INTRODUCTION

Key terms:

• A *variable* is a characteristic that differs in amount or kind within a person (for example from time to time), or from one person to another. The opposite is a *constant*, which always remains the same.

• *Measurement* involves systematically assigning labels (names) or values (scores) to variables in order to show in what way or how much they differ.

• A *scale* is a system of labels (names) or values that express the kind or the amount of difference between variables.

• The different labels or values of different people on a scale provide *data* about differences among the people.

Differences

The thing that interests social scientists is that people differ from one another. If no such differences existed there would be no social sciences, since there would be nothing to study. The differences are often readily visible – one person may usually be cheerful, another usually gloomy, one person learns fast, another slowly, one is stubborn, another gives in easily – but some are less obvious and need to be detected through more subtle instruments such as psychological tests. The first task is thus to identify the differences. Having been detected and described, they are given labels: In the case of psychology, examples are “moods,” “attitudes,” “values,” motives,” “interests,” “abilities,” “skills,” and the like. There are, however, different kinds of differences:

• *Within-person differences*: A single person may differ across areas (for example, a person's *interest* in football may be high, but the same person's football *skill* may be low). An individual person may also change with the passage of time (for example, the person just mentioned may become less interested in football as time passes and more interested in studying statistics).

• *Between-person differences*: The differences may relate to different people: One person may be good at, let us say, football, a different person less good at the same sport. Such between-person differences may be larger or smaller in different domains or may become larger or smaller with the passage of time.

• *Between-group differences*: The differences may relate to groups of people (e.g., artists versus engineers, people who have had therapy versus those who have not, the elderly versus the youthful).

A specific dimension which is bigger or smaller (such as body weight) or stronger or weaker (such as the tendency to be cheerful) in the same person from time to time, in some people than in others, or between groups of people is referred to as a *variable* because it varies within a person or between people or groups of people. A dimension which never changes is referred to as a "constant," although constants are of only passing interest in these notes.

Measurement

Having identified a variable (an area of difference), defined it, and given it a name (motivation, personality, intelligence, or whatever), the next broad issue is to work out where these differences come from (for example, from physical development or from learning), and whether and how they can be influenced (e.g., encouraged/discouraged, developed, improved, etc). To do this, however, it is necessary to be able to *measure* the variable. For instance, in order to be able to say that a person now has a higher level of motivation to learn statistics, you need to be able to say how much motivation the person used to have and how much he or she now has. In fact, to work out how big the differences are (a) within a single person (e.g., by how much has the interest in football of the person mentioned above changed over the years?), (b) from person to person (e.g., how big is the difference in interest in football between Person A and Person B?), or (c) from group to group (e.g. men versus women, engineers versus artists, patient versus impatient people) it is necessary to be able to *measure* the amount, strength, or level of a variable. To do this you need a measuring device of some kind. For example, a thermometer is used to measure whether a person's temperature is higher today than it was yesterday (within-person difference), or whether there is a difference in temperature between two people (between-person difference). In social sciences the measuring instrument is often, although far from always, some kind of test.

Measurement is simply the process of rating the kind, level or strength of some variable (IQ, interest in football, etc). For example, we could simply say that one person is heavy, another light. "Light" versus "heavy" is a rather undifferentiated system for measuring body weight, but it gives an idea of the difference in weight between the two people. We could also say that one person weighs 74.45kg, whereas another weighs 74.87kg. Compared with "light" and "heavy" this is a more precise statement about the difference between the two people, but it requires a more precise measuring device. In fact, the exactness of measurements depends on the qualities of the system we use to measure them

Scales

The various scores provided by a measuring instrument are sometimes given *names*, such as "very small," "small," "about average," "quite large," "very large," and "huge." Such a sequence is referred to as a "scale." All human beings could be rated on a particular variable (such as body weight) by being given one of the ratings just listed (e.g. "large" or "small"). An alternative scale for rating body weight would be a set of values ranging from, let us say, 20kg to 300kg. Although the two scales both rate body weight, it is obvious that they yield rather different information and that the second scale permits more precise statements: For example, if one person were rated "about average" on body size, another "quite large," you would have only an approximate idea of the difference between them, whereas if the first person were rated 75kg, the second 92kg you would have a much more exact idea of the difference. This is because there are several key differences between the two scales and the scores they yield.

