26. THE STEPS TO MEASUREMENT

Everyone who studies measurement encounters Stevens's levels (Stevens, 1957). A few authors critique his point of view, but most accept his propositions without deliberation. An enumeration, with some examples, suffices.

Stevens worked in the psychophysics of Weber and Fechner. But current authors on measurement see little connection between psychophysics and modern measurement practice. This primer shows a connection between psychophysics, Stevens's levels and Rasch measurement.

THE FUNDAMENTAL STEPS TO MEASUREMENT

When Stevens specifies four levels, he is identifying not four kinds of measurement but the four fundamental steps which lead to measurement. These steps are necessary to make measures. Each step must be satisfied to reach generalizable findings. The steps are: categorizing, ordering, constructing a unit, and setting an origin. The correspondence between the fundamental measurement steps to Stevens's levels is shown in Figure 26.1.

Figure 26.1

The steps of measurement.

FUNDAMENTAL STEPS STEP AND FEATURE	STEVENS' LEVELS LEVELS REACHED
1. Categorizing - deciding what to collect	1. Nominal
2. Ordering - defining what to count	2. Ordinal
3. Constructing an Abstract Unit - establishing a real number line	3. Interval
4. Setting an Origin - incorporating the logarithmic/ exponential connection between addition and multiplication	4. Ratio

On the left of Figure 26.1 are the steps to measurement: categorizing, ordering, constructing a unit, and setting an origin. These steps correspond to Stevens's nominal, ordinal, interval, and ratio levels on the right of Figure 26.1.

CATEGORIZING

Categorizing is the first step to measuring. We begin by determining what is to be noticed and collected, and also what is to be disregarded. In order to focus, we fix on single aspects isolated from the infinite variety of observations we might make. Until we can identify and maintain a single focus in our observations, i.e. categorize, we remain overwhelmed by the volume of possibilities that we perceive.

ORDERING

The second measurement step is to identify and isolate a useful line of inquiry along which elements can be ordered and comparisons made. This becomes the potential "variable," that guides us in collecting relevant observations which are relatively uncontaminated by irrelevant complications. It is not that complications cannot be informative, it is only that complications must become irrelevant in order to focus upon the one variable of interest. Sole focus evokes the clear determinations not possible when we admit a clutter of complications. Multivariate analysis is useful only after each variable has, itself, been realized as a single workable measure.

Stevens' nominal level concerns what is accomplished by categorizing.

CONSTRUCTING A UNIT: ADDITION

Constructing an abstract unit is the third step. We need to determine "how much," along the abstract variable, is indicated by observations of concrete counts.

Determining "how much" models the units as additive and hence linear. This results from item calibrations which define distances between observations categorized, ordered and counted.

SETTING AN ORIGIN: MULTIPLICATION

Fechner's postulation of a logarithmic relationship between stimuli and sensation enabled him to restate Weber's law to show that sensations are proportional to the logarithms of their exciting stimuli.

The third and fourth steps to measurement - units and origins are shown to merge by the logarithmic/exponential relationship between additive and multiplicative functions.

The logarithmic function (and its inverse, the exponential function) connect addition and multiplication. This connection is the tool we need to make measures.

Stevens calls the additive function "interval" measurement and the multiplicative function "ratio" measurement. However, the difference is merely the two sides of one characteristic, numerosity. The additive and multiplicative functions are dualities that bring out the joint necessity of determining a unit of measurement and setting an origin.

MAKING MEASURES

Raw counts of observations represent the additive function in its primitive concrete form. But counts are not measures. Measures are constructed from counts by transforming counts of concrete observations into abstract measurement. It is this transformation which constructs measures. How is this transformation made? What are the steps?

Georg Rasch addresses this in his *Probabilistic Models for Some Intelligence and Attainment Tests* (1960, 1993).

