SCALES OF MEASUREMENT: A DEMYSTIFICATION OF THE ORDINAL SCALE

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ABSTRACT: *The ordinal scale of measurement is not understood by many researchers, especially in the social and business fraternities. The thinking that coding values of ordinal scale variables convert data from being qualitative into being quantitative is held by these researchers. A sample of randomly selected articles on factors affecting students' academic performance is studied to establish how ordinal level variables are analyzed. Results show that the greater part of researchers do not know that, although it is correct that where there is quantity there is number, the converse is incorrect. Parametric techniques dominate in the analysis of ordinal data. Scenarios are forwarded for the purpose of sending home the message of differentiating when number is quantity and when it is not. Techniques that are designed for the analysis of ordinal data are then shared.*

KEYWORDS: Ordinal, non-parametric, rank-correlation coefficient, regression analysis, variable.

INTRODUCTION

Measurement is the assignment of numerals to objects or events according to rules (Stevens, 1946). Some of these rules are simple while others are complex. The numbers 1, 2, 3, 4 and 5 can be assigned to the favorite colors (yellow, green, blue, purple and brown) and also to job satisfaction ("very dissatisfied," "somewhat dissatisfied," "neutral," "somewhat satisfied" or "very satisfied"). The variables here are favorite color and job satisfaction. The individual colors yellow, green, blue, purple and brown as well as the satisfaction levels "very dissatisfied," "somewhat dissatisfied," "neutral," "somewhat satisfied" and "very satisfied" are the values of the variables. This is in line with Kaur (2013) who defined the term variable as a characteristic that changes values. If we were to ask a group of people to give their favorite colors, they would mention different colors, hence favorite color constitutes a variable by virtue of it assuming different values.

The values of both variables above are not numbers. Variables whose values are not numbers are said to be qualitative. It is important to note that although the two variables above are both qualitative, the values of one cannot be arranged in any order, whereas those of the other can be arranged in some order. There is nothing in one color, which can be said to be more or less than in another color, but there is more satisfaction in "very satisfied" than in "somewhat satisfied." Although job satisfaction is a construct which cannot be measured directly, at least its values can be arranged in some order. The understanding of the difference in the two variables above helps when one wants to analyze data with these different features. Numbers can be used as codes to replace the values of the variables above. However, the mathematical operations $+, -, \times \ and \ \div$ cannot be applied to these codes.

Several other examples of variables are gender, religion, marital status, military rank, political party, problem-solving strategy, qualification, social class, type of teaching approach, method of treatment, native language, age, weight, height, income, temperature, time, group size, university size, number of errors, percentage of lectures attended and number of publications. If the values of these variables are numbers, we say we have quantitative data; otherwise, the data is qualitative. Of the data listed above, gender to native language are qualitative and the rest are quantitative.

The next section of the paper looks at the four scales of measurement, Section 3 gives the details of the ordinal scale of measurement, Section 4 is on methodology, Section 5 displays the results, Section 6 is discussion and Section 7 is conclusion.

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The Four Scales of Measurement

According to Stevens (1946), measurement is the assignment of numerals to objects or events in accordance with some rules. Numbers or numerals can be assigned to objects for identification purposes, like 0 and 1 for females and males respectively. Numbers can be assigned to athletes as 1, 2, 3, 4 and so on or 1st, 2nd, 3rd, and 4th position as they complete a track event. Temperature is recorded and read in numerals and "the number of….," is all numerals. Numerals have been assigned to objects differently in each of the four situations above. These different ways are the so-called scales of measurements. This study defines 'scales of measurement' as the four different ways in which numbers can be used or assigned to objects. This section of the paper identifies a sample of objects and discusses how numbers are assigned to them. The study will explicitly explain the four different ways of using numbers.

Table 1 uses the variables native language, military ranks, time and age to distinguish between these four different ways.

Table 1: Scales of Measurement and Examples of Variables and Sample Values

Variable			
Nominal	**Ordinal**	**Interval**	**Ratio**
Native Language	**Military Ranks**	**Time**	**Age**
Sample Values	Sample Values	Sample Values	Sample Values
Spanish	Lieutenant-Colonel	1500	2.4
English	Colonel	0630	11
French	Brigadier-General	0000	17
Russian	Major-General	1221	21
Chinese	Lieutenant-General	2215	33
Korean	General	1137	56

We define a variable as a characteristic that changes values at a given time or location. In Table 1, the variables are native language, military rank, time and age. The values of each variable, for native language, the different languages spoken by people and for military ranks are the different positions in the army. Both native language values and military rank values are not numbers. Such variables are said to be qualitative. The other two variables (Time and Age) are quantitative since their values are numbers. These values are, different times of the day, for Time, and different ages, for Age.

