Commentary/Bridgeman et al.: Visual stability

position. Indeed, as Bridgeman et al. point out in their target article, there is good evidence that the computations of motion and position are anatomically segregated in the brain. Thus, the results of Bridgeman et al. (1979, 1981) may be explained by the fact that the cognitive system was asked to report only on image displacement, whereas the skeletomotor system was asked to report only on image position.

In summary, substantial new evidence throws doubt on the pertinence of postulating separate mechanisms for perceptual and visuomotor localization. This evidence indicates that egocentric localization is computed with a unified mechanism, or with two that are very similar if not identical in nature. As to the use of retinal cues, conflicts in the available evidence make it somewhat premature to speculate on the existence of a single mechanism or separate ones.

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Perceptual stability and postsaccadic visual information: Can man bridge a gap?

H. Deubel and W. X. Schneider
deb@inf-mppg-muenchen.mpg.d400.de; Max-Planck-Institute for Psychological Research and Ludwig-Maximilians-University, D-80802 Munich, Germany

Bridgeman et al. present a sound analysis of the informational requirements of perceptual stability. They demonstrate that in principle visual direction constancy can be brought about simply by a new calibration of the retinotopic maps with each fixation. Although their analysis is convincing, it does not exclude the possibility of stored presaccadic information (e.g., in the sense of correlation) for achieving perceptual stability. Indeed, we cannot see how the calibration model could possibly predict the ability to detect intrasaccadic displacements (larger than 20% of the saccade size, Bridgeman et al. 1975). Displacement detection strongly seems to require some kind of transsaccadic memory of the presaccadic world. It is not clear to us whether the authors claim there was relevance of such a representation for visual stability. Anyway, a useful theory of visual stability must be explicit on when and how violations of stability are detected on the basis of presaccadic information.

Bridgeman et al. would probably agree that for various aspects of motor control, evaluation procedures must exist that determine the adequacy of reactions on the basis of a comparison of intended and actual consequences of movements. For eye movements, we emphasized this aspect before for the programing of correction saccades and for the adaptive control of saccade metrics (e.g., Deubel 1991; Deubel et al. 1984). For both cases, the visual feedback occurring in the initial 100 msec after the saccade is essential.

We hypothesize here that this time interval is also highly relevant for direction constancy. This assumption is based on a new experimental finding that seems to suggest that visual information intake immediately after the saccade is of vital importance for the "saccadic suppression of image displacement." In these experiments, subjects had to discriminate between the directions of intrasaccadic displacements of the saccade target (onward vs. backward with respect to the saccade direction). As an essential modification to the classical displacement detection paradigm (e.g., Bridgeman et al. 1975), we introduced a temporal gap of variable duration between the intrasaccadic offset of the target and the onset of the displaced target. The details of the experimental paradigm are given in Figure 1, top. Figure 1, bottom, presents the discrimination

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er involved in its own visuomotor reason put visual-motor on perceptions, called x localiza tions. The accepted that based on an exception or
efferent copy) that moves with a velocity considerably less than the saccadic velocity of the eye itself (e.g., Matin 1972), this leads to a breakdown of egocentric space constancy around the time of each saccade. Oculomotor localization, however, has been thought to be based on an extraretinal representation that accurately portrays the velocity of the eye. The major impetus behind this idea came from the work of Hallett and Lightstone (1976), in which subjects were found to direct their eyes accurately to the location of a flash presented at the onset of an intervening saccade. However, recent investigations in our laboratory (Dassonville et al. 1992) and that of Honda (1990a), using paradigms modified from that of Hallett and Lightstone, have found evidence to the contrary: flashes, if presented near the time of an intervening saccade, are mislocalized by the oculomotor system in a manner that leads one to conclude that oculomotor egocentric abilities are based on an internal representation of eye position that is qualitatively similar to that of perceptual localization. Indeed, Honda found that the time courses of the representations were virtually identical when directly compared in individual subjects. In a similar manner, Miller (in press) has cast doubt on the notion, championed by Hansen and Skavenski (1985), that the skeletomotor system calculates the goal of a visually evoked arm movement by combining retinal information with an accurate representation of eye position. In Miller's investigation, subjects, when pointing with the hand to the location of a persaccadic flash, made errors indicative of the skeletomotor system's reliance on a sluggish representation of eye position. These studies, and that of Bridgeman and Stark (1991) demonstrating the similar use of static eye position signals by the cognitive and skeletomotor systems during target fixation, lead one to speculate on the existence of a single, unified mechanism for egocentric localization in the cognitive, oculomotor and skeletomotor systems.

