EFFECTS OF VESTIBULAR STIMULATION
ON THE REFLEX AND MOTOR DEVELOPMENT
IN NORMAL INFANTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

by

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* * * * *

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INTRODUCTION

In order for the normal maturation of motor development to occur in an infant, accurate sensory input from his environment is necessary. The infant must be able to integrate his sensory input in order to be able to inhibit inappropriate responses (Ayres, 1972; Langworth, 1970; Pfaltz and Kato, 1975; Young and Henn, 1975). The inability to integrate sensory input leads to the developmental delay of the infant (Chee, 1975). The inability to inhibit inappropriate responses will continue in the infant until such time as the centers of inhibition can be trained to recognize inappropriate responses and, thus, inhibit these responses.

Physical, occupational and speech therapists have tried to influence the abnormal postural responses by the use of stimulus (input), integration (interpretation) and response (output) techniques of therapy with the intent of increasing motor achievement in the developmentally delayed child.
(Kantner, 1974; Kantner et al., 1975). Several investigators have developed therapeutic techniques in this area. Among the most prominent are Rood (1963), Bobath and Bobath (1971), Fay (1954) and Ayres (1972). All of these special therapeutic techniques have in common the influencing of the postural responses by exteroceptive, visual and vestibular systems by both direct and indirect involvement. However, in each of these techniques no single sensory system is identified as directly increasing motor development. It might be pointed out that the most primitive of all sensory systems is the vestibular system, which appears as the only sensory system in primitive life (Torok and Perlstein, 1962; Ayres, 1972). This suggests that this system might play an integral part in the early development of normal motor behavior. It has been suggested that vestibular dysfunctioning may be responsible for the delayed motor development in cerebral palsy children (Torok and Perlstein, 1962; Rapin, 1974).

The human infant, in his first year of life, is involved with a developmental sequence of reflexes leading to motor achievement of bipedal ambulation (Fiorentino, 1974). These reflexes are vestibular oriented. The primitive reflexes, the righting reflexes and the equilibrium reflexes are all initiated through stimulation of the vestibular system.

The importance of the vestibular system to the developing neonate is further emphasized by the recent study of Korner and
Thoman (1970; 1972) and Pederson and TerVrucht (1973). These investigators found that vestibular stimulation, a component of most caretaking activities, is more crucial than the tactile stimulation of being held by the mother in reduction of infant crying. Korner and Thoman (1970) further added that vestibular stimulation may be more crucial than the contact of the mother for certain aspects of early human development.

Sensory deprivation studies have shown that lack of vestibular stimulating types of input result in stimulus seeking activities such as head rocking, head rolling and body rocking (Prescott, 1970; Harlow and Zimmerman, 1959; Solomon, 1969).

Recent studies by Kantner and Clark (1975) and Chee (1975) have shown that by increased vestibular stimulation in both developmentally delayed and in normal infants, the reflex and motor performance can be accelerated.

Zubeck (1963) totally immobilized adult males for one week. No tactile-kinesthetic (vestibular) stimulation was allowed. The subjects still received all other sensory input of a normal environment. The results showed that immobilization produced disturbances in both performance and the electrical activity of the brain. These results further substantiate the effect that vestibular stimulation has on normal postural and motor control.
In another study, premature infants were exposed to daily sessions of vestibular stimulation. The premature infants were at a gestational age of 28-32 weeks. Stimulation began on the fifth day of life. Results showed significant improvement in motor, visual and auditory responses. It was also noted that motor development seemed to be accelerated (Neal, 1967).

Physical and occupational therapists incorporate forms of vestibular stimulation in their therapeutic programs in an attempt to disrupt the abnormal postural and motor patterns found in developmentally delayed children. This is accomplished by such techniques as swinging the child in a net or by rolling the child over a large beach ball (Ayres, 1972). At the same time, the therapists are trying to facilitate normal postural and motor responses through methods such as placing the child in a normal posture pattern (Bobath, B., 1971; Collis, 1953a, 1953b).

A review of the literature indicates that vestibular stimulation, directly or indirectly, is being implemented in the therapeutic programs by physical and occupational therapists with the intent of improving motor performance. Due, however, to the complexity of the therapy programs, the effects of vestibular stimulation cannot be isolated from the effects of
other forms of stimulation, such as visual and tactile. The optimal level of vestibular stimulation necessary to provide the most beneficial results is unknown. It is suggested that the levels of vestibular stimulation employed in most therapeutic programs is relatively minimal in comparison to that experienced by normal children during unmodified daily activities. It is this investigator's contention that the literature indicates that more specific and quantified research is necessary on the effects of vestibular stimulation on the motor and reflex development in normal infants both immediate and long-term.

Habituation is the response decline of postrotatory nystagmus upon repeated vestibular stimulation (Young and Henn, 1974). The habituation of the postrotatory nystagmus is the development of conditioned compensatory reaction to oppose inappropriate responses related to visual-vestibular conflicts (Collins, 1973).

In this study we used a cupulogram, developed by Van Egmond (1949), to assess the degree of habituation that would occur after 16 sessions of vestibular stimulation over a four week period. The cupulogram allows us to determine the time
constant for the observable cessations of the vestibulo-ocular reflex. The time constant, \( \tau / \Delta \), is the slope of a line that best fits the mean values of, in the case of our study, the duration of postrotatory nystagmus of five angular velocity stimuli plotted on semilogarithmic scale graph paper.

The literature has shown investigations of the time constants in adults and children. Groen (1963; 1965) found the time constant of a subject at birth to be 20 seconds. Kantner (1974) showed the time constant in three infants to be 19 seconds. Van Egmond, et al, (1949) reported the time constant for a normal adult was 10.0 seconds. Benson and Bodin (1966) found the time constant of ten adults to be an average of 7.8 seconds.

The literature indicates that only three children have been tested to determine the time constant for the cessation of vestibular ocular reflex. This investigator contends that more specific and quantified research is necessary on the effects of vestibular stimulation on the habituation of the postrotatory nystagmus in normal infants.

**HYPOTHESIS:**

It is hypothesized:

1. That 16 sessions of vestibular stimulation over a four week period will significantly
improve reflex and motor performance as measured by the reflex test and motor achievement test developed by Chee, Kantner and Kreutzberg. The Control Groups will show no significant improvement on their reflex and motor scores.

2. That 16 sessions of vestibular stimulation over a four week period will cause habituation of the postrotatory nystagmus in the Treatment Group. No significant change in the postrotatory nystagmus will occur in the Control Groups.
MATERIALS AND METHODS

Population

The population for this study consisted of twenty-six (26) normally developing subjects ranging from a chronological age of three months to thirteen months with the mean age of seven months. The basic motor skills criteria for eligibility to the study were that the subjects were not classified as developmentally delayed by their physician, and that they were, as yet, non-ambulatory in their motor skills. All subjects completed the study.

Experimental Design

The experimental design was a basic Pretest, Treatment, Post-test format (fig. 1). The pretest consisted of three types of data collecting tests, each given in the week prior to the initiation of the Treatment sessions. The three tests were: a reflex, a motor and a vestibular assessment exam. During the Pretest week, the motor and reflex tests were administered first,
followed by a one day rest and then the vestibular test. Two independent observers who were licensed physical therapists were used to grade both the reflex and the motor skills tests to insure the reliability of the examination. The independent observers were not informed as to which group the subjects were assigned. Throughout the study an attempt was made to assign the same subject to the same independent observer. The Post-test week consisted of the exact same examinations except the vestibular test was presented first, followed by a day of rest, and then the motor and reflex examinations.

Immediately after the motor and reflex tests were administered and recorded during the Pretest week, the reflex and motor tests scores were combined for each subject. The scores were then divided into matched pairs and ordered by rank in which the first score was placed into the Control Group, the second score into the Treatment Group, the third into the Treatment Group and the fourth into the Control Group, etc., until the entire range of scores was categorized. This technique was utilized to insure that the mean and standard deviation profile of each group, Pretest, was almost identical. The Control Group (N=13) was further divided into a Control Non-Handled
Group (N=7) and a Control Handled Group (N=6) by the same method of matched pairs. The rationale for this further subdivision of the Control Group was to control for the effects of handling as a variable in this study.

Motor Test

The motor achievement test, developed by Kantner and modified by Chee and Kreutzberg (Appendix A), was designed to evaluate specific, measurable motor tasks such as head righting, sitting, creeping, standing and walking. Each task was broken down into five approximating steps. Each approximating step was essential for the total task to be accomplished. Thus, it was necessary for each task to be successfully accomplished before the subject was examined for the next higher level motor skill (Appendix A). The handler attempted to elicit each motor skill task up to three separate times. If the motor skill was not seen by the third attempt, it was assumed to be not present in the subject. The correlation between observers scoring the motor skills test was 90.2% for both the Pretest and the Post-test.

Reflex Test

The reflex assessment was evaluated using a reflex test
developed by Chee (1975) and modified by this investigator. The test was designed to evaluate the normal or abnormal presence of central nervous system reflexes which are, in the normal case, essential for normal motor development, and in the abnormal, an indicator of developmental delay of motor skills. Each reflex was broken down into four approximating steps from the most severe abnormal reflex posture to the normal motor response (Appendix B). The handler attempted to elicit each reflex up to three separate times. If the reflex was not seen by the third attempt, it was assumed that it was not present in the subject, in which case the independent observer would score his observation in accordance with the subject's age. The reliability of the test was insured by the physical therapist observer's independent evaluation of the subject. The correlation between observers in scoring the reflex test was 97.7% for both the Pretest and the Post-test.

**Nystagmus Recording**

Postrotatory nystagmus was evaluated both in the Pretest and Post-test using impulsive decelerative stimuli of a magnitude of 20°/sec., 30°/sec., 50°/sec., 100°/sec., and 150°/sec. angular velocity. The nystagmus measurement was performed in a darkened room in order to prevent the subject from fixating on
an object, which inhibits nystagmus. The duration of the postrotatory nystagmus was measured using a standard stop watch and indirect lighting with a penlight flashlight in order to visualize the nystagmus. The penlight flashlight was held at the horizontal level of the eye at about the vertical level of the ear. Frenzel's glasses could not be used due to the intolerance of the subjects. The chair was accelerated, held at the pre-selected velocity for one minute, then impulsively decelerated. The one minute rotation was to insure that the cupula had returned to the resting position. The vestibular testing was done by rotating the subject while sitting in the lap of a researcher. The subject's head was placed so that the horizontal semicircular canals would be maximally stimulated. This was accomplished by flexing the head approximately 30° nose down (Fig. 2). This placed the lateral semicircular canals in the horizontal plane. The stimulation of the horizontal semicircular canals was given in a clockwise (cw) direction for one minute, impulsively stopped and the postrotatory nystagmus was recorded. Then stimulation was given in a counterclockwise (ccw) direction for one minute. This was done in order that both the right and left horizontal semicircular canals received approximately equal vestibular stimulation. In addition, the left posterior semicircular canals and the right anterior semicircular
canals were also stimulated. This was accomplished by placing the subject in the supine position across the research assistant's lap, placing the head on the right arm of the assistant. The head was then flexed on the midline approximately 20° and rotated to the right approximately 45° (Fig. 3).

To minimize against the systematic biasing of the data by habituation, which may occur during a sequential presentation of angular velocities from 20°/sec. to the 150°/sec., the angular velocities were randomly presented with the order of presentation determined using a random numbers table. The acceleration to each of these angular velocities occurred within 0.5 to 1.0 seconds and the constant velocity rotation was maintained for one minute to insure cupular return. The period of constant velocity rotation was followed by an impulsive stop which required a fraction of a second; approximately 0.5 second. It was at this time that the initiation of the duration of the postrotatory nystagmus was determined. Cessation of nystagmus was defined as the last observable nystagmus beat. The duration of the nystagmus was measured by a standard stop watch and recorded. The data collected was used to produce a cupulogram analysis of the vestibular function for each of the subjects tested. This procedure shows a quantitative assessment of the vestibular function, and allowed us to obtain a base line to evaluate the effects of treatment on the habituation process.
Equipment

The vestibular stimulation was administered in an ordinary swivel chair adapted for the rotation (Fig. 5). The swivel chair was manually propelled and the velocity was monitored by illuminated velocity indicators. The chair was equipped with safety belts for the subject and researcher and a battery pack for the Frenzel glasses; however, they were not used due to the intolerance of the subjects. The simplicity of this design of the swivel chair is essential for the adaption of the procedure at a minimal expense in physical therapy clinics.

Treatment

The treatment sessions for both the Treatment Group and the Control Handled Group were given twice per treatment day over a four week period. The intertreatment interval per treatment session was four days between the last treatment session of one week and the first treatment session of the next week, followed by a one day intertreatment interval between the first treatment day and the second treatment day of the week. The result being that each subject received four treatment sessions per week or a total of 16 treatment sessions per four week period. The four week treatment sessions were preceded by
a one week Pretest and followed by a one week Post-Test (Fig. 1). The Control Non-Handled subjects received the Pretest and Post-test with only normal maturation in the intervening four weeks in their own environment. The Control Handled subjects received handling by the same individual who held the treated subjects during their treatment sessions in the same conditions as the Treatment Group subjects except the Control Handled subjects did not receive vestibular stimulation.

The treatment consisted of stimulation of each of the three pairs of semicircular canals using 100°/sec. impulse stop stimuli. The first rotation provided stimulation to the horizontal semicircular canals. In order for both right and left horizontal semicircular canals to have approximately the same stimulation, the subject was rotated clockwise (cw) for one minute then impulsively stopped and postrotatory nystagmus was recorded. The subject was then rotated counterclockwise (ccw) in the same manner. Two paired vertical semicircular canals were stimulated while holding the subject in a supine position with the subject's head resting on the right arm of the research assistant. Vestibular stimulation during each treatment session consisted of both clockwise (cw) and counterclockwise (ccw) rotations of 100°/sec. angular velocity impulsive stop stimuli. The subject's position was then reversed so that the head was then placed on the left arm of the research
assistant and the same procedure was again administered (Fig. 4). Each rotation consisted of a rapid acceleration to a constant angular velocity within 0.5 to 1.0 seconds. The constant angular velocity of $100^\circ$/sec. lasted one minute to insure the system was at rest, followed by an impulsive stop within 0.5 to 1.0 seconds.

The first session of the treatment day for the Treatment Group consisted of ten controlled and quantified vestibular stimuli. One clockwise (cw) and one counterclockwise (ccw) rotation stimulus for the horizontal semicircular canals and two cw and ccw for the vertical semicircular canals. This session was followed by a rest of 30 minutes and then the second treatment session consisting of six vestibular stimuli, cw and ccw for the horizontal, the anterior and posterior semicircular canals or a single vestibular stimulation of each of the semicircular canals.

Subjective Comments

Throughout the study, subjective comments were made by parents and teachers of the subjects on the behavioral and motor changes observed in each subject. These comments were recorded on the Pretest data sheet (Appendix C), the Treatment data sheet (Appendix D) and the Post-test data sheet (Appendix E). The week after the Post-test a questionnaire was administered
either in person or over the telephone to the parents and teachers of the subject. The questionnaire was developed by Chee (1975) and Kreutzberg (1975) (Appendix F). The questionnaire consisted of various motor skills areas where the parents or teachers may have noticed changes.

**Delayed Post-Test**

Six weeks after the Post-test, a Delayed Post-test was administered to 23 of the original 26 subjects. Three subjects dropped out of the study for various reasons. The Delayed Post-test consisted of the exact format as the Post-test of the main study. The scores were then analyzed statistically, and were recorded. The correlation between the independent observers in scoring the Delayed Post-test reflex test was 95.4%. The correlation between independent observers in scoring the Delayed Post-test motor test was 99.9%.
RESULTS

Nystagmus Response

The time constant, $\pi/\Delta$, for the Treatment Group, Control Handled Group and the Control Non-Handled Group at the Pre-test were compared statistically by a One Way Analysis of Variance for the horizontal semicircular canals (Table 1), and for the vertical semicircular canals (Table 2). The time constant for each group for both the horizontal and vertical semicircular canals was found to be not significantly different from each other, $F_{2,23} = 0.8500$ for the horizontal and $F_{2,23} = 0.9100$ for the vertical semicircular canals. The data was then combined to establish Pretest values. The Pretest nystagmus data is illustrated in Table 3. The Pretest time constant for all subjects was 6.05 sec. (S.D. 1.36 sec.) for the horizontal semicircular canals and 5.77 sec. (S.D. 1.48 sec.) for the vertical semicircular canals (Table 3). The Linear Regression coefficient
for the data points plotted on semilogarithmic graph paper was 0.9719 (S.D. ± 0.0211; Table 3). The threshold sensitivity was at 3.37°/sec. (S.D. ± 1.66°/sec.) for the horizontal semicircular canals (Table 3). The vertical semicircular canals data points plotted on semilogarithmic graph paper showed a Linear Regression coefficient of 0.9638 (S.D. ± 0.0352). The threshold sensitivity was at 3.32°/sec. (S.D. ± 1.859°/sec.; Table 3).

Post-test scores were first analyzed with a One Way Analysis of Variance in order to determine if a difference occurred between groups in the Post-test scores. This test showed a highly significant difference between groups (F2,23 = 19.0700, P < 0.0001) for the horizontal semicircular canals (Table 1) and (F2,23 = 17.3200, P < 0.0001) for the vertical semicircular canals (Table 2). Further analysis was performed with a Student's 't' test in order to determine which group was responsible for the difference. This test showed that the time constant of the Control Handled Group, Pretest versus Post-test, for the horizontal semicircular canals was not significantly different ('t' = 0.4600, Table 4). The difference between the Pretest versus Post-test time constant for the Control Non-Handled Group was also found not to be significant for the horizontal semicircular canals ('t' = 0.6200, Table 4). The difference
between the Pretest versus Post-test time constant for the Treatment Group was, however, found to be highly significant (\( t' = 7.7300, P < 0.001, \text{Table 4} \)). The same results were seen with the time constant of the vertical semicircular canals. The differences between the time constant of the Control Handled Group, Pretest versus Post-test, was not significant (\( t' = 0.1300, \text{Table 4} \)). The differences between the Pretest versus Post-test time constant for the Control Non-Handled Group were also found to be not significant (\( t' = 0.0800, \text{Table 4} \)). However, the differences between Pretest versus Post-test time constant for the Treatment Group was found to be highly significant (\( t' = 7.8600, P < 0.001, \text{Table 4} \)).