Qualitative variables are either nominal or ordinal. Table 2 will help us understand a native language better as a nominal variable.

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Table 2: Native Language As an Example of a Nominal Variable

Native Language	Spanish	English	French	Russian	Chinese	Korean
Code	1	2	3	4	5	6
Frequency	3	6	5	4	5	2

In Table 2, the variable, native language, has the different languages shown as the values. The languages are given codes as seen in the table, with Spanish being coded 1, English coded 2, and so on. The codes here do not carry any mathematical meaning since there is nothing more in Korean (that makes it have Code 6) than in English whose code is 2. These codes are just names. They are for identification purposes only. The languages cannot be compared. There is no bigger or smaller one. We cannot add, subtract, multiply or divide the languages. We cannot obtain the meanings of English and Spanish because these are not quantities. This remains the case when we code. In the table, $2 = English\ and\ 6 = \ Korean$. If we were to calculate the mean of the two, it would be 4. Now in the table, $4 = Russian$. Does this mean that the meanings of English and Korean are Russian? No, there is nothing like that. The 2 that corresponds to English is just a name and has nothing to do with quantity in it. It is as good as any word that has nothing to do with numbers. In fact, when 2 is used in this manner, its "**twoness**" is lost. The same thing applies to any other number. Anything that we cannot do with the names of the languages cannot be done with the numerical codes assigned to them (the languages). The numbers are the new names of the languages and nothing else. Figure 1, from Raghunath (2019), puts it right to say that the only measure of central tendency that is applicable for such data is the mode. Table 2 also shows a total of 25 people, say at a workshop. Their native languages are shown and the numbers of people with these native languages are the frequencies. We normally define the mode as the number with the highest frequency. Here the values of our variable, native language, are not numbers but languages. Therefore, the language with the highest number of native speakers in this workshop is the mode. This happens to be English. The modal code, therefore, is 2.

We cannot arrange the languages in order of size because they are not quantities but qualities. This remains the case when we use the codes. No median, no mean. Just the mode. When numbers are used this way, they are said to be at a nominal scale. This means they are just names or identifiers.

Table 3: Military Rank as an Example of an Ordinal Variable

Military Rank	Lieutenant-Colonel	Colonel	Brigadier-General	Major-General	Lieutenant-General	General
Code	1	2	3	4	5	6
Frequency	9	5	5	3	2	1

Military ranks that are shown in Table 3 are arranged in ascending order of authority from Lieutenant-Colonel to general. Military rank is the variable and the values are the rank-names. The variable is still qualitative but the values have a sense of order this time around. There is more of something in Colonel than in Lieutenant-Colonel. Of course, we cannot measure how much but we know there is more. It is this sense of comparison that brings the difference between nominal

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and ordinal. Like in the nominal case, what cannot be done with the values of these variables cannot be done with the numerical codes.

The mode is the rank with the highest frequency which is Lieutenant-Colonels. For ordinal data, we can obtain the median rank this time, since the values are ordered. With 25 officers, the median officer is officer number 13, that is, position number $(25 + 1) \div 2$. The first 9 positions are occupied by Lieutenant-Colonels. The next 5 positions are occupied by Colonels. This takes our cumulative frequency to $9 + 5$ which is 14. Position 13 is therefore among the five Colonels. Colonel is, thus, the median rank. As has been observed here, the mode and the median called for none of the four mathematical operations. Anything that has to do with the operations cannot be accommodated here. Figure 1 shows some of the features of variables in this category. Because the values of the variables in this category can be ranked, researchers are often misled into thinking that all operations are possible, which is not so. It is such misconceptions that this study intends to put straight by allocating a separate section on this level of measurement. The analysis section will also look only at documents that have analyzed ordinal variables.

Unlike the nominal and ordinal variables where the values of the variables start as categories, the interval scale has values that are numbers. Here the numbers are not codes like in the previous two cases. The values of time, an example of variables that are measured at this level, give us more information than just the order. The differences between values of the variables in the scale can be calculated and have meaning. Addition and subtraction are meaningful. There is a reference point this time. This reference point is like the origin and is denoted 0000. However, this does not mean that there is no time at 0000. The 0000 is not a true but arbitrary 0. Figure 1 shows what is possible with data at this scale.

