Testing Vestibular Function: Problems With the Southern California Postrotary Nystagmus Test

Since its publication in 1975, the Southern California Postrotary Nystagmus Test (SCPNT) (Ayres, 1975) has been widely used by clinicians and is often cited in the clinical literature (e.g., Bundy, Fisher, Freeman, Lieberg, & Izravelitz, 1987; Mayberry & Gilligan, 1985; Otenbacher, Johnson, & Hojem, 1988). This test is purportedly valuable for assessing postrotatory nystagmus, which helps in the evaluation of vestibular system function (Ayres, 1975). Although postrotatory nystagmus is indicative of vestibular system function, the SCPNT does not provide a valid measure of that behavior. Therefore, results from this test are not valid indicators of vestibular function.

This problem is significant for occupational therapists who work with patients with vestibular dysfunction, because many therapists use the SCPNT or similar tests. The validity of the SCPNT has been examined by Polatajko (1983), but her elegant paper may not have been widely read in this country. The present paper reviews some of the issues discussed previously and presents new arguments as well.

The SCPNT is based on valid principles. When a subject is rotated in darkness about the vertical axis with the neck flexed 30°, which brings the horizontal semicircular canals into the earth-horizontal plane (a geometric plane horizontal to the earth's surface), these canals are maximally stimulated. If the subject is given a velocity step, which changes head acceleration, the eyes compensate by moving in the opposite direction, as if to stabilize gaze in space. (A velocity step is a sudden, rapid change in velocity, for example, from 0° to 60°/s over 1 sec. When plotted on a graph of continuous velocity over time, the resulting figure resembles a step because of the steep slope.) This compensatory eye movement is called the vestibulocular reflex (VOR). If the subject is rotated continuously or sinusoidally, a repetitive pattern of eye movements called nystagmus is produced, characterized by compensatory slow phases in the direction opposite the stimulus and by resetting quick phases in the same direction as the stimulus.

In the current oculomotor literature, time constant and gain are the parameters most commonly used to describe the response to a velocity step. Time constant is related to duration but is a more reliable measure. (In physiology, time constant refers to the length of time required for the parameter of interest to change approximately 63%. See Kandel & Schwartz, 1985.) Gain is a dimensionless number that represents the ratio of the output to the input. It is determined by the division of the magnitude of the maximum response to the stimulus (maximum excursion in the SCPNT manual) by the magnitude of the stimulus (i.e., output/input = gain). For example, if the subject is given a step of velocity at 30°/s and compensates with an eye movement at 24°/s, the gain = 0.8; the subject's VOR compensated 80%.

Gain describes the accuracy of the VOR in compensating for head movement. Thus, gain can be a more useful measure than time constant in an assessment of the ability of the vestibular system to detect head movements and to generate appropriate compensatory eye movements. Although the SCPNT manual suggests the estimation of the maximal excursion of the eye, the significance of that measure is not discussed. Instead, duration is emphasized.

Subjects rotated about the vertical axis in the light in a stationary visual surround have a gain of 1.0. In the dark, the gain in humans can be as low as 0.60 (Robinson, 1981). In the light, the gain of the response to a velocity step is increased with a contribution from the optokinetic system, a primitive visual processing system. The optokinetic system input is eliminated in darkness. Therefore, to evaluate pure vestibular function without optokinetic input, the VOR must be tested in darkness. On the SCPNT, subjects are tested in the light.

When tested in the light, subjects have a combination of the VOR and optokinetic nystagmus (OKN). When rotated in darkness or light, and then stopped in light, subjects can stop their nystagmus immediately by fixating on the stationary surround.
interruption or cessation of nystagmus with conflicting visual input is called visual suppression (Cohen, Raphan, & Waepe, 1986). The conflict induced by the stationary visual surround versus the vestibular signal causes the nystagmus to stop (see Henn, Cohen, & Young, 1980, for a review). The SCPNT manual alludes to the problem of visual suppression and states that subjects should be instructed to gaze aimlessly when stopped. It is unlikely, however, that all subjects will do so.