The Post-test time constant for the horizontal semicircular canals for the Treatment Group was 2.75 sec. (S.D. \( \pm \) 0.8445 sec.), a 3.3 sec. decline or a 54.5% decrease in the time constant. The vertical semicircular canals had a time constant of 2.51 sec. (S.D. \( \pm \) 0.7269 sec.), which is a 3.3 sec. decline or a 56.6% decrease in the time constant. The Linear Regression coefficient for the data points was 0.9488 (S.D. \( \pm \) 0.0322) for the horizontal semicircular canals and 0.9530 (S.D. \( \pm \) 0.0240) for the vertical semicircular canals. The threshold sensitivity was 3.2°/sec. (S.D. \( \pm \) 2.0°/sec.) for the horizontal semicircular canals and 2.9°/sec. (S.D. \( \pm \) 1.8°/sec.) for the vertical semicircular canals (Table 3).
The Control Groups were combined since statistical analysis showed no significant difference between the two groups. The Combined Control Group time constant was 5.80 sec. for the horizontal semicircular canals on the Post-test. This was a 0.27 sec. decline or a 4.4% decrease in the time constant when compared with the Pretest value. A time constant of 5.32 sec. was obtained for the vertical semicircular canals on the Post-test which was a 0.46 sec. decline or a 7.9% decrease in the time constant when compared with the Pretest value. The Linear Regression coefficient for the data points was 0.9716 (S.D. ± 0.0332) for the horizontal semicircular canals and 0.9743 (S.D. ± 0.0284) for the vertical semicircular canals.

The threshold sensitivity was 4.0°/sec. (S.D. ± 2.8°/sec.) for the horizontal semicircular canals and 3.9°/sec. (S.D. ± 3.0°/sec.) for the vertical semicircular canals (Table 3).

The subjects were categorized into two groups according to their age (Table 5). This was done in order to determine if a critical period existed for the response decline of the time constant. The first group (Group I) consisted of all subjects between three months and seven months of age and the second group (Group II) consisted of all subjects between eight months and thirteen months of age. Group I had a population of 12 subjects and Group II had a population of 14 subjects. Statistical
analysis was then performed using a Student's 't' test. The Treatment subjects' horizontal semicircular canal time constant between Group I and Group II showed a 't' = 0.5382, which was not significant. The time constant of the Treatment Group subjects for the vertical semicircular canals showed a 't' = 0.1754, which was not significant. The Control Group subjects' horizontal semicircular canal time constant between Group I and Group II showed a 't' = 1.6986, which was not significant. The Control Group subjects' vertical semicircular canal time constant between Group I and Group II showed a 't' = 2.4927, P < 0.05, which for this study was still considered to be not significant (Table 6).

Threshold sensitivity data for all groups, Pretest versus Post-test, were statistically analyzed using a Mixed Model Analysis of Variance test. The difference in horizontal semicircular canal threshold sensitivity, Pretest versus Post-test, was found not to be significant (F_{2,23} = 1.3900, Table 7). Threshold sensitivity difference for the vertical semicircular canals, Pretest versus Post-test, was found not to be significant (F_{2,23} = 1.8300, Table 7).

The duration of postrotatory nystagmus during each treatment session is recorded in Table 8 and graphically represented in Figure 6 for the horizontal semicircular canals and Table 8 and Figure 7 for the vertical semicircular canals. The impulse
stop velocity stimulus for the treatment sessions was 100°/sec. Pretest and Post-test time constants for all groups are represented in a cupulogram in Figure 8 for the horizontal semicircular canals and in Figure 9 for the vertical semicircular canals. The mean duration and standard deviation of the postrotatory nystagmus recorded during the Pretest and Post-test are recorded in Table 9. The data were recorded following impulsive stop stimulation of the horizontal and vertical semicircular canals at angular velocities of 150°, 100°, 50°, 30° and 20°/sec.

Six weeks after the Post-test was administered, a Delayed Post-test was administered to the same population. The horizontal semicircular canal time constant of the Treatment Group was 4.59 sec. (S.D. ± 1.64 sec.). This was an increase of 1.84 sec. over Pretest levels; a 30.4% increase. The vertical semicircular canal time constant was 3.93 sec. (S.D. ± 1.47 sec.) or a 1.42 sec. increase; a 24.6% increase. The Linear Regression coefficient for the data points plotted semilogarithmically was 0.9647 (S.D. ± 0.0244) for the horizontal semicircular canals and 0.9304 (S.D. ± 0.0328) for the vertical semicircular canals. The threshold sensitivity for the horizontal semicircular canals was 1.9°/sec. (S.D. ± 1.809°/sec.) and 1.6°/sec. (S.D. ± 1.724°/sec.) for the vertical semicircular canals (Table 10).
The Combined Control Group time constant was 5.47 sec. (S.D. ± 1.19 sec.) for the horizontal semicircular canals, a 0.33 sec. decline from the 5.80 sec. time constant of the Post-test. The vertical semicircular canals showed a time constant of 4.90 sec. (S.D. ± 1.05 sec.), a 0.42 sec. decline from the 5.32 sec. time constant of the Post-test. The Linear Regression coefficient of the data points was 0.9647 (S.D. ± 0.0244) for the horizontal semicircular canals and 0.9581 (S.D. ± 0.0381) for the vertical semicircular canals. The threshold sensitivity was 2.4°/sec. (S.D. ± 0.950°/sec.) for the horizontal semicircular canals and 2.2°/sec. (S.D. ± 0.949°/sec.) for the vertical semicircular canals (Table 10). The time constant representing the horizontal semicircular canals of Treatment Group subjects, Post-test versus Delayed Post-test, showed a 't' = 3.966, P < 0.01, a highly significant difference. The time constant representing the vertical semicircular canals of the Treatment Group subjects, Post-test versus Delayed Post-test, showed a 't' = 3.297, P < 0.01, a highly significant difference. The time constant of the Combined Control Group horizontal semicircular canals showed a 't' = 1.070, not a significant difference.

The threshold sensitivity was statistically analyzed to determine if a change occurred between the Post-test and the Delayed Post-test. The Student's 't' test, paired observation,
was used. The results showed that there was no significant difference in threshold sensitivity between the Post-test and the Delayed Post-test (Table 12). The time constant for the Post-test versus Delayed Post-test for the Treatment Group and the Control Group can be seen graphically represented in a cupulogram in Figure 10 for the horizontal semicircular canals and Figure 11 for the vertical semicircular canals. The mean duration and standard deviation of the postrotatory nystagmus in the six week Delayed Post-test are illustrated in Table 13. The data was recorded following impulsive stop stimulation of the horizontal and vertical semicircular canals at angular velocities of 150°, 100°, 50°, 30°, and 20°/sec.

The subjects were again categorized into two groups according to their ages (Table 14). This was done to determine if age can be correlated with the results obtained by the vestibular stimulation. The first group consisted of all subjects between three months and seven months of age at the beginning of the study (N=12). The second group consisted of subjects between eight months and thirteen months of age (N=14, Table 14). Statistical analysis was performed using a Student's 't' test. The results showed no correlation between age and values for the time constant (Table 15).
Reflex Response

The individual scores for each subject on the reflex test, as scored by each independent observer \( O_1 \) and \( O_2 \), on the Pretest and Post-test are illustrated in Table 16.

The Treatment Group had a Pretest score of 50.53 points (S.E. \( \pm 3.29 \)) and a Post-test score of 62.53 points (S.E. \( \pm 1.56 \)). The Post-test score was a 12.0 point increase or a 17.65% change (Table 17). The Control Group had a Pretest score of 51.51 points (S.E. \( \pm 2.10 \)) and a Post-test score of 55.8 points (S.E. \( \pm 2.39 \)). The Post-test score was a 4.29 point increase or a 6.31% change (Table 17). Points scored during the Pretest and Post-test can be graphically seen in Figure 12 and in Figure 13. The points increased are graphically represented in Figure 14. The percent increased is represented in Figure 15.

The reflex scores on the Pretest were examined using a One Way Analysis of Variance statistical test. The results showed no significant difference between groups on the Pretest (\( F_{2,23} = 0.49, \text{ N.S., Table 18} \)). The Pretest versus Post-test scores were then compared statistically using a Student's 't' test. The results showed that the Treatment Group showed a significant improvement over Pretest values ('t' = 5.99, \( P < 0.001 \), Table 19). The Control Handled Group and the Control Non-Handled Group showed no significant change over Pretest values.
The subjects were then categorized into two groups according to age (Table 20). The first group (Group I) consisted of subjects whose ages were between three months and seven months (N=12). The second group (Group II) consisted of subjects between eight months and thirteen months (N=14, Table 20). The reflex Treatment Group I compared using the Student's 't' test, randomized sample, to Group II showed a 't' = 4.0937, P < 0.01, thus, Group I showed a significant difference on the reflex score over that of Group II. The reflex Control Group I compared statistically to Group II showed a 't' = 0.3126 indicating that there was no significant difference in reflex scores between Group I and Group II (Table 21).

Six weeks after the completion of the Post-test, a Delayed Post-test was administered to the same population. The individual scores for each subject on the reflex test, as scored by each independent observer, $o_1$ and $o_2$, on the Post-test and the Delayed Post-test, are presented in Table 22.

The Treatment Group had a Post-test score of 62.53 points (S.E. $\pm$ 1.56) and a Delayed Post-test score of 63.96 points (S.E. $\pm$ 1.43, Tables 17 and 23). The Delayed Post-test score was a 1.37 point increase or a 2.0% change. The Control Group had a Post-test score of 55.8 points (S.E. $\pm$ 2.39) and
a Delayed Post-test score of 63.82 (S.E. ± 1.93). The Delayed Post-test score was an 8.01 point increase or a 11.78% change (Table 23). Points scored on the Delayed Post-test are graphically represented in Figure 16 and Figure 17. Points increased are represented in Figure 18 and percent change is represented in Figure 19.

The Delayed Post-test reflex scores were analyzed statistically by using the Analysis of Covariance test. The covariate was the improvement in the tests scores due to normal maturation, as reflected in the Control Group. Results of the reflex test showed no significant change due to vestibular stimulation, alone ($F_{1,24} = 3.0455$, N.S., Table 24).

The subjects were again categorized into two groups according to age (Table 25). The first group (Group I) consisted of subjects whose ages were between three months and seven months at the beginning of the study ($N=12$). The second group (Group II) consisted of subjects between eight months and thirteen months ($N=14$; Table 25). Statistical analysis was performed using a Student's 't' test, randomized sample. The reflex Treatment Group I compared statistically to Group II showed a 't' = 4.8179, $P < 0.01$ value. Group I showed a significant difference on the reflex score over that of Group II. The reflex Control
Group I compared statistically with Group II showed a 't' = 1.9926, which indicates no significant difference in reflex scores between Group I and Group II (Table 26).

**Motor Response**

The individual scores for each subject on the motor test, as scored by each independent observer, $O_1$ and $O_2$, on the Pre-test and Post-test are illustrated in Table 16.

The Treatment Group had a Pre-test mean score of 59.0 points (S.E. $\pm$ 9.66) and a Post-test mean score of 86.38 points (S.E. $\pm$ 9.89). The Post-test score was a 27.38 point or a 18.25% increase (Table 17). The Control Group had a Pretest mean score of 58.55 points (S.E. $\pm$ 6.50) and a Post-test mean score of 68.5 points (S.E. $\pm$ 9.22). The Post-test score was a 9.95 point or a 6.6% increase (Table 17). Points scored during the Pretest and Post-test can be graphically seen in Figure 12 and in Figure 20. The points increased are presented in Figure 14. The percent increased is presented in Figure 15.

The motor Pretest scores were examined using a One Way Analysis of Variance statistical test. Results showed that there was no significant difference between groups on the Pretest ($F_{2,23} = 0.49$, N.S., Table 18). The Pretest versus Post-test scores were then compared statistically using a Student's
't' test. The results showed that the Treatment Group showed a highly significant improvement over Pretest scores ('t' = 10.56, \( P < 0.001 \), Table 19). The Control Handled Group's motor scores showed a significant improvement over Pretest values ('t' = 2.53, \( P < 0.05 \), Table 19). The Control Non-Handled Group's motor scores showed a significant improvement over Pretest values, ('t' = 3.11, \( P < 0.01 \), Table 19). Further analysis was performed in order to control for the significant effect of maturation on the motor test scores. This was done by using an Analysis of Covariance statistical test. The covariate was the improvement in test scores due to normal maturation, as reflected in the Control Groups. Results of the statistical test showed a highly significant improvement in motor performance due to the vestibular stimulation, alone (\( F_{1,24} = 21.6005, P < 0.001 \), Table 24). No difference was found between the Control Handled and the Control Non-Handled Groups' motor test scores (Table 24).

The subjects were then categorized into two groups according to age (Table 20). The first group (Group I) consisted of subjects whose ages were between three months and seven months (\( N=12 \)). The second group (Group II) consisted of subjects between eight months and thirteen months of age (\( N=14 \), Table 20).
Statistical analysis was performed using a Student's 't' test, randomized sample. The motor Treatment Group I compared statistically to Group II showed a 't' = 0.9963, N.S. The motor Control Group I compared statistically to Group II showed a 't' = 1.5195, N.S. (Table 21).

Six weeks after the completion of the Post-test, a Delayed Post-test was administered to the same population. The individual scores for each subject on the motor test, as scored by each independent observer, $O_1$ and $O_2$, on the Post-test and the Delayed Post-test, are represented in Table 22.

The Treatment Group had a Post-test score of 86.38 points (S.E. $\pm$ 9.89) and a Delayed Post-test score of 95.54 points (S.E. $\pm$ 9.01). The Delayed Post-test score was 9.16 points, or a 6.1% increase (Table 23). The Control Group had a Post-test score of 68.5 points (S.E. $\pm$ 9.22) and a Delayed Post-test score of 94.09 points (S.E. $\pm$ 9.60). The Delayed Post-test score was a 25.59 point, or a 17.06% increase (Table 23). Points scored on the Delayed Post-test are graphically represented in Figure 21 and Figure 22. Points increased are represented in Figure 18 and percent change is represented in Figure 19.

The Delayed Post-test scores were analyzed statistically
by using the Student's 't' test, paired observation (Table 27). Results showed a significant improvement in the Treatment Group's Delayed Post-test scores (t = 3.1544, P < 0.01, Table 27). The Control Group also showed significant improvement in the Delayed Post-test scores (t = 8.5816, P < 0.001, Table 27). Results seem to indicate that maturation, alone, caused a significant improvement in both groups. To determine if this assumption was correct, the motor scores were analyzed statistically by using the Analysis of Covariance test. The covariate was the improvement in the tests scores due to normal maturation. Results of the test showed that the Control Group still had a significant increase in motor scores on the Delayed Post-test (F_{1,24} = 10.2948, P < 0.005, Table 24).

The subjects were again categorized into two groups according to the subject's age (Table 25). The first group (Group I) consisted of subjects whose ages were between three months and seven months (N = 12). The second group (Group II) consisted of subjects between eight months and thirteen months (N = 14, Table 25). Statistical analysis was performed using a Student's 't' test, randomized sample. The motor scores for Treatment Group I compared statistically to Group II motor scores showed no significant difference on the motor scores over
that of Group II ('t' = 1.4193, N.S.). The motor scores of the Control Group I compared statistically to Group II motor scores showed a 't' = 1.1534, N.S. This indicates no significant difference in motor scores between Group I and Group II (Table 26).

**SUBJECTIVE RESPONSE**

**Treatment Group**

This investigator, the parents and teachers observed behavioral and motor modifications throughout the study. All of the observers noted that all treated subjects, to some degree, were more active, had improved balance and improved hand-to-mouth coordination and were more curious and alert by the end of the study. The subjects assigned to the Treatment Group tended to progress through the stages of locomotion at an accelerated pace as compared with subjects assigned to the Control Groups. No behavioral changes were noted in either Control Groups. Further behavioral and motor modifications will be reported below, subject by subject.

**Subject #1, (Male, age 3 months; 1 twin sister)**

Subject number one was noted by the investigator to progress to independent sitting very rapidly. By the third week
of the study, the subject, when placed in a sitting position, was able to maintain his balance. His strength and muscle tone improved, and an overall increase in activity and curiosity was noted. Balance was noted to be greatly improved as depicted by his ability to independently sit at four months of age. At four months of age, which was the fourth week of the study, the subject was also creeping and his attention span appeared to be lengthening as noted when he played with toys. Hand-to-mouth and hand-to-hand coordination was improved as noted when subject would pick up objects and place in mouth.

Subject number one was calm and relaxed throughout all the rotations and seemed to enjoy the vestibular stimulation. The half hour between treatment sessions the subject usually slept.

The parents stated that the pediatrician noticed a definite advancement in motor ability for his age. The above subjective comments were especially significant since his co-twin female had been assigned to a control group. The remainder of the parents' comments were the same as those of the investigator.

Subject #2 (male 8 months; 1 sibling, a twin brother who is a C.P.)

It was observed by this investigator that at the end of the first week of treatment the subject was attempting to sit.
Vocalization was increasing and at the end of the second week of vestibular stimulation, the subject was reaching for objects with more control and with successful completion of the task than at the beginning of the study. The subject was, at this time, becoming more alert than at the beginning of the study. The subject was also beginning to rock in the sitting position.

By the end of the third week of the study, the subject was sitting independently and erect, for as long as he desired. At this time, the third week of the study, the subject was beginning to rotate the trunk. At the end of the study, it was noted that the subject was sitting erect and seemed to be stronger in head and trunk control as compared to his control at the beginning of the study.

The subject enjoyed the rotation throughout the vestibular stimulation. Quite often he would vocalize in a pleasing manner. He seemed to be quite content throughout the study.

The parents stated that the subject seemed to lie around very lethargically prior to the study, but by the end of the study, the subject was very active and alert. The parents also noted that the subject's swallowing, chewing and drinking improved greatly. The subject also was now able to hold a cup without spilling and generally appeared to be more coordinated. The subject was also noted to finger feed much
better. The parents stated that at the time the study began their son was barely sitting independently, and they felt that he was retarded in development. After the treatment of four weeks, the subject was sitting and playing in the sitting position. The subject was also creeping and was standing independently. The parents also noted a general increase in the subject's curiosity and alertness levels over the four week period. The parents stated that their pediatrician noted a great deal of advancement in motor performance.