> [Rasch] makes use of none of the classical psychometrics, but rather applies algebra anew to a probabilistic model. The probability that a person will answer an item correctly is assumed to be the product of an ability parameter pertaining only to the person and a difficulty parameter pertaining only to the item. Beyond specifying one person as the standard of ability or one item as the standard of difficulty, the ability assigned to an individual is independent of that of other members of the group and of the particular items with which he is tested; similarly for the item difficulty... Indeed, these two properties were once suggested as criteria for absolute scaling (Loevinger, 1947); at that time proposed schemes for absolute scaling had not been shown to satisfy the criteria, nor does Guttman scaling do so. Thus Rasch must be credited with an outstanding contribution to one of the two central psychometric problems, the achievement of non-arbitrary measures (Loevinger, 1965, p. 151).

RASCH'S METHOD OF PARAMETER ESTIMATION

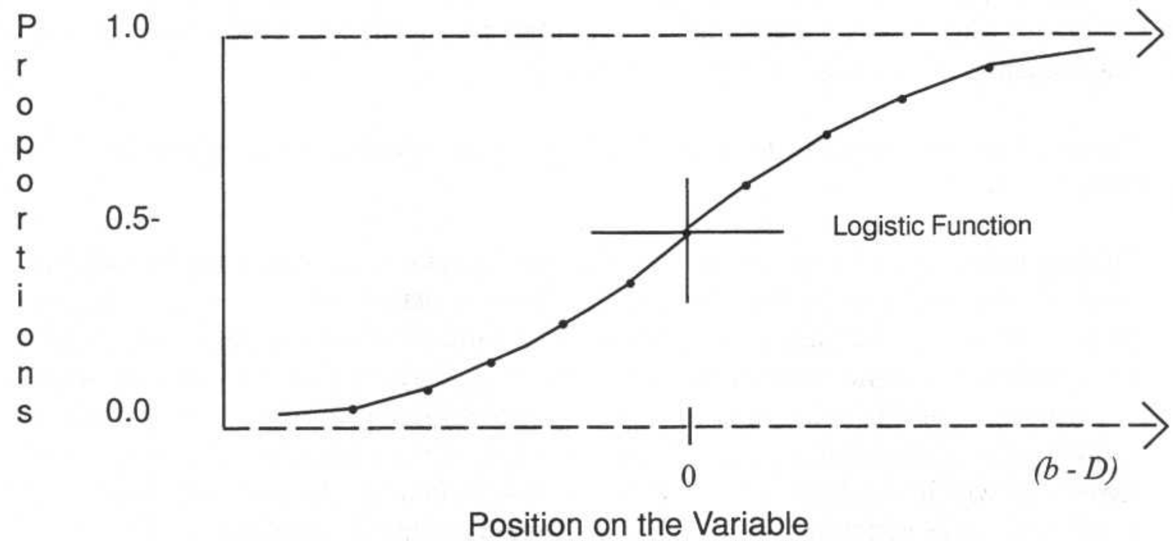
In *Probabilistic Models*, Rasch groups persons by their scores and takes the log ratio of successes to failures for each score group. He then fits these log odds to a two-way linear model to derive item-by-score group logits.

The log odds (logit) transformations of the original success-failure counts (when there are no interactions) produce parallel straight lines when item-by-score group logits are plotted against their averages over items or score groups. The logit transformation connects the two-factor multiplicative function to a one-dimensional additive function.

In Figure 26.2 we see how counts of success/failure on the ordinate can be transformed into measures on the abscissa by the logistic function. The bounded values of counts are transformed into unbounded measures. Given score groups large enough to give every item some successes and some failures, this logit transformation enables estimation of the simple linear structure that Rasch called objective measurement. Methods of parameter estimation are described in Wright & Douglas (1975), Choppin (1978), and Wright & Stone (1979).

Figure 26.2

Relating counts to measures.



Ordinate: counts expressed as $0 \leq$ proportion ≤ 1 (bounded).
Abscissa: Differences expressed as logits $-\infty < (B - D) < +\infty$ (unbounded).

MEASUREMENT ESSENTIALS

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