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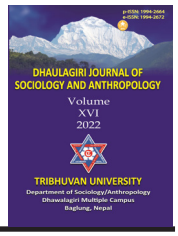

A Note on Survey Research Methods Levels of Measurement: Foundational Basis for Quantitative Analysis of Survey Data

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Abstract

This research note briefly describes the levels of measurement of variables and their applications in the quantitative analysis of survey data. It first presents the concept of the measurement of variables. Second, the four levels of measurements, namely, nominal, ordinal, interval, and ratio, with examples are offered. Then, the application of these measurement levels to the statistical analysis of data at the univariate (descriptive statistics), bivariate, and multivariate (e.g., binary logistic and multiple linear regression) levels are discussed. This note is expected to be useful to the beginning (naïve) scholars for real-world application of statistical tools to analyze survey data.

Keywords: analysis, data, measurements, statistics

Introduction

Are you engaged in a statistical (quantitative) analysis of survey data or interested in a quantitative analysis of survey data? Are you facing a problem in choosing the appropriate statistical tool to be used for the analysis of your data? This research note describes the concept of the levels of measurement of variables and their applications in the quantitative analysis of survey data. First, the concept and the types of levels of measurement of variables with examples are discussed. Next, this note provides brief information on how these measurement levels may be applied to the statistical analysis of survey data for univariate (descriptive statistics), bivariate and multivariate (at least for binary logistic and multiple regression) analysis. Understanding the variables' measurement levels is quite useful for those planning to use survey data in their research. While the knowledge of basic statistics is necessary, the knowledge of the levels of measurement is vital to identify and choose the appropriate statistical analytical tools for data analysis.

Measurement

Measurement refers to the process of assigning numbers or labels to the concepts[1] or variables[2] (or the characteristics of the unit of analysis[3]) under investigation. A researcher begins to think about the measurement process during formulating a research question or a hypothesis. A researcher first conceptualizes the research problem, identifies various concepts within the problem or hypothesis, and plans operationally defining or measuring the concepts (operational definitions) under investigation. A researcher assigns numbers to these concepts (or variables) to objectively measure and analyze them.

1. Entities that exist in the mind (mental objects).
2. A quantity that may assume any one of a set of values.
3. A unit of analysis is the subject or an entity under investigation or about which information is being collected. A unit of analysis may be an individual, a group or a group of people (or a household), a community, organization, a nation state and so on.

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What are the Levels of Measurement of Variables?

There are four different ways of assigning numbers to variables. Or, variables under investigation may be measured in four different scales: (1) Nominal scale, (2) Ordinal scale, (3) Interval scale, and (4) Ratio scale (Figure 1).

i. Nominal Scale

A nominal scale is used to measure variables that may be used to classify qualitative attributes of a variable into several groups. The attributes of any individual or an informant or the unit of analysis are assigned with numbers. For example, sex of a respondent may be defined or measured as a male or a female, or the color may be specified as white or black, or the names of countries may be specified as Nepal, India, and USA. For analysis, these attributes are assigned numerical codes or numbers such as 1=male and 2=female (Table 1).

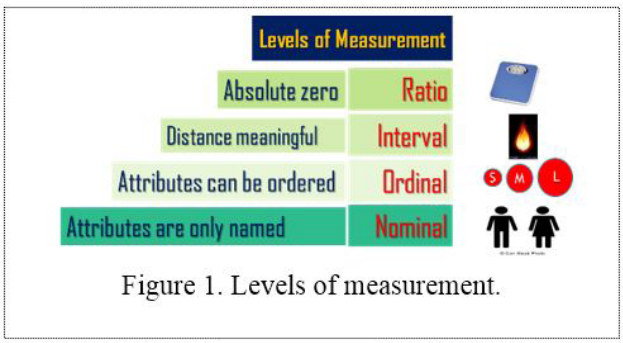

Figure 1. Levels of measurement.

Table 1. Examples of nominal scale variables.

Sex	Color	Country	Flowers
1. Male	1. Black	1. Nepal	1. Rose
2. Female	2. White	2. India	2. Rhododendron
3. Other	3. Red	3. Bangladesh	3. Daffodil
	4. Green	4. USA	

We must understand that these are just numbers and these numbers do not carry any values attached to them. A nominal scale is considered the lowest measurement level where the numeric labels or codes assigned to the attribute do not carry any meaning. These numbers are used for classification only. Thus, none of the mathematical operations such as addition, subtraction, multiplication, and division can be performed with these numbers. For example, a sex variable may be coded as 1 = male and 2= female. These numbers do not mean that females (code 2) are at a higher rank than males (code 1).

ii. Ordinal Scale

Rank ordering is possible for some qualitative concepts or variables. Attributes of such concepts or variables are also assigned with numbers. For example, small, medium, and large farmers. The numbers assigned to these numbers denote their ranks (Table 2).

Table 2. Examples of rank-ordered variable codes.