**Subject #3 (male 3 months; 1 older sibling)**

This investigator observed that subject number three was able to sit independently with head erect by the end of the four weeks. The subject showed an increase in overall strength by the end of the study.

The subject enjoyed the rotation throughout the length of the study. During each rotation he was quiet and relaxed. Between treatment sessions on the same day he would usually sleep.

The parents stated the subject became happier and more content in his overall disposition by the end of the study. An increase in the subject's curiosity and alertness levels was also noted by the parents. The subject began to vocalize more
by the end of the study. The parents generally stated that the subject improved at a faster rate due to the four weeks of treatment than did their first child without the treatment.

**Subject #4 (female 7 months; 1 older sibling with congenital phocomelia)**

This investigator observed that subject number four was able to roll over by the second week of treatment. Balance was also improved when the subject was placed in a walker. By the middle of the third week, the subject began patty cake motions with the hands, showing her increased hand-to-hand coordination. The subject was also able to roll over from back to stomach and from stomach to back. By the third week of the study the subject was able to bring a spoon to her mouth successfully for the first time and was able to catch herself when falling to one side. The subject was also able to rotate with her trunk by the end of the third week of treatment. It should be noted that this subject was extremely obese. This obese condition stopped her accelerated motor progress at the crawling phase. Getting to the four point position for creeping was impossible, simply due to the excessive weight of the subject.

During rotation the subject was calm and totally relaxed. However, when rotation stopped and postrotatory nystagmus
ceased, the subject would fuss and cry in the same manner as she would do before being rotated. Interestingly, the subject would stop crying mid-tom as soon as rotation began.

The parents stated at the end of the study that finger food eating and bringing a spoon to her mouth was greatly improved. The parents also stated the subject was beginning to get up in a creeping position. The subject showed a higher level of alertness and curiosity along with increased vocalization by the end of the study. The parents also stated that the subject was mimicking movement and gestures by the fourth week of the study. General comments by the parents were that they were very pleased with the effects of the study on the subject's motor development. An example of her motor development that they stated was that of the subject's ability to slide down a sliding board without losing her balance in the sitting position.

Subject #5 (male 10 months; 1 older sibling)

It was observed by this investigator that this subject showed, by the second week of the study, an increase in alertness and head, neck and trunk control. The subject was also pulling to a standing position and was cruising around the furniture. This subject by the second week showed improvement in
finger feeding as observed when the subject was eating.

Throughout the treatment sessions the subject would begin
to cry whenever he would be brought up to the vestibular room or
was able to see either myself or the co-investigator, Frank Chee.
When rotation began the subject would stop all fussing and would
relax. In fact, many times he would try to sleep.

The parents at the end of the study noted improvement in
the subject's balance and noted that he was very active. They
also noted that the subject's hand-to-mouth coordination was
improved and that the subject was able to hold a cup better.
It was also noted by the parents that the subject was vocalizing
a great deal more than before the study and that his curiosity
level was very high. General comments by the parents were that,
"last month he really progressed rapidly, first creeping and
then walking; we are very pleased with the results".

Since this subject, unlike many of the others, was
tested while at a preschool, the teachers' comments were also
obtained. The subject's teachers noted over the course of the
study an increase in his balance and head control. They also
noted improvement with the handling of a cup and an increase in
alertness and curiosity of the subject. The teachers also
stated that the subject was now very vocal and active as com-
pared to the subject's behavior before the study. Generally,
the teachers felt that there was an overall accelerated motor behavior in the subject in comparison with other preschoolers of similar age.

Subject #6 (male 13 months; no siblings)

This investigator observed that this subject by the beginning of the third week of treatment seemed to walk all at once. His first day after getting to the standing position he walked 8-10 steps. His balance improved in his trunk and head position. The subject also was very alert and was feeding himself by the third week of the study.

This subject was very cooperative throughout the treatment sessions and seemed to enjoy the rotation.

The parents at the end of the study noted a great deal of improvement in his walking. Previous to the study the subject was content to creep for locomotion. The treatment seemed to push him off this plateau. The parents also noted improvement in the subject's alertness and curiosity and that he had become very active by the end of the study. It might be noted that the father of this subject is a physician.

The teachers' comments mimicked those of the parents, but in addition, they added he seemed happier and calmer than before the study and that he also really improved in areas of fine motor skills, such as placing cubes inside each other.
Subject #7 (male 3 months; no siblings)

This investigator observed that by the middle of the second week of treatment this subject was sitting independently. Balance was greatly improved with improved head control at this time. The subject was beginning to demonstrate pivoting motions of the trunk.

Throughout the treatment sessions this subject was very cooperative and appeared to enjoy the rotation. After the treatment sessions were completed the subject would fall asleep easily for his afternoon nap.

The parents at the end of the study noted improvement in balance and head control. The parents noted that the subject was reaching for the bottle and bringing it back to his mouth successfully by the end of the study. The subject was able to sit independently and was more curious and alert than prior to the study. The subject began handling his toys and was rolling or crawling backwards for locomotion, a new skill since the beginning of the study. The subject was noted to be quite vocal and talked to himself a great deal by the end of the study.

The teachers' comments were that he accelerated quickly to a sitting position and his balance, head and trunk control, were greatly improved since the study began. They also noted that he was more alert and curious than previous to the study and that the study seemed to have accelerated him through the
stages of motor development more quickly than compared to other preschoolers of the same age.

Subject #8 (female 3 months; no siblings)

This investigator observed that by the third week of treatment, this subject showed improved alertness, increased vocalization, improved swallowing, increased hand-to-mouth coordination and increased balance in trunk and head control. The subject by the third week of the study was reaching for toys successfully. By the end of the study this subject was able to sit independently and was able to rotate with head and trunk in the sitting position. The subject was also able to stand independently by the end of the study.

This subject oscillated randomly between crying and enjoying the spinning throughout the entire length of the study.

The parents noted at the end of the Post-test that the subject was calmer, more active and more alert. They also noted the subject was more vocal than she was previous to the study. This subject also showed increased motor skills. She was able to independently sit and was able to stand independently by the end of the treatment sessions. She was also able to initiate rotation of head and trunk in the sitting position.
The teachers also noted an increase in trunk and head control, increased hand-to-mouth coordination, increased alertness and an overall increase in curiosity by the end of the study. They noted that the subject was able to sit independently and her eye-hand coordination was also improved by the end of the study. Generally, the subject was more active in motor activity than she was previous to the study.

Subject #9 (male 6 months; 1 sibling)

This investigator observed that this subject was pulling to standing, eating independently and was more alert by the beginning of the third week of treatment.

The subject enjoyed the rotation and was very cooperative throughout the study.

The parents at the end of the study noted the subject was more active and alert. They stated a definite increase in eye-hand coordination and in balance and posture as compared to before the study. They noted the subject was able to creep, pull to standing and crawl up the stairs by the end of the treatment sessions.

Subject #10 (male 11 months; 1 older sibling)

This investigator observed that this subject showed increased hand-to-mouth coordination, increased curiosity and
increased vocalization by the end of the study. The subject was also able to stand alone by the middle of the second week of treatment. By the end of the treatment sessions, the subject was able to walk three steps.

This subject was very cooperative and appeared to enjoy the rotation throughout the study.

The parents stated they noticed an increase in hand-to-mouth coordination, an increase in activity and in trunk and head control by the end of the study. They also stated the subject took his first steps in walking by the fourth week of the study.

The teachers' observations were essentially the same as those of the parents and the investigator. In addition, the teachers noted that the subject was more tolerant of the other children and enjoyed group play.

**Subject #11 (male 11 months; no siblings)**

This investigator observed that by the third week of the study this subject began walking. He showed greater hand-to-mouth coordination and was able to turn the pages, individually, in a book. The subject progressed from a non-ambulatory to an ambulatory stage very quickly.

This subject was, for the most part, cooperative and enjoyed the rotation throughout the study.
The parents noted that the subject was more active and that hand-to-mouth coordination was improved since the beginning of the study. They stated the subject was more curious and was vocalizing a great deal more since being involved in the study. The parents stated they were amazed how quickly the subject learned to walk independently and that they were very satisfied with the effects the study had on the subject.

Subject #12 (male 11 months; no siblings)

It was observed by the investigator that this subject by the end of the study had improved head and trunk control, which in turn improved his balance. The subject became more active than he was before the study and the subject's coordination had improved rapidly. By the beginning of the fourth week of the study, the subject had progressed to independent walking.

This subject, for the most part, enjoyed the rotation. The subject cried or fussed only occasionally. This was attributed to the subject's teething.

The mother of this subject is a high school teacher. Her comments were the same as this investigator. However, in addition, she noted the subject was now able to throw a ball a few feet.
Subject #13 (male 11 months; two older siblings, one foster child who was a C.P.)

The investigator observed that this subject began walking after four treatments of vestibular stimulation. By the end of the third week of the study the subject was walking independently.

The subject tended to whine a great deal. All fussing and whining ceased when rotation began and resumed when rotation stopped. The fussing appeared worse when the subject saw his mother following the treatment session.

The parents noted by the end of the study an increase in activity level, curiosity and alertness. They also noted the subject generally seemed more coordinated and seemed to learn tasks faster. The subject was now vocalizing a great deal and loved to rock in the rocking chair more now than before the study.

Control Handled Group

For the most part, no striking behavioral or motor changes were observed by the investigator, teachers or parents of the subjects in the Control Handled Group. However, some comments were made and are discussed subject-by-subject below.

Subject #14 (female 3 months; 1 sibling, twin)

This subject had a twin in the Treatment Group, subject #1. The parents noted that this subject (subject #14) was not
progressing as rapidly as her twin brother. The parents noted no dramatic motor changes by the end of the study in subject #14 as they had noted in subject #1.

Subject #15 (female 11 months; no siblings)

The parents, teachers and investigator noted no outstanding changes. The subject appeared to progress at a normal maturational rate.

Subject #16 (female 8 months; 1 sibling)

It was felt by all observers that this subject progressed at a normal maturational rate. The parents stated that this subject was a little slower in development than the older sibling at the same age.

Subject #17 (female 7 months; 1 sibling)

One parent of this subject is a clinical psychologist. The parents, the investigator and the teachers all felt the subject had developed in the last four weeks at a normal maturational rate. No dramatic changes in behavior or attitude like those seen in the treatment subjects were observed in this subject.

Subject #18 (female 9 months; no siblings)

One parent of this subject is an occupational therapist. She felt, as did the other observers, the subject developed at a normal maturational rate during the four weeks of the study.
Subject #19 (female 10 months; no siblings)

The parents of this subject felt the subject progressed through the crawling stage a little fast, but, all in all, they felt that development proceeded at a normal rate. All other observers agreed that development occurred at a normal rate.

Control Non-Handled Group

All subjects in the Control Non-Handled Group were felt by all observers to develop at a normal maturational rate. The subjects of this group are listed below with their age and siblings. There were no additional remarks by any of the observers.

Subject #20 (male 11 months; 1 sibling)
The mother is a registered nurse.

Subject #21 (male 5 months; 1 sibling, C.P.)

Subject #22 (female 4 months; 2 siblings)

Subject #23 (3 months; 1 sibling)
This subject is the investigator's child

Subject #24 (male 9 months; no siblings)
The subject's father is a physical therapist.

Subject #25 (female 8 months; 2 siblings)

Subject #26 (female 3 months; 1 sibling)
The subject's father is a physiologist.
**Effects of Vestibular Stimulation on Adults**

The research assistant, the investigator and the two volunteers who held the subjects in the chair during the rotation sessions noted a variety of subjective responses during and following the treatment sessions. The investigator after immediate cessation of the third rotation noted sensations of dizziness, sweating, pallor and vomiting. A headache soon followed, which lasted until the night sleep. Between the end of the treatment session and night rest, extreme sleepiness and lethargy were present. Also present was an inability to concentrate on any reading. The co-investigator (Frank Chee) noted sensations of dizziness, nausea, headache and pallor immediately after the impulsive stop of the chair. He also noted extreme sleepiness and lethargy and an inability to concentrate. The subjective responses of dizziness and nausea were the first to be completely diminished, within two to three hours. The remaining subjective responses were completely obliterated after a full night of sleep. The sensations of the co-investigator diminished over the subsequent sessions; however, they never completely disappeared, i.e., lasting from one to two hours after the rotation. A general feeling of out of sorts remained after each rotation session and lasted until a nap or a full night sleep was obtained.
However, after the six weeks rest between the Post-test and the Delayed Post-test, the co-investigator again felt the same sensations as he did at the start of the study when rotated.

Two female volunteers noted only mild dizziness and stomach discomfort after the first session. They did note that they were very sleepy and lethargic for the remainder of the day. After a full night of sleep no sensations were noted. They noted that during the rotations it was difficult to follow commands due to their relaxed condition. They stated it was difficult to concentrate. The sensations of dizziness and stomach discomfort for the female volunteers only occurred the first few sessions and were absent the remainder of the sessions.
DISCUSSION

Nystagmus Response

The Pretest time constant, \( \tau/\Delta \), was calculated to be 6.05 seconds for the horizontal semicircular canals and 5.77 seconds for the vertical semicircular canals in 26 subjects. The mean linear regression coefficient was 0.9719 for the horizontal semicircular canals and 0.9638 for the vertical semicircular canals. Van Egmond et al., (1949), reported the time constant of cupular return for a normal adult was 10.0 seconds. Groen (1963, 1965) found the time constant of a subject of three months of age to be 7.5 seconds. Benson and Bodin (1966) found the time constant in ten adults to be an average of 7.8 seconds. Groen (1963) found that a newborn subject of nine days showed a time constant of 20 seconds (Young and Oman, 1968). Kantner (1974) used three normal subjects between three and six months of age in his study and
found the time constant, \( \tau / \alpha \), to be 19.0 seconds. Malcolm (1968) recently determined that the time constant in eight human subjects was 11.5 seconds. Chee (1975), using the same experimental design as this study, tested the vestibular function of 22 cerebral palsy children. Chee (1975) found the time constant to be 10.2 seconds for the horizontal semicircular canals and 8.3 seconds for the vertical semicircular canals. The higher time constant values of the study by Chee as compared to the normal values of this study indicate a hyperactive labyrinth functioning.

Groen (1963, 1965) and Kantner (1974) are the only studies cited that used a population of infants in their investigations of the time constant of postrotatory nystagmus. Both studies showed a time constant of 19 to 20 seconds. The results of this study showed a time constant of approximately 6.0 seconds for normal infants. The 6.0 second time constant is probably the more realistic time constant for infants due to the large population tested in this study. A recent investigation by Clark and this investigator (unpublished work) concur with the findings of a 6.0 second time constant for infants. The time constant of a six-year-old child was found using electro-nystagmographic recordings. This child showed a time constant
of the duration of postrotatory nystagmus of 5.53 seconds. However, when the time constant was determined using the velocity of the slow-phase, as recorded by electronystagmographic technique, a higher value was obtained for the time constant. Velocity of the slow phase of postrotatory nystagmus gave a 12.0 second time constant, suggesting adaptation has a modifying effect on duration of postrotatory nystagmus. Adaptation is the short term change in response resulting from a continuous stimulus (Young and Oman, 1968). It has been suggested that the values obtained by measuring the duration of postrotatory nystagmus are underestimates of the true time constant, due in part to the adaptation (Malcolm, 1968). Visual fixation due to the use of an opthalmic penlight to observe the postrotatory nystagmus may also be responsible for a lower time constant value.

The threshold sensitivity level has been reported to be 40/second in one infant (Groen, 1963, 1965). Van Egmond (1949) found in one normal adult a 1.50/second threshold sensitivity level. In this study of 26 normal subjects, the threshold sensitivity level was 3.40/second for the horizontal semicircular canals and 3.30/second for the vertical semicircular canals. Chee (1975) found in his study of 22 cerebral palsy children
a threshold sensitivity level of 3.1°/second for the horizontal semicircular canals and 2.1°/second for the vertical semicircular canals.

Statistical analysis using a Mixed Model Analysis of Variance test showed no significant difference between Pretest versus Post-test values for both horizontal and vertical semicircular canal threshold sensitivity levels for both normal subjects of this study and the cerebral palsy subjects of Chee's (1975) study.

The normal range for the threshold sensitivity, as indicated in the literature, is between 0.035°/second and 8.2°/second (Groen, 1963, 1965; Van Egmond, 1949; Chee, 1975; Clark, 1967).

Habituation of postrotatory nystagmus was seen in the Treatment Group after 16 sessions of vestibular stimulation over a four week period. The Post-test Treatment Group's horizontal semicircular canal time constant was 2.75 seconds. This was a 3.3 second decline or a 54.5% decrease in the time constant. Statistical analysis, using a Student's 't' test, showed a highly significant change between Pretest versus Post-test values ('t' = 7.7300, P < 0.001). The vertical semicircular canals had a Post-test time constant of 2.51 seconds. This was a 3.3 second decline or a 56.6% decrease in the time constant.
Statistical analysis, using a Student's 't' test, showed a highly significant change between Pretest versus Post-test values ('t' = 7.8600, P < 0.001).

Similar findings were shown in Chee's (1975) study in which the Treatment Group's time constant declined to 4.6 seconds for the horizontal semicircular canals and to 4.4 seconds for the vertical semicircular canals. These time constants of Chee's study indicate a normalization of the previous hyperactive labyrinth to that of the time constants of the Pretest for the normal infants. It is suggested that the result of the 16 sessions of vestibular stimulation was the maturation of the circuits involved with inhibition of the vestibular ocular reflex (Chee, 1975).