Similarities in the use of retinal cues for perceptual and visuomotor localization have also become apparent recently. In one of the first studies to directly address the issue of retinal cues in visuomotor control, Conti and Beaubaton (1980) found that subjects are able to point to visual targets with greater accuracy when a fully structured visual field is present. Hayhoe et al. (1992) presented direct evidence that localization in the oculomotor system is partially based on retinal cues. In their study, two simultaneous visual stimuli were briefly presented while the subject maintained fixation. Later, one of the two was reilluminated; the subject was required to saccade first to the reilluminated target, and then to the remembered location of the other target. On random trials in which the position of the reilluminated target was shifted vertically (without the subject's knowledge), localization of the remembered target was similarly shifted, albeit to a lesser extent. Thus, oculomotor localization seems to rely on a weighted average of the available egocentric and retinal cues. In a recent investigation in our laboratory (Dassonville et al. 1993), we found that subjects make use of retinal cues to decrease the oculomotor errors associated with the breakdown of egocentric space constancy near the time of a saccade (Dassonville et al. 1992, described above). Furthermore, the oculomotor system's ability to use these cues depends on the spatial proximity between cue and target. This effect (called the "adjacency principle" by Cogel) has been previously noted for several types of perceptual tasks (see Cogel 1979 for a review) and specifically for perceptual space constancy (Mateeff & Holmsbein 1989).

Are there differences in the cognitive and visuomotor system's use of retinal motion cues? Bridgeman and his colleagues have provided evidence that when a target is displaced during a saccade (Bridgeman et al. 1979) or undergoes induced motion (Bridgeman et al. 1981) the visuomotor system apparently has access to motion cues unavailable to the cognitive system. Abrams and Landgraf (1990), however, have demonstrated that this distinction may instead be attributable to the existence of separate neural mechanisms to calculate target motion and
Voluntary oscillopsia: Watching the world go round

J. T. Enright
jenrig@ucsd.edu; Neurobiology Unit A-002, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093

1. Dare a new theory ignore relevant phenomena? One way to evaluate a new theory like that proposed by Bridgeman et al. to account for perception of egocentric directions is to test its predictions (sect. 4.3). The alternative course taken here is instead to consider certain phenomena that are already known and with which the theory has not yet come to grips. At least three kinds of observation deserve our attention:

1.1. MacKay’s illusion was ignored. Although Bridgeman et al. otherwise rely heavily on the views of MacKay (1975), they have neglected a relevant phenomenon that MacKay (1958) discovered: if the glowing filament of an old-fashioned vacuum tube is observed in a darkened room while the tube itself is illuminated stroboscopically (5 to 6 Hz), gentle tapping on the observer’s eyelid causes apparent displacement of the filament relative to its surrounding glass enclosure. This paradoxical perception, involving retinally adjacent images led MacKay (1973) to propose that visual grasp (achieved when viewing a real, continuously visible target) is essential for achieving spatial stability across saccades. In my opinion, “visual grasp” represents an important concept, although it is, of course, a metaphor that needs further explication (sect. 4.2, below).

1.2. Vvergence eye movements were ignored. Vergence eye movements play a major role in perceived egocentric space, but Bridgeman et al. explicitly excluded this topic from consideration (sect. 1). The illusory shifts in apparent direction associated with changes in vergence led to the term “cyclopean eye” (von Helmholz 1867; Hering 1861), a convenient fiction that is still widely used (e.g., Bridgeman & Stark 1991) to define the origin of the coordinate system underlying all of our spatial perception. To exclude vergence from consideration is to ignore the very center of visual space.

Additional anomalies of spatial perception during changes in vergence were treated by Enright (1985), including one that greatly resembles MacKay’s illusion described above: a “visually grasped” target (i.e., continuously seen) appears to shift in egocentric direction while a simultaneously seen target that cannot be “grasped” (an afterimage or a stroboscopically lit target) does not, although the positions of both images on the retina remain fixed.

According to the theory proposed by Bridgeman et al., specification of egocentric direction depends only on currently available information: momentary retinal stimuli and the accompanying neural “outflow” to, and “inflow” from, the eye muscles. Supplementary assumptions would, I think, be required to account for these simultaneous, dichotomous perceptions.

1.3. Intentional suspension of cross-movement spatial stability. The third phenomenon of concern here is a breakdown in the stability of spatial perception, which is not ordinarily mentioned in treatments of egocentric space, but which should, I think, be brought into the mainstream of discussion: “voluntary oscillopsia,” described below.

2. Voluntary oscillopsia: Creating an unstable world. Many people – more than half the adults polled – can “do something” with their eyes, so that during relatively rapid eye movements, sustained over a few seconds, the entire visual surround seems to oscillate or “jump around” in counterpoint to the eye’s motion. Similar perceptual instability called “oscillopia” by clinicians: a pathological symptom associated with serious neurological problems. Because comparable subjective impressions can be deliberately self-evoked by healthy people, I propose the term “voluntary oscillopsia” for this (maladaptive) perception.

A complementary phenomenon arises when a lover views the world in darkness, while one makes eye movements like those while moving about.

Vigorous eye movements like those described above result in oscillation of the perceived egocentric space (like the oscillation of the surround when a head is moved, with each up-and-down saccade). It is likely that subjects with each record saccade reported by the present experiment, and not the forward saccades that are not reported. This is the concept that I call “oscillopia.”

Since one would not usually record saccades like those while moving about, it is likely that the oscillation of the surround is self-generated by moving the eye. The feeling may be like those while moving about.