Effect of State on Nystagmus Duration on the Southern California Postrotary Nystagmus Test

(vestibular assessment, pediatric assessment, sensory integration)

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The purpose of this study was to determine the effect of state on nystagmus duration following administration of the Southern California Postrotary Nystagmus Test (SCPNT). Twenty-four normal children, 12 first-graders and 12 fourth-graders, were administered the SCPNT under three conditions: aroused, relaxed, and alert (standard instructions). Six boys and six girls in each grade participated. First-grade boys and fourth-grade girls demonstrated a statistically significant response decline in the aroused condition, and a further decline in the relaxed condition as compared to the alert condition. Further analyses demonstrated that the first-grade boys accounted for most of the variance. Possible reasons for the results obtained are discussed, and suggestions are made for future research.

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The Southern California Postrotary Nystagmus Test (SCPNT) developed by Ayres (1) is commonly used by occupational and physical therapists to determine vestibular responsivity in children primarily because of its rapid and convenient administration. Although the nystagmus response, either during or following angular acceleration and deceleration, is used as a measure of vestibular sensitivity, it is subject to inter- and intrasubject variability. Holsopple (2) identified three possible reasons why different results in the nystagmus response to vestibular stimulation may occur: 1. differences in the physiologic condition of the subjects; 2. differences in methods of applying stimuli; and 3. differences in methods of measuring results. When the SCPNT is used to compare the responses of an experimental group to the responses of normal children, two of the three factors that may produce variable results are held constant: 1. the method of applying stimuli (10 rotations in 20 sec in both directions); and 2. the method of measuring results (visual inspection of duration of postrotary nystagmus in seconds). The physiologic condition of the subjects, however, may vary. Many studies of human adults...
and a few studies of children have demonstrated that a number of extravestibular influences can modify the nystagmus response. Before postrotary nystagmus obtained on the SCPNT can be considered a valid and reliable measure of vestibular sensitivity in children, extravestibular influences must be determined and taken into consideration. The purpose of this study was to determine the effect of one extravestibular influence — state — on the postrotary nystagmus duration of normal children on the SCPNT.

In this study, state refers to the degree of arousal of an individual. Berlyne (3) described arousal as a measure of how wide awake an organism is or how ready it is to react to environmental demands. State encompasses a continuum ranging from the lowest level of arousal as in sleep or coma to the highest level of arousal as in frantic excitement or mania.

Review of the Literature

Extravestibular influences that produce different nystagmus responses to vestibular testing have been identified. These include the influence of visual stimulation, physiologic factors such as age, whether the individual is in an alert state, and the presence of certain drugs (4, 5). Most of these extravestibular influences have been studied in adult subjects; however, the effect of visual fixation and light on postrotary nystagmus has been studied in normal children (6), and Eviatar and Eviatar (7) and Ornitz et al. (8) have studied the effect of age or developmental changes on the nystagmus response of infants and young children.

Although the process by which state affects the nystagmus response is not well understood, reciprocal connections between the reticular formation and the cortex in varying arousal states may be one source of extravestibular influence. The vestibular-ocular reflex has more than one pathway (9). In addition to the medial longitudinal fasciculus, which is considered the basic threeneuron structure comprising the vestibular-ocular reflex, a second pathway exists that contains internuclear chains within the reticular formation. These connections provide the probable anatomical and physiological means for arousal to influence nystagmus. The reticular formation exerts its influence on the fast phase of nystagmus, whereas the slow component reflects vestibular function. Sleep or unconsciousness may result in blockage of the quick component, leaving only tonic deviation reflecting vestibular sensitivity.

Several investigators have suggested an interaction between state and nystagmus in infants and children. Pendleton and Paine (10) studied normal newborns and reported that tonic eye deviations (slow component only) appeared with early drowsiness, even before a change was reflected in the pattern of the electroencephalogram. Ritvo and coworkers (11) demonstrated that the average nystagmus duration in light for normal children was significantly longer than that for autistic children; however, in darkness, the mean nystagmus duration for both groups was similar. It was hypothesized that in autistic children, the optokinetic response or the effects of vision inhibited the vestibular response more than in normal children or that autistic children were in a state of lower arousal in light, which resulted in a depressed response, and, in the dark, became more alert so their response more closely resembled that of the normal children. Caloric testing was used to document transitory decreased vestibular responses in infants born to schizophrenic mothers (12). It was suggested that some covert decrease in arousal, rather than an organic lesion of the vestibular system, was responsible for the depressed responses.

A series of studies investigating the effect of arousal on the nystagmus response was conducted by Collins et al. (13) with normal human adults. Nystagmus parameters during angular acceleration stimulations of varying intensities and also during caloric stimulation were measured under various states. In general, the nystagmus parameters were greater in a condition in which the subject performed mental arithmetic (arousal) and less in a reverie condition, a state induced in the subject by asking him to relax, daydream, and to ignore the environment (14).

