Commentary

LOCALIZING THE SPATIAL LOCALIZATION SYSTEM: Helmholtz or Gibson?

Felice L. Bedford
University of Arizona

McCloskey and a team of authors (1995) documented a fascinating deficit involving the localization of objects. When subject A.H. reaches for objects placed in different positions, she is often wrong about direction but not amount. An object located 30° to her left, say, might cause her to reach 30° to the right. The authors demonstrated that her motor abilities are flawless and that the errors are genuinely in vision. But precisely where in the visual localization process does the deficit occur?

I suggest that an analysis of how objects are normally localized may point to the source of error. I begin with a description of two separate visual localization systems, and then discuss how the nature of the deficit seems to implicate one of these systems over the other. Both localization systems can deal with the inherent ambiguity of a single retinal location. The ambiguity is easily appreciated by considering a simple example in which the image of an object is centered on the fovea. This retinal image can be caused by an object that is straight ahead of the person's nose, but only if the person is fixating the object. If the fixation is to the left, then the same retinal image will be produced by an object to the person's left. That is, one retinal image position could be produced by any position in the world, and one position in the world can produce an image anywhere on the retina.

The first proposed solution to this problem is one of Helmholtz's unconscious inference models (1866/1962). We owe the retinal ambiguity to the fact that we are movable observers; our eyes can move, our head can move, and so forth. Consequently, if we include information about the current state of the body in our visual calculations, we can uniquely recover the position of the object that produced the ambiguous retinal image. According to this model, then, the ambiguity is resolved by considering the extraretinal information about the position of the eyes in the head along with the retinal information. If head position is held constant, the simple cancellation method (eye position − retinal position) will reconstruct the correct position of the object in the world.

The second model is best known from the work of Gibson (1959). Gibson's general solution to ambiguity was to look over a wider area of the retina, rather than to calculate the state of the observer. As the eyes sweep across a scene, the retinal position of a single object changes, but the relationship between the retinal position of that object and the positions of other objects remains invariant. Thus, without ever referring to the position of the eyes in the head, information about the location of objects can be obtained through their relation to other fixed objects in the scene.

Can a breakdown in either one of these methods account for A.H.'s difficulties? In the first model, any incorrect value for retinal position or eye position would produce an incorrect calculation. For instance, if the retinal position is indeterminate, then the final location of the object would be indeterminate. If the eyes feel 5° further left than they actually are (e.g., as a consequence of artificial exposure to optical displacement—see Bedford, 1995—or because of natural syndromes such as past pointing), then the location percept would always be 5° off. A.H. has a different deficit: She is incorrect about left-right direction, yet correct about amount. Note that there is nothing about the Helmholtzian model which suggests that amount and left-right direction are naturally dissociable from one another. It is logically possible that the felt direction of the eyes is swapped left for right, but this substitution into the equation would produce a left-right reversal with amount preserved only in the special case when the value for the retinal position is 0. Amount and side are not obviously separate components in this method of determining location.

In the second model, the position of an object, B, is determined by its relation to other things, such as another object, A, or to an edge of the frame. The comparison provides information relevant to B's location in the world, such as "B is 4 feet from the wall." But is B to the left or to the right of A? This further judgment depends on the perspective one adopts when using the frame of reference. From where I am sitting, the lounge chair in my office is to the left of the door, but it is easy to appreciate that for someone facing me, the chair is to the right of the door. When using frames of reference, there is ambiguity about where to view the frame. The Helmholtzian model described earlier does not have this problem because that system calculates the position of an object with respect to the observer. Once the location judgment is detached from calculations of the state of the observer, as it is with environment-relative frames of reference, then ambiguity about perspective arises. In a frame of reference, there

Address correspondence to Felice L. Bedford, Department of Psychology, University of Arizona, Tucson, AZ 85721; e-mail: bedford@ccit.arizona.edu.

must be a decision about the perspective to adopt with respect to the frame (e.g., front or back). Yet the distance of a point from another point or from the frame can be determined even without the information on perspective. That is, amount and left-right direction are inherently dissociable entities in this system. The nature of A.H.'s disorder, whereby side is confused but amount is preserved, suggests that she is using frames of reference rather than taking eye movements into account in order to gather information about the position of an object. Further, the deficit may reside specifically in the ability to consistently adopt the standard perspective that most observers use.

