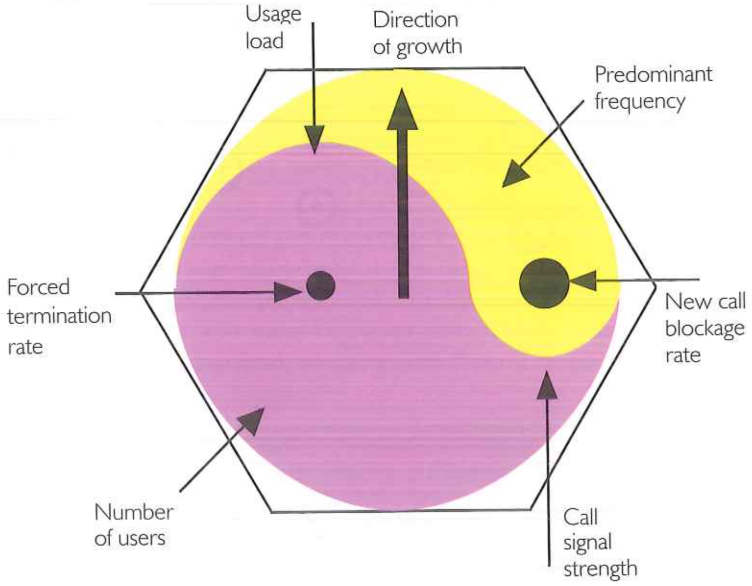

FIGURE 3.38 Representation of attributes associated with a mobile telephone network cell

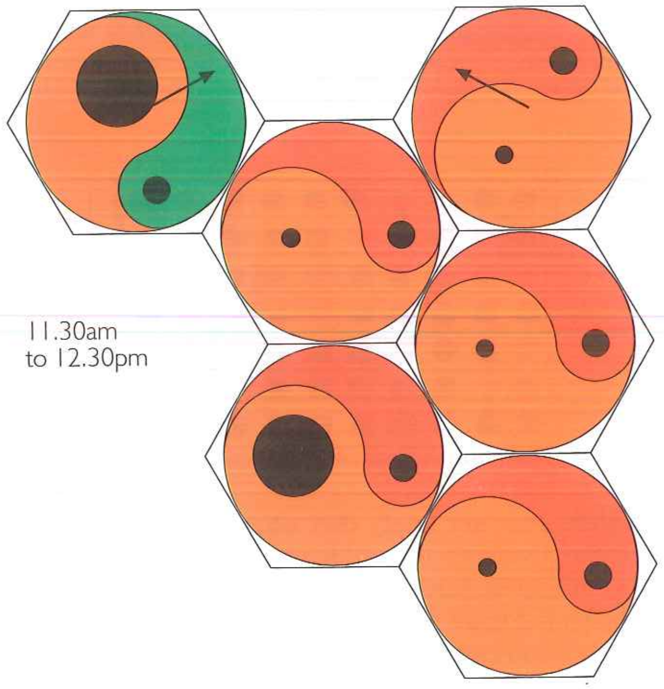

FIGURE 3.39 Representation of attributes associated with a network of mobile telephone cells, averaged over one hour

The examples provided above involve *static* representations of data. Fortunately, the advantages to be gained from pre-attentive processing can be extended through the use of animation, whether automatically or manually controlled. For example, Figure 3.40 shows the map display of Figure 3.32 but with