The Control Group's Pretest time constant was 5.80 seconds for the horizontal semicircular canals. This was a 0.27 second decline or a 4.4% decrease. The time constant for the vertical semicircular canals was 5.32 seconds. This was a 0.46 second decline or a 7.9% decrease in the time constant. Statistical analysis, using a Student's 't' test, showed no significant change over Pretest values. Thus, no habituation occurred in the Control Group's postrotatory nystagmus. Chee's (1975) Control Group showed a time constant of 7.3 seconds for the horizontal and 6.9 seconds for the vertical semicircular canals.
The vestibular stimulation received on the Pretest day can account for the decline of the time constants in Chee's (1975) Control Group. Crampton (1964) has stated that the greatest degree of habituation will occur within the first several treatments of vestibular stimulation. However, Chee (1975) noted that the Control Group did not improve in motor or reflex skills. He attributed this to an insufficient amount of vestibular stimulation. The results of this study also showed there was no improvement in motor or reflex scores in the Control Groups. This investigator also suggests that the lack of improvement in motor and reflex scores was due to an insufficient amount of vestibular stimulation.

The threshold sensitivity for the horizontal semicircular canal on the Post-test was 3.2°/second for the Treatment Group and 4.0°/second for the Combined Control Group. The vertical semicircular canals threshold sensitivity was 2.9°/second for the Treatment Group and 3.9°/second for the Combined Control Group. Statistical analysis showed no significant change over Pretest values using a Mixed Model Analysis of Variance test. In the study by Chee (1975) the threshold sensitivity for the Treatment Group on the Post-test was 4.0°/second
for the horizontal semicircular canals and 3.6°/second for the vertical semicircular canals. Chee's Combined Control Group had a threshold sensitivity level of 1.2°/second for the horizontal semicircular canals and 1.6°/second for the vertical semicircular canals. These values are well within the normal range.

The duration of postrotatory nystagmus at each of the angular velocities tested in the normal subjects was noted to be distinctly separate from the duration of postrotatory nystagmus of the cerebral palsy subjects at the same angular velocities in Chee's (1975) study. At 20°/second the postrotatory nystagmus ranges were 8.1-14.2 seconds in the normal subjects and 13.1-30.3 seconds in the cerebral palsy subjects. At 30°/second the normal subjects range was 11.0-18.6 seconds while the cerebral palsy subjects was between 19.2-36.4 seconds. At 50°/second the normal subjects range of the duration of postrotatory nystagmus was 11.9-21.0 seconds while the cerebral palsy subjects ranged from 22.1-40.3 seconds. At 100°/second the normal subjects ranged from 16.6-24.7 seconds while the cerebral palsy subjects ranged between 24.1-53.5 seconds. At 150°/second the normal subjects ranged from 16.5-28.2 seconds while the cerebral palsy subjects ranged from 28.6-60.9 seconds. The distinct separation of the time durations for the postrotatory nystagmus
between the normal and cerebral palsy subjects suggests the possible use of the cupulogram in early detection of aberrant neurological functioning of the brain. It might be possible with this technique to determine aberrant neurological functioning as early as three months of age.

The horizontal semicircular canal time constant at the time of the Delayed Post-test was 4.59 seconds. This was an increase of 1.84 seconds (30.4%) over the Post-test level.

The vertical semicircular canal time constant for the Treatment Group at the time of the Delayed Post-test was 3.93 seconds; a 1.42 second (24.6%) increase. The Combined Control Group time constant at the time of the Delayed Post-test was 5.47 seconds for the horizontal semicircular canals. This was a 0.33 second (1.9%) decline from the 5.80 second time constant of the Post-test. The vertical semicircular canals showed a time constant of 4.90 seconds at the time of the Delayed Post-test. This was a 0.42 second (2.2%) decline from the 5.32 second time constant of the Post-test. It is apparent, by the Delayed Post-test Treatment Group values, that the response decline, or habituation that occurred over the four weeks of vestibular stimulation, does not have a permanent effect. What we do see after the six weeks without the quantified vestibular stimulation is a
return towards the Pretest time constant value. Statistical analysis, using a Student's 't' test, paired observation, showed a highly significant increase, P < 0.01, for both horizontal and vertical semicircular canals time constants. The Control Group showed essentially the same time constant on the Delayed Post-test as the Post-test and Pretest values.

The threshold sensitivity level for the horizontal semicircular canal for the Treatment Group, as recorded on the Delayed Post-test, was 1.9°/second and 1.6°/second for the vertical semicircular canal. The Combined Control Group showed a threshold sensitivity level on the Delayed Post-test of 2.4°/second for the horizontal semicircular canal and 2.2°/second for the vertical semicircular canal. These values are well within the normal limits previously described (Groen, 1964, 1965; Van Egmond, 1949; Chee, 1975).

**Reflex Response**

The reflex assessment for each subject was evaluated using a reflex test developed by Chee (1975) and modified by this investigator. The test was designed to evaluate the presence of normal or abnormal central nervous system reflexes which are, in the normal case, essential for normal motor development, and in the abnormal case, an indicator of developmental delayment of motor skills.
The reflex Pretest scores were examined using a One-Way Analysis of Variance. Results showed that there was no significant difference on the reflex scores between groups on the Pretest, \( F_{2,23} = 0.63, \text{ N.S.} \). The Pretest versus Post-test scores were then compared statistically using a Student's 't' test. The results showed that the Treatment Group obtained a highly significant improvement over Pretest scores ('t' = 5.99, \( P < 0.001 \)). The Control Handled Group and the Control Non-handled Group showed no significant change between the Pretest and the Post-test reflex scores. The Control Groups were consequently combined for convenience of description.

The Treatment Group had a Pretest score of 50.53 points and a Post-test score of 62.53 points. The Post-test score was a 12.0 point increase or a 17.65% change over Pretest scores.

The Combined Control Group, which did not receive the 16 sessions of vestibular stimulation, had a Pretest score of 51.51 points and a Post-test score of 55.8 points. The Post-test score was a 4.29 point increase or a 6.31% change over Pretest scores. This 4.29 point increase or 6.31% increase over the Pretest values in the Combined Control Group indicates the effects of normal maturation and was shown statistically not to be a significant factor in the change of scores.
By subtracting the effects of maturation, which was a 4.29 point or 6.31% increase shown by the Combined Control Group, from that of the Treatment Group, we find that a 7.71 point increase or a 11.34% increase was due to vestibular stimulation, alone. This was highly significant at the $P < 0.001$ level of confidence.

Analysis was performed on each reflex tested to determine if improvement in the reflex occurred due to vestibular stimulation. It was noted that the greatest improvement occurred with reflexes 7 through 17 on the reflex test (Appendix A). Reflexes 7 through 17 are the Righting reflexes, Protective Parachute reflexes and the Equilibrium reflexes. These reflexes are normally manifested at six months of age or later. Reflexes one to six on the reflex test are present from one to four months of age and are the Primitive reflexes. Only 3 subjects out of 13 in the Treatment Group were three months of age, while the remaining subjects were five months of age or older. Thus, the subjects who were older than three months of age had already matured through these Primitive reflexes and, therefore, scored maximum on the primitive reflex portion of the Pretest. This explains why vestibular stimulation had a significant effect on the reflexes from 7 to 17. The three subjects that were three months of age did show improvement in reflexes one through
six on the reflex test. It is suggested that the vestibular stimulation had an effect on the inhibition or normalization of all reflexes.

The subjects were then categorized into two groups according to age. The first group (Group I) consisted of subjects whose ages were between three months and seven months of age at the beginning of the study; a total of twelve. The second group (Group II) which consisted of subjects who were between eight and thirteen months of age at the beginning of the study, had a total of 14 subjects. Statistical analysis was performed using a Student's 't' test, randomized sample.

The point improvement in reflex test scores of Treatment Group I compared statistically with the point improvement in reflex test scores of Treatment Group II showed a 't' = 4.937, P < 0.01, thus, Treatment Group I was shown to improve significantly more than Treatment Group II. The points improvement in reflex test scores of Control Group I compared statistically to points improvement in reflex test scores of Control Group II showed a 't' = 0.3126 indicating there was no significant difference in reflex scores between Group I and Group II.

It is logical that Treatment Group I subjects would show a significant improvement over Treatment Group II subjects simply due to their younger ages. It is known that the first year of life is a time of rapid development. As the child
grows older his development slows down and the brain becomes less plastic (Bobath, K., 1959; Greenough, 1975). Treatment Group I subjects are younger than Treatment Group II subjects and would thus show greater motor improvement due to a greater plasticity of the brain (Bobath, 1959; Greenough, 1975).

The Treatment Group had a Post-test score of 62.53 points and a Delayed Post-test score of 63.96 points. The Delayed Post-test score was a 1.37 point increase or a 2.0% change. The Control Group had a Post-test score of 55.8 points and a Delayed Post-test score of 63.82 points. The Control Group's Delayed Post-test score was an 8.01 point increase or a 11.78% increase.

The Delayed Post-test reflex scores were analyzed statistically using the Analysis of Covariance test. The covariate was the improvement in the tests scores due to normal maturation, as reflected in the Control Group. Results of the reflex test showed no significant change due to vestibular stimulation, alone ($F_{1,24} = 3.0455$, N.S.).

The subjects were categorized into two groups according to age in the same manner as was previously described for the Post-test. The first group (Group I) consisted of subjects whose ages ranged from three to seven months of age at the beginning of the study; a total of 12 subjects. The second group (Group II)
consisted of subjects who were between 8 and 13 months of age at the beginning of the study; a total of 14 subjects.

Statistical analysis was performed using a Student's 't' test, randomized sample. The points improved on the reflex test scores for the Treatment Group I compared statistically to the points improved on the reflex test scores for Group II showed a 't' = 4.8179, \( P < 0.01 \) value. Group I showed a significant improvement on the reflex scores over that of Group II. The points improved on the reflex test scores for the Control Group I compared statistically with the points improved on the reflex test scores for Group II showed a 't' = 1.9926, which indicates no significant difference in reflex scores between Group I and Group II.

The significant improvement of Group I over Group II can be attributed to age. These subjects were younger, three to seven months of age at the beginning of the study; however, at the time of the Delayed Post-test the subjects were 12 weeks older. Group I ranged from six months to ten months of age, while Group II subjects were now 11 to 16 months of age. The Group II subjects had at this time matured beyond the Primitive reflexes and were well into the normal responses for the Righting and Equilibrium reflexes. Group I was at the age range where
the Righting and Equilibrium reflexes were still developing, consequently, the greater improvement response on the reflex test.

In summary, the data suggests that the vestibular stimulation was effective in inhibiting the reflexes that were present in the subjects at the time of the Pretest. Inhibition of the reflexes would allow the subjects to advance to the next reflex level. Inhibition of inappropriate reflexes accelerated the subject's reflex performance with respect to his age, as controlled for by the Control Group.

The study by Chee (1975) showed that vestibular stimulation given to non-ambulatory cerebral palsy children had a significant effect on the inhibition of abnormal reflexes in the Treatment Group subjects. The Control Group subjects in Chee's (1975) study showed no significant change over Pretest scores.

It is difficult to determine whether vestibular stimulation given in this study produced long-term continued acceleration of reflex performance. The subjects of Group II of the Delayed Post-test matured beyond the sensitivity level of the reflex test. However, the acceleration made during the four weeks of vestibular stimulation was still maintained by the six weeks Delayed Test. No regression in reflex skills occurred in any of the three groups.
Motor Achievement Test

The motor achievement test, developed by Kantner (1974) and modified by Chee and Kreutzberg (1975), was designed to evaluate specific, measurable motor tasks such as head righting, sitting, creeping, standing and walking.

The motor Pretest scores were examined using a One-Way Analysis of Variance statistical test. Results showed that there was no significant difference between groups on the Pretest ($F_{2,23} = 0.49$, N.S.). The Pretest versus Post-test scores were then compared statistically using a Student's 't' test. The results showed that the Treatment Group showed a highly significant improvement over Pretest scores ('t' = 10.56, $P < 0.001$). The Control Handled Group showed a significant improvement over Pretest values ('t' = 2.53, $P < 0.05$). The Control Non-handled Group also showed a significant difference over Pretest values ('t' = 3.11, $P < 0.01$).

The Treatment Group improved at a greater level of significance than did the Control Groups. This seems to indicate that normal maturation, alone, caused a significant change in all three groups. To determine if this assumption was correct, the motor test scores were analyzed statistically using an Analysis of Covariance statistical test. The covariate was the improvement in test scores due to the normal maturation, as
reflected in the Control groups. Results of the statistical test showed a highly significant improvement in motor performance due to the vestibular stimulation, alone ($F_{1,24} = 21.6005, P < 0.001$). No difference was found between Control Handled and Control Non-Handled Groups.

The Treatment Group had a Pretest score of 59.0 points and a Post-test score of 86.38 points. The Post-test score was a 27.38 point increase or an 18.25% change.

The Combined Control Group had a Pretest score of 58.55 points and a Post-test score of 68.5 points. The Post-test score was a 9.95 point increase or a 6.6% change over Pretest scores. This 9.95 point increase or 6.6% change over Pretest values in the Control Group indicates the effects of normal maturation which, in itself, was shown to be significant as indicated by the Student's 't' test.

By subtracting the effects of maturation, which was 9.95 points or a 6.6% change from the Treatment Group's increase, we find that a 17.43 point increase or a 11.65% increase was due to vestibular stimulation, alone. This was found to be highly significant at the $P < 0.001$ level of confidence.

Analysis was performed on each motor task by investigating which motor tasks in all 13 treated subjects showed improvement due to vestibular stimulation. The first four motor tasks had
little change in score from Pretest to Post-test. The small change in the first four motor tasks was due to the fact that most of the subjects were developmentally beyond this level of motor performance. The first four motor tasks were involved with the head righting in the prone position. Vestibular stimulation caused the greatest change between the fifth motor task, an equilibrium task in the prone position, through the 26th motor task, walking up stairs independently. Motor tasks 6-26 were involved with sitting, creeping, standing and walking. The motor tasks from 27 to 30 were motor tasks too far advanced for most of the subjects to be able to accomplish. One example of an advanced motor task was: child is able to balance on one foot without support for more than five seconds. This is a motor skill of a three year old child (Frankenburg and Dodds, 1969).

The subjects were then categorized into two groups according to age. The first group (Group I) consisted of subjects whose ages ranged from three months to seven months at the beginning of the study; a total of 12 subjects. The second group (Group II) consisted of subjects who were between 8 months and 13 months of age at the beginning of the study; a total of 14 subjects. Statistical analysis was performed using a Student's 't' test, randomized sample. The points improved for the motor
test scores for the Treatment Group I compared statistically
to points improved for the motor test scores from the Treatment
Group II, showed a 't' = 0.9963, N.S. Group I showed no signi-
ficant difference on motor scores over that of Group II. The
points improved for the motor test scores for the Control Group
I compared statistically to points improved for the motor test
scores for the Treatment Group II showed a 't' = 1.5195, N.S.
The results showed that there was no significant difference on
motor scores between Group I and Group II. The results seem to
indicate that the age of the subject in each group was not a
critical factor in the overall motor score increase of the De-
layed Post-test. Indeed, both groups improved about the same
as shown by the statistics.

Six weeks after the completion of the Post-test, a De-
layed Post-test was administered to the same population. The
Treatment Group had a Post-test score of 86.38 and a Delayed
Post-test score of 95.54 points. The Delayed Post-test score
was a 9.16 point increase or a 6.1% change. The Control Group
had a Post-test score of 68.5 points and a Delayed Post-test
score of 94.09 points. The Delayed Post-test score was a 25.59
increase or a 17.06% change.

The Delayed Post-test scores were analyzed statistically
by using the Student's 't' test, paired observation. Results
showed a significant improvement in the Treatment Group's Delayed Post-test scores (\(t' = 3.1544, P < 0.01\)). The Control Group also showed a significant improvement in the Delayed Post-test scores (\(t' = 8.5816, P < 0.001\)). Results seem to indicate that maturation, alone, caused a significant change of Delayed Post-test scores over Post-test scores in both groups. To determine if this assumption was correct, the motor scores were analyzed statistically using the Analysis of Covariance test. The covariate was the improvement in the tests scores due to normal maturation. Results of the test showed that the Control Group still had a significant increase in motor scores on the Delayed Post-test (\(F_{1,24} = 10.2948, P < 0.005\)). It is suggested from the results of the Delayed Post-test and the results from the main study that the Treatment subjects, through the effects of vestibular stimulation, were accelerated to the next higher level of motor skills functioning at an earlier chronological age than the Control subjects. During the intervening six weeks between the Post-test and the Delayed Post-test, the Treatment subjects were still maturing, but apparently, at a slower rate than that of the Control Group. The Treatment subjects, it is suggested, had begun to plateau off until the next critical period or phase of motor development. The Control
Group, however, maintained their normal maturational rate throughout the intervening six weeks between the Post-test and the Delayed Post-test. The result being a significant increase in their Delayed Post-test scores as compared with the Delayed Post-test scores of the Treatment Group.

In summary, the data suggest that the vestibular stimulation was effective in the acceleration of motor performance in the Treatment Group subjects. Similar findings were reported by Kantner (1974) and Chee (1975). Kantner (1974) showed that after ten days of vestibular stimulation normal and Down's Syndrome children showed improved motor skills, especially in the areas of equilibrium responses. Chee (1975) using the same experimental design as this study, also showed highly significant improvement in motor responses in cerebral palsy children. Chee (1975) noted specific improvement in the motor control of the head, neck and trunk. These motor responses were involved with postural righting and equilibrium reactions.

Clinicians, such as physical therapists, involved with the treatment of developmental disabilities have used purposefully or inadvertently labyrinthine righting and equilibrium reactions in their techniques to acquire postural balance of the head, neck and trunk (Bobath, 1963, 1964, 1967; Ayres, 1972). Torok and Perlstein (1962) and Rapin (1974) have indicated that
vestibular system dysfunction may be responsible for delayment in motor development. Eviatar, Eviatar and Naray (1974) have stated that the functioning level of the vestibular system may be an indicator for determining development delayment.

Observations

Motor achievement test scores in this study are somewhat depressed. The explanation for this is that the test, itself, was not sensitive enough to be able to reflect the change in fine motor movements, such as hand-to-mouth coordination. The test was also unable to detect behavioral changes such as increased alertness and curiosity. These were scored through subjective comments and not by objective scoring. In addition, the test was divided into five areas of motor skills. Each motor skill was further broken down into between three and nine motor tasks. This tended to favor one motor skill over another in regards to points possible. An example is the creep motor skills area which is worth a total of 16 points while the standing motor skills area is worth a total of 30 points.

