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RESEARCH ARTICLE

Statistical Methods and Appropriate Selection Criteria

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ABSTRACT

This research aims to present a simplified method for selecting the appropriate statistical technique to process quantitative research data. The selection method is primarily based on the objective of the research question or hypothesis: whether the aim is to study differences, describe the correlational relationship between variables, or predict future behavior of a phenomenon. This primary criterion encompasses additional factors such as the number of samples and their relationship, the number of variables applied to the sample, and their classification as independent or dependent variables, as well as the levels of measurement of these variables. Notably, the most commonly used and applied statistical analysis techniques in scientific research were selected.

INTRODUCTION

Statistics holds significant importance in modern scientific research as it serves as a crucial tool for handling research problem data, enabling better understanding of the studied phenomenon and facilitating critical decision-making. Statistics refers to the methods of organizing and summarizing data, as well as the techniques used in analyzing, interpreting results, and drawing conclusions to generalize findings to the study population. Consequently, almost no study or scientific research is devoid of the use of various statistical analysis methods selected according to appropriateness.

Choosing the statistical method for research is among the greatest challenges researchers face during their study preparation. This task requires careful attention to several factors, such as sampling methods, the nature of the dependent variable distribution, the level of measurement of the variable, and other factors. Thus, researchers must possess substantial skill and expertise to select the appropriate statistical method for their research and ensure that the chosen method aligns with the data collected. It is worth noting that no single method is universally applicable to all types of raw data and capable of achieving the researcher's goals for accurate statistical decisions.

Proper statistical analysis is generally an objective way to understand data, whereas inappropriate use of statistical methods often results from flawed statistical reasoning. In this study, we will explore the most commonly used statistical methods in social studies and research, presenting them in a straightforward and accessible manner after outlining the fundamental concepts involved in the selection process.

Variables and their types

A variable is a characteristic or property of a unit within the target population under study. The term "variable" stems from the fact that a given attribute can differ or change from one unit to another within the same population (Lahcene Abdallah Bachioua, 2011, p. 20). Variables are classified into the following types:

A. Descriptive variables:

These are non-measurable variables, meaning they do not have a unit of measurement (Fathi Ahmed Aarouri, p. 24), such as gender, marital status, or place of residence.

B. Quantitative variables:

These are measurable variables, which are further divided into

- **Discrete variables:** Variables that take whole number values, such as the number of students, family members, or workers.
- **Continuous variables:** Variables that take fractional values, such as height, weight, or age.

Levels of measurement

The types of measurement used to convert observations into numerical data are divided into four categories, known as levels of measurement.

1. Nominal measurement

Nominal measurement involves assigning numbers or symbols to nominal variables. These numbers replace names or symbols that represent variables (Murad, Salah Ahmed, 2011, p. 12). For example, students can be classified into males and females, with the number 1 assigned to males and 2 to females. Similarly, students can be classified based on their specialization, place of residence, or other criteria. It is important to note that the numbers assigned to any classification do not convey any quantitative meaning or indicate preference. These numbers serve only as substitutes for names.

2. Ordinal measurement

Ordinal measurement is a level higher than nominal measurement. In addition to classifying objects or individuals into distinct groups, it ranks individuals or objects in ascending or descending order based on a specific attribute. This level of measurement assumes an order among the data, assigning numbers to these ranks. However, these numbers do not convey a quantitative meaning but imply a sense of preference or order.

Ordinal measurement only indicates the position of each entity relative to others. For example, ranking a group of students based on their academic performance in year-end exams: one student may achieve first place, another second place, and so on. It is worth noting that the differences between ranks are not uniform. The gap between the first and second ranks does not necessarily equal the gap between the second and third ranks, and so forth.

3. Interval measurement

When assuming that the differences between measurement units are equal throughout the scale, interval measurement is used. In this case, the equality of intervals or distances between the units of the scale represents equal differences in the properties being measured (Mustafa Abdel Hafiz, 2002, p. 29). In addition to the ordering characteristic of ordinal measurement, interval measurement uses numbers to express the differences between individuals or entities, with these numbers having a quantitative meaning related to the measured property.

It is important to note that the zero point in interval measurement is arbitrary, not absolute. In other words, a property having a value of zero does not imply its absence. A common example is temperature: the difference between 20°C and 30°C equals the difference between 30°C and 40°C. However, a temperature of 0°C does not mean the absence of heat.

4. Ratio measurement

This level of measurement encompasses all the characteristics of the previous levels. Additionally, the measured property having a value of zero indicates its complete absence. Moreover, the ratio between any two values remains constant, even if multiplied by a constant factor, meaning that the units of this measurement are equal and uniform.

