

2.6: Levels of Measurement

2.6.0.0.1 Levels of Measurement

Numbers mean different things in different situations. Consider three answers below that appear to be the same, but they really are not. All three questions pertain to a running race that you just finished. The three 5s all look the same. However, the three variables (identification number, finish place, and time) are quite different. Because of these different variables, the way we interpret 5 is unique for each variable.

- What number were you wearing in the race?
- What place did you finish in?
- How many minutes did it take you to finish the race?

To illustrate the difference, consider your friend who also ran the race. Their answers to the same three questions were 10, 10, and 10. If we take the first question by itself and know that you had a score of 5, and your friend had a score of 10, what can we conclude? We can conclude that your race identification number is different from your friend's number. That is all we can conclude. On the second question, with scores of 5 and 10, what can we conclude regarding the place you and your friend finished in the race? We can state that you were faster than your friend in the race and, of course, that your finishing places are different. Comparing the 5 and 10 on the third question, what can we conclude? We could state that you ran the race twice as fast as your friend, you ran the race faster than your friend and that your time was different than your friend's time. The point of this discussion is to demonstrate the **relationship between the questions we ask, and what the answers to those questions can tell us**. Chances are, much of your past experience with numbers has been with pure numbers or with measurements such as time, length, and amount. "Four is twice as much as two" is true for the pure numbers themselves and for time, length, and amount –but this statement would not be true for finish places in a race. Fourth place is not twice anything in relation to 2nd place. Fourth place is not twice as slow or twice as far behind the 2nd place runner. The types of descriptive and inferential statistics we can use depend on the type of variable measured. Remember, a variable is defined as a characteristic we can measure that can assume more than one value.

For statistical analysis, exactly how the measurement is carried out depends on the type of variable involved in the analysis. Different types are measured differently. To measure the time taken to respond to a stimulus, you might use a stopwatch. Stopwatches are of no use, of course, when it comes to measuring someone's attitude towards a political candidate. A rating scale is more appropriate in this case (with labels like "very favorable," "somewhat favorable," etc.). For a dependent variable such as "favorite color," you can simply note the color-word (like "red") that the subject offers.

Although procedures for measurement differ in many ways, they can be classified using a few fundamental categories. The psychologist S. S. Stevens suggested that scores can be assigned to individuals so that they communicate more or less quantitative information about the variable of interest (Stevens, 1946). Stevens actually suggested four different levels of measurement (which he called "scales of measurement") that correspond to four different levels of quantitative information that can be communicated by a set of scores. In a given category, all of the procedures share some properties that are important for you to know about. The categories are called "scale types," or just "scales," and are described in this section.

Nominal scales

When measuring using a nominal scale, one simply names or categorizes responses. Gender, handedness, favorite color, and religion are examples of variables measured on a nominal scale. The essential point about nominal scales is that they do not imply any ordering among the responses. For example, when classifying people according to their favorite color, there is no sense in which green is placed "ahead of" blue. Responses are merely categorized. Nominal scales embody the lowest level of measurement.

Ordinal scales

A researcher wishing to measure consumers' satisfaction with their microwave ovens might ask them to specify their feelings as either "very dissatisfied," "somewhat dissatisfied," "somewhat satisfied," or "very satisfied." The items in this scale are ordered, ranging from least to most satisfied. This is what distinguishes ordinal from nominal scales. Unlike nominal scales, ordinal scales allow comparisons of the degree to which two subjects possess the dependent variable. For example, our satisfaction ordering makes it meaningful to assert that one person is more satisfied than another with their microwave ovens. Such an assertion reflects the first person's use of a verbal label that comes later in the list than the label chosen by the second person.

On the other hand, ordinal scales fail to capture important information that will be present in the other scales we examine. In particular, the difference between two levels of an ordinal scale cannot be assumed to be the same as the difference between two other levels. In our satisfaction scale, for example, the difference between the responses “very dissatisfied” and “somewhat dissatisfied” is probably not equivalent to the difference between “somewhat dissatisfied” and “somewhat satisfied.” Nothing in our measurement procedure allows us to determine whether the two differences reflect the same difference in psychological satisfaction.

Statisticians express this point by saying that the differences between adjacent scale values do not necessarily represent equal intervals on the underlying scale giving rise to the measurements. (In our case, the underlying scale is the true feeling of satisfaction, which we are trying to measure.)

What if the researcher had measured satisfaction by asking consumers to indicate their level of satisfaction by choosing a number from one to four? Would the difference between the responses of one and two necessarily reflect the same difference in satisfaction as the difference between the responses two and three? The answer is No. Changing the response format to numbers does not change the meaning of the scale. We still are in no position to assert that the mental step from 1 to 2 (for example) is the same as the mental step from 3 to 4.

