Abstract

Systematic errors in perception and memory present a challenge to theories of perception and memory and to applied psychologists interested in overcoming them as well. The present paper reviews a number of systematic errors in memory for maps and graphs, and accounts for them by an analysis of the perceptual processing presumed to occur in comprehension of maps and graphs.

Visual stimuli, like verbal stimuli, are organized in comprehension and memory. For visual stimuli, the organization is a consequence of perceptual processing, which is bottom-up or data-driven in its earlier stages, but top-down and affected by conceptual knowledge later on. Segregation of figure from ground is an early process, and figure recognition later; for both, symmetry is a rapidly detected and ecologically valid cue. Once isolated, figures are organized relative to one another and relative to a frame of reference. Both perceptual (e.g., salience) and conceptual factors (e.g., significance) seem likely to affect selection of a reference frame.

Consistent with the analysis, subjects perceived and remembered curves in graphs and rivers in maps as more symmetric than they actually were. Symmetry, useful for detecting and recognizing figures, led to distortions in map and graph figures alike. Top-down processes also seem to operate in that calling attention to the symmetry vs. asymmetry of a slightly asymmetric curve yielded memory errors in the direction of the description. Conceptual frame of reference effects were demonstrated in memory for lines embedded in graphs. In earlier work, the orientation of map figures was distorted in memory toward horizontal or vertical. In recent work, graph lines, but not map lines, were remembered as closer to an imaginary 45 degree line than they had been. Reference frames are determined by both perceptual and conceptual factors, leading to selection of the canonical axes as a reference frame in maps but selection of the imaginary 45 degree line as a reference frame in graphs.
Distributions in memory for visual displays

Figure 1: Hypothetical graph taken from Sherman, C.M. (1961).

Figure 2: Graph taken from the New York Times, August 2, 1987. Reproduced by permission.
power, not the area, yet it is the area that is picked up by the human observer. So, although the Carter dollar purchased a bit less than half of the Eisenhower dollar, the Carter dollar looks less than a quarter of the area of the Eisenhower dollar.

The next example of distorted perception brings me to research in my laboratory. Let me first tell you about a number of different phenomena we have studied, and then I will try to account for them in an analysis of perceptual organization, where both perceptual and conceptual factors are operative. First, I will discuss examples of perceptual factors. Jennifer Freyd and I (1984) asked subjects to look at figures like that at the top of Figure 5, and then decide whether it was more similar to a slightly more symmetric figure or to an equally different but slightly less symmetric figure. When we selected nearly symmetric figures like that one, subjects nearly always chose the more symmetric alternative as the more similar. What's more, when subjects were asked to select which of the bottom figures was identical to the top figure, subjects were faster to select the identical figure when the alternative figure was less symmetric than the original (as in Figure 5) than when it was more symmetric than the original. These effects obtained for nearly symmetric figures, but not for less symmetric ones. That is rather complicated, but these experiments, and others like it (see Riley, 1962, and Freyd and Tversky, 1984, for reviews) suggest that there is a symmetry bias in perception. Not only do viewers rapidly detect symmetry, but they also perceive nearly symmetric figures as more symmetric than they are. That is, small deviations from symmetry are overlooked. Human faces, for example, are rarely perfectly symmetric, though we think of them as such. The outer men in Figure 6 (taken from Neville, 1977, p. 335), for example, are actually the same man at the same time. The two outer pictures were constructed by taking the right and left halves of the actual face in the center, and reproducing them in mirror image. It is only by seeing how different the two constructed symmetric faces are that we become aware of the asymmetry of the original face.

Diane Schiano and I (1989) looked for and found distortions toward symmetry in memory for maps and graphs. We presented maps or graphs like those in Figure 7 to different groups of subjects. Sometimes, the subjects were asked to sketch the curves of the graphs or the rivers of the maps, and other times, they were asked questions about the content of the maps or graphs. This was done to induce a natural comprehension attitude toward the figures, and to prevent subjects from simply memorizing line shapes. We then asked judges who knew nothing about the hypotheses to rate whether
The second widespread error I have found in maps I correct occasion...
asked a group of subjects to place a cut-out of South America in a frame where the canonical directions, north-south and east-west, corresponded, as usual, to the vertical and horizontal sides of the frame (Figure 10). Although the actual orientation is on the right, most of the subjects uprighted South America to the angle of the left-hand figure, or even more so. Not only South America is perceived as tilted. Those of you who live in the Bay Area, or who arrived from the San Francisco airport may think that you drove southwest to Monterey. Most of my local respondents made mistakes like that, for example, thinking that Berkeley is east of Stanford and Santa Cruz west of Palo Alto. Not so, as this true map of the area shows (Figure 11). Just as for alignment, I have found memory errors of rotation toward the axes for real map figures, for directions between cities on them, for roads, for artificial maps, and for visual blobs (Tversky, 1981). Others have found these effects as well (Byrne, 1979; Moar and Bower, 1983). Unlike the symmetry distortion, the distortions produced by alignment and rotation are stronger in memory than in perception; that is, small tendencies toward alignment and rotation appeared in a memory task.