Size	Rank	Degree	Concurrence
1. Small	1. First	1. Excellent	1. Strongly disagree
2. Medium	2. Second	2. Good	2. Disagree
3. Large	3. Third	3. Fair	3. Neither
		4. Poor	4. Agree
			5. Strongly agree

Table 2 shows that subjects can be ranked based on their response to the variables. For example, a small farmer has less land than a medium-sized farmer. Similarly, a large farmer has more land than a medium and small farmer.

The numbers assigned to the attributes do carry values attached to them. These numbers are used for classification as well as for ranking. However, it is not a good idea to perform any of the mathematical operations with these numbers.

iii. Interval Scale

Some variables are measured in continuous (continuous or discrete) scales, for example, temperature, IQ score, population, height, and weight. One important characteristic of the interval scale measurement is the absence of an absolute zero point. Or, the zero-point assigned to the value of such variables is arbitrary, which does not mean a complete absence of the measurable property. For example, if we measure the temperature as 0 degrees Celsius, it does not mean there is no temperature at all. If this same temperature is measured in another unit, e.g., Fahrenheit, it is 32 degrees Fahrenheit.

Table 3. Examples of interval and ratio scale variable codes.

Interval scale	Temperature 0 degree 1 degree 2 degree . 100 degree	Grade or IQ score 0 score 50 score 60 . 100 score	Opinion/perception scale 0 1 2 . 100
Ratio scale	Height 0 feet 2.5 feet 5 feet 10 feet . 100 feet	Weight 0 Kg 5.5 Kg 10 feet 50 feet . 100 feet	Income 0 5$ 10.5$. 100$ 1000$

These numbers are used for classification and ranking. Subjects may be ranked as high or low based on the values of these variables. The numbers in this scale, however, have an equal distance between two points (equal interval property). For instance, the interval between 0-10 degrees

is the same as the interval between 10-20. However, we must be careful in interpreting these values. A temperature of 20 degrees Celsius (68 degrees Fahrenheit) is not double of 10 degrees Celsius (which is 50 degrees Fahrenheit, not 34-degree Fahrenheit). It is because the zero point in this scale is not an absolute zero point. Thus, basic mathematical operations such as addition and subtraction may be used but not multiplication and division (theoretically).

iv. Ratio Scale

A ratio scale is the highest level of measurement. This level of measurement includes all the features of the other levels, i.e., classification, rank ordering, equal interval and absolute zero point. The main difference is that the zero point in this scale is a true zero point (or an absolute zero point). It means a variable with a 0 value, meaning it has a complete absence of this characteristic. This unique characteristic makes all the mathematical operations – addition, subtraction, multiplication, and division – possible. For example, an individual's earnings may be zero or 1,000 per month, or 10,000 per month. Zero income means that the person does not earn at all and a 10,000 income is ten times greater than a 1,000. Other examples are height and weight.

Table 4. Properties of the four levels of measurement.

Information	Nominal	Ordinal	Interval	Ratio
Classification	Yes	Yes	Yes	Yes
Rank order	-	Yes	Yes	Yes
Equal interval	-	-	Yes	Yes
Nonarbitrary zero	-	-	-	Yes

Some scholars refer to nominal and ordinal scale variables as qualitative (or categorical) variables and interval scale and ratio scale variables as quantitative variables. Because both interval and ratio scale variables are continuous (and discrete), in SPSS, these data are known as scale variables. The quantitative data may be either continuous (e.g., income, age, height, and weight) that can take each value in the series or discrete (number of individuals, number of visits and so on) that can take only discrete or single numbers in a series.

Application of the Knowledge of the Levels of Measurement

An understanding of the levels of measurement is very helpful in choosing appropriate statistical techniques to analyze the data[4].

4. Here, I focus only on parametric tests (i.e. non-parametric tests are not included).

Univariate Statistics[5]

Depending upon the measurement of a variable, the following univariate statistical tools may be used to analyze the variables (Table 5).

Table 5. Applications of levels of measurement in survey data analysis – univariate statistics.

Level of Measurement	Univariate analysis
Nominal	Frequency, percent, mode, bar charts, histogram, pie chart
Ordinal	Frequency, percent, median, mode (sometimes, mean, standard deviation), bar charts, histogram, pie chart
Interval	Mean, mode, median, standard deviation, range, line graph
Ratio	Mean, mode, median, standard deviation, range, line graph

If a variable is measured in a nominal scale, we can use frequencies and percent to describe the data. Similarly, bar charts, histograms and pie charts may be used to display the distribution graphically. For ordinal scale variables, we generally use frequency and percent. Occasionally, mean and standard deviation are used to examine the central tendency. Because both interval and ratio scale variables are continuous data, we use the techniques of central tendency, such as mean, mode and median, and dispersion, such as standard deviation and range.