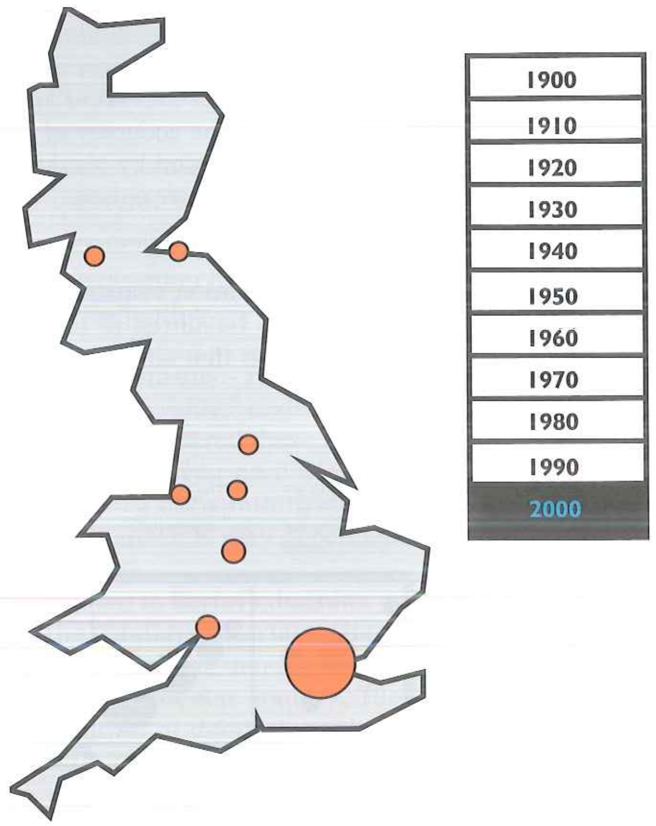

FIGURE 3.40 Circles change in size as the decades are animated, so that sudden changes in population 'pop out'

the addition of a scale calibrated in the decades since 1900 AD. If successive steps on the scale are now highlighted in sequence at a rate of about 5–10 per second, and circles are correspondingly sized, then a mental model of the changes in city populations could quickly be formed. Especially, the emergence of new centres of population would immediately be apparent and, just as with a static representation, 'pop out'. The idea that animation can facilitate 'pop-out' is examined further in Chapter 5.

Although it seems reasonable to employ circle size to encode city populations in Figure 3.40, it is natural to ask 'Why?' Why not use shading? Or bars? Or colour? Or shape? We have seen examples (e.g. Minard) where circle or line size or thickness are suited to the encoding of quantity, and where colour or shape would be inappropriate; colour and shape are perhaps more suited to situations where objects must be perceived as similar or different. Obviously guidance is needed as to the most appropriate encoding for a given task, though it must be realized that the most appropriate encoding depends upon many factors. We briefly discuss this matter below.

Choice of encoding

Although, as Mackinlay (1986) stated, 'there does not exist an empirically verified theory of human perceptual capabilities that can be used to prove theorems about the effectiveness of graphical languages', guidance regarding a choice of encoding is available from many sources, of which three are considered here. The first example is provided by Bertin (1967, 1983), a French pioneer of information visualization. The second comes from the statisticians Cleveland and McGill (1984) following an experiment in which they assessed the accuracy of judging variously encoded quantitative variables. The third is provided by Mackinlay (1986) who considered ordinal and categorical as well as quantitative data.

Bertin's guidance

Bertin identified four *tasks* common to information visualization and identified the encoding mechanisms he considered to be suited to those tasks. He presented his conclusions in a diagram similar to that shown in Figure 3.41, using

