Post-suppression vestibulo-ocular reflex in man: visual and non-visual mechanisms

B.N. Segal

Aerospace Medical Research Unit, Department of Physiology, McGill University, 3655 Drummond St., Rm 1225, Montreal, Quebec H3G 1Y6, Canada

Summary. The vestibulo-ocular reflex (VOR) was intermittently suppressed by fixating a head-fixed target (light on: 9 s; darkness: 2 s) during whole-body (60–100 deg/s peak; 0.01–0.17 Hz) sinusoidal and triangular oscillation about the vertical axis for about 2 min. Eye movements associated with intervals of darkness at different phases of body oscillation were stimulus-locked averaged, thereby estimating the “post-suppression VOR”. The gain (eye velocity/head velocity) of the post-suppression VOR was generally 26–50% of the normal gain in maintained darkness. During sinusoidal body oscillation, the phase lead of the post-suppression VOR equalled or, at low frequencies, appeared to exceed the normal lead in maintained darkness. When the light was permanently extinguished after 2 min of intermittent suppression, an initially reduced VOR rapidly (e.g., 0.4 s) appeared and required 6–30 s to build up to normal again. These observations indicated that visual suppression of the VOR dissipated in darkness with rapid and slow components. During 0.17 Hz, 60 deg/s sinusoidal oscillation, the rapid (perhaps visual) component was responsible for 1/3, and the slow (perhaps non-visual) component for 2/3, of all suppressive effects.

Key words: Nystagmus – Vestibulo-ocular reflex – Vision – Psychomotor performance – Rotation

Introduction

Clear vision during normal head movements is only possible when vestibular information stabilizes the eyes in space by means of the vestibulo-ocular reflex (VOR) (e.g., Wilson and Melvill Jones 1979). However, in some instances the VOR is counterproductive, such as when a target moving with the head is pursued during, say, prey catching. This calls for suppression of the reflex, a matter studied in both animals (Haddad and Robinson 1977; Lanman et al. 1978) and man (Barnes 1983; Barnes and Edge 1983; Barr et al. 1976). Recently, interest has focussed on how such suppression occurs. The controversial nature of this issue has been highlighted by Tomlinson and Robinson (Robinson 1982; Tomlinson and Robinson 1981) who listed observations which, on the one hand, imply that visual processes (i.e., pursuit) could be involved in VOR cancellation, and, on the other hand, argue against their involvement. Robinson and Tomlinson concluded that visual pursuit is probably not mainly responsible for VOR suppression. Barnes (1983), however, has emphasized that optimal suppression requires visual feedback from a foveal target. Thus, at present the matter remains unsettled.

Human optokinetic nystagmus appears to be the product of visual (perhaps pursuit) processes that respond rapidly to optokinetic stimulation, as well as of other (velocity storage) processes that respond more slowly. The relative contributions of these processes to such nystagmus have been clarified by using periods of optokinetic stimulation which were followed by darkness intervals, both prolonged (Cohen et al. 1981) and brief (Segal and Liben 1985). Velocity storage behaviour could be characterized because rapidly-responding visual processes dissipated rapidly (within 1 s) in darkness, whereas velocity storage did not.

In the present study a similar attempt was made to determine the relative contributions of visual and non-visual processes to VOR suppression by examining the VOR in darkness after periods of its suppression, achieved during passive rotation in a darkened room while fixating on a point that moved with the head and was subsequently extinguished. If the VOR were to be suppressed by vision, then major visual suppressive effects should dissipate rapidly in dark-
ness, thereby permitting the VOR to reappear rapidly. Moreover, if simultaneously active non-visual processes were also to suppress the VOR in the light, and if their suppressive effects were to dissipate in darkness more slowly than visual ones, then overall suppressive effects would dissipate in darkness with two components, one rapid and the other slow. This would again permit the VOR to rapidly reappear in darkness, but with a magnitude that was reduced until non-visual suppressive effects completely dissipated. That is, a difference would appear between the VOR just following suppression (i.e., the “post-suppression VOR”) and the “normal” reflex found in maintained darkness. Thus, it might be possible to clarify the relative roles of visual and non-visual processes during VOR suppression in the light.

Methods

Methods were identical to those described in a previous study of human velocity storage (Segal and Liben 1985), with the exception of the stimuli employed. Briefly, subjects were oscillated in darkness while the VOR was suppressed by fixation on a small (0.25 deg visual angle), stationary (re:head), red light. Periodically, the light was briefly extinguished (light-on: 9 s; light-off: 2 s). Two series of experiments were performed: The first series employed only sinusoidal whole-body oscillation (0.01, 0.02, 0.05, 0.1 and 0.17 Hz) stimuli all at 60 deg/s peak). The second series employed both sinusoidal (0.033 and 0.17 Hz each at 60 deg/s peak) and triangular oscillation (0.033 Hz at 60 deg/s peak; 0.01 Hz at 100 deg/s peak) in order to test the post-suppression VOR with a wider range of stimulus profiles. Note that head velocity, not position, was triangular. In both series, the post-suppression VOR was examined for about 2 min while the fixation light was periodically extinguished. Then without stopping oscillation, the “normal” VOR in maintained darkness was examined, over an additional 0.5–1 min period, by “permanently” extinguishing the