Notes and Comment

Space constancy and corollary discharge

LAWRENCE STARK

University of California, Berkeley, California

Hershberger, in his recent note (Hershberger, 1984), attempts to extend the "eyepress" experiments of Stark and Bridgeman (1983), who were restricted to initial conditions at the primary vertical meridian. Hershberger attempted wider deviations of initial eye position before eyepress. The kinematics of the eye has been known to be complex since the early work of Helmholtz (1867) and Hering (1868/1977): it is difficult to be certain of vectorial forces with eyepress onto widely deviated eyes. One straightforward measure that should be carried out in further studies is the direction of associated movement of the nonviewing fellow eye, as was done by Stark and Bridgeman (1983). Bridgeman and Delgado (1984) have performed further such experiments recently, and concluded that visual phenomena in the pressed, seeing eye are in accord with movement of the fellow, nonseeing eye. These results relieve one from postulating that red hering variously named proprioception, inflow information, nonefferent copy, or noncorollary discharge extraretinal perception. Table 1 may serve to clarify the disparate protocol conditions and observations obtained in many space constancy experiments; it indicates the four different conditions of match of afferent and corollary discharge-efferent copy information.

The author's mailing address is: Neurology Unit, 481 Minor Hall, University of California, Berkeley, CA 94720.

Block Diagram

A block diagram (Figure 1) is a useful device or tool to expose our understanding about a process and to coordinate different levels of information—*anatomical*, *behavioral* (either *physiological* or *psychological*), and *control theoretic*. Lower and higher level feedforward motor controllers follow an error-processing sensory block and then control the eye muscle actuator and eyeball-orbit "plant" to produce output eye angle. Eye-angle information via the visual feedback path is differenced from target angle by a comparator. The higher level controller might include the sampled data mechanism of Young and Stark (1963) and be located in both frontal eye fields of the frontal cortex and superior colliculus. The superior colliculus has been shown, at least in part, to lie before the sampled data operator (Sparks & Mays, 1983; Sparks & Porter, 1983), and also before the junction for corollary discharge (Guthrie, Porter, & Sparks, 1983). The lower level controller might include the brainstem pulse shaping mechanism for time-optimal saccades (Clark & Stark, 1975; Lehman & Stark, 1979, 1983).

The highest level controller, the block named "Helmholtzian frame-of-reference comparator for space constancy," receives afferent signals (AFF) and efferent copy or corollary discharge (CD) information. When these angles are equal, the percept of space constancy is maintained. When these angles are almost equal, saccadic suppression (SS) and saccadic suppression of image displacement (SSID) provide tolerance for small errors, and space constancy is still maintained (Stark, Kong, Schwartz, Hendry, & Bridgeman, 1976). In an unstructured visual world with large errors, target or world mo-

Table 1
Four Types of Space Constancy Experiments: Match of Retinal Afferent (AFF) and Efferent (EFF) Signals (in Different Protocol Conditions) and the Resultant Perceptions

Type	AFF REF	EFF COPY	Perception	Protocol Condition
I	+	+	No movement Space constancy	Normal saccade
II	+	0	Movement of target Movement of world Oscillopsia	Normal object motion Lightly and quickly jiggle eye Quick eyepress* Voluntary nystagmus or patients with deficient vestibular-ocular reflex
III	0	+	Movement of target Movement of world	Afterimage and saccade Slow eyepress** in restricted viewing Patients with fresh paralysis
IV	0	0	No movement Space constancy	Voluntary nystagmus with afterimage†

*Lightly and quickly jiggle eye; no eye muscle resistance (Descartes 1664/1972). **Sustained and resisted slow eyepress in restricted viewing conditions (Helmholtz, 1867; also Stark & Bridgeman, 1983). With structured visual field conditions, visual capture provides finally for space constancy. †Nagle, Bridgeman, and Stark (1980); also Grusser (1984).

Figure 1. Hypothetical block diagram for space constancy.

tion occurs. With a structured visual field, visual capture of Matin (VCM) allows for visual space constancy, even for large discrepancies (Matin et al., 1982; Stark & Bridgeman, 1983). Stark and Bridgeman (1983) suggested incomplete (90%) visual dominance, Shebilske (1976; also personal communication, 1984) 50%, and Mittelstaedt (1985) exact summation of visual tilt and vestibular signals. A voluntary nystagmus (VN) brainstem oscillator, accessible to 5% of the population, is a remarkable mechanism for producing "oscillopsia," a symptom of disruption of space constancy; VN controls eye movement *after* the corollary discharge has parted company from the efferent pathway.

It is hoped that this block diagram may serve as a framework for discussion and corrective modifications by workers in this evolving field of the rapid interaction of perceptual and motor processes.

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