Examples of commonly used ratio scales include those measuring length, weight, and time, which allow for the interpretation of ratios. For instance, one person may weigh twice as much as another, or the time recorded by a runner in a race may be four times that of their competitor.

In summary, the measurement of a variable depends on the nature of that variable. Furthermore, statistical analysis of a set of variables depends on the nature of these variables and the methods by which they are measured. (Turkiya Baha El-Din, 2002, p. 54)

Parametric and non-parametric statistics

Parametric tests are statistical methods that rely on population parameters and are used when data follows a normal distribution. In contrast, non-parametric tests refer to methods that do not depend on population parameters and are considered distribution-free tests, meaning they are used when data distribution is non-normal or unknown.

The choice between parametric and non-parametric methods depends on several factors, including the level of measurement, data distribution, and sample size.

- **Parametric methods:** These are used for interval or ratio measurements when data follows a normal distribution.
- **Non-parametric methods:** These are applied for nominal or ordinal measurements. Additionally, when sample size is small, non-parametric methods are used regardless of the level of measurement in data collection (Murad, 2002, p. 20).

It is noteworthy that most parametric tests have corresponding or alternative non-parametric tests. Parametric tests are generally considered more powerful as they provide a better chance of detecting statistically significant results when they exist (Abu Badr, 2019, p. 282).

Independent and dependent samples

Independent samples refer to samples that differ in the characteristic or property being measured. They also indicate that the process of selection for one sample is completely independent of the selection process for the other sample. In other words, the selection of elements in the first sample is entirely separate from the selection of elements in the second sample. For example, selecting a group of males and a group of females separately results in independent samples, as would selecting a group of students from different academic levels.

On the other hand, dependent samples, also known as paired or related samples, are those in which the selection of elements in the second sample depends on the selection of elements in the first sample. In some cases, the same elements appear in both samples. For instance, if "a scale is applied to a sample of participants and then reapplied to the same sample at a later time, this constitutes two related (non-independent) groups" (Barakat, 2014, p. 270).

Steps for choosing the appropriate statistical method

The process of selecting the appropriate statistical test for a study is influenced by several factors that must be considered. These include the number of samples used in the study, the method of sampling in terms of independence or dependence, the nature of the studied variables, the distribution of the data (normal or non-normal), and the levels of measurement. To determine the suitable statistical test, this section will outline the process by identifying relevant criteria through guiding questions and providing immediate responses to these questions.

The first question that naturally arises pertains to the number of variables involved: Does the study include only two variables, or does it involve multiple variables? In other words, are you investigating the relationship between two variables or several variables? Let me clarify this distinction further.

Studies focused on the relationship between two variables fall under **bivariate studies**, where one variable is dependent, and the other is independent. Examples include studies examining gender and academic achievement, where the goal might be to determine which gender scored higher in exams, or studies on education level and smoking, aimed at understanding their relationship. Other examples include examining the relationship between women's employment and fertility rate.

In contrast, studies involving multiple variables are referred to as **multivariate studies**, where one variable is dependent, and the others are independent. For instance, a study might explore the effects of age and income level on blood pressure or investigate the impact of income, educational level, age at first marriage, and family size on the likelihood of divorce.

Answering the question of whether the study includes two variables or more is crucial. Therefore, I will begin by discussing statistical methods for bivariate studies, followed by methods for multivariate studies.

1. Statistical methods for bivariate studies

Let us assume, for example, that our study includes only two variables: one dependent and one independent. In this case, the given information is not sufficient to choose the appropriate statistical method. Instead, it requires knowing whether we are seeking to compare differences, meaning testing the differences between the two variables, or whether we are investigating the correlation and relationship between them. Therefore, we will distinguish between two cases here:

A. Methods for comparing two variables

Let us choose the case of testing differences, which is frequently used by statisticians, especially when they need to compare the options available to them. Of course, we are still unable to determine the appropriate test with these conditions alone, as this choice is also influenced by the nature of the relationship between the samples. In other words, it depends on whether these samples are independent of each other or paired.

It is evident that the results will undoubtedly differ between studying the difference between groups and studying the difference within groups. From this perspective, it is appropriate to pose the following question: **Are the data we have for independent samples or paired samples?**

2. The case of independent samples

Assuming that the samples we are using are independent, meaning that our study is conducted on different groups; such comparisons are typically made to determine whether the difference between the samples is significant or merely due to chance. Examples include comparing the average age of marriage between groups from different regions or comparing the average academic achievement of males and females.

Even though we have chosen one type of sample only, which is independent samples, this is still insufficient to determine the appropriate statistical method. This indicates the need to define the nature of the data for these selected samples. In other words, are our data continuous and follow a normal distribution, continuous but do not follow a normal distribution, nominal, ordinal, or represent sequential events taken at a specific time?