The ratio scale of measurement is the most informative scale. It has all the four relations: equality, rank-order, equality of intervals, and equality of ratios (Stevens, 1946). This is the most common of all the four scales. It is well known for its true zero origin. Unlike time where the time of 0000 does not mean that there is no time, when a variable at this scale takes value zero, it means that there is nothing. Age is a good example of such variables. A person who is of age zero does not exist. This is the level which is well known by people. Many researchers take numbers from other scales as if they were from this scale. All the four mathematical operations are possible on data at this scale of measurement.

Figure 1, from Raghunath (2019), shows the four scales of measurement and the measures that are appropriate for their analyses.

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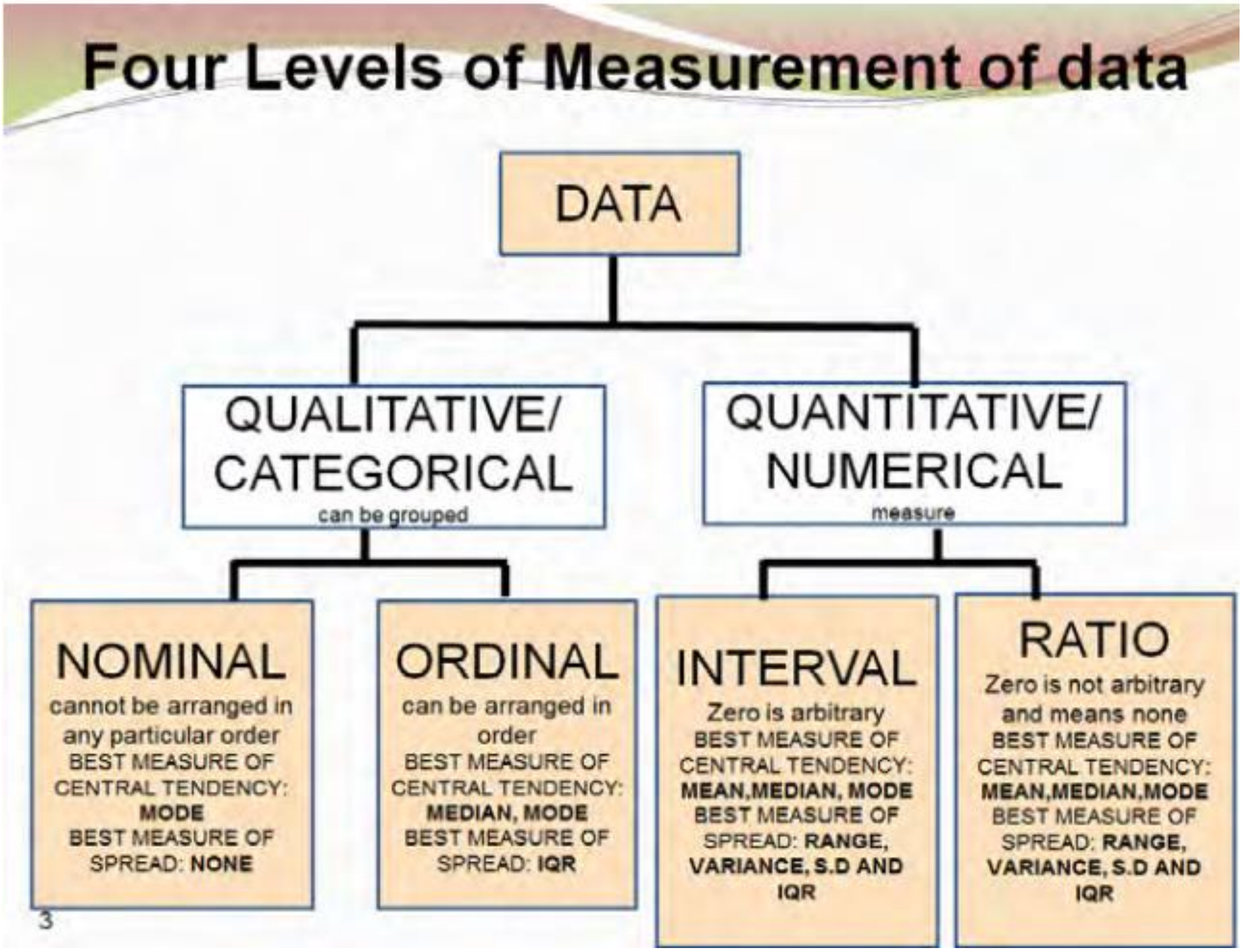

Figure 1: Scales of Measurement and Their Analysis Techniques

Ordinal Scale

Of all the four scales of measurement, ordinal scale is the most misunderstood level. This is evidenced by its misuse in several articles that include Singh et al. (2016), Le et al. (2020), Son (2020), Mushtaq et al. (2019), Lee (2022), Ruby-Ann (2013) and Yusuf (2020). Values of nominal variables are often not coded because researchers are aware of the fact that there is neither quantity nor quality to compare in these values. It is this sense of comparability in the values of ordinal variables that tempts researchers into coding and applying quantitative techniques in situations that are inappropriate. Researchers need to know that all quantities are numbers but not all numbers are quantities.