The duration of the nystagmus or the time constant indicates the functioning of another mechanism related to the VOR and OKN—the velocity storage integrator (Cohen, Matsuo, & Raphan, 1977; Raphan, Matsuo, & Cohen, 1979). The time constant of the response to the velocity step in darkness in a naive subject is several times longer than the time constant of the vestibular nerve. Raphan et al. explained this phenomenon with the concept of a velocity storage integrator, a neural mechanism that stores that velocity information for a period of time, losing it gradually. With repeated testing, however, the time constant decreases and can become as short as the time constant of the cupula, which is 5 s to 6 s in primates (Cohen, Cohen, & Raphan, 1987; Goldberg & Fernandez, 1971). This decrement in the response caused by repeated testing is called habituation (Thorpe, 1956).

The time constant dishabituates or increases to its original value only in the case of lesions of the cerebellar vermis, including the nodulus and uvula, which are parts of the vestibulocerebellum (Waespe, Cohen, & Raphan, 1985). These lesions occur naturally in humans and they can be produced in the laboratory. Although the time constant of a normal subject can dishabituate when not tested for long periods (Cohen & Cohen, 1989), no evidence in the oculomotor literature, either with human or with animal subjects, supports the notion that after stimulation the time constant becomes longer than the subject’s initial time constant. If vestibular function were to improve, the time constant would be expected to become shorter, not longer. Thus, the premise of the SCPNT, that decreased nystagmus duration indicates impaired vestibular function, is incorrect.

The SCPNT manual states that a shorter duration of nystagmus after a second test may represent cortical inhibition, and a longer duration may represent priming or excitation. No evidence in the empirical literature supports this theory. The vestibulocerebellar pathways are almost entirely subcortical (Wilson & Melvill Jones, 1979). The small, diffuse vestibular cortical pathways are not heavily involved. In fact, animals with minimal neocortical tissue, such as goldfish, have fully functional VORs, which appear to operate in the same way as the human VOR (Balo & Honrubia, 1979).

A subject could have a well-habituated response with a short time constant due to previous experience with the SCPNT or similar tasks. For example, self-stimulation activities such as spinning or twisting could cause habituation of the time constant, because the stimulus is similar to that experienced during the test. Although the subject may be naive to the test itself, he or she may not be naive to the stimulus. Also, differences in alertness caused by internal or external stimuli produce differences in duration (Balo & Honrubia, 1979). For example, increased duration in a second trial could indicate improved alertness. Time constant is less susceptible than duration to variation due to changes in the level of alertness.

During the SCPNT, the subject must obtain and maintain a fixed posture with the head in a specified relationship to the horizontal. No rigid external aids, however, are available to set the position before the test, and no aids are available to help maintain the position during the test, which lasts approximately 20 sec while the subject is rotated at 0.5 Hz. Without external perturbations, it would still be unlikely that any subject, no matter how well trained, could obtain the correct position, even with assistance, and maintain it. During the test, the subject’s posture is perturbed on every cycle because the examiner starts and maintains the rotation by pushing on the subject’s left knee once every cycle. This procedure introduces variation into the subject’s position, because the subject compensates for the perturbation with each turn. Finally, when stopped suddenly, the subject must look up. Subjects probably move their heads as well as their eyes. A change in head position causes suppression of the nystagmus, or tilt suppression (Cohen et al., 1986). The otolith signal introduced by tilting the head conflicts with the signal from the velocity storage integrator, thereby canceling the nystagmus. Thus, decreased duration could indicate either decreased alertness, habituation of the time constant, tilt suppression, or visual suppression.

Some other technical deficits also mar the design of this test. It is virtually impossible for the examiner’s unaided eye to determine the onset and offset of nystagmus. Furthermore, use of a hand-held stopwatch to time the nystagmus introduces measurement error of at least the observer’s reaction time, 150–200 ms (Marteniuk, 1976) twice—once at the beginning and once at the end of the observation period. For an unskilled observer, this error is likely to be greater.

Occupational therapists are concerned with the execution and accomplishment of functional daily life tasks. Successful occupational performance usually requires an intact VOR and adequate postural control for eye–head–hand coordination. Therefore, it is appropriate for therapists to be concerned with vestibular function, just as they are concerned with somatosensory and visual perception. As with the kinesthetic system, the vestibular system is difficult to test in isolation. An assessment can include observation of compensatory eye movements. Unfortunately, the SCPNT is not a valid vehicle for testing vestibular function, although vestibular input is generated during the passive rotation task.

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References


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