Until now, we have demonstrated that there is a bias toward symmetry in both maps and graphs that appears in perception and is preserved in memory. I have also demonstrated, primarily in maps, biases toward alignment with other figures and rotation to a vertical/horizontal frame of reference that appear slightly in perception and stronger in memory. Now is the time to start to account for these systematic errors by an analysis of perceptual organization, or more specifically, by the effects of perceptual factors in

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**Figure 9.** Map of the Americas used by Tversky (1981). Subjects prefer the incorrect left one.

**Figure 10.** The correct orientation of South America is on the right, but subjects typically upright it, as in the example on the left (from Tversky, 1981). Reprinted with permission of Academic Press.

**Figure 11.** The correct map of the San Francisco Bay area. Subjects erroneously report that Berkeley is east of Stanford and Palo Alto is east of Monterey (from Tversky, 1981). Reprinted with permission of Academic Press.

Figure 12. Summary of process and result.

- Cognitive processes
- Encoding (e.g., classification)
- Feedback
- Attention to features
- Mental representation
- Selection
- Retrieval of information
- Memory trace
- Identification
- Recognition
- Discrimination
- Process of memory
- Conceptual level
- Knowledge structure
- Contextual level
- Semantic level
- Sensory level
- Motor level

In the next section, we will discuss the role of context in memory, focusing on how different contexts can affect the way information is encoded and retrieved. This will involve examining how contextual cues can influence memory performance, as well as discussing the implications for memory research and practical applications.
frame for graph functions, but unlike streets, graphed functions are rarely perfectly horizontal or vertical. Moreover, there is another reference frame for graphed lines, the (in this case) implicit forty-five-degree line. This is the identity line, where $x = y$, and as such it provides a very important reference point for graphed lines. Above it, rises are steep, and below it, shallow. The experiments we ran were very similar to the previous graph experiments: there were critical stimuli and distractors, and the memory task was designed to elicit comprehension of content, not just remembering the line. The exact same stimuli labelled differently were presented as maps to another group of subjects. Subjects were told that the angled lines were paths or short-cuts; they weren’t very convincing maps, as can be seen in Figure 13. In contrast to the prior work on maps showing alignment to the closest axis, horizontal or vertical, the graph lines were remembered as closer to the imaginary forty-five-degree line than they actually were. The map lines differed considerably and significantly from the graph lines, yet showed no systematic distortion. We ran this study again, this time using dotted graph lines rather than filled ones. Again, graph lines were remembered as closer to the forty-five-degree line. The results of both experiments appear in Table 1. In yet another study (Schiano and Tversky, 1990), we presented lines in axes as a simple memory or copying task, without labels and without calling them graphs. The pattern of errors was systematic, yet very different from the present pattern. However, when we invoked the imaginary forty-five-degree line as an anchor by asking subjects to judge whether the line was above or below forty-five degrees before drawing it, remembered lines were drawn closer to the forty-five-degree line. This is evidence, we believe, for conceptual factors that influence selection of frame of reference and thereby affect the perceptual analysis, representation, and veridicality of memory of visual displays.

I have presented an analysis of the perceptual processes, particularly figure segregation and organization, that are used in viewing and comprehending visual stimuli. Both these processes can lead to systematic distortions, which were demonstrated in perception and memory of maps and graphs. Thus symmetry, a property more likely to appear in figures than grounds, and therefore useful in figure segregation, is exaggerated in memory for curves in graphs and rivers in maps. Conceptual factors were also shown to affect the perceptual analysis and encoding of visual scenes, and to yield errors of memory, the description of symmetry in one case, and the selection of a frame of reference in the other. The bottom line is “What you see ISN’T what you get”.

### Table 1. Average deviation toward 45° of drawn (remembered) lines from presented lines in maps and graphs in experiments 5 and 6

<table>
<thead>
<tr>
<th>Line angle</th>
<th>20°</th>
<th>25°</th>
<th>30°</th>
<th>35°</th>
<th>55°</th>
<th>60°</th>
<th>65°</th>
<th>70°</th>
</tr>
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<tr>
<td>Experiment 5</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Graph lines</td>
<td>+3.4</td>
<td>+1.7</td>
<td>+1.0</td>
<td>+1.2</td>
<td>+1.1</td>
<td>+2.9</td>
<td>+2.4</td>
<td>+1.1</td>
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<tr>
<td>Map lines</td>
<td>+0.2</td>
<td>-0.2</td>
<td>+0.4</td>
<td>-2.2</td>
<td>+0.7</td>
<td>+0.5</td>
<td>0.0</td>
<td>+1.5</td>
</tr>
<tr>
<td>Experiment 6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Graph lines</td>
<td>+1.5</td>
<td>+0.1</td>
<td>+1.0</td>
<td>+1.0</td>
<td>+2.8</td>
<td>+2.6</td>
<td>+2.0</td>
<td>+2.3</td>
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</table>

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