All of the above comments tend to reflect that the improvement in the motor test scores is a conservative estimate of the motor improvement in the treated subjects. It is suggested that additional tests should be added to objectively appraise
the domain of fine motor skills and the areas of behavior modification. It is further suggested that each of the five areas of motor skills have equal amounts of total points possible. This would be possible by equalizing the number of tasks under each motor skills area.

Speculation

The vestibular system has been shown to be the earliest of all sensory systems to differentiate. In the development of the mammalian embryo the vestibular system is fully differentiated by mid-term and the myelinization of the vestibulospinal tracts are complete by the twenty-first week of gestation (Bast and Anson, 1949; Klosovskii, 1963; Shambaugh, 1967). At seven months of gestational age the vestibular and auditory portion of the inner ear are completely developed and are nearly the size and shape of an adult (Klosovskii, 1963). It is suggested that the rapid development of the vestibular system is necessary, for at this time, the main sensory input into the central nervous system of the infant is vestibular in nature. The fetus is constantly floating and turning while maturing in the uterus (Neal, 1967).

The newborn human infant needs an intact vestibular system in order to respond to sensory input through reflexive
movement. At birth the vestibular system is intact and functional (Groen, 1963). The newborn infant, when exposed to vestibular stimulation either by rotatory or caloric stimulation, will respond with a recognizable nystagmus (Michishita, 1967; Eviator, L., Eviator, A. and Naray, I., 1974).

The human infant, in his first year of life, is involved with a developmental sequence of reflexes leading to motor achievement of bipedal ambulation (Fiorentino, 1974). These reflexes, for the most part, are vestibular oriented. The Primitive reflexes, the Righting reflexes and the Equilibrium reflexes are all initiated through stimulation of the vestibular system.

The importance of the vestibular system to the developing neonate is further emphasized by the study of Korner and Thoman (1970, 1972) and Pederson and Ter Vrugt (1973). These investigators found that vestibular stimulation, which attends most caretaking activities, is more crucial than the contact of the mother in reduction of the infant's crying. Korner and Thoman (1970) further added that the vestibular stimulation may be more crucial than the contact of the mother for certain aspects of early human development. It has also been hypothesized that vestibular dysfunction in infancy could lead to developmental delayment of gross motor skills (Rapin, 1974).
Earlier studies concur with this hypothesis of Rapin. These earlier studies showed that sensory deprivation to the vestibular system will cause stimulus seeking activities such as head rocking, head rolling and body rocking (Prescott, 1970; Harlow and Zimmerman, 1959).

In another study, premature infants were exposed to daily sessions of vestibular stimulation. The premature infants were at a gestational age of 28-32 weeks. Stimulation began on the fifth day of life. Results showed significant improvement in motor, visual and auditory responses. It was also noted that motor development was accelerated (Neal, 1967).

Recent studies by Kantner and Clark (1974) and by Chee (1975) have shown that by increased vestibular stimulation, in both developmentally delayed and in normal infants, the reflex and motor performance could be accelerated. Chee’s study used the same experimental design as this study on a population of cerebral palsy children. His results concur with this study in that motor, reflex and habituation of postrotatory nystagmus were accelerated. Kantner’s (1974) study on Down’s Syndrome and normal infants also showed that both motor performance and habituation of postrotatory nystagmus could be accelerated through the use of vestibular stimulation.
The mechanism by which vestibular stimulation accelerates motor and reflex behavior and causes the habituation of the vestibular ocular reflex (nystagmus) is open to speculation. This investigator offers a possible mechanism that may account for the improved reflex and motor behavior due to the vestibular stimulation.

An animal or human must be able to orient itself to its environment to survive. The vestibular system, through the use of reflexes, is the system primarily responsible for the orientation of an infant to his environment. One of the reflexes used is the vestibular ocular reflex or nystagmus. This reflex maintains a stable retinal image as the head moves, thus, producing a stable background against which the infant is able to orient (Wilson, 1975; Mountcastle, 1974). If the retinal image becomes unstable, dysequilibrium results and if it persists motor delayment will ensue in a developing animal or human (Rapin, 1974; Chee, 1975; Robinson, 1975). However, with repetitive vestibular stimulation or by repetitive optokinetic stimulation, the vestibular system will become more efficient in providing a stable retinal background. Optokinetic stimulation is the use of a large peripheral field, moving uniformly around a subject, producing a sensation of
self-rotation (Young and Yenn, 1974). The efficiency of providing
a stable retinal background is accomplished through habituation
of the nystagmus. Habituation is a compensatory reaction to
oppose inappropriate responses of disorientation (McCabe, 1960;
Pfaltz and Kato, 1974; Young and Henn, 1974). We are now
reasonably confident that habituation does not occur at the
vestibular end organ. Recent studies have shown that by exposing
a subject to a rotating visual field, which produced a sensa-
tion of self-rotation, habituation or response decline through
the use of optokinetic stimulation occurred with the nystagmus
(Young and Henn, 1974; Pfaltz and Kato, 1974). The degree to
which an animal is able to habituate a nystagmus reflects the
development or maturation of an inhibitory circuit. It is also
suggested that the inhibitory center which causes inhibition
of inappropriate responses is responsible for the inhibition or
modulation of other reflex and motor systems (Chee, 1975).

Two questions now need to be answered. First, by what
mechanism does the inhibitory center influence the improvement
of motor and reflex skills in infants and developmentally de-
layed children. Second, where is the inhibitory center located
in the central nervous system.

The first question might be answered by increasing
synaptic connectivity (Greenough, 1975; Purpura, 1975). Recent studies have shown that critical or sensitive periods exist when an animal must receive a particular sensory input for maximum development to occur (Greenough, 1975). Valverde (1967, 1971) showed that when mice first opened their eyes and were exposed to light, new dendritic spines were formed in the visual cortex. However, if the mice were kept from exposure to light, fewer dendritic spines were formed. Valverde also reported that if mice raised in a dark environment were exposed later in life to light, new dendritic spines were formed, but never the amount formed as shown in the normal mice.

It is then suggested that a sensory enriched environment was provided for the normal infants, above and beyond their already normal sensory input. This was done through a quantified amount of vestibular stimulation. This sensory input was given at the critical phase of development for the normal infants, which is suggested to be the first year of life. It could be possible that the vestibular stimulation experienced by the infants in this study accelerated the maturation of synaptic connectivity of some inhibitory circuitry allowing the infants to accelerate the inhibition of undesirable reflex and motor responses. This would create a more stable environment
and allow the infant to accelerate in motor development. Recent studies tend to collaborate with this hypothesis. Purpura (1975) has shown that children with chromosomal aberrations and children who were diagnosed as unclassified mentally retarded exhibited abnormal characteristic dendritic spines.

In answer to the second question, it is suggested that the area of the inhibitory circuitry is the cerebellum (Ito, 1972; Wilson, 1975; Robinson, 1975). The extensive neuronal connectivity from and to the cerebellum has been well documented (Wilson, 1975; Brodal, 1972). It has been proposed that the floccular-nodular lobe of the cerebellum is the structure of the cerebellum responsible for the inhibition (Ito, 1972). The cerebellum receives fibers from the semicircular canals and then projects to the vestibular nuclei via Purkinje cells (Robinson, 1975; Wilson, 1975). Ito (1972) suggested that the input from the vestibular end organ allowed the cerebellum to make appropriate adjustments through the vestibular nuclei to maintain the image on the retina. The cerebellum, as the center of inhibition, helps to explain the decreased tonus in the infants when they were subjected to vestibular stimulation. It has been documented
that the cerebellum modulates muscle tonus (Sprague, 1953; Tarnecki and Konorski, 1970; Wilson, 1975).

The subjective results from the parents and teachers consistently referred to increased hand-to-mouth coordination and increased levels of alertness and curiosity in all treated subjects. These reactions are associated with the cerebellum. The cerebellum is known to control coordination of muscular activity (Barr, 1972). Pompeiano (1972) described the connections between the vestibular nuclei and the reticular formation. The reticular formation has been demonstrated to influence arousal (Segundo, et al., 1967). It is suggested that the vestibular stimulation increased the arousal level of the Treatment subjects through the cerebellum to the reticular formation, directly or indirectly. This allows the infant to appraise his sensory inputs and respond to them in an efficient manner.

In summary, the subjective and quantified results of this study seem to suggest the cerebellum as the source of the inhibitory circuitry. The results of this study and the study by Kantner (1974) and Chee (1975) have far-reaching implications for the early detection and treatment of neurologically aberrant and developmentally delayed children.
SUMMARY

1. The 16 sessions of semicircular canal stimulation over a four week period in preambulatory infants showed a highly significant effect on the improvement of motor and reflex skills of the Treatment Group.

2. The Control Handled Group and the Control Non-handled Group showed no significant change beyond normal maturation. This indicates that handling was not responsible for any improvement in motor or reflex skills.

3. The postrotatory nystagmus of the Treatment Group was shown to habituate over 16 sessions of semicircular canal stimulation over a four week period significantly. The Control Groups showed no significant change over pretest values of postrotatory nystagmus.
4. A Delayed Post-test administered six weeks after the Post-test showed that the continued acceleration of the motor and reflex performance and the habituation of the postrotatory nystagmus was not maintained. Reflex, motor skills and vestibular time constant values of the Control Groups by the six weeks Delayed Post-test, statistically, were the same as those of the Treatment Group.

5. This study substantiates the findings of Kantner (1974) and Chee (1975), and suggests the importance of vestibular stimulation in facilitating acceleration of motor and reflex performance in developmentally delayed children. This study also suggests that the duration of postrotatory nystagmus may be a diagnostic tool for the early detection of aberrant neurological pathology.
TABLE 1

Effects of Successive Sessions of Stimulation of the Horizontal Semicircular Canals on the Time Constant of Postrotatory Nystagmus. Statistical Analysis was Performed Using a One-Way Analysis of Variance Test Between the Treatment Group, the Control Handled Group and the Control Non-Handled Group

<table>
<thead>
<tr>
<th>Vestibular Stimulation</th>
<th>Control Handled</th>
<th>Control Non-Handled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{2,23} = 0.8500$</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td>$N = 13$</td>
<td>5.852</td>
<td>5.631</td>
</tr>
<tr>
<td>b. Post-Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{2,23} = 19.0700$</td>
<td>$P &lt; 0.0001$</td>
<td></td>
</tr>
<tr>
<td>$N = 13$</td>
<td>5.344</td>
<td>6.025</td>
</tr>
<tr>
<td>Vestibular Stimulation</td>
<td>ControlHandled</td>
<td>Control Non-Handled</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_{2.23} = 0.9100</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td>N = 13</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>V = 6.152</td>
<td>5.508</td>
<td>5.277</td>
</tr>
<tr>
<td>b. Post-Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_{2.23} = 2.507</td>
<td>P &lt; 0.0001</td>
<td></td>
</tr>
<tr>
<td>N = 13</td>
<td>6.0</td>
<td>7.0</td>
</tr>
<tr>
<td>V = 2.507</td>
<td>5.417</td>
<td>5.227</td>
</tr>
<tr>
<td></td>
<td>L.R.</td>
<td>S.D.</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>0.9779</td>
<td>0.0211</td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.9638</td>
<td>0.0352</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.9488</td>
<td>0.0322</td>
</tr>
<tr>
<td>Post-Test Control</td>
<td>0.9530</td>
<td>0.0240</td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.9729</td>
<td>0.0312</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.9779</td>
<td>0.0246</td>
</tr>
<tr>
<td></td>
<td>L.R.</td>
<td>S.D.</td>
</tr>
<tr>
<td>----------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Post-Test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Handled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.9705</td>
<td>0.0372</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.9713</td>
<td>0.0329</td>
</tr>
<tr>
<td><strong>Post-Test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handled and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Handled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.9716</td>
<td>0.0332</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.9743</td>
<td>0.0284</td>
</tr>
</tbody>
</table>
TABLE 4

Effects of Four Weeks (16 Sessions) of 100°/sec. Impulsive Stimuli on $\pi/\Delta$, the Time Constant of Cupula Return, for the Horizontal and Vertical Semicircular Canals. The $\pi/\Delta$ Values Were Individually Compared, Pretest Versus Post-Test, Using the Student's 't' test

| A. Treatment Group - Horizontal Semicircular Canals | 't' = 7.7300 df 23 P < 0.001 |
| B. Treatment Group - Vertical Semicircular Canals | 't' = 7.8600 df 23 P < 0.001 |
| C. Control Handled - Horizontal Semicircular Canals | 't' = 0.4600 df 23 N.S. |
| D. Control Handled - Vertical Semicircular Canals | 't' = 0.1300 df 23 N.S. |
| E. Control Non-Handled - Horizontal Semicircular Canals | 't' = 0.6200 df 23 N.S. |
| F. Control Non-Handled - Vertical Semicircular Canals | 't' = 0.0800 df 23 N.S. |
TABLE 5
Mean Time Constant of Cupular Return in Seconds for the Horizontal and Vertical Semicircular Canals of the Subjects Grouped by Age, as Recorded During the Pretest

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Treatment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Vertical</td>
</tr>
<tr>
<td>1</td>
<td>5.94</td>
<td>5.46</td>
</tr>
<tr>
<td>3</td>
<td>3.55</td>
<td>3.23</td>
</tr>
<tr>
<td>4</td>
<td>6.46</td>
<td>5.76</td>
</tr>
<tr>
<td>7</td>
<td>9.18</td>
<td>9.33</td>
</tr>
<tr>
<td>8</td>
<td>6.90</td>
<td>6.30</td>
</tr>
<tr>
<td>9</td>
<td>7.56</td>
<td>7.33</td>
</tr>
<tr>
<td>X</td>
<td>6.5983</td>
<td>6.2350</td>
</tr>
</tbody>
</table>

<p>| Group II (8-13 Months) | Treatment Group | Control Group | |
|------------------------|-----------------|---------------|
|                        | Horizontal      | Vertical      | Horizontal | Vertical |
| 2                      | 4.75            | 4.46          | 15         | 7.60      | 7.28 |
| 5                      | 6.74            | 6.74          | 16         | 6.07      | 5.92 |
| 6                      | 7.30            | 6.64          | 18         | 5.81      | 5.33 |
| 10                     | 7.08            | 6.88          | 19         | 6.26      | 6.09 |
| 11                     | 5.21            | 5.53          | 20         | 6.08      | 6.56 |
| 12                     | 5.81            | 5.86          | 24         | 5.28      | 5.22 |
| 13                     | 6.12            | 6.44          | 25         | 6.88      | 6.94 |</p>
<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Horizontal</td>
</tr>
<tr>
<td>df - 13</td>
<td>df - 13</td>
</tr>
<tr>
<td>'t' = 0.5382, N.S.</td>
<td>'t' = 1.6986, N.S.</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Vertical</td>
<td>Vertical</td>
</tr>
<tr>
<td>df - 13</td>
<td>df - 13</td>
</tr>
<tr>
<td>'t' = 0.1754, N.S.</td>
<td>'t' = 2.4927, P &lt; 0.05</td>
</tr>
</tbody>
</table>
TABLE 7

Effects of Vestibular Stimulation on the Threshold Sensitivity Level of the Horizontal and Vertical Semicircular Canals, Pre-test Versus Post-Test. Statistical Analysis was Performed Using A Mixed Model Analysis of Variance.

<table>
<thead>
<tr>
<th></th>
<th>Between Subjects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( F_{2,23} = 0.0500 )</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td>a. Horizontal Semicircular Canals</td>
<td>Worksheet Subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( F_{2,23} = 1.3900 )</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Between Subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( F_{2,23} = 0.4400 )</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Worksheet Subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( F_{2,23} = 1.8300 )</td>
<td>N.S.</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 8
The Mean and Standard Deviation of the Duration of Postrotatory Nystagmus of Each Treatment Session in Seconds

H = Horizontal Semicircular Canal Response
V = Vertical Semicircular Canal Response
Stimulus was 100°/sec. Impulse

<table>
<thead>
<tr>
<th>Treatment Session</th>
<th>X (H)</th>
<th>V (H)</th>
<th>S.D. (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.0</td>
<td>18.1</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>18.4</td>
<td>17.5</td>
<td>2.3</td>
</tr>
<tr>
<td>3</td>
<td>17.5</td>
<td>16.1</td>
<td>1.9</td>
</tr>
<tr>
<td>4</td>
<td>16.7</td>
<td>15.5</td>
<td>1.7</td>
</tr>
<tr>
<td>5</td>
<td>15.7</td>
<td>14.7</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>15.0</td>
<td>14.1</td>
<td>2.0</td>
</tr>
<tr>
<td>7</td>
<td>13.1</td>
<td>12.1</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>12.6</td>
<td>11.9</td>
<td>2.1</td>
</tr>
<tr>
<td>9</td>
<td>12.1</td>
<td>10.7</td>
<td>2.0</td>
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<td>10</td>
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<td>11</td>
<td>10.5</td>
<td>9.6</td>
<td>1.6</td>
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<td>12</td>
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</tr>
<tr>
<td>15</td>
<td>8.1</td>
<td>8.2</td>
<td>1.1</td>
</tr>
<tr>
<td>16</td>
<td>8.6</td>
<td>8.1</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>150°</td>
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<td>----------------------</td>
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</tr>
<tr>
<td></td>
<td>H</td>
<td>V</td>
<td>H</td>
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<tr>
<td>Pretest X</td>
<td>23.6</td>
<td>22.6</td>
<td>20.6</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.73</td>
<td>3.11</td>
<td>2.70</td>
</tr>
<tr>
<td>Post-Test X</td>
<td>11.4</td>
<td>10.5</td>
<td>8.7</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.77</td>
<td>1.54</td>
<td>0.84</td>
</tr>
<tr>
<td>Post-Test Control</td>
<td>X</td>
<td>19.4</td>
<td>17.6</td>
</tr>
<tr>
<td>S.D.</td>
<td>1.91</td>
<td>1.91</td>
<td>1.29</td>
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TABLE 9 (con't)

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<th>100° V</th>
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<th>50° V</th>
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<th>30° V</th>
<th>20° H</th>
<th>20° V</th>
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<tr>
<td>Control</td>
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</tbody>
</table>

X
S.D. 2.89

21.3  19.8  19.2  17.4  15.2  14.3  12.4  11.5  9.5  8.8
2.89  2.89  3.37  2.70  2.22  2.10  3.19  2.63  2.23  1.93
TABLE 10

Delayed Post-Test Mean Values for the Linear Regression Coefficient, in which the Dependent Variable, the Duration of the Postrotatory Nystagmus was on the Y-axis and the Impulsive Stop Velocity on the X-axis. The Time Constant of Postrotatory Nystagmus, the Y-Intercept of the Cupulogram and the Threshold Sensitivity of the Horizontal and Vertical Semicircular Canals for the Treatment Group, the Control Handled Group, the Control Non-Handled Group and the Combined Handled and Non-Handled Control Group are also Included.