The greater part of studies carried out in business and social sciences deal with variables that are mostly qualitative. Questionnaires are designed in such a way that responses to the items are ordinal. The levels of agreeing 'strongly disagree,' 'disagree,' 'neutral,' 'agree' and 'strongly agree'—are a good example. For convenience, the values of the variables are often coded 1, 2, 3, 4 and 5. The letters A, B, C, D and E or any other 5 letters could serve the same purpose.

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Unfortunately, researchers are misled by numbers, thinking that mathematical operations can be done on these numbers. Little do researchers know that when numbers are used to code values of qualitative variables, there is no mathematical operation that can be done to these numbers as they intrinsically bear the qualitative nature of what they represent. The codes 1, 2, 3, 4 and 5 are equally spaced. It is not possible to establish the widths of the intervals between consecutive values of ordinal data. It is also not correct to assume that these values are equally spaced. Manipulating the codes would only be valid if we were able to prove the equality of the intervals between consecutive values of a variable that they represent. For better understanding of this, consider the numbers 40, 45, 78, 87 and 95, which are ages of five people. Ranking these marks and calculating the mean of the ages and that of the ranks, we obtain results that are shown in Table 4.

Table 4: Mean of Ages and Mean of Ranks

						Mean
Age	71	75	76	80	98	80
Rank	1	2	3	4	5	3

Looking at the table, we discover that the mean age is 80. The mean of ranks is 3 whereas the rank of the mean is 4. Now that the mean of ranks is different from the rank of the mean, ranks should be used with caution as they mislead. In this case, if the actual values were not there, one would be tempted to think that the 3rd value in the arrangement is the mean, but that is not it. This is a clear indication that the results that we obtain from applying mathematical operations on the ranks of variables are not valid.

The military ranks given in Table 3 are clearly ordered, with Lieutenant-Colonel being the lowest and General being the highest of those in the table. The numerical ranks that are assigned to these positions in the table carry only the sense of order. We know that there is more in Rank 2 than in Rank 1 and less in Rank 5 than in Rank 6. Nevertheless, we do not know how much more or how much less. Similar to the nominal scale, the four mathematical operations cannot be applied to ordinal data. Again, the ranks assigned to the positions do not change the variable to quantitative. All what we cannot do with the military ranks that are in the table can still not be done with the numerical codes, 1 to 6 assigned to the positions. A rank of 3 only tells us that there are two observations that have more or less of the quality of interest. We can neither count nor measure what is being ranked. The ratings of product satisfaction (very unsatisfied - 1, unsatisfied - 2, neutral - 3, satisfied - 4, very satisfied - 5), evaluations of the frequency of occurrences (very often - 1, often - 2, not often - 3, not at all - 4) and the assessments of the degree of agreement (totally agree - 1, agree - 2, neutral - 3, disagree - 4, totally disagree - 5) all fall under the ordinal scale (Shukla, 2024). Since we cannot obtain the mean of unsatisfied and satisfied under product satisfaction, then the mean of their ranks $\frac{2+4}{2} = 3$ is meaningless. This does not mean neutral. In addition to the mode, the median of ordinal data has meaning. Ordinary statistics like mean and standard deviation should not be used with ordinal data because these statistics imply that one knows more about the variable of interest than just the rank (Stevens, 1946).

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METHODOLOGY

A sample of 20 randomly downloaded articles on the topic, "Factors affecting academic performance," was studied. Of interest in the study was the scale of measurement of each of the variables in each study together with the technique used in the analysis of the data.

FINDINGS

Table 5 shows some of the information that is contained in the sampled papers. The author, dependent variable, scale of measurement of the factors and the technique of analysis used are the variables shown. It is evident from the table that researchers in education favor to structure the items of their data-collection-instruments for qualitative data in a way that makes the responses ordinal. Each of these ordinal variables was measured on a Likert-scale. It can also be seen in some cases that academic performance was also a categorical variable.