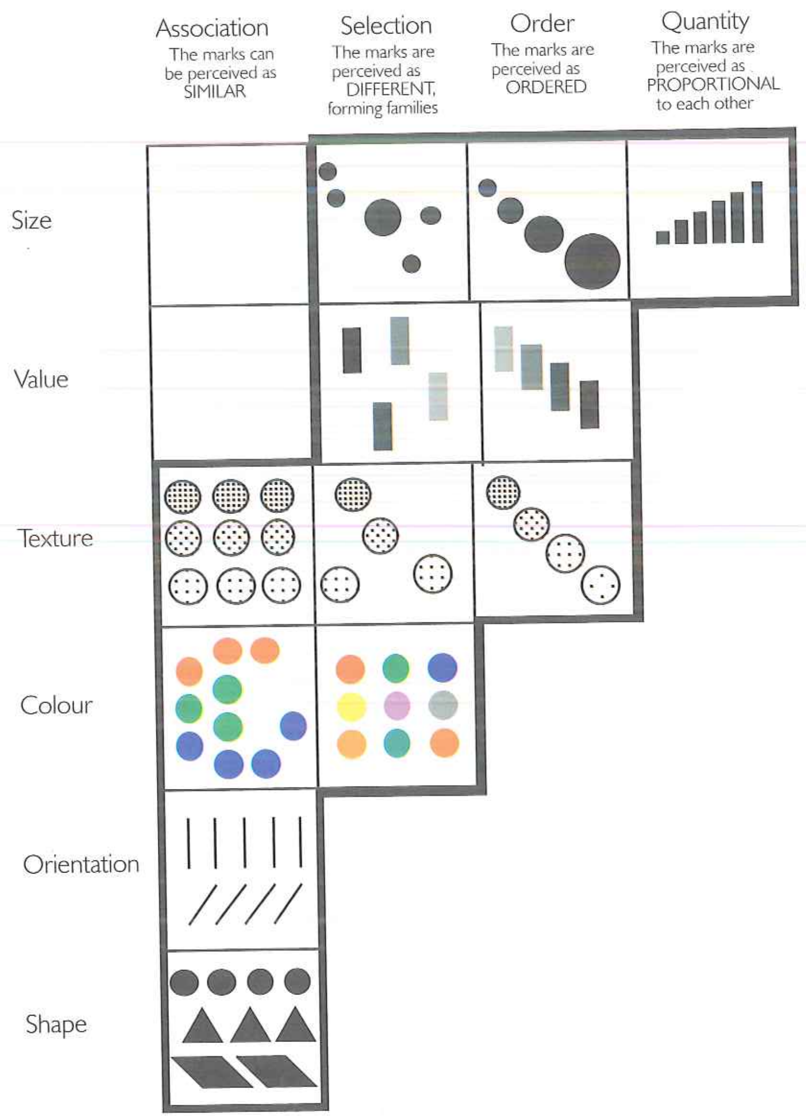

FIGURE 3.41 Interpretation of Bertin's guidance regarding the suitability of various encoding methods to support common tasks

the term 'mark' to denote the result of encoding (e.g. a line or a coloured circle). There are four columns associated with some fundamental tasks. They are:

ASSOCIATION: the question here is how well the marks can be perceived as similar.

SELECTION: here Bertin was concerned with whether the marks can be perceived as different, 'forming families'.

ORDER: Can the marks be perceived as ordered?

QUANTITY: The question here is whether the marks can be perceived as proportional to each other.

The encoding mechanisms – *retinal variables* as they are often called – that he considered were size, value,[2] texture, colour, orientation and shape. As seen from Figure 3.41, Bertin ordered these roughly according to the number of tasks each encoding mechanism can usefully support. Detailed examination of Figure 3.41 shows the guidance to be intuitively reasonable. However, the most appropriate encoding mechanism is very dependent upon context and the guidance is certainly open to debate.

An example related to Bertin's diagram, and illustrating the influence of task, is provided by the TileBars interface (Hearst, 1995). The task supported by TileBars is that of identifying, among a collection of documents, a subset that may be relevant to a particular enquiry. TileBars accepts, from a user, a set of topics and a collection of documents that may or may not be relevant. For example, an investigator interested in research into the prevention of osteoporosis would make the entry shown in Figure 3.42. In response, the TileBars system would return, for each document, a representation of the form shown in the upper portion of Figure 3.43. On the left is a colour-coded reminder of the topics. The TileBar itself contains the same number of rows as there are topics and columns corresponding to segments of the document: these can be paragraphs, pages or chapters. By its density of shading, each rectangle shows, for the corresponding topic and segment, the relative frequency of occurrence of that topic word. Thus, the example shows that in the first segment of the document 'Recent advances in the world of drugs' there is mention of *prevention* but little of *research* or *osteoporosis*. The fifth segment of the document, however, contains substantial mention of all three topics, from which it may be judged

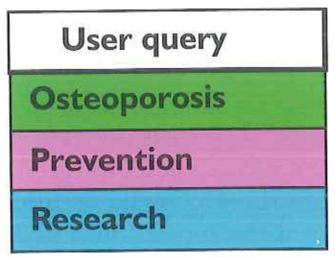

FIGURE 3.42 The specification of three topics of interest

[2] As defined by Bertin (1967; 1983, page 73), 'value' is not restricted to a grey scale. As Bertin remarks, 'One can pass from black to white by grays, by blues or by reds . . . '

that the document may be worth examining, perhaps beginning with that fifth segment. Interaction with the fifth column then leads to the representation in the lower part of Figure 3.43 showing the relevant paragraph with the topic words highlighted. TileBars provides yet another example of the benefit to be obtained from derived values.