L.R. = Linear Regression Coefficient  
S.D. = Standard Deviation  
$\pi/\Delta$ = Time Constant of Postrotatory Nystagmus  
Y-INT. = Y-Intercept  
X-INT. = X-Intercept

<table>
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<th>L.R.</th>
<th>S.D.</th>
<th>$\pi/\Delta$ (sec)</th>
<th>S.D.</th>
<th>Y-Int.</th>
<th>S.D.</th>
<th>X-Int.</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
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<td>0.0244</td>
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<td>1.643</td>
<td>-2.662</td>
<td>5.315</td>
<td>1.993</td>
<td>1.809</td>
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<td>0.0348</td>
<td>3.932</td>
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<td>-1.327</td>
<td>4.842</td>
<td>1.624</td>
<td>1.724</td>
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<td>5.676</td>
<td>0.976</td>
<td>-4.857</td>
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<td>2.377</td>
<td>0.778</td>
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<td>-4.530</td>
<td>3.038</td>
<td>2.431</td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Non-Handled</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.9698</td>
<td>0.0182</td>
<td>5.225</td>
<td>1.483</td>
<td>-4.751</td>
<td>3.984</td>
<td>2.508</td>
<td>1.220</td>
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<td>Vertical</td>
<td>0.0648</td>
<td>0.0194</td>
<td>4.475</td>
<td>1.110</td>
<td>-3.261</td>
<td>2.840</td>
<td>2.071</td>
<td>0.895</td>
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<td>S.D.</td>
<td>( \pi/\Delta ) (sec)</td>
<td>S.D.</td>
<td>Y-Int.</td>
<td>S.D.</td>
<td>X-Int.</td>
<td>S.D.</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
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<td>-------</td>
<td>--------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
</tbody>
</table>
| Combined  
Handled and  
Non-Handled  
Control    |       |       |                          |       |        |       |        |       |
| Horizontal       | 0.9700 | 0.0201 | 5.471                   | 1.187 | -4.809 | 3.092 | 2.437  | 0.950 |
| Vertical         | 0.9581 | 0.0381 | 4.901                   | 1.051 | -3.953 | 2.877 | 2.268  | 0.949 |
TABLE 11

Post-Test Versus Delayed Post-Test Differences for each Group for the Time Constant of the Horizontal and Vertical Semicircular Canals. Statistical Analysis was Performed using a Student's 't' test

<table>
<thead>
<tr>
<th>Group</th>
<th>t' Value</th>
<th>df</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Treatment Group - Horizontal Semicircular Canals</td>
<td>3.966</td>
<td>12</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>B. Treatment Group - Vertical Semicircular Canals</td>
<td>3.2970</td>
<td>12</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>C. Control Group - Horizontal Semicircular Canals</td>
<td>0.6930</td>
<td>12</td>
<td>N.S.</td>
</tr>
<tr>
<td>D. Control Group - Vertical Semicircular Canals</td>
<td>1.0700</td>
<td>12</td>
<td>N.S.</td>
</tr>
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</table>
TABLE 12

Effects of Vestibular Stimulation on the Threshold Sensitivity Level of the Horizontal and Vertical Semicircular Canals, Post-Test Versus Delayed Post-Test. Statistical Analysis was Performed using a Student's 't' Test, Paired Observation

<table>
<thead>
<tr>
<th></th>
<th>Treatment Group - Horizontal Semicircular Canals</th>
<th></th>
<th>Treatment Group - Vertical Semicircular Canals</th>
<th></th>
<th>Control Group - Horizontal Semicircular Canals</th>
<th></th>
<th>Control Group - Vertical Semicircular Canals</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>'t' = 1.858</td>
<td>df 12</td>
<td>N.S.</td>
<td>B.</td>
<td>'t' = 1.858</td>
<td>df 12</td>
<td>N.S.</td>
</tr>
<tr>
<td>C.</td>
<td>'t' = 1.8854</td>
<td>df 12</td>
<td>N.S.</td>
<td>D.</td>
<td>'t' = 1.7827</td>
<td>df 12</td>
<td>N.S.</td>
</tr>
</tbody>
</table>
### TABLE 13
Mean Duration and Standard Deviation of Postrotatory Nystagmus (in seconds) of the Horizontal (H) and Vertical (V) Semicircular Canals at 150°, 450°, 300°, and 200°/sec. Impulse Stimuli in the (six weeks) Delayed Post-Test

<table>
<thead>
<tr>
<th>Delayed Post-Test</th>
<th>150° H</th>
<th>150° V</th>
<th>50° H</th>
<th>50° V</th>
<th>30° H</th>
<th>30° V</th>
<th>20° H</th>
<th>20° V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
</tr>
<tr>
<td>X</td>
<td>20.4</td>
<td>3.8</td>
<td>18.0</td>
<td>3.7</td>
<td>16.3</td>
<td>2.2</td>
<td>15.0</td>
<td>3.2</td>
</tr>
<tr>
<td>S.D.</td>
<td>10.6</td>
<td>1.6</td>
<td>10.3</td>
<td>1.3</td>
<td>12.2</td>
<td>1.3</td>
<td>9.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Control Handled</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
</tr>
<tr>
<td>X</td>
<td>22.8</td>
<td>2.9</td>
<td>20.9</td>
<td>2.3</td>
<td>21.4</td>
<td>2.3</td>
<td>21.3</td>
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</tr>
<tr>
<td>S.D.</td>
<td>10.1</td>
<td>1.0</td>
<td>10.6</td>
<td>0.5</td>
<td>10.6</td>
<td>0.5</td>
<td>10.2</td>
<td>0.5</td>
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<tr>
<td>Control Non-Handled</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
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<td>S.D.</td>
</tr>
<tr>
<td>X</td>
<td>20.2</td>
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<td>19.0</td>
<td>2.6</td>
<td>17.6</td>
<td>2.6</td>
<td>15.0</td>
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<tr>
<td>S.D.</td>
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<td>1.7</td>
<td>15.0</td>
<td>0.9</td>
<td>2.3</td>
<td>0.6</td>
<td>2.1</td>
<td>0.9</td>
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<tr>
<td>Combined Control</td>
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<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
<td>X</td>
<td>S.D.</td>
</tr>
<tr>
<td>X</td>
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<td>2.5</td>
<td>20.3</td>
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<td>19.0</td>
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<td>17.6</td>
<td>2.5</td>
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<tr>
<td>S.D.</td>
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<td>10.9</td>
<td>0.5</td>
<td>10.5</td>
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<th>Group II (8-13 Months of Age)</th>
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TABLE 15
Effects of Stimulation of the Horizontal and Vertical Semicircular Canals on Motor and Reflex Performance as Recorded During the Delayed Post-Test, Grouped by Age. Statistical Analysis was Performed using a Student's 't' test, Randomized Sample on the Change Between Group I and Group II

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<td>---------------</td>
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<td>Vertical</td>
<td>Vertical</td>
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<tr>
<td>df - 13</td>
<td>df - 13</td>
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<td>11 months</td>
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<td>12</td>
<td>11 months</td>
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<tr>
<td>13</td>
<td>11 months</td>
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<tr>
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<td>14</td>
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<td>15</td>
<td>11 months</td>
</tr>
<tr>
<td>16</td>
<td>8 months</td>
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<td>17</td>
<td>7 months</td>
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<td>18</td>
<td>9 months</td>
</tr>
<tr>
<td>19</td>
<td>8 months</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Chronological Age at Start of Study</td>
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<td>----------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Treatment</td>
<td>01</td>
</tr>
<tr>
<td>Control Non-Handled</td>
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</tr>
<tr>
<td>20</td>
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</tr>
<tr>
<td>21</td>
<td>5 months</td>
</tr>
<tr>
<td>22</td>
<td>4 months</td>
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<tr>
<td>S.E.</td>
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<tr>
<td>Control Non-Handled</td>
<td>49.64</td>
</tr>
<tr>
<td>S.E.</td>
<td>3.98</td>
</tr>
<tr>
<td>Combined Control</td>
<td>51.51</td>
</tr>
<tr>
<td>S.E.</td>
<td>2.10</td>
</tr>
</tbody>
</table>
TABLE 18

Reflex and Motor Pretest Scores for the Treatment Group, Control Handled Group and the Control Non-Handled Group were Subjected to Statistical Analysis Using a One-Way Analysis of Variance Test to Determine if Differences Existed Between Groups

<table>
<thead>
<tr>
<th>Pretest-Motor Test Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{2,23} = 0.4900$</td>
</tr>
<tr>
<td>N.S.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control Handled</th>
<th>Control Non-Handled</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X = 59.00$</td>
<td>68.17</td>
<td>49.50</td>
</tr>
<tr>
<td>$N = 13$</td>
<td>6.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pretest-Reflex Test Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{2,23} = 0.6300$</td>
</tr>
<tr>
<td>N.S.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control Handled</th>
<th>Control Non-Handled</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X = 50.54$</td>
<td>55.83</td>
<td>49.64</td>
</tr>
<tr>
<td>$N = 13$</td>
<td>6.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>
TABLE 19

Effects of Four Weeks (16 Sessions) of 100°/sec. Impulsive Stimuli on the Motor and Reflex Scores Pretest Versus Post-Test. The Reflex and Motor Scores were Compared Individually Using the Student's 't' test.

<table>
<thead>
<tr>
<th></th>
<th>Motor Test</th>
<th>Reflex Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I. Motor Test</td>
<td>II. Reflex Test</td>
</tr>
<tr>
<td></td>
<td>A. Treatment Group</td>
<td>A. Treatment Group</td>
</tr>
<tr>
<td></td>
<td>'t' = 10.56, df 23, P &lt; 0.001</td>
<td>'t' = 5.99, df 23, P &lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>B. Control Handled Group</td>
<td>B. Control Handled Group</td>
</tr>
<tr>
<td></td>
<td>'t' = 2.53, df 23, P &lt; 0.05</td>
<td>'t' = 0.74, df 23, N.S.</td>
</tr>
<tr>
<td></td>
<td>C. Control Non-Handled Group</td>
<td>C. Control Non-Handled Group</td>
</tr>
<tr>
<td></td>
<td>'t' = 3.11, df 23, P &lt; 0.01</td>
<td>'t' = 1.57, df 23, N.S.</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Treatment Group</td>
<td>Subject Number</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Motor</td>
<td>Reflex</td>
</tr>
<tr>
<td>1</td>
<td>24.5</td>
<td>13.0</td>
</tr>
<tr>
<td>3</td>
<td>13.0</td>
<td>16.0</td>
</tr>
<tr>
<td>4</td>
<td>5.5</td>
<td>17.5</td>
</tr>
<tr>
<td>7</td>
<td>45.0</td>
<td>25.0</td>
</tr>
<tr>
<td>8</td>
<td>22.0</td>
<td>30.5</td>
</tr>
<tr>
<td>9</td>
<td>31.5</td>
<td>13.5</td>
</tr>
<tr>
<td>X</td>
<td>23.58</td>
<td>19.25</td>
</tr>
</tbody>
</table>

**Group II (8-13 Months of Age)**

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Treatment Group</th>
<th>Subject Number</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motor</td>
<td>Reflex</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>54.0</td>
<td>10.5</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>33.0</td>
<td>2.0</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>28.0</td>
<td>- 0.5</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>30.5</td>
<td>8.5</td>
<td>19</td>
</tr>
<tr>
<td>11</td>
<td>22.0</td>
<td>8.5</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>27.0</td>
<td>8.5</td>
<td>24</td>
</tr>
<tr>
<td>13</td>
<td>20.0</td>
<td>4.0</td>
<td>25</td>
</tr>
<tr>
<td>X</td>
<td>30.64</td>
<td>5.92</td>
<td>X</td>
</tr>
</tbody>
</table>
TABLE 21

Effects of Stimulation of the Horizontal and Vertical Semicircular Canals on Motor and Reflex Performance as Recorded During the Post-Test and Grouped by Age. Statistical Analysis was Performed using a Student's 't' test, Randomized Sample, on the Change Between Group I and Group II

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor</strong></td>
<td><strong>Motor</strong></td>
</tr>
<tr>
<td>df = 13</td>
<td>df = 13</td>
</tr>
<tr>
<td>'t' = 0.9963, N.S.</td>
<td>'t' = 1.5195, N.S.</td>
</tr>
<tr>
<td><strong>Reflex</strong></td>
<td><strong>Reflex</strong></td>
</tr>
<tr>
<td>df = 13</td>
<td>df = 13</td>
</tr>
<tr>
<td>'t' = 4.0937, P &lt; 0.01</td>
<td>'t' = 0.3126, N.S.</td>
</tr>
</tbody>
</table>
TABLE 22
Scores for each Subject on the Motor and Reflex Tests as Scored by Each Independent Observer, $O_1$ and $O_2$, on the Six Week Delayed Post-Test

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Chronological Age at Start of Study</th>
<th>Motor Test Correlation Coefficient=.999</th>
<th>Reflex Test Correlation Coefficient=.954</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$O_1$</td>
<td>$O_2$</td>
</tr>
<tr>
<td>1</td>
<td>3 months</td>
<td>53.0</td>
<td>52.0</td>
</tr>
<tr>
<td>2</td>
<td>8 months</td>
<td>98.0</td>
<td>97.0</td>
</tr>
<tr>
<td>3</td>
<td>3 months</td>
<td>59.0</td>
<td>59.0</td>
</tr>
<tr>
<td>4</td>
<td>7 months</td>
<td>80.0</td>
<td>83.0</td>
</tr>
<tr>
<td>5</td>
<td>10 months</td>
<td>120.0</td>
<td>120.0</td>
</tr>
<tr>
<td>6</td>
<td>13 months</td>
<td>116.0</td>
<td>116.0</td>
</tr>
<tr>
<td>7</td>
<td>3 months</td>
<td>63.0</td>
<td>63.0</td>
</tr>
<tr>
<td>8</td>
<td>3 months</td>
<td>55.0</td>
<td>55.0</td>
</tr>
<tr>
<td>9</td>
<td>6 months</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>10</td>
<td>11 months</td>
<td>123.0</td>
<td>123.0</td>
</tr>
<tr>
<td>11</td>
<td>11 months</td>
<td>127.0</td>
<td>127.0</td>
</tr>
<tr>
<td>12</td>
<td>11 months</td>
<td>128.0</td>
<td>128.0</td>
</tr>
<tr>
<td>13</td>
<td>11 months</td>
<td>125.0</td>
<td>123.0</td>
</tr>
<tr>
<td>Control Handled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>3 months</td>
<td>55.0</td>
<td>55.0</td>
</tr>
<tr>
<td>15</td>
<td>11 months</td>
<td>121.0</td>
<td>121.0</td>
</tr>
<tr>
<td>16</td>
<td>8 months</td>
<td>93.0</td>
<td>93.0</td>
</tr>
<tr>
<td>17</td>
<td>7 months</td>
<td>101.0</td>
<td>102.0</td>
</tr>
<tr>
<td>18</td>
<td>9 months</td>
<td>120.0</td>
<td>118.0</td>
</tr>
<tr>
<td>19</td>
<td>8 months</td>
<td>116.0</td>
<td>116.0</td>
</tr>
<tr>
<td>Subject Number</td>
<td>Chronological Age at Start of Study</td>
<td>Motor Test Correlation Coefficient=.999</td>
<td>Reflex Test Correlation Coefficient=.954</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------</td>
<td>------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>0₁</td>
<td>0₂</td>
<td>X</td>
</tr>
<tr>
<td>Control Non-Handled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>11 months</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>21</td>
<td>5 months</td>
<td>92.0</td>
<td>92.0</td>
</tr>
<tr>
<td>22</td>
<td>4 months</td>
<td>absent</td>
<td>absent</td>
</tr>
<tr>
<td>23</td>
<td>3 months</td>
<td>63.0</td>
<td>62.0</td>
</tr>
<tr>
<td>24</td>
<td>9 months</td>
<td>122.0</td>
<td>122.0</td>
</tr>
<tr>
<td>25</td>
<td>8 months</td>
<td>123.0</td>
<td>123.0</td>
</tr>
<tr>
<td>26</td>
<td>3 months</td>
<td>30.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>
TABLE 23

Motor and Reflex Tests Mean Score, Points Difference and Percent Change Between the Post-Test and the Delayed Post-Test. The Delayed Post-Test was Administered Six Weeks After the Post-Test.

<table>
<thead>
<tr>
<th>Motor Test</th>
<th>Delayed Post-Test Mean Score</th>
<th>Points Difference</th>
<th>Percent Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment S.E.</td>
<td>95.54</td>
<td>9.16</td>
<td>6.1</td>
</tr>
<tr>
<td>Control Handled S.E.</td>
<td>100.92</td>
<td>23.07</td>
<td>15.4</td>
</tr>
<tr>
<td>Control S.E.</td>
<td>85.90</td>
<td>25.40</td>
<td>16.9</td>
</tr>
<tr>
<td>Combined S.E.</td>
<td>94.09</td>
<td>25.59</td>
<td>17.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflex Test</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment S.E.</td>
<td>63.96</td>
<td>1.37</td>
<td>2.0</td>
</tr>
<tr>
<td>Control Handled S.E.</td>
<td>63.83</td>
<td>5.80</td>
<td>8.5</td>
</tr>
<tr>
<td>Control S.E.</td>
<td>63.80</td>
<td>5.80</td>
<td>8.5</td>
</tr>
<tr>
<td>Combined S.E.</td>
<td>63.82</td>
<td>8.01</td>
<td>11.78</td>
</tr>
</tbody>
</table>
### TABLE 24

Effects of Successive Sessions of Vestibular Stimulation of the Horizontal and Vertical Semi-circular Canals on the Motor and Reflex Performance as Recorded during the Post-Test and during the Delayed Post-Test. Statistical Analysis was Performed using an Analysis of Covariance Test.