Let us assume in advance that our data are continuous and normally distributed. In this case, we must answer whether we are comparing two independent samples or multiple independent samples. This is the final step in determining the appropriate statistical test in this part.

If the answer is comparing two independent samples only, the most suitable statistical method is the Student’s t-test. This test is one of the most important and widely used statistical tests in research aimed at determining the significance of the differences between the means of two independent samples (i.e., the individuals in the first group are not the same as those in the second group). This test aims to determine whether the difference between the means of the two samples drawn from independent populations is due to chance or whether the difference is statistically significant. Examples include testing the difference between the average academic achievement of males and females on a specific measure or comparing the average number of children for urban versus rural women.

If the answer involves comparing the means of more than two independent samples or levels of a variable, One-Way Analysis of Variance (One-Way ANOVA) is the most suitable method. For instance, this test is used when comparing the monthly income of households in four different countries or determining whether there are differences in the average scores of three groups of students on a specific measure, where each group was taught using a different method.

One-way ANOVA is an important statistical tool for identifying differences between groups, especially when these differences cannot be determined using the t-test, which is limited to comparing only two groups at a time. "ANOVA ultimately depends on measuring the closeness or divergence of internal variance from external variance" (Hassan Al-Jundi, 2014, p. 171). Internal variance refers to error variance within the groups, while external variance measures the combined effect of independent variable variations on the error. When the differences between groups exceed those within groups, it indicates actual differences between groups due to variations in the independent variable.

It is not always necessary to assume normal distribution for continuous quantitative data, as previously noted. For continuous data that do not follow a normal distribution, we must also determine whether we are comparing two independent samples or multiple independent samples. This step is crucial for identifying the appropriate statistical test in this context.

If the answer is comparing two independent samples, the most appropriate test is the Mann-Whitney test. This test is "one of the most powerful tests that rely on ordinal scales, designed to measure whether the two experimental groups were drawn from the same population, and thus corresponds to the t-test" (Al-Kinani, 2014, p. 161).

For comparing more than two independent samples with continuous data that do not follow a normal distribution, the Kruskal-Wallis test is the most suitable. This test compares the overall values of multiple groups when the data are quantitative but do not meet the requirements for ANOVA, particularly when the groups are heterogeneous. Accordingly, the Kruskal-Wallis test serves as a non-parametric alternative to one-way ANOVA. Additionally, the Kruskal-Wallis test can be used when a Mann-Whitney test is applicable but cannot be performed due to having more than two groups to compare (Bouhafs, 2017, p. 251). Thus, this test is a generalization of the Mann-Whitney test.

At this point, a significant question arises: what if the data we are working with are categorical, and the independent sample condition is met? To answer this, let us first discuss nominal data, followed by data representing sequential events, and continuously ask whether we are working with two independent samples or more.

If we are working with the first option, i.e., two independent samples, the appropriate statistical method in this case is the Fisher test. This test is one of the statistical tools used to determine the significance of differences in proportions between variables. It aims to compare two independent groups in terms of a binary nominal variable, such as testing the hypothesis that there is no difference between genders (males and females) in viewing patterns (active or inactive). This assumes the data follow Fisher's distribution.

If we are working with more than two independent samples, the most suitable statistical method is the Chi-square test. "This test is one of the most useful statistical tests and is therefore among the most commonly used tools in statistics. It is often referred to as a test of goodness of fit because it measures the differences between observed frequencies (actual) and expected frequencies (theoretical) predicted in the null hypothesis" (Carpenter & Vasu, 1998, p. 134).

For data representing sequential events, i.e., data where time is a fundamental factor in analyzing the studied phenomenon (e.g., the time preceding death), with independent samples, the most appropriate statistical test is the Log-Rank Test. This test, also known as the rank test in variables with a start and end time for a specific event, considers the time interval between the start and the event. Time can be measured in days, weeks, or months, provided the independence of samples is maintained.

3. The case of dependent samples

After identifying the appropriate tests for studying differences or variations in independent samples, let us now assume a research scenario involving dependent samples. In other words, we are measuring differences in samples where the same subject is studied under two or more different conditions. Accordingly, we must always ask whether the data we have is continuous and follows a normal distribution, continuous but does not follow a normal distribution, or nominal from the outset.

Let us propose that the answer this time is that the data is continuous and follows a normal distribution. This answer itself leads us to question the number of measurements conducted. Was a pre-and-post measurement conducted, referred to as "before-after" the experiment, or paired samples, where the post-experiment data is usually not independent of the pre-experiment data? This scenario requires conducting the Paired Samples T-test.

Alternatively, were more than two measurements conducted for the same sample group, such as retesting the same individuals several times at different intervals, or even changing the type of test while keeping the same group under different conditions? In this case, the Repeated Measures ANOVA is the appropriate test.