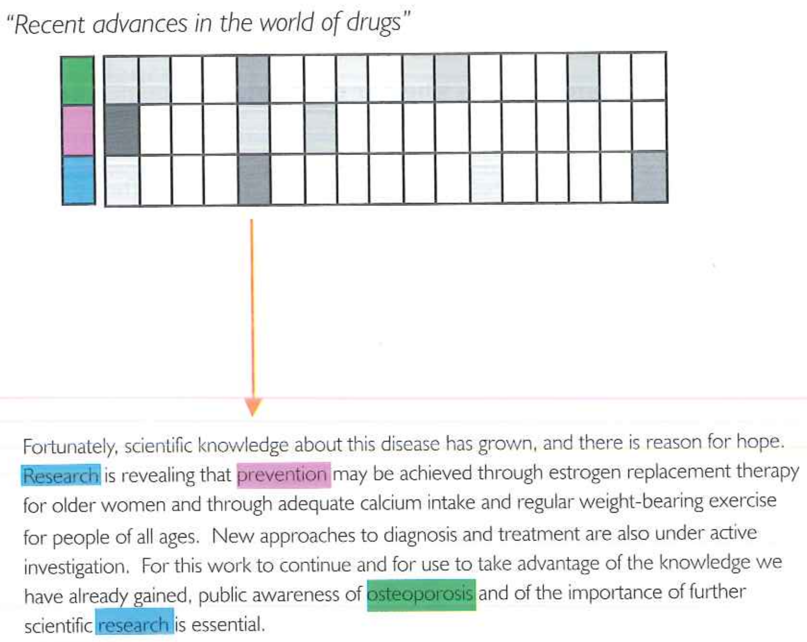

FIGURE 3.43 (top) The TileBar representation of the relevance of paragraphs to the topic words; (bottom) a selected paragraph with topic words highlighted

Accuracy of judgement of encoded quantitative data

The statisticians Cleveland and McGill (1984) addressed a different problem, concerned only with the accuracy with which subjects could assess *quantitative* data encoded in a variety of ways, some identical to the encoding mechanisms considered by Bertin. In one sense they investigated the last column of Bertin's matrix, concerned with quantity and which contained only one entry. Their result is shown in Figure 3.44, where the encoding mechanisms are ordered according to the accuracy with which they were found to support judgement of quantity.

Quantitative, ordinal and categorical data

Mackinlay (1986) addressed the encoding of non-quantitative as well as quantitative data and presented the rankings shown in Figure 3.45. The different positions of a given encoding mechanism on the three rankings are due, as Mackinlay points out, to 'the fact that additional perceptual tasks are involved'.

Representations we have already encountered have been located within Mackinlay's rankings in Figure 3.45, partly as illustrative examples but also because they do not appear at the top of the rankings; they illustrate the fact that many factors influence the choice of encoding. Minard, for example, might have had difficulty, in the context of other desirable features of his map, in encoding the population of the army by position as opposed to length (i.e. the width of a line) and Beck might have faced a similar problem in encoding differ-