Discrete versus continuous variables

A *discrete* variable is one where no values exist between adjacent units on the scale. The number of children in a family is an example of a discrete variable. A family can only have 1, 2, 3, or more children. You cannot have families with 1½ or 2½ children. No values exist between 1 and 2, between 2 and 3, etc. A *continuous* variable**,** on the other hand, is one where there are is, at least in theory, an infinite number of values between adjacent units on the scale. Distance, weight and time are examples of continuous variables. In theory, there are an infinite number of values between, say, 1cm and 2cm (e.g., 1.1cm, 1.2cm etc) or between 1gram and 2grams or 1sec and 2 secs, etc.

Different kinds of data

The ratings given to a particular variable by using a scale can be referred to as "data." For example, the statement that Person A is "large" and Person B is "small" contains data on the body size of the two people whose weight was assessed using the scale outlined above. However, it is apparent that there is a difference between the statement that Person A is large whereas Person B is small and the statement that Person A weighs 120.4kg whereas Person B weighs 59kg. In fact, there are four classes of data:

- *Nominal data*[1] merely give a name or label to something ("nomen" is Latin for "name"). For example, the term "bottle" on the scale "cup," "bottle," "plate," "saucepan" simply tells you that a bottle is a different *kind* of thing from a plate. It does not tell you that a bottle has less or more "plateness" than a cup, or vice- versa. Thus, a nominal scale tells you only the name of something, and the data such a scale yields are *nominal data*. There are two important points to note about nominal scales. First, no distinction is made between members belonging to a particular class or category. For example, all bottles are bottles and all plates are plates. There is no distinction made as to the degree of "plateness" or "bottleness" *within* each category, even though such differences may exist. Second, differences *between* categories on the scale do not reflect any differences on some broader characteristic such as "containerness." The names comprising the data yielded by the scale signify only that a particular object (or it could be a person) belongs to a particular category: A plate is a different *kind* of thing from a bottle.[2]

[1] Please note that the word "data" is *plural*; "data give" not "data gives" or, a few lines later, "data are" not "data is."

[2] Note that the scale for body weight discussed so far is not a nominal scale and its data are not nominal data, because values on the scale such as "large" and "small" do reflect differences on a broader concept (body size): See the next category.

To sum up: Nominal data consist of names or labels indicating differences in *kind*. If people were asked, "What is your favourite sport?" the answers (*data* on favourite sports) might be: Person A "football;" Person B "tennis;" Person C "swimming;" Person D "hockey." The ratings "football," "tennis," "swimming," and "hockey" are ratings on a *nominal* scale and provide nominal data.

• *Ordinal Data*: Unlike nominal scales, ordinal scales provide rudimentary data on magnitude (size, strength, amount etc). They do this by arranging the points on a scale *in order*, according to how much of some variable the object or person being measured possesses. First position on the scale means either the least or the most of whatever the scale measures and the last position means the opposite. Successive positions along the scale indicate intermediate values for the variable in a logical sequence (for example: biggest first, second-biggest next, …. smallest last). The resulting data are *ordinal* data. However, ordinal data only indicate *position in an ordered series*. They do not indicate the size of the difference between successive positions on the scale. For example, ratings on the scale "very small," "small," "about average," "quite large," "very large," and "huge" form an ordered sequence: "Small" is larger than "Very small," "About average" is larger than "Small," and so on. However, the scale does not tell us *how much* bigger "Small" is than "Very Small," or how much bigger "Average" is than "Small." The distance between "Very Small" and "Small" may be greater or less than the distance between "Small" and "Average," or it may even be the same; *An ordinal scale takes no notice of the size of differences between positions on* *the scale and indicates only their order.* Thus, the body weight scale described above goes beyond a nominal scale, because each successive point on the scale is not just different from the others, but it is also bigger or smaller, but it does not go as far as the next kind of scale.