Still within the context of dependent groups and quantitative data, let us now choose the opposite of what was previously mentioned, i.e., data that does not follow a normal distribution. Here, too, we have two proposals to consider for selecting the appropriate statistical method.

Firstly, if we are dealing with only two samples, we will choose the Wilcoxon Signed Rank Test. This test determines the extent of the differences between dependent samples, where the researcher applies a pre-test and a post-test on the same sample.

Secondly, if we are dealing with more than two samples, we will choose the Friedman Test. This test assigns ranks from 1 to kkk to kkk variables and then calculates the value of the statistic.

It is worth noting here that in the case of dependent groups with nominal data, we must resort to the McNemar Test. This test aims to determine whether the response rate before the change is equal to the rate after the change. If the equality between the two rates is achieved, it indicates no differences between the means of the two populations under study.

Let us now recap what we have learned above. Up to this point, we have examined some statistical methods for bivariate studies, specifically those related to studying differences or comparisons between two variables. We discussed how to choose these methods in the case of independent samples, whether with continuous data following a normal distribution or continuous data not following a normal distribution. We also reviewed how to select these statistical methods with nominal data or data representing sequential events. Subsequently, we addressed methods for choosing statistical tests for dependent samples, explaining this in detail. Now, we move on to exploring how to select these tests for studies related to the relationship and correlation between two variables.

B. Methods for correlational relationship between two variables

In this section of the criteria for selecting the appropriate statistical method for bivariate studies related to correlation and relationship, we always ask ourselves about the nature of the data we are dealing with. Are they continuous and follow a normal distribution, continuous but do not follow a normal distribution, or nominal from the outset?

- **Case 1:** If the data are continuous and follow a normal distribution, this naturally leads us to use Pearson's correlation coefficient. The value of this coefficient ranges between +1 and -1. The closer the value is to zero, the weaker the relationship between the two variables. Conversely, the closer it is to +1 or -1, the stronger the direct or inverse relationship.

- **Case 2:** If the data are continuous but do not follow a normal distribution or are ordinal, this leads us to use Spearman's correlation coefficient. The strength or weakness of the relationship between the two variables is determined by the distance of the correlation coefficient from 0 or 1.
- **Case 3:** If the data are qualitative with a nominal level of measurement and naturally binary, we will use the Phi coefficient. The same considerations mentioned above regarding the strength or weakness of the relationship between the two variables apply.

4. Statistical methods for multivariate studies

Research based on multiple variables is referred to as multivariate studies. These studies typically include one dependent variable and several independent variables. For instance, we might study the effect of the following independent variables: a woman's educational level, employment, number of live births, place of residence, gender of the child, and type of child on the dependent variable, child mortality.

In this section, we will focus on the criteria for selecting the appropriate statistical method for such studies. Similarly, we will rely on asking about the nature of the data: are the data under study quantitative, ordinal, nominal, or sequential events occurring at specific times, taking time into account?

First: Assuming the obtained data are quantitative, meaning they are expressed numerically, we will certainly resort to **linear regression**. This does not refer to classical regression, which involves a single independent variable and one dependent variable.

In general, linear regression is an advanced statistical method that ensures accurate inference to improve research results by optimizing data use to estimate the relationship between the dependent variable and a set of independent explanatory variables.

Second: If the obtained data are ordinal, we will use **ordinal logistic regression**. If the data are nominal and classified into two categories, we will employ **binary logistic regression**. In another case, we should use **multinomial logistic regression** when the nominal data are divided into more than two categories.

Third: If the data consider time as a fundamental factor in analyzing the phenomenon under study, such as dealing with the time preceding death, making the events sequential, we must choose **Cox regression analysis** in this case.

CONCLUSION

Selecting the appropriate statistical method to test the study's hypotheses is an essential and indispensable process. Given the importance of this step, researchers must adhere to a set of fundamental criteria aligned with this selection process. Generally, the process of selecting the suitable statistical method requires knowledge of the number of samples and their relationships, the number of variables applied to the sample, their classification as independent or dependent, and the levels of measurement of these variables.

Based on the above, to achieve the objective and produce accurate quantitative studies, we propose the following recommendations:

- Do not underestimate the theoretical aspect of statistics, as it is the primary driver of statistical reasoning.
- Think statistically before resorting to statistical processing using any software, as every statistical method is based on logic. Avoid blindly imitating previous studies that may contain errors.
- Ensure the availability of specialized statistical consultants who can assist researchers and students in selecting the appropriate test.

- Engage in serious learning of statistical analysis methods through participation in training courses or by consulting relevant references.
- Adhere to the criteria for determining the appropriate statistical method, as this enhances the quality of quantitative research studies, leading to reliable results that help build a beneficial strategy for society.

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