There has been less research on the effect of state on the nystagmus response of children. One study of 12 normal children between 5 1/2 and 8 1/2 years of age demonstrated that state could be manipulated by verbal instructions and the nystagmus response to sinusoidal angular acceleration modified (15). Children were tested using electronystagmography in an electrically controlled chair in a totally dark room. Verbal instructions during the reverie condition included the following: "I want you to relax, but keep your eyes open. Pretend you are sleepy — it's late at night and time to go to bed, and you are very tired." The aroused condition consisted of asking the child to perform arithmetic or spelling problems. In all cases, a decline in the nystagmus response was demonstrated in the reverie condition and, in some instances, when the child was asked to relax,
the response almost totally disappeared. The results suggested that state affects the nystagmus response in normal children and that reverie can be easily induced by verbal instruction.

The purpose of this study was to determine whether duration of nystagmus on the SCPNT could be manipulated in normal children by verbal instruction and physical activity. The hypothesis was that nystagmus duration would be greater under a state of high arousal, achieved by running and mental arithmetic, and less under a relaxed state, achieved by inducing reverie or daydreaming, than the nystagmus duration elicited in a standard condition or alert state. The independent variables were state, sex, and age of the children and the dependent variable was the duration of the nystagmus response.

Method

Subjects. Twenty-four children, 12 first-graders (mean age: 86 months) and 12 fourth-graders (mean age: 123 months), attending a public elementary school participated in the study. Six boys and six girls in each grade were randomly chosen and their parents contacted to receive permission for the child to participate in the study. Parents completed questionnaires designed to elicit information regarding their children's vestibular history. None of the children had a previous diagnosis of inner ear or vestibular dysfunction.

Procedure. The SCPNT was administered to each child in three different sessions, separated by an interval of 1 to 3 days. The three sessions consisted of the following conditions: 1. Alert state—the child was not given any special instructions before administration of the SCPNT. A rest period of 1½ minutes separated rotation to the left and right. 2. Aroused state—the child was asked to run approximately 100 meters, quickly assume the test position on the turntable, and perform an arithmetic problem during rotation. Following a 30-second rest period the child performed the same tasks before and during rotation to the opposite side. The arithmetic task for the first-graders was to add numbers such as 0 + 1 = 1, 0 + 2 = 2, and 1 - 1 = 2. Because it was difficult for the first-grade children to verbalize the sequence out loud during spinning, one examiner asked each child—"What is 0 + 1?"—waited for the child to respond, then asked the next problem, e.g., "What is 2 + 2?". The fourth-graders were asked to verbalize a multiplication series such as 1 x 7 = 7, 2 x 7 = 14, 3 x 7 = 21, and so forth, during spinning. The multiplication series each child performed was determined by the classroom teacher to ensure that each series would be moderately difficult for the child. 3. Relaxed state—the child was seated on the turntable and approximately 1 minute was spent trying to get the child to relax or achieve a reverie state. Instructions to the child included: "We would like for you to be as relaxed as possible before we spin you. Close your eyes and try to relax your arms and legs. Think about how you feel when it's bedtime and you are very sleepy. Take a few deep breaths." Verbal instructions were used intermittently with periods of silence. Then the child was asked to open his or her eyes and the SCPNT was administered in one direction. Following a 30-second test period, the entire procedure was repeated before spinning the child in the opposite direction.

A 1½-minute rest period was used in the alert condition, and a 30-second rest period was used in the other two conditions, in which 1 minute was used in instruction. This was an attempt to make the interval between spinning to the left and right similar in the three conditions.

There were six possible orders of administration of the three sessions. One boy and one girl in each grade were randomly assigned to each of the six possible combinations. All test sessions were administered between 9 and 12 noon. The standard test procedure for the SCPNT was used (1). The child was seated cross-legged on the turntable and asked to hold on to the front of the board with both hands. A white sheet was hung on the wall and the child was instructed to keep his or her eyes open during spinning and to look up at the sheet following rotation and not to look at either of the examiners. The exception to the standardized procedure was that the child was asked to bend his head forward slightly rather than using an angle card to position the head. This was done because it was time consuming to use the angle card and, in this design, it was desirable to begin the spinning as soon after inducing an arousal or reverie state as possible. The head was in approximately 30° of flexion to achieve maximal stimulation to the horizontal semicircular canals, and the rotation was first to the subject's left, followed by rotation to the subject's right.