Table 5: Types of Variables and Analysis Technique

Authors	Dependent Variable	Factors	Analysis Technique
(Dasanayake T.N. Jayasinghe, J.A.G.P., 2021)	CGPA	Ordinal	Regression analysis.
(Singh et al., 2016)	Academic performance	Ordinal	Regression analysis.
(Le et al., 2020)	Academic performance	Ordinal	Regression analysis.
(Son, 2020)	Academic satisfaction	Ordinal	Regression analysis.
(Mengestu et al., 2022)	Average mark	Scale	Regression analysis.
(Yeshimebrat et al., 2013)	GPA	Ordinal	Regression analysis.
(Sujin et al.,	Academic performance	Ordinal	Regression analysis.
(Hijaz et al., 2006)	Academic performance	Scale & Ordinal	Regression analysis.
(Zahid et al., 2022)	Ordinal	Ordinal	Regression analysis.
(Vinita and Shreya, 2018)	GPA	Ordinal	Regression analysis.
(Hamid et al., 2022)	Academic performance	Ordinal	Correlation.
(Aneesa et al., 2024)	GPA	Nominal	Thematic Approach
Khumalo and Utete	Academic performance	Ordinal	Percentages.
(Frimpong et al., 2016)	CGPA	Ordinal	Mean and SD.
(Vijayamalar, 2024)	Academic performance	Ordinal	Mean and SD.
(Mushtaq et al., 2019)	Academic performance	Ordinal	Mean and SD.
(Lee, 2022)	Academic performance	Ordinal	Mean and SD.
(Ruby-Ann, 2013)	Academic performance	Ordinal	ANOVA
(Yusuf, 2020)	Academic performance	Ordinal	ANOVA
(Nazir et al, 2022)	Academic performance	Nominal	Factor analysis.

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Ordinary least squares multiple linear regression analysis was the most common technique used in the analyses. The mean and standard deviation were calculated and used by some of the authors. Analysis of Variance, Factor Analysis, Correlation, Thematic Approach and Percentages were also used. Ten of the twenty articles used multiple linear regression analysis, ANOVA was used twice, mean and standard deviation four times, with the rest being used once each. Of the 20 articles studied, 16 used explicitly ordinal data. One used ordinal together with scale as independent variables.

Table 6: Summary of the Techniques Used in the Analyses

	Frequency			
Technique	**Correct use**	**Wrong Use**	**Total**	**Percentage Use**
Regression Analysis	1	9	10	50%
Mean and SD	0	4	4	20%
Correlation	0	1	1	5%
Thematic Approach	1	0	1	5%
Percentages	1	0	1	5%
ANOVA	0	2	2	10%
Factor Analysis	1	0	1	5%

A summary of how many researchers used each technique and on whether each technique was correctly used or not is given in Table 6. The table shows that out of the 20 articles, 16 used inappropriate analysis techniques. Regression analysis was inappropriately used nine of the ten times that it featured in the twenty papers.

DISCUSSION

Regression Analysis, Correlation Analysis and Analysis of Variance are techniques that are meant for quantitative data. The mean and standard deviation are measures that are also reserved for data, that is, scale. The use of these techniques and measures suggests that researchers have the misconception that when they code data to numeric, the data becomes quantitative. In Section 2, this paper defined ‘scales of measurement’ as the four different ways in which numbers can be used. We can use numbers as values of variables of any scale of measurement. This does not convert qualitative data to quantitative. When we use numbers for values of qualitative variables, the numbers are called ‘codes’. These codes do not carry the usual sense of number that the general people know. Regression Analysis, Correlation Analysis and Analysis of Variance are called parametric techniques and these do not work with qualitative data. Even after coding, it is misleading to be found using the mathematical operations $+, -, \times \; and \; \div$ for these codes, in Parametric Statistics.

Statisticians have developed Non-Parametric Techniques that are meant for analysis of these codes. These include Spearman's rank correlation coefficient, Mann-Whitney U test, Friedman’s ANOVA and Kruskal-Wallis H test. All these have been developed for the analysis of ordinal data,

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and this was after realizing the shortfalls of parametric techniques in dealing with such data. Tabular or graphical formats and descriptive statistics such as percentile, quartile, median and mode are applicable for ordinal scale data. Since the interval between the codes is not significant, mathematical operations and measures of dispersion are not applicable.

CONCLUSION

This study looked at the four scales of measurement in general and the ordinal scale in particular. Articles on factors affecting students' academic performance were analyzed for purposes of finding out how researchers analyze ordinal data. It was discovered that researchers think that ordinal data, which is qualitative, when coded, becomes quantitative, which is not the case. It was found out that researchers are using parametric methods for ordinal data, suggesting that they (researchers) are not aware of the non-parametric techniques that are reserved for such data. Researchers are encouraged to learn these non-parametric methods for improvement of the validity of ordinal data analysis results.

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