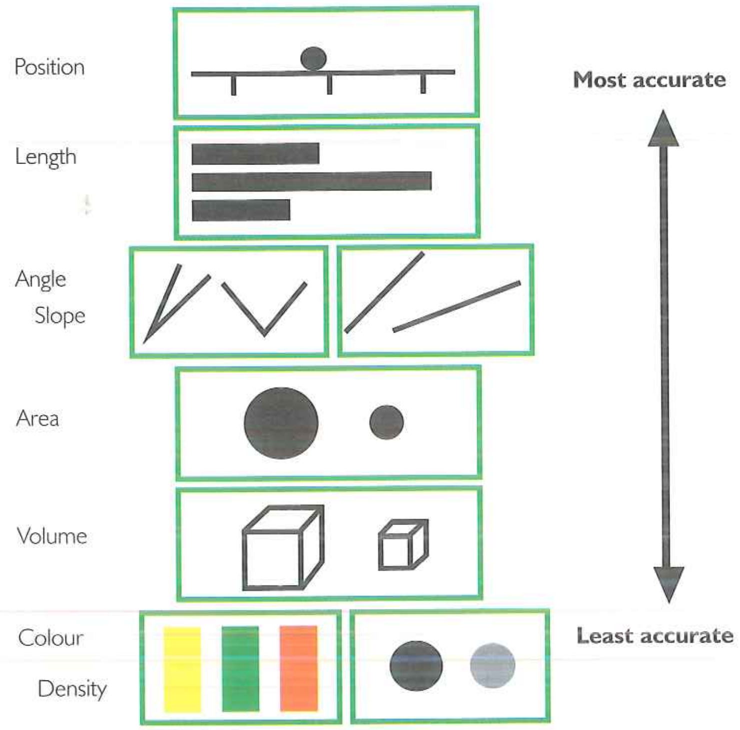

FIGURE 3.44 The relative difficulty of assessing quantitative value as a function of encoding mechanism, as established by Cleveland and McGill

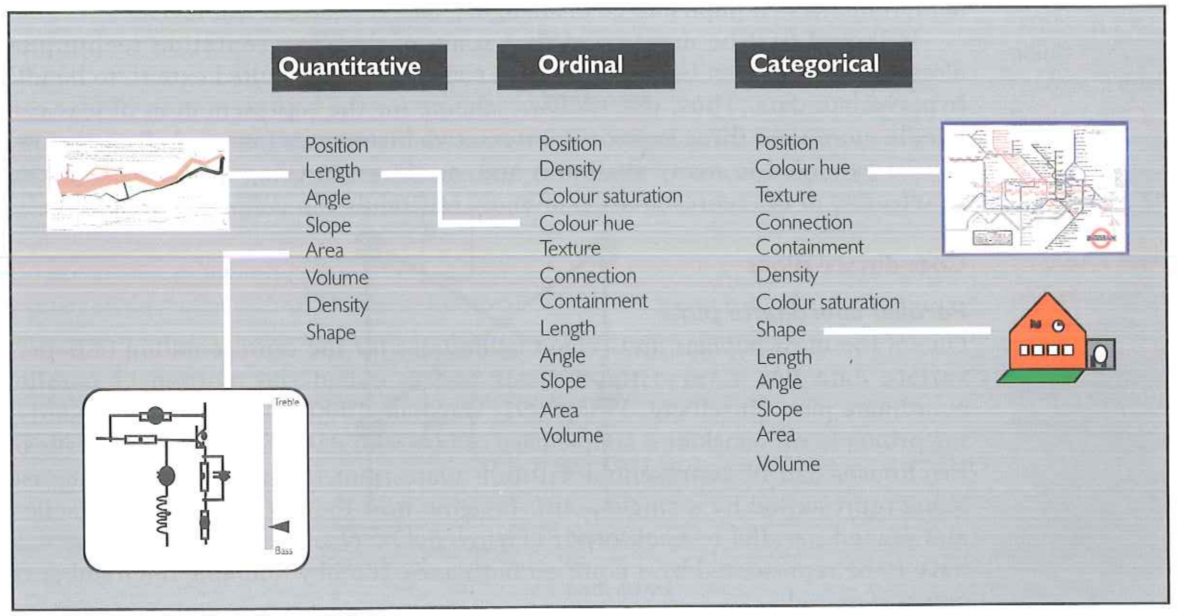

FIGURE 3.45 Taken from Mackinlay's guidance for the encoding of quantitative, ordinal and categorical data

ent Tube lines in anything but colour. It is also difficult to see how Minard could have employed 'position' to indicate the ordering 'advance, retreat'. One must additionally bear in mind that the map was designed to ensure that