Two experimenters participated in the study. One therapist had 10 years, and the other had 5 years of pediatric experience. Both were certified in the administration and interpretation of the Southern California Sensory Integration Test and had extensive experience in administering the SCPNT. The same experimenter provided instructions to all subjects at all sessions and the
Table 1

<table>
<thead>
<tr>
<th></th>
<th>First-Graders</th>
<th></th>
<th>Fourth-Graders</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males Females</td>
<td></td>
<td>Males Females</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (x) S.D.</td>
<td></td>
<td>Mean (x) S.D.</td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>31.0 (9.0)</td>
<td>25.8 (3.1)</td>
<td>23.3 (5.4)</td>
<td>30.1 (6.6)</td>
</tr>
<tr>
<td>Aroused</td>
<td>25.2 (8.4)</td>
<td>25.2 (7.2)</td>
<td>24.1 (6.1)</td>
<td>28.6 (6.6)</td>
</tr>
<tr>
<td>Relaxed</td>
<td>22.8 (7.0)</td>
<td>25.8 (4.9)</td>
<td>25.8 (10.7)</td>
<td>26.0 (9.1)</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
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<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>42.0</td>
<td>.36</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>2.3</td>
<td>.02</td>
</tr>
<tr>
<td>Sex x Grade</td>
<td>1</td>
<td>95.7</td>
<td>.82</td>
</tr>
<tr>
<td>Error</td>
<td>20</td>
<td>1.164</td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>2</td>
<td>37.6</td>
<td>1.74</td>
</tr>
<tr>
<td>State x Sex</td>
<td>2</td>
<td>3.2</td>
<td>.15</td>
</tr>
<tr>
<td>State x Grade</td>
<td>2</td>
<td>19.6</td>
<td>.91</td>
</tr>
<tr>
<td>State x Sex x Grade</td>
<td>2</td>
<td>82.5</td>
<td>3.82*</td>
</tr>
<tr>
<td>Error</td>
<td>40</td>
<td>21.6</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05

Results

Interexaminer reliability coefficients were computed and ranged from .97 to .99 among the three sessions. When the examiners disagreed on the duration of nystagmus, the mean value of the two scores was used as the duration measurement.

Means and standard deviation scores for total nystagmus duration for boys and girls in the first and fourth grades are listed in Table 1. A Biomedical Computer Program for a repeated measures design with two grouping factors (grade and sex) and one trial factor (state) with three levels (aroused, alert, relaxed) was used. A three-way analysis of variance was computed for total duration of nystagmus (Table 2). There were no main effects because of grade, sex, or state, but there was a statistically significant interaction between state, grade, and sex (F = 3.82, p = .03). First-grade boys and fourth-grade girls showed a response decline in the aroused condition and a further decline in the relaxed condition as compared to the alert condition. However, multiple comparisons of means via a Newman-Keuls test revealed that only differences in nystagmus duration for the alert versus aroused and alert versus relaxed conditions among the male first-graders were statistically significant at a .05 level.

Responses to rotation to the left were compared to responses to rotation to the right to obtain an asymmetry measure \( \frac{\text{left} - \text{right}}{\text{left} + \text{right}} \times 100 \).

A Biomedical Computer Program for a repeated measures design was used; no significant effects were evident. Correlation coefficients between left/right responses within sessions and for asymmetry measurements and total duration scores across sessions are listed in Table 3.

Discussion

Based on the data analyses, significant differences in nystagmus duration among the three state levels, between the age groups, or between the sexes were not evident for the total group. However, close inspection of the data suggests that state did affect the nystagmus responses.

Previous investigators have demonstrated that the nystagmus response as measured by the SCPNT is relatively stable, with correlation coefficients in test-retest situations ranging from .80 to .85 (1, 16, 17). Because percent asymmetry measures (Table 3c) were generally more stable across the three sessions than were total duration scores (Table 3a), and the correlation scores for duration on the SCPNT in this study were lower than those of previous investigators, it suggests that the nystagmus responses were affected by the various conditions.

First- and fourth-grade children were tested in order to detect developmental trends in the data. Because differences in nystagmus duration in the three conditions were statistically significant only for the first-grade boys, it is possible that the first-grade boys were more easily manipulated by the instructions and that their state was changed to a greater extent than that of the other children. Standard deviation scores suggest that the
Table 3
Nystagmus: Correlation Matrices

<table>
<thead>
<tr>
<th></th>
<th>Alert</th>
<th>Aroused</th>
<th>Relaxed</th>
</tr>
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<tbody>
<tr>
<td>Alert</td>
<td>.40</td>
<td>.58</td>
<td>.65</td>
</tr>
<tr>
<td>Aroused</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relaxed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Durations Scores—Left and Right—Within Sessions

<table>
<thead>
<tr>
<th></th>
<th>Alert Right</th>
<th>Aroused Right</th>
<th>Relaxed Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert Left</td>
<td>.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aroused Left</td>
<td>.70</td>
<td>.70</td>
<td></td>
</tr>
<tr>
<td>Relaxed Left</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c. Percent Asymmetry Scores Across Sessions

<table>
<thead>
<tr>
<th></th>
<th>Alert</th>
<th>Aroused</th>
<th>Relaxed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert</td>
<td></td>
<td>.89</td>
<td>.82</td>
</tr>
<tr>
<td>Aroused</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relaxed</td>
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</tbody>
</table>

state levels or nystagmus responses of the first-grade boys were more variable than those of the other children. Ayres (1) reported that the variance in nystagmus duration on the SCPNT among boys was greater than that among girls; however, because the interaction among state, sex, and age in this study is based on a cell size of six children, apparent differences in nystagmus responses of first-grade boys may be due to a sampling error.