Bi-variate Statistics

Bivariate statistics are used when we examine the distribution of two variables at the same time or when we examine the relationships or associations between two variables. Those two variables in question may be nominal-nominal, nominal-ordinal, nominal-interval/ratio, ordinal-ordinal, ordinal-interval/ratio, and interval/ratio-interval/ratio. As presented in Table 6, the following bivariate statistical tools may be used to analyze the variables.

If both the variables (variable 1 and variable 2, no matter whether dependent or independent variable) under investigation are measured in nominal scales, a cross-tab (or chi-square test) is used to examine or describe the associations. This same tool can be used to analyze if two variables are – nominal-ordinal or ordinal-ordinal. However, if one variable is nominal or ordinal and other variable is interval or ratio, we use mean comparisons (t-test) or one-way of analysis of variance (ANOVA). If both the variables under investigation are interval or ratio scale, a Pearson Square correlation is used to examine the relationships.

5.Examination of only one variable at a time.

Table 6. Application of the knowledge of levels of measurement in bivariate analysis.

Levels of measurement: **Variable 1**	Level of measurement (**Variable 2**)			
	Nominal	Ordinal	Interval	Ratio
Nominal	Cross tab	Cross tab	Mean comparison (t-test, anova)	
Ordinal	Cross tab	Cross tab (Chi-square)	Mean comparison (t-test, anova)	
Interval	Mean comparison (t-test, anova)	Correlation (?), Mean comparison (?)	Correlation, Mean comparison	
Ratio	Mean comparison (t-test, anova)	Correlation (?), Mean comparison (?)	Correlation, Mean comparison	
Note: Non-parametric tests are not included due to space limitations. (?) Occasionally, we may use correlation to examine the relationship between two variables.				

Multivariate Statistics

A multivariate analysis technique is chosen to examine the relationships among three or more variables at the same time. Generally, these are multivariate regression techniques, for example, multiple linear regression (ordinary least square technique), binary logistic (probit) regression, ordinal regression, and multinomial regression techniques. These regression techniques are used to examine or explain the effect of (relationship or association between) or influence of or impact of an independent variable on the dependent variable.

Table 7. Application of the knowledge of levels of measurement in multivariate analysis.

Level of measurement: Independent Variable(s)	Level of measurement of Dependent variable			
	Nominal	Ordinal	Interval	Ratio
Nominal	Binary logistic regression or Multinomial logistic regression	Ordinal logistic regression, Multiple regression (?), Ordinal Logistic (or OLS?)	Multiple regression (ordinary least square (OLS))	
Ordinal	Same tool as above	Same tool as above	Same tool as above	
Interval	Same tool as above	Same tool as above	Same tool as above	
Ratio	Same tool as above	Same tool as above	Same tool as above	
Note: ? Sometimes, a researcher may decide on an ordinal scale variable as a scale variable and may use multiple regression techniques to estimate or predict the effect of the independent variable on the dependent variable. For example, self-reported health status measured as excellent, good, fair, and poor (an ordinal scale variable) is commonly analyzed using the multiple (linear) regression technique (considering it as a scale variable).				

In multivariate analysis, the measurement scale of the dependent variable is important in determining the type of multivariate regression technique to be used, irrespective of the measurement of the independent variable(s). The measurement scale of the independent variable does not have any say in determining the type of multivariate tool to be used. For example, if the dependent is nominal scale, a binary logistic ((if the dependent variable is binary coded/measured as Yes or No or Agree or Disagree (or otherwise), or Employed or unemployed (or otherwise)) is applied. If the dependent variable (a categorical variable) is measured as a nominal variable with multiple categories (e.g., Fully employed, partially employed and unemployed), a multinomial regression technique is used. Similarly, an ordinal regression technique is used if the dependent variable is measured on an ordinal scale (e.g., excellent, good, fair, poor). If the dependent variable is measured as an interval or a ratio scale variable, a multiple (linear) regression (also commonly known as the ordinary least square technique – OLS) is used. Note that the level

of measurement of an independent variable does not affect the type of multivariate statistical tool being used.

Conclusion

As a beginner, it is common to face problems choosing an appropriate statistical tool (a univariate, a bivariate or a multivariate) to analyze the survey data. This research note briefly described the concept of the levels of measurement of variables and their applications in the quantitative analysis of survey data. Only the commonly used statistical (parametric) techniques are provided in the examples. The understanding of the measurement scale of variables is important in choosing the type of univariate (frequency, percent, mean, mode, median, standard deviation, and range), bi-variate (cross-tab, mean comparisons and correlation) and multivariate (binary logistic or multiple linear regression) analysis techniques. This research note, however, does not discuss non-parametric tests (that do not require normal distribution and no parameter estimates are necessary) due to space limitations. It is expected that this research note will be useful to the beginning (naïve) scholars for choosing an appropriate statistical tool to analyze survey data.

Declarations

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This writing follows ethical values.

Ethical Approval for the Research:
Ethical approval not required.

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