Why would A.H. fail to use information about eye position to localize objects, and instead use less precise external frames of reference? Is this another deficit? Apparently not: There is evidence that the frame of reference is always the preferred system. Matin, Stevens, and Picoult (1982) injected subjects with curare, which partially paralyzes all muscles, including those that move the eyes. This intervention causes the extraretinal eye position information to be displaced systematically (a greater effort is required to maintain a desired eye position), which in turn would cause the calculation of an object's position to be systematically false—if the cancellation (eye position) method is used. The investigators found that a person's visual perception of location was altered accordingly, but only in darkness. When the room was illuminated and the full structure of the room was visible, perception was completely accurate. The authors suggested that under normally illuminated viewing conditions, the contribution of the cancellation system for localizing objects is suppressed in favor of the frame-of-reference system. A.H.'s case may provide further support for this conclusion, and may suggest that this preference is so strong as to be upheld even when it yields inconsistent and inaccurate judgments.

The frame-of-reference interpretation may help explain other aspects of A.H.'s disorder, including the substitution of one letter for another while reading and writing, because letters viewed, as it were, from the other side can appear to be different letters. This interpretation also makes a prediction about A.H.'s abilities. If the room lights are extinguished and she is required to point to a glow-in-the-dark target, she should point at the target perfectly, or at least as well as you or I. In such a visually impoverished environment, the only visual localization system that can be used involves taking one's own eye position into account. The absence of other visible objects or extended contours precludes frames of reference from providing any information, as in the study by Matin et al. Would A.H.'s deficit appear to get better, rather than worse, under such impoverished conditions? If so, then the direct investigation of perspective taking and *movable egocenters* (Kubovy, 1986; see also Bedford, 1994) would be a useful direction for future research. If A.H. still shows the deficit, then a closer look at revised Helmoltzian-like eye position models would be useful, as well as a closer look at the linkages between vision and touch, and whether amount really is always preserved when left-right direction errors occur.

In sum, this case study taps into a classic debate between Helmholtzian and Gibsonian views on perception. In addition, it may help shed light on how people adopt viewpoints that differ from where they are physically located, an important but little understood factor in perception.

REFERENCES

Bedford, F.L. (1994). Of computer mice and men. *Cahiers de Psychologie Cognitives, 13,* 405–426.

Bedford, F.L. (1995). Constraints on perceptual learning: Objects and dimensions. *Cognition, 54,* 253–297.

Gibson, J.J. (1959). Perception as a function of stimulation. In S. Koch (Ed.), *Psychology: A study of a science* (pp. 265–285). New York: McGraw Hill.

Helmholtz, H., von. (1962). Vol. 3, Section 26. In *A treatise on physiological optics* (J.P.C. Southall, Ed. and Trans.). New York: Dover. (Original work published 1866)

Kubovy, M. (1986). *The psychology of perspective and Renaissance art.* Cambridge, England: Cambridge University Press.

Matin, L., Stevens, J.K., & Picoult, E. (1982). Perceptual consequences of experimental extraocular muscle paralysis. In A. Hein & M. Jeannerod (Eds.), *Spatially oriented behavior* (pp. 243–262). New York: Wiley.

McCloskey, M., Rapp, B., Yantis, S., Rubin, G., Bacon, W.F., Dagnelie, G., Gordon, B., Aliminosa, D., Boatman, D.F., Badecker, W., Johnson, D.N., Tusa, R.J., & Palmer, E. (1995). A developmental deficit in localizing objects from vision. *Psychological Science, 6,* 112–117.

(Received 10/20/94; Accepted 2/22/95)