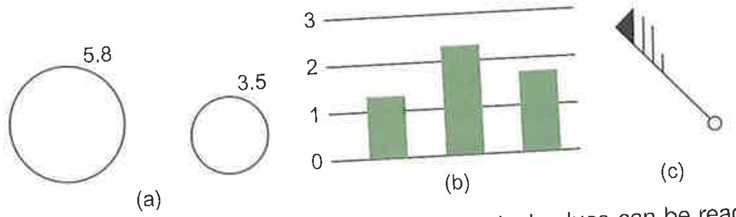

Figure 5.25 Three different ways that more exact numerical values can be read from a diagram.

There are a number of solutions to the problem of representing quantities. One is simply to add numbers to a glyph, or a numerical scale; see Figure 5.25(a, b). But, unless it is done carefully, the numbers will add visual noise, obscuring important patterns in data. A second solution is to create a glyph that by its shape conveys numerical values. The best known example of this is the wind barb, which is shown in Figure 5.25(c). A wind barb is a glyph widely used in meteorology that is a kind of hybrid of perceptual features and symbolic features. The shaft of the barb represents the direction of the wind. The "feathers" of the barb encode wind speed, so that someone familiar with the code can read off the wind speed to an accuracy of 5 knots. Given that surface wind speeds range up to about 150 knots, this means that wind barbs have about 30 steps of resolution, far better than any simple variation in size or color. The wind barb, however, has perceptual problems. The barb feathers greatly interfere with the perception of wind direction and because of this wind barbs are very poor at showing patterns in the winds.

Multidimensional Discrete Data: Uniform Representation versus Multiple Channels

This is a good place to step back and look at the general problem of multivariate discrete data display in light of the concepts that have been presented here and in previous chapters. It is worth restating this problem. We are provided with a set of entities, each of which has values on a number of attribute dimensions. For example, we might have 1000 beetles, each measured on 30 anatomical characteristics, or 500 stocks, each described by 20 financial variables. The reason for displaying such data graphically is often data exploration—to find meaning in the diversity. In the case of the beetles, the meaning might be related to their ecological niche. In the case of the stocks, the meaning is likely to lie in opportunities for profit. In either case, we are likely to be interested in patterns in the data, such as clusters of beetles that share similar attribute values.

If we decide to use a glyph display, each entity becomes a graphical object and data attributes are mapped to graphical attributes of each glyph. The problem is one of mapping data dimensions to the graphical attributes of the glyph. The work on preattentive processing, early visual processing, and integral and separable dimensions

Table 5.1 *Graphical attributes that may be useful in glyph design.*

Visual Variable	Dimensionality	Comment
Spatial position	Three dimensions: *X*, *Y*, *Z*	
Color	Three dimensions: defined by color opponent theory	Luminance contrast is needed to specify all other graphical attributes.
Shape	Size and orientation are basic but there may be more usable dimensions	The dimensions of shape that can be rapidly processed are unknown; however, the number is certainly small.
Surface texture	Three dimensions: orientation, size, and contrast	Surface texture is not independent of shape or orientation; uses one color dimension.
Motion coding	Approximately two to three dimensions; more research is needed, but phase is critical	
Blink coding	One dimension	Motion and blink coding are highly interdependent.

suggests that a rather limited set of visual attributes is available to us if we want to understand the values rapidly. Table 5.1 lists the most useful low-level graphical attributes that can be applied to glyph design, with a few summary comments about the number of dimensions available.

Many of these display dimensions are not independent of one another. To display texture, we must use at least one color dimension (luminance) to make the texture visible. Blink coding will certainly interfere with motion coding. Overall, we will probably be fortunate to display eight types of dimensional data clearly, using color, shape, spatial position, and motion to create the most differentiated set possible.

There is also the issue of how many resolvable steps are available in each dimension. The number here is also small. When we require rapid preattentive processing, only a handful of colors are available. The number of orientation steps that we can easily distinguish is probably about four. The number of size steps that we can easily distinguish is no more than four, and the values for the other data dimensions are also in the single-digit range. It is reasonable, therefore, to propose that we can represent about 2 bits of information for each of the eight graphical dimensions. If the dimensions were truly independent, this would yield 16 displayable bits per glyph (64,000 values). Unfortunately, conjunctions are generally not preattentive. If we allow no conjunction searching, we are left with four alternatives on each of eight dimensions, yielding only 32 rapidly distinguishable alternatives, a far smaller number. Anyone