> **To sum up**: Ordinal scales place what is being rated in order, for example from smallest to largest or from strongest to weakest (you can start at either end). However, the distances between points on the scale do not indicate how large the distances between the points are. Such scales yield *ordinal data*.

• *Interval Data*: Interval scales, yield the information obtained from ordinal scales (i.e., order on the scale), but go a step further: difference between adjacent points on the scale represent equal increases (or decreases) in the amount of the variable being measured; the difference in height between 1.50m and 1.60m (10 cm) is identical to the difference between 1.80m and 1.90m (also 10 cm), and so on. This is the special quality of interval data. Social scientists are usually satisfied with interval data.

> **To sum up**: An interval scale does what an ordinal scale does (it tells you that something is bigger than something else, or there is more of it), but then goes further and tells you how much bigger or smaller it is.

• *Ratio Data*[3]: However, interval scales only have arbitrary zero points. For example, on the Celsius temperature scale 0° does not represent the complete absence of heat! The temperature 0°C is merely an arbitrary point on the Celsius scale, the point at which water freezes at normal atmospheric pressure. With interval scales, then, we cannot say that one value on the scale represents so many *times* more or less of the variable being measured than another value on the scale. Water at 40°C does not contain twice as much heat as water at 20°C, although in everyday conversation we may say that it is twice as hot.[4] To be able to say that one value represents a certain percentage of whatever is being measured, we need a *ratio* scale. The crucial property of ratio scales is that the value zero really does mean complete absence of whatever is being measured. Such scales are relatively common in the physical sciences (e.g., weight, volume, speed): For example, a parked car really does have a speed of 0k/h because it is not moving at all. However, ratio data are rare in the social sciences, because we are not usually dealing with variables that have an absolute zero: an IQ of 0 would mean that the person in question knew absolutely nothing about anything at all – hard to imagine. Ratio data provide all the information provided by interval data (e.g., amount and not just kind, equal intervals between adjacent values) but, in addition, also possess an absolute zero point. This means that we can now say that a value on the scale represents so many times more or less of the variable being measured than another value on the scale.

[3] If you don't understand this, don't worry. As a rule social scientists are satisfied with interval data and, indeed, often work with merely ordinal or even simply nominal data. For example, the widely-used statistic Chi-Square uses nominal data.
[4] For those who are interested, water at 40°C contains 1.07 times as much heat as water at 20°C.

Special note: Higher-order scales, yield data containing all the information in lower-order scales, but add something more: nominal data tell you only that things are different; ordinal data add to this by indicating the rank or order according to which they differ (e.g. "big," "bigger," "biggest"). Interval data add to ordinal data by telling you by how much they differ (e.g. "10kg," "20kg," "30kg"). Finally, ratio data tell you not only that things differ (nominal data), and that they differ in a particular order (ordinal data), and not only how big the differences are (interval data), but also the ratio of the differences (e.g. 20kg is twice 10 kg, 30kg is half 60kg, etc). This cumulation of information means that ratio data can be converted into lower-order data. For example, a list of body weights, let us say 120kg, 100 kg, 84kg, 60kg, (interval data) could be simplified to ordinal data (heaviest, second heaviest, third heaviest, lightest). The sacrifice of information by converting "down" from interval to ordinal data means, for example, that in the example of body weight data just given, you no longer know that the difference in weight between the second heaviest person and the third heaviest was smaller than the difference between the third heaviest and the least heavy person. However, merely knowing that one person weighed more than another (or less) may suffice. See, for example, later discussions of "parametric" versus non-parametric" statistics (but do not be intimidated by these terms).