGNIFICANT DIFFERENCES

### Case 1 - Unique Samples

5/17 Table 27 in Fisher's book >1880

a. First assume that two samples of 10 had been drawn from normal bowls.

b. Assume that they were observed in practice. Here we would doubt existence of randomness.

c. In either case test does not tell us which one to choose if considered as unique and of same cost.

5/18 Table 16 in Rider's book >1881

d. Usually want to know the difference and not simply the null hypothesis. Hence errors of first and second kind.

### Case 2 - Samples not unique

Comments

1. Significant tests have increased caution in education and elsewhere.

2. All engineers are more cautious because they have had to live up to tolerances. Hence what they want is something more.

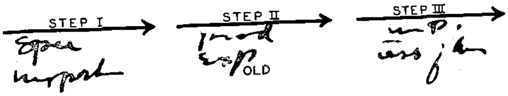
(cont'd)

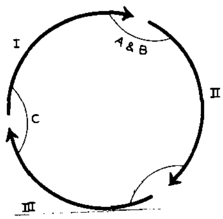
3. This want satisfied by operation of control.

4. After engineer gets control then he can use distribution theory in design of overall tolerances as will be discussed elsewhere. Here we have only treated a part of control theory.

## CONCLUSION

Mass Production + statistical control is new tool of research. Without it maximum efficiency in use of raw and fabricated materials cannot be attained. Attainment means long succession of small samples. Engineer cannot reasonably assume randomness - he must attain it. It is of interest to everyone of us because it should be used in the control of everything we use. Operation of control should be applicable in any applied science. It focusses attention on causes.




Statistical state of control(randomness) cannot be attained in a day - it can only be attained in a continuing and self-corrective mass production process.