<table>
<thead>
<tr>
<th></th>
<th>Pretest - Post-test</th>
<th>Pretest - Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{1,24} = 21.6005, P &lt; 0.001$</td>
<td>$F_{1,24} = 16.8088, P &lt; 0.001$</td>
<td></td>
</tr>
<tr>
<td><strong>Reflex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{1,24} = 10.2948, P &lt; 0.005$</td>
<td>$F_{1,24} = 3.0455, N.S.$</td>
<td></td>
</tr>
<tr>
<td><strong>Post-test - Delayed Test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{1,24} = 10.2948, P &lt; 0.005$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reflex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{1,24} = 3.0455, N.S.$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject Number</td>
<td>Group I (3-7 Months of Age)</td>
<td>Group II (8-13 Months of Age)</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
<td>Treatment Group</td>
<td>Reflex</td>
</tr>
<tr>
<td>1</td>
<td>17.0</td>
<td>12.0</td>
</tr>
<tr>
<td>3</td>
<td>25.5</td>
<td>17.0</td>
</tr>
<tr>
<td>4</td>
<td>26.5</td>
<td>21.0</td>
</tr>
<tr>
<td>7</td>
<td>5.0</td>
<td>16.5</td>
</tr>
<tr>
<td>8</td>
<td>10.5</td>
<td>23.0</td>
</tr>
<tr>
<td>9</td>
<td>12.0</td>
<td>22.5</td>
</tr>
<tr>
<td>X</td>
<td>14.4466</td>
<td>X</td>
</tr>
</tbody>
</table>

TABLE 25

Individual Subjects Motor and Reflex Point Increase Grouped by Age as Recorded during the Delayed Post-Test
TABLE 26
Effects of Stimulation of the Horizontal and Vertical Semicircular Canals on Motor and Reflex Performance as Recorded during the Delayed Post-test with Subjects Grouped by Age. Statistical Analysis was performed using a Student's 't' Test, Randomized Sample on the Change Between Group I and Group II

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>Motor</td>
</tr>
<tr>
<td>df -13</td>
<td>df -13</td>
</tr>
<tr>
<td>'t' = 1.4193, N.S.</td>
<td>'t' = 1.1534, N.S.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflex</th>
<th>Reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>df -13</td>
<td>df -13</td>
</tr>
<tr>
<td>'t' = 4.8179, P &lt; 0.01</td>
<td>'t' = 1.9926, N.S.</td>
</tr>
</tbody>
</table>
**TABLE 27**

Effects of Four Weeks (16 Sessions) of 100°/sec. Impulsive Stimuli on the Motor Scores Post-Test Versus Delayed Post-Test. The Motor Scores were Compared using the Student's 't' Test, Paired Observation

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>'t' = 3.1544</th>
<th>df 12</th>
<th>P &lt; 0.01</th>
</tr>
</thead>
</table>

| Combined Control Group | 't' = 8.5816 | df 12 | P < 0.001 |
Figure 1 - The Experimental Design was a Basic Pretest, Treatment Post-test Format. The Pretest was given one week prior to the treatment sessions. During the pretest week, the motor and reflex tests were administered first, followed by a one day rest and then the vestibular test. The treatment sessions consisted of four weeks of 16 sessions of vestibular stimulation. The Post-test was administered the week after the treatment sessions. During the Post-test week the vestibular test was given first, followed by a one day rest and then the motor and reflex tests.
<table>
<thead>
<tr>
<th>EXPERIMENTAL DESIGN</th>
<th>WEEKS</th>
<th>TREATMENT GROUP</th>
<th>CONTROL HANDLED GROUP</th>
<th>CONTROL NON-HANDLED GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
<td>MVT-TEST</td>
</tr>
<tr>
<td>POST TEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERVAL TREATMENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRETEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2 - Positioning subject for horizontal semicircular canals stimulation. The subject's head was flexed approximately 30°, nose down. This placed the horizontal (lateral) semicircular canals in the horizontal plane and the plane of rotation.

Figure 3 - Positioning subject for right anterior and left posterior semicircular canal stimulation. The subject's head was flexed approximately 20°, nose down and then laterally rotated to the right approximately 45° in regards to the subject's mid-line. This placed the right anterior and left posterior semicircular canals in the horizontal plane and the plane of rotation.

Figure 4 - Positioning subject for left anterior and right posterior semicircular canal stimulation. The subject's head was flexed approximately 20°, nose down and then laterally rotated to the left approximately 45° in regards to the subject's mid-line. This placed the left anterior and right posterior semicircular canals in the horizontal plane and the plane of rotation.

Figure 5 - Standard Swivel chair adapted for rotation. The swivel chair was manually propelled and the velocity was monitored by illuminated velocity indicators.
Figure 6 - Habituation of horizontal semicircular canals postrotatory nystagmus using 100°/sec. impulsive stop stimuli (±S.D.)
Figure 7 - Habituation of vertical semicircular canals post-rotatory nystagmus using 100°/sec. impulsive stop stimuli (±S.D.).
Figure 8 - Cupulogram representing horizontal semicircular canals function: normal subjects (±S.D.).
A = PRETREATMENT GROUP, N = 26, \( \pi/\Delta = 6.05 \text{ sec} \)
B = COMBINED CONTROL GROUP, N = 13, \( \pi/\Delta = 5.80 \text{ sec} \)
C = TREATMENT GROUP, N = 13, \( \pi/\Delta = 2.75 \text{ sec} \)
Figure 9 - Cupulogram representing vertical semicircular canals function: normal subjects (±S.D.).
A = PRETREATMENT GROUP, N = 26, Π/Δ = 5.77 SEC
B = COMBINED CONTROL GROUP, N = 13, Π/Δ = 5.31 SEC
C = TREATMENT GROUP, N = 13, Π/Δ = 2.51 SEC
Figure 10 - Cupulogram representing horizontal semicircular canals function, six weeks after the Post-test: normal subjects (+S.D.).
A = TREATMENT GROUP, N = 12, $\pi/\Delta = 4.59$ SEC
B = COMBINED CONTROL GROUP, N = 11, $\pi/\Delta = 5.47$ SEC
Figure 11 - Cupulogram representing vertical semicircular canals function, six weeks after the Post-test. Normal subjects (±S.D.).
A = TREATMENT GROUP, N = 12, \( \mu/\Delta = 3.93 \) SEC
B = COMBINED CONTROL GROUP, N = 11, \( \mu/\Delta = 4.90 \) SEC
Figure 12 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor and reflex performance in normal subjects (±S.E.).
PRETEST GROUP, N = 26
TREATMENT GROUP, N = 13
COMBINED CONTROL GROUP, N = 13

POINTS SCORED ON MOTOR TEST

POINTS SCORED ON REFLEX TEST

PRETEST  T  C  PRETEST  T  C
MOTOR TEST  REFLEX TEST
Figure 13 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the reflex performance in normal subjects (+S.E.).
PRETEST GROUP, N = 26
A = TREATMENT GROUP, N = 13
B = COMBINED CONTROL GROUP, N = 13

POINTS SCORED ON REFLEX TEST

PRETEST  TREATMENT  POST-TEST
TIME IN WEEKS

A
B

1 2 3 4 5 6

10 20 30 40 50 60

1 2 3 4 5 6

10 20 30 40 50 60

68 68
Figure 14 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor and reflex performance in normal subjects. Points increased on Post-test performance over Pretest performance.
TREATMENT GROUP, N = 13
COMBINED CONTROL GROUP, N = 13
Figure 15 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor and reflex performance in normal subjects. Percent increase on post-test performance over pretest performance.
TREATMENT GROUP, N = 13
COMBINED CONTROL GROUP, N = 13

<table>
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<tr>
<th>Motor Test</th>
<th>Treatment (T)</th>
<th>Control (C)</th>
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<td>18.3%</td>
<td>6.6%</td>
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<th>Reflex Test</th>
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<td>6.3%</td>
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Figure 16 - Effects of vestibular stimulation on reflex performance in normal subjects, six weeks after the Post-test (±S.E.).
TREATMENT GROUP, N = 13
CONTROL GROUP, N = 13

TREATMENT GROUP, N = 12
CONTROL GROUP, N = 11

POINTS SCORED ON REFLEX TEST

POST-TEST

DELAYED POST-TEST
Figure 17 - Effects of vestibular stimulation on reflex performance in normal subjects as recorded on the six weeks Delayed Post-test. Points increased on Delayed Post-test performance over Post-test performance (+S.E.).
A = TREATMENT GROUP, N = 12
B = CONTROL GROUP, N = 11
Figure 18 - Effects of vestibular stimulation on motor and reflex performance in normal subjects, six weeks after the Post-test. Points increased on the Delayed Post-test over Post-test performance.
TREATMENT GROUP, N = 12
CONTROL GROUP, N = 11

POINTS INCREASED ON DELAYED POST TEST

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Figure 19 - Effects of vestibular stimulation on motor and reflex performance in normal subjects, six weeks after the Post-test. Percent increase on Delayed Post-test over Post-test performance.
TREATMENT GROUP, N = 12
CONTROL GROUP, N = 11
Figure 20 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor performance in normal subjects, six weeks after the Post-test (±S.E.).
A = TREATMENT GROUP, N = 13
B = COMBINED CONTROL GROUP, N = 13
Figure 21 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor performance in normal subjects, six weeks after the Post-test (±S.E.).
TREATMENT GROUP, N = 13
CONTROL GROUP, N = 13
TREATMENT GROUP, N = 12
CONTROL GROUP, N = 11

POINTS SCORED ON MOTOR TEST

T C T C
POST-TEST DELAYED POST-TEST

21
Figure 22 - Effects of 16 sessions of vestibular stimulation, over four weeks, on the motor performance in normal subjects, six weeks after the Post-test. Points increased on Delayed post-test over post-test performance (+S.E.).
A = TREATMENT GROUP, N = 12
B = CONTROL GROUP, N = 11
APPENDIX A

MOTOR ACHIEVEMENT SCALE

Areas of Evaluation

I. Prone and Supine

II. Sitting

III. Creeping

IV. Standing

V. Walking

Tasks

I. Prone and Supine

IA. Position - Head righting (prone).
    Task 1

IB. Position - Head righting (prone).
    Task 2

IC. Position - Head righting (prone).
    Task 3

ID. Position - Head righting (supine).
    Task 4

IE. Position - Maintaining equilibrium while displacing
    center of gravity (prone).
    Task 5

II. Sitting

IIA. Position - Head right reaction.
    Task 1

IIB. Position - Head and spine (lateral righting).
    Task 2
IIC. Position - Independent sitting with support from hands.
   Task 3

IID. Position - Rotational component, equilibrium.
   Task 4

IIE. Position - Maintaining equilibrium while displacing center of gravity, sideways, while sitting.
   Task 5

IIF. Position - Maintaining equilibrium while displacing center of gravity forward in sitting.
   Task 6

III. Creeping

IIIA. Position - Static balance, head righting.
   Task 1

IIIB. Position - Dynamic balance, rotation, head righting.
   Task 2

IIIC. Position - Reciprocal creeping.
   Task 3

IID. Position - Equilibrium (sideways).
   Task 4

IV. Standing

IVA. Position - Achievement of standing position.
   Task 1

IVB. Position - Maintaining independent standing position and balance (static).
   Task 2

IVC. Position - Standing posture and balance (dynamic).
   Reaching and rotational components, laterally.
   Task 3
IVD. **Position - Standing posture and balance** (dynamic). Reaching and rotational components, medially.  
Task 4.

IVE. **Position - Standing posture and balance (dynamic).** Reaching and rotation components (rotate 180 degrees).  
Task 5

IVF. **Position - Maintaining equilibrium in standing position.**  
Task 6

V. **Walking**

VA. **Position - Cruising component.**  
Task 1

VB. **Position - Walking with support.**  
Task 2

VC. **Position - No support when walking.**  
Task 3

VD. **Position - Walking independently backwards.**  
Task 4

VE. **Position - Walking up stairs.**  
Task 5

VF. **Position - Kicks ball forward.**  
Task 6

VG. **Position - Walking on tiptoes.**  
Task 7

VH. **Position - Balancing on one foot.**  
Task 8

VI. **Position - Jumping.**  
Task 9
PROCEDURE:

Grading of Motor Achievement Scale

A. Scoring

1. Each task is broken down into 5 steps, with step #5 being the highest step or "terminal" motor behavior within a task.

2. Each step is worth 1 point, the highest possible point being 5.

3. Subject must pass or "demonstrate" the particular step as described in the task in order to be scored a point.

B. Method

1. It would be best if one person puts the subject through the different tasks, while the examiner records the results.

2. Consistency should be used in materials, i.e., in Section II position II B, if you sit the subject over your knee, do this for each trial. Indicate by underlining or commenting at the bottom of the task.

3. It may be necessary for 2 but no more than 3 trials to be performed of a particular task or parts of a task if the child appears apprehensive. Score zero if in doubt after allotted number of trials.

4. In the case of normal children, the tasks as written may be fully accomplished. If this is the case, perform Section IV F and Section V ABC with vision occluded (blindfold or Frenzel's glasses) and note this at the bottom of the task and incorporated into the total score.
*5. In task requiring a right and/or left distinction, circle side (R or L) demonstrating weakest response. Circle both (L and R) if response is equal on both sides.

*Except in areas noted otherwise.
I. PRONE AND SUPINE

I A. POSITION - Head right (prone).
   Task 1: Objects, toys, to motivate.
   __  5. Head held approximately vertical to floor with horizontal plane of mouth approximately parallel to the floor. Able to turn head left, right, and maintain position for more than 10 seconds.
   __  4. Same as above. Able to turn head left and right and maintain position for more than 5 seconds.
   __  3. Same as above, only infant maintains head position for more than 5 seconds but unable to turn head left or right.
   __  2. Infant is able to raise head above horizontal position and head momentarily approximates the vertical position, but then drops below the vertical.
   __  1. Infant is able to raise and turn head to clear breathing passages. (protective turning).
   __  0. Able to accomplish any of the above.
   TOTAL

I B. POSITION - Head righting (prone). Place infant in prone position resting on elbows and hands (prone prop).
   Task 2: Objects, toys to motivate.
   __  5. Head held approximately vertical to floor with horizontal plane of mouth approximately parallel to the floor. Able to turn head left, right and maintain position for more than 10 seconds.
4. Same as above. Able to turn head left and right and maintain position for more than 5 seconds.

3. Same as above, only infant maintains head position for more than 5 seconds but unable to turn head left or right.

2. Same as above, only infant maintains head position for less than 5 seconds, then drops head below the vertical position.

1. Infant is able to raise head above horizontal position and head momentarily approximates the vertical position, but then drops below the vertical.

0. Unable to accomplish any of the above.

TOTAL

I C. POSITION - Head righting (prone).
Task 3: Objects, toys, etc. to motivate.

5. Infant in prone position, pushes up on hands with extended elbows, head above the axis of the body, mouth in a horizontal plane with the floor. Able to turn head left, right and maintain position for more than 10 seconds.

4. Same as above, able to turn head left and right and maintain position for more than 5 seconds.

3. Same as above, but unable to turn head left and right, and only hold position for more than 5 seconds.

2. Same as above, only infant maintains head position less than 5 seconds then drops head below the vertical position.

1. Same as above, only infant is able to approximate position on hands. Position on hands is held only momentarily, less than 2 seconds.

0. Unable to accomplish any of the above.

TOTAL
I D. POSITION - Head righting. Place infant in supine position, grasp each upper extremity with one hand, slowly raise infant towards sitting position.

Task 4:

5. Able to raise head to 0° in reference to trunk when trunk is approximately 45° and maintains position for 5 seconds.

4. Same as above but maintains head position for less than 5 seconds.

3. Same as above but maintains head position at less than 0°.

2. Infant approximates head raising toward 0°.

1. Infant attempts to raise head.

0. Unable to accomplish any of the above.

TOTAL

I E. POSITION - Maintaining equilibrium while displacing center of gravity (prone).

Task 5: Use equilibrium board, all tilting approximates 30 degree angle; all tilting done slowly, i.e., 1-2 seconds to achieve 30 degree angle. Tilt right and left.

5. Infant prone on elbows, head approximate the midline and spine curves to opposite side of tilt. Holds this position after the 30 degree angle is reached for 10 seconds, both sides. Head maintained above axis of body. R or L side.

4. Same as above, infant maintains position for less than 10 seconds, but more than 5 seconds. R or L side.

3. Same as above, only maintains position for 5 seconds.

2. Head position only approximates 90 degrees in relation to the floor but more than 45 degrees.
1. Head only makes initial movements toward vertical, less than 45 degrees.

0. Unable to accomplish any of the above.

TOTAL

II B. POSITION - Head and spine (lateral righting).
Task 2: Support at hips only; sitting on floor or over knee; tilt body 45 degrees, laterally, left and right.

5. Head and spine assume or approximate vertical position (90 degrees) in relation to the floor; maintains for 10 seconds. R or L side.

4. Same as above, only maintains position for less than 10 seconds but more than 5 seconds. R or L side.

3. Same as above, only maintains position for less than 5 seconds. R or L side.

2. Head position approximates 90 degrees, spine approximates more than 45 degrees but less than 90 degrees. R or L side.

1. Head and spine only makes initial movements toward vertical, less than 45 degrees. R or L side.

0. Unable to accomplish any of the above.

TOTAL

II C. POSITION - Independent (long) sitting with support from hands.
Task 3: Child sitting on floor; have toys, etc. to motivate him.

5. Child has hands on floor in front of him/her, maintains 5 seconds or over; momentarily lifts one hand R or L (circle) off the floor, for an object without falling.

4. Same as above, only lift either hand off the floor for an object and falls immediately.
3. Same as above, only does not lift hands and maintains position more than 5 seconds.

2. Same as above, only maintains position between 5 and 3 seconds.

1. Same as above, only momentary support (less than one second) before collapsing, i.e., subject collapses almost immediately.

0. Unable to accomplish any of the above.

TOTAL

II D. POSITION - Rotational component, equilibrium.

Task 4: Child sitting on floor, have toys to motivate.

