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# Types of uncertainty with a focus on uncertainty arising from the randomness of events

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## Editorial

Events are subject to various classifications; one useful and practical classification is as follows: a) Certain events and b) Uncertain events. It should be noted that the inherent uncertainty of an event gives rise to a mental concept referred to as uncertainty.

For example, when a physician requests two diagnostic tests for a specific disease, and one result is positive while the other is negative, the physician experiences diagnostic uncertainty. This uncertainty arises directly from the contradiction in the test results or observations.

However, if the physician requests three tests, yielding two positive results but leaving the third result undetermined, the physician still experiences uncertainty. In this case, it stems from a deficiency or incompleteness in the observations.

Furthermore, in concepts such as merit, beauty, or prudence, or in ill-defined sets like "large numbers" or "hot days," an uncertainty exists that is commonly referred to as uncertainty arising from vagueness, or more precisely, fuzzy uncertainty.

One of the most important-and perhaps oldest-types of uncertainty is that which arises from the randomness of an event's occurrence. A random event is defined as one where no known factors can be identified as influencing its occurrence or non-occurrence.

A crucial question arises: Do all uncertain events derive from a single source?

The answer is definitively no. Consequently, it is logical that for each uncertain event, a specific type of uncertainty corresponding to its source will emerge.

It appears that a complete understanding or clear conception of the differences between uncertainty types was lacking until recent decades. However, it is now established that various types of uncertainty exist, dependent on the source and cause of the event's indeterminacy.

For the formulation or modeling of any uncertain event-that is, modeling any instance of uncertainty-its specific type must be identified, and an appropriate approach, based on its source, must be adopted.

For modeling uncertainty specifically arising from event randomness, a theory known as probability theory has been proposed and subsequently expanded and developed throughout history.

A significant historical error seems to have occurred wherein the source of most or all uncertain events was assumed to be randomness. Consequently, probability theory and its established achievements have been employed for their modeling.

It must be emphasized that probability theory is strictly capable of modeling uncertain events that originate from randomness.

**Hypothesis:**

A hypothesis is a declarative proposition. Such a proposition can result from an educated guess. It is logical to anticipate that a hypothesis is based on knowledge, experience, or a combination of both.

An ancient yet practical method for classifying a declarative proposition or hypothesis is the Aristotelian classification.

**Aristotle's bivalent logic:**

Aristotle classified every declarative proposition into one of two possible states, thereby establishing the bivalent system of reasoning known as Aristotle's bivalent logic.

According to Aristotelian bivalent logic, every declarative proposition regarding the true state of nature is either true or false. If the goal of a research study is to decide on a hypothesis, the decision-making process can assume various states, the simplest being the acceptance or rejection of that hypothesis. Based on the above, the following table can be constructed (Table 1):

**Table 1.** Decision Matrix Based on Aristotle's Bivalent Logic

| Hypothesis | | The true state of nature | |
|---|---|---|---|
| | | True | False |
| Decision region | Accept | Correct decision | Incorrect decision |
| | Reject | Incorrect decision | Correct decision |

If a true proposition is incorrectly rejected, a Type I error occurs; if a false proposition is incorrectly accepted, a Type II error occurs. Therefore, the preceding table can be formalized as follows (Table 2):

**Table 2.** Decision Matrix Based on Aristotle's Bivalent Logic

| Hypothesis | | The true state of nature | |
|---|---|---|---|
| | | True | False |
| Decision region | Accept | Correct decision | Type I error |
| | Reject | Type II error | Correct decision |

It is evident that each of the four outcomes in this matrix can arise from various sources, including knowledge, experience, culture, conscience, insight, bias, stubbornness, or chance. For instance, if an investigator rejects a true proposition due to bias or limited knowledge, an incorrect decision-specifically, a Type I error-has been made, but regardless of the cause, this error is not inherently random.

If the objective of a research study is to achieve a correct decision regarding a hypothesis, the probability of each of the four states listed above can only be modeled using probability theory when the source of error in the decision is attributable to the randomness of observations.

In such a case, the decision matrix is structured as follows (Table 3):

**Table 3.** Decision Matrix Based on Aristotle's Bivalent Logic Using Random Observations

| Hypothesis | | The true state of nature | |
|---|---|---|---|
| | | True | False |
| Decision based on random observations | Accept | Probability of accepting a true hypothesis | Probability of Type I error |
| | Reject | Probability of Type II error | Probability of rejecting a false hypothesis |

As established, according to Aristotle's dual-value logic, any hypothesis within the true state of nature is either true or false.

The ideal decision rule is one that leads to a conclusion with the minimum possible error; that is, the goal is to minimize the probabilities of both Type I and Type II errors based on random observations.

The probability of committing a Type I error is denoted by $\alpha$, and the probability of committing a Type II error is denoted by β. Correspondingly, the probability of correctly accepting a true hypothesis is (1−α), and the probability of correctly rejecting a false hypothesis is (1−β).

We designate α as the statistical significance level, (1−α) as the statistical confidence level, and (1−β) as the power of the test. On this basis, the probability-based decision matrix is as follows (Table 4):

As noted, to avoid incorrect decisions, efforts focus on minimizing the probability of Type I and Type II errors. However, their specific values depend on numerous conditions, factors, and parameters. Currently, for most research in health sciences, social sciences, and economics, the maximum acceptable value for the probability of committing a Type I error (Significance level) is conventionally set at 0.05, and the maximum acceptable value for the probability of committing a Type II error is set at 0.20.

**Table 4.** Probability Decision-Making Matrix Based on Aristotle's Bivalent Logic

<table>
<tr><td colspan="2" rowspan="2">Hypothesis</td><td colspan="2">The true state of nature</td></tr>
<tr><td>True</td><td>False</td></tr>
<tr><td rowspan="2">Decision based on random observations</td><td>Accept</td><td>Statistical confidence level (1−α)</td><td>Probability of type II error (β)</td></tr>
<tr><td>Reject</td><td>Statistical significance level (α)</td><td>Power test (1−β)</td></tr>
</table>

Research involving hypotheses that can be evaluated using quantitatively measurable variables generally yields a value known as the Probability Value (P-value) following data analysis-provided that the observations are obtained from a random sample. The nature of this value, the methods of its calculation, and the manner in which it is compared with the significance level will be discussed subsequently.

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