(Equal) Interval scales

Interval scales are numerical scales in which intervals have the same interpretation throughout. As an example, consider the Fahrenheit scale of temperature. The difference between 30 degrees and 40 degrees represents the same temperature difference as the difference between 80 degrees and 90 degrees. This is because each 10-degree interval has the same physical meaning (in terms of the kinetic energy of molecules).

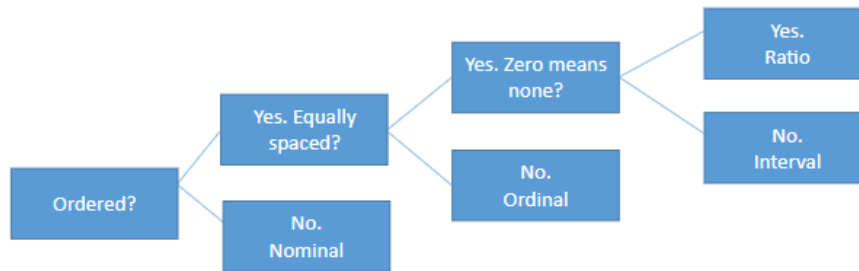
Interval scales are not perfect, however. In particular, they do not have a true zero point even if one of the scaled values happens to carry the name “zero.” The Fahrenheit scale illustrates the issue. Zero degrees Fahrenheit does not represent the complete absence of temperature (the absence of any molecular kinetic energy). In reality, the label “zero” is applied to its temperature for quite accidental reasons connected to the history of temperature measurement. Since an interval scale has no true zero point, it does not make sense to compute ratios of temperatures. For example, there is no sense in which the ratio of 40 to 20 degrees Fahrenheit is the same as the ratio of 100 to 50 degrees; no interesting physical property is preserved across the two ratios. After all, if the “zero” label were applied at the temperature that Fahrenheit happens to label as 10 degrees, the two ratios would instead be 30 to 10 and 90 to 40, no longer the same! For this reason, it does not make sense to say that 80 degrees is “twice as hot” as 40 degrees. Such a claim would depend on an arbitrary decision about where to “start” the temperature scale, namely, what temperature to call zero (whereas the claim is intended to make a more fundamental assertion about the underlying physical reality).

Ratio scales (Absolute zero)

The ratio scale of measurement is the most informative scale. It is an interval scale with the additional property that its zero position indicates the absence of the quantity being measured. You can think of a ratio scale as the three earlier scales rolled up in one. Like a nominal scale, it provides a name or category for each object (the numbers serve as labels). Like an ordinal scale, the objects are ordered (in terms of the ordering of the numbers). Like an interval scale, the same difference at two places on the scale has the same meaning. And in addition, the same ratio at two places on the scale also carries the same meaning.

The Fahrenheit scale for temperature has an arbitrary zero point and is therefore not a ratio scale. However, zero on the Kelvin scale is absolute zero. This makes the Kelvin scale a ratio scale. For example, if one temperature is twice as high as another as measured on the Kelvin scale, then it has twice the kinetic energy of the other temperature.

Another example of a ratio scale is the amount of money you have in your pocket right now (25 cents, 55 cents, etc.). Money is measured on a ratio scale because, in addition to having the properties of an interval scale, it has a true zero point: if you have zero money, this implies the absence of money. Since money has a true zero point, it makes sense to say that someone with 50 cents has twice as much money as someone with 25 cents (or that Bill Gates has a million times more money than you do).



Here is a decision tree that you might find helpful for classifying data into N-O-I-R

Kara's note: I use the acronym NOIR (pronounced like the French word meaning dark or black: nuh-waar) to help me remember the order of the levels.

Digging deeper: What about the number value? It is important to know what number values mean. Is the number meaningful or it is a category? This section briefly reviews how numbers can be categorized according to meaning.

Binary numbers. The simplest are binary numbers – that is, zero or one. We will often use binary numbers to represent whether something is true or false, or present or absent. For example, I might ask 10 people if they have ever experienced a migraine headache, recording their answers as “Yes” or “No”. It’s often useful to instead use *logical* values, which take the value of either `TRUE` or `FALSE`. This can be especially useful for programming languages to analyze data, since these languages already understand the concepts of `TRUE` and `FALSE`. In fact, most programming languages treat truth values and binary numbers equivalently. The number 1 is equal to the logical value `TRUE`, and the number zero is equal to the logical value `FALSE`.

Integers. Integers are whole numbers with no fractional or decimal part. We most commonly encounter integers when we count things, but they also often occur in psychological measurement. For example, in my introductory survey I administer a set of questions about attitudes towards statistics (such as “Statistics seems very mysterious to me.”), on which the students respond with a number between 1 (“Disagree strongly”) and 7 (“Agree strongly”). Integers are discontinuous.

Real numbers. Most commonly in statistics we work with real numbers, which have a fractional/decimal part. For example, we might measure someone’s weight, which can be measured to an arbitrary level of precision, from kilograms down to micrograms. Real numbers can be discontinuous or continuous.

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