Although there were modest correlations among total duration scores for the three sessions (.40 to .65), wide individual differences were apparent. For example, one male first-grader had a total nystagmus duration of 49 seconds in the alert condition and 33 seconds in the relaxed condition. One male fourth-grader had a total nystagmus duration of 33 seconds in the alert condition and 43 seconds in the relaxed condition. This suggests that the nystagmus response can either be affected by varying conditions or that intrasubject variability from one test session to another may be large.

In a previous study, in which similar verbal instructions to decrease arousal markedly affected the nystagmus response (15), the children were tested in a completely dark room. The alerting effects of light and vision may have prevented some children in this study from achieving or maintaining a relaxed condition.

Mental arithmetic and physical exercise were used to produce arousal because previous studies had demonstrated an enhanced effect of these two factors on the nystagmus response (13, 18). It is surprising that these manipulations produced an attenuated nystagmus response in some subjects. It did appear that many of the children moved their eyes as they concentrated and performed the math problems; this may have increased visual fixation, thereby decreasing the nystagmus response. Since the SCPNT is performed in light, it may have been more effective to have had the children perform only the physical activity in an attempt to achieve an aroused state.

The SCPNT appears to be a stable measure; however, it provides a gross measure of nystagmus duration (as compared to ENG recordings) that allows less variability in test-retest situations and thus may increase reliability coefficients as compared to ENG measurements. On the other hand, it is possible that nystagmus duration on the SCPNT is more resistant to changes in state than other nystagmus measures. Fluur and Mendel (19) studied the nystagmus response of normal adult subjects following various acceleration schedules. The duration of postrotary nystagmus during constant velocity (following acceleration and deceleration) tended to be longer with increasing acceleration rates, but the data suggested that the nystagmus duration elicited by weak acceleration stimuli was more variable than that elicited by strong stimuli. One explanation was that weak stimuli may allow central nervous system extravestibular influences to affect the response.

The major limitation of this study was the qualitative nature of the attempts to manipulate state. In future studies, independent measures of state, such as galvanic skin resistance, pupil dilation, and heart rate, need to be taken simultaneously with measures of the nystagmus response during vestibular testing. This would require sophisticated laboratory equipment that is seldom available in clinical settings.

Conclusions

Although significant differences were not apparent in the nystagmus durations of the total group of normal children in the various conditions used in this study, it is possible that state may affect the nystagmus response in various patient populations. For example, Collins stated that "the absence of alertness
or arousal, whatever its neuro-psycho-physiological cause, is probably a major factor in vestibular findings which indicate substantial or total suppression of nystagmus responses in schizophrenic patients.” (13, p 365) Therapists should consider the interaction between nystagmus and state, particularly in the evaluation of individuals who demonstrate an abnormal nystagmus response but do not display other clinical signs of vestibular dysfunction.

However, the cause and effect relationship between state and nystagmus responses is unclear. Perhaps vestibular processing deficits may alter state. Ayres (20) considers the vestibular system to be an important contributor to the general energizing properties of the reticular arousal system; and Fredrickson et al. (21, p 574) in a discussion of general cortical arousal stated that “vestibular stimuli cause more arousal than sensory stimuli, except for pain.”

Until the relationship between state and nystagmus is better understood, caution should be employed in interpreting results of studies using the nystagmus response. A depressed nystagmus may not be directly attributable to the vestibular system, but may be due to other CNS mechanisms. Likewise, an increase in nystagmic parameters following treatment intervention may not signify a change in vestibular functioning but may be the result of other CNS changes, such as an increase in arousal. Drugs that depress (e.g., barbiturates) or excite (e.g., amphetamines) the reticular formation may also influence the nystagmus response (9, 22).

Research studies that include nystagmus measurements should include task control of the subject's mental activity to prevent the subject from lapsing into a reverie state (23). The effect of task-control, such as mental arithmetic, on the nystagmus response has not been determined in clinical situations with subjects with various neurologic disorders and may be an area for future research.

This study was a preliminary investigation of the effect of state on the nystagmus duration of normal children following administration of the SCPNT. Because it is possible that children with a variety of developmental deficits have altered states of arousal that may alter their nystagmus response to vestibular testing, it is essential that these effects be determined.

Acknowledgments
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