5. Infant can reach for a toy (held by examiner) on her R side with her R hand, and on L side with her L hand (circle); infant either places opposite hand on floor in front or to the side momentarily or not at all.

4. Same as above, only infant keeps opposite hand on floor half the time while getting the object. R or L side (hand in contact with floor).

3. Same as above, only infant maintains opposite hand on the floor during the entire time of reaching for toy. R or L side. (Hand in contact with floor).

2. Same as above, only infant brings hand with object almost immediately to the floor for support. R or L side.

1. Same as above, only infant is able to approximate grasping or touching toy before bringing hand down immediately to maintain balance. Unable to grasp toy. R or L side.

0. Unable to accomplish any of the above.

TOTAL
II E. POSITION - Maintaining equilibrium while displacing center of gravity, sideways, while sitting.

Task 5: Use equilibrium board if possible, 30 degrees in a side-to-side motion. If you have to use a bolster or your leg, tilt side-to-side the approximate same angle.

5. While infant is being tilted at a slow (approximately 30 degrees in 1-2 secs.) pace, infant shifts head and spine to the midline without placing hands on board; holds at least 5 seconds at angle of tilt. R or L side.

4. Same as above, only infant holds for more than 2 seconds but less than 5 seconds before positioning hand on board at angle of tilt. R or L side.

3. Same as above, only infant puts one hand down for support before 2 seconds are up at angle of tilt. R or L side.

2. Same as above, only infant puts one hand down as soon as tilting begins and throughout return to horizontal. R or L side.

1. Same as above, only infant places both hands to the side as soon as tilting begins and throughout return to horizontal. R or L side.

0. Unable to accomplish any of the above.

TOTAL

II F. POSITION - Maintaining equilibrium in sitting while displacing center of gravity forward.

Task 6: Same directions as Task 5 only tilt 30 degrees forward from horizontal.

5. While infant is being tilted slowly (approximately 30 degrees in 1-2 secs.), infant approximates head and spine in vertical with the floor without placing hands on board. Holds at least 5 seconds before being returned to the horizontal.

4. Same as above, only infant holds for more than 2 seconds but less than 5 seconds before placing one hand down for support.
3. Same as above, only infant puts one hand down before 2 seconds are up at angle of tilt.

2. Same as above, only infant puts one hand down on the board as soon as tilting begins and throughout return to horizontal.

1. Same as above, only both hands are placed on the board as soon as tilting begins and throughout return to horizontal.

0. Unable to accomplish any of the above.

TOTAL

III: CREEPING

III A. POSITION - Static balance, head righting.
   Task 1: Toys, etc. to motivate

5. Infant is on all fours or creep position (infant may be placed on all fours); infant holds head above the axis of the body, so that the mouth approximates the horizontal position. Position maintained for 10 seconds.

4. Same as above, only position maintained for more than 5 seconds, but less than 10 seconds.

3. Same as above, only infant maintains position for less than 5 seconds.

2. Same as above, only infant keeps head approximating or just above axis (mouth not horizontal to floor), while maintaining all fours position for at least 5 seconds.

1. Same as above, only infant maintains position for less than 5 seconds.

0. Unable to accomplish any of the above.

TOTAL
III B. POSITION - Dynamic balance, rotation, head righting.
   Task 2: Toys, etc. to motivate. With infant in creep position, hold object in front, slightly away and above infant's midline but within reach of infant.

   5. Infant is on all fours position (may be placed), looks in direction of the object held by examiner, grasps object and brings hand (with object) back to all fours position without falling. R or L hand side.

   4. Same as above, only infant approximates grasping (touches) object, but immediately brings hand back down for support without object. R or L side.

   3. Same as above, only infant brings hand approximately halfway to object, and/or makes groping motions for object but misses entirely, bring hand back down for support. R or L side.

   2. Same as above, only infant makes initial moves with hand towards object (raises hand off the floor 4 to 6 inches), and immediately brings hand back down. R or L side.

   1. Same as above, only infant only looks towards object, or lifts hand off floor but immediately collapses. R or L side.

   0. Unable to accomplish any of the above.

   TOTAL

III C. POSITION - Reciprocal creeping.
   Task e: Toys, objects to motivate.

   5. Infant is on all fours position (may be placed), head above axis of the body, mouth approximately on horizontal plane to the floor. Infant reciprocally creeps forward 5 or more steps.

   4. Same as above, only infant reciprocally creeps forward 3 or 4 steps.
III D. POSITION - Achievement of standing position.
Task 1: Placing infant near small table or chair, using toy, etc. to motivate to assume a standing position.

5. Infant comes to standing position by pushing off floor or simply rising from the squat position with no external support (i.e., chair or table).

4. Infant comes to standing by using one hand on the chair and coming up on one foot first. Indicate R or L foot, R or L hand.

3. Same as above, only infant is placed in kneeling-standing position.

2. Same as above, only infant uses both hands, and only pulls halfway up to standing position.

1. Same as above, infant uses one or both hands but only makes initial movements to pull to standing sometimes achieving placement of a foot and sometimes not.

0. Unable to accomplish any of the above.
IV. STANDING

IV. A POSITION - Achievement of standing position.

Task 1: Place infant near small table or chair, using toy, etc. to motivate to assume a standing position.

5. Infant comes to standing position by pushing off floor or simply rising from the squat position with no external support (i.e., chair or table).

4. Infant comes to standing by using one hand on the chair and coming up on one foot first. Indicate R or L foot, R or L hand.

3. Same as above, only infant is placed in kneel-standing position.

2. Same as above, only infant uses both hands and only pulls halfway up to standing position.

1. Same as above, infant uses one or both hands but only makes initial movements to pull to standing, sometimes achieving placement of a foot and sometimes not.

0. Unable to accomplish any of the above.

TOTAL

IV B. POSITION - Maintaining independent standing position and balance (static).

Task 2: Have chair or table for child to balance if necessary; have toys, etc., for motivation if necessary; place child in position (standing); make sure he/she is not supporting with abdomen.

5. Infant looking straight ahead; does not put hands on table for support. Arms can be spread out to the side. Maintains 10 seconds or more.

4. Same as above, only position held for more than 5 but less than 10 seconds.
3. Same as above, only position held for less than 5 seconds.

2. Same as above, only infant has one hand on the table for support; maintains for 5 or more seconds.

1. Same as above, only infant has both hands on table for support; maintains for 5 or more seconds.

0. Unable to accomplish any of the above.

TOTAL

IV C. POSITION - Standing posture and balance (dynamic).
Reaching and rotation components, laterally.

Task 3: Have low table, toys, various objects to motivate infant. Place infant in standing position slightly away and facing table. Place object to one side of infant but within reach.

5. Infant stabilizes with L hand and reaches for object placed to the R side with the R hand; L foot may or may not leave the ground, infant is able to pick up or pull object towards himself/herself without falling. Reverse for L hand reaching, R or L side.

4. Same as above, hand that is reaching (R or L) remains on table part of the time while reaching or retrieving object.

3. Same as step #5, only the object to be retrieved is placed in front of the infant.

2. Same as above, hand that is reaching (R or L) remains on the table part of the time while reaching for or retrieving object.

1. Same as above, only infant makes attempt to reach forward for an object but either loses balance and/or reaches with both hands placing upper body on the table for support.
0. Unable to accomplish any of the above.

TOTAL

IV D. POSITION - Standing posture and balance (dynamic). Reaching and rotation components, medi-
ally.
Task 4: Have low table, toys, various objects to motivate infant. Place child in standing position as described in IV C, task 3. Child is to grasp object by crossing mid-
line with the opposite hand, i.e., right hand crosses midline of body to grasp toy placed on left side.

5. Infant supports with one hand on table while reaching with the other: R or L hand that is reaching for toy crosses the midline. Infant's foot may rise but he/she doesn't fall or lose balance.*

4. Same as above, only infant accomplishes this only on one side: R or L side.

3. Same as above, infant brings hand (R or L circle) to the midline before losing balance or putting weight on both hands for support.

2. Same as above, infant brings hand to midline and/or across the midline by successively having both hands on the table.

1. Same as above, only infant constantly maintains both hands on the table.

0. Unable to accomplish any of the above.

TOTAL

*The idea is to get the infant to reach without touching the table; examiner may first put the toy in the infant's hand and gently pull on it towards the midline, or see if she/he will reach for it across the midline; some infants may just shift weight to the other arm at midline, and then reach with the hand that is on the same side of the object.
IV E. POSITION - Standing posture and balance (dynamic).
   Reaching and rotation components (rotate 180 degrees).

Task 5: Have low table, toy, various objects to motivate infant. Place child in same position as described in IV C, task 3. Child is to grasp object placed behind by rotating 180 degrees in the trunk with one hand support.

___ 5. Infant standing, head and spine rotate approximately 180 degrees from midline to reach back and stoops to retrieve toy (or other object) that has been placed behind him/her. Infant may hold on to table with other hand. Reaches with R and L (circle), and returns object to table.*

___ 4. Same as above, only infant goes down on one or both knees when reaching and stooping for object, R or L side.

___ 3. Same as above, only infant rotates spine approximately halfway, and either brings hand back to the table for support or almost immediately falls towards the floor at the beginning of reaching. R or L side.

___ 2. Same as above, only infant cannot begin to rotate spine and stoop without losing balance; either falls down when approximating object, or brings hand back to the table for support. R or L side.

___ 1. Same as above, only infant turns head with minimal to no spine rotation, either brings hand back to the table and/or falls towards the floor almost immediately upon turning head and reaching with arm. R or L side.

___ 0. Unable to accomplish any of the above.

TOTAL

*Have object close enough that child or infant will be able to retrieve it without leaving the table; start with an object the child is interested in on the table, and then move it behind him/her.
IV F. POSITION - Maintaining equilibrium in the standing position.

Task 6: Use manual force, enough to displace imaginary center of pelvis approximately 6 inches to either side, R and L. Place child in standing position close to table.

5. Infant maintains head and spine closely to vertical while examiner slowly applies force to the infant's pelvis on the side; force maintained for 5 seconds once maximum displacement of center of pelvis is reached. Infant does not grab onto table for balance. R or L side.

4. Same as above, only infant places one hand on the table for support within 5 seconds after maximum displacement. R or L side.

3. Same as above, only infant places both hands on the table within 3-5 seconds after maximum displacement. R or L side.

2. Same as above, only infant places both hands on table for support before maximum displacement is reached. R or L side.

1. Same as above, only infant places one or both arms on table for support almost immediately as force is applied. R or L side.

0. Unable to accomplish any of the above.

TOTAL

V A. POSITION - Cruising component.

Task 1: Have table, and toys, etc. that infant will be motivated to go for. Place infant in standing position facing low table. Watch abdomen!

5. Infant is able to cruise 5 or more steps consecutively in both directions, alternating placing of hands for support, infant picks up one foot at a time bringing foot out to the side, i.e., side-steps. Watch abdomen!
4. Same as above, only infant makes 3-4 steps in both directions.

3. Same as above, only infant takes at least 2 steps in both directions.

2. Same as above, only infant takes one step in both directions.

1. Infant makes placing motions of the foot out to the side but does not shift weight on to either foot, or picks foot up and out to the side without placing it down.

0. Unable to accomplish any of the above.

TOTAL

V B. POSITION - Walking with support.

Task 2: Use mobile type push object or hand of examiner if absolutely necessary. Infant standing, observer holds one hand of infant.

5. Infant maintains erect posture (i.e., does not bend forward at the waist more than approximately 45 degrees) while hanging on to one hand of the examiner with one hand (or pushing on mobile object with one hand); infant makes at least 5 consecutive, alternate steps forward, infant's other arm can be out to the side.

4. Same as above, only infant makes 3-4 steps.

3. Same as above, only infant takes 2 steps.

2. Same as above, only infant takes 1 step forward, R or L (circle).

1. Infant takes 1 or more steps, but is bending forward at the waist more than approximately 45 degrees and/or putting both hands on one hand of the examiner.

0. Unable to accomplish any of the above.

TOTAL
V C. POSITION - No support when walking.
   Task 3: Toys, etc., to motivate.

   5. Infant takes at least 5 consecutive alternate steps without any support.
   4. Infant takes 3-4 consecutive, alternate steps.
   3. Same as above, only infant takes 2 steps.
   2. Infant takes 1 step forward, R or L (circle), maintains standing position for at least 1 second.
   1. Infant places foot forward, either R or L (circle), but does not shift weight forward, or falls forward in the act of stepping.
   0. Unable to accomplish any of the above.

   TOTAL

V D. POSITION - Walking independently backwards.
   Task 4: Toys, etc. to motivate.

   5. Child is able to walk backwards over five feet in a smooth coordinated movement.
   4. Child is able to walk backwards between 2-4 feet, in a smooth coordinated movement.
   3. Child is able to walk backwards, but has a wide base of support.
   2. Child places only one foot behind in an attempt to walk backwards.
   1. Child lifts foot behind, but loses balance. May fall.
   0. Unable to accomplish the above task.

   TOTAL
V E. POSITION - Walking up stairs.
   Task 5: toys, etc. to motivate.

   ___ 5. Child is able to walk up stairs independently (no support).
   ___ 4. Child is able to walk up stairs with the use of a hand rail or wall (no human support).
   ___ 3. Child will climb stairs holding on to adult's hand.
   ___ 2. Child is able to raise foot and place it on stairs in order to attempt to climb stairs.
   ___ 1. Child creeps or hitchies up stairs.
   ___ 0. Child unable to accomplish any of the above.

      TOTAL

V F. POSITION - Kicks ball forward.
   Task 6: Toys, etc. to motivate.

   ___ 5. Child is able to kick ball forward without losing his/her balance.
   ___ 4. Child is able to kick ball forward, but loses balance and falls.
   ___ 3. Child attempts to kick ball forward, but misses ball altogether.
   ___ 2. Child runs at ball without actually kicking ball.
   ___ 1. Child runs at ball, without actually kicking ball, but loses balance and falls.
   ___ 0. Unable to accomplish any of the above.

      TOTAL
V G. POSITION - Walking on tiptoes.
   Task 7: Toys, etc. to motivate

   5. Child is able to walk on tiptoes at least five consecutive alternate steps without any support.
   4. Child is able to walk on tiptoes at least 3-4 consecutive steps.
   3. Same as above, only child takes 2 steps then assumes normal standing posture.
   2. Child takes 1 step forward, maintains standing position for at least 1 second.
   1. Child assumes toe position for a moment, then assumes a normal standing position.
   0. Unable to accomplish any of the above.

   TOTAL

V H. POSITION - Balancing on one foot.
   Task 8: Toys, etc. to motivate.

   5. Child is able to balance on one foot without support for more than 5 seconds.
   4. Child is able to balance on one foot, without support for 2-5 seconds.
   3. Child is able to balance momentarily on one foot, without support.
   2. Child is able to balance on one foot for at least 5 seconds with support by one hand.
   1. Child is able to balance on one foot momentarily with support by one hand.
   0. Unable to accomplish any of the tasks.

   TOTAL
V I. POSITION - Jumping.
   Task 9: Motivate with toys, etc.

   5. Child is able to jump two feet in distance with both feet, without losing balance.

   4. Child is able to jump one foot or less in distance with both feet, without losing balance.

   3. Child is able to jump two feet in distance with only one foot, without losing balance.

   2. Child is able to jump one foot or less in distance with just one foot without losing balance.

   1. Child attempts to jump, moves slightly.

   0. Unable to accomplish any of the above.

   TOTAL
APPENDIX B

REFLEX TEST

CONTENTS
A. Primitive and Tonic Reflexes
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RATIONALE

Primitive reflexes, present at birth, are essential in normal motor development. They appear, diminish or become modified in the maturing infant and child. These primitive reflexes form the bases for progressive motor development, such as rolling, sitting, crawling, standing, balancing, etc. (Fiorentino, 1970).

With normal motor development, there is a gradual inhibition of the primitive reflexes so that higher patterns of motor development may become manifested. When the inhibitory influence of the higher centers, especially that of the cortex, are disrupted or delayed, there is a release of primitive reflexes or abnormal postural patterns (Bobath, B., 1954). The abnormal release or disorganization of the primitive reflexes then dominate or delay evolution of the higher motor patterns.

Specific C.N.S. lesion release patterns of posture that are typical and stereotyped as seen in cerebral palsy children can be assessed according to the sequential development of reflex maturation. The assessment is useful in determining the level of motor development and maturation, improvements and treatment planning.

This researcher will assess only some of the primitive and higher reflexes that are typically displayed in cerebral palsy children. It should be noted that spinal reflexes (motor responses) such as cross extension, flexor withdrawal and extension thrust will not be tested. These reflexes are usually "masked" by spasticity (Bobath, 1954).

Other reflexes also may be masked by a strong spastic subject. For this investigation, we will assume that the reflex is not masked, based on the subject's motor response. For example, if the subject does not demonstrate an expected reflex (A.T.N.R.) to a specific stimuli (turning head to side), the reflex will be assumed not to be present.

Reflexes appear at different times during development and may vary by three months. The time period for reflex appearance, modification or disappearance, used in this investigation, is

Method of Grading:

1. A test stimuli will be used to elicit the primitive and higher postural reflex. The reflex (motor response) may be a normal or abnormal reaction depending on the chronological age of the individual.
2. The reflex is graded normal if the reaction corresponds with the chronological age of the individual.
3. The reflex is graded abnormal if the reflex does not correspond with the chronological age of the individual.
4. Abnormal reflexes will be then classified as:
   a. Severe: 3 latent or immediate response to 3 test stimuli and displays total abnormal posture.
   b. Moderate: 3 latent or immediate response to 3 test stimuli and displays half of abnormal posture.
   c. Mild: 3 latent or immediate response to 3 test stimuli and displays approximation of abnormal posture.

Scoring:

1. Normal response equal to 4 points.
2. Abnormal response:
   a. severe equal to 1 point
   b. moderate equal to 2 points
   c. mild equal to 3 points.

NOTE: Before beginning test, remove subject's shoes.
Observer

Pre Date Post

I.D. (Group)
Chronological Age of Development

PRIMITIVE REFLEX

Asymmetrical Tonic Neck: present from 1-4 months normal.
Placement: Supine, arms and legs extended, head in midline.
Stimulus: Motivate subject to turn head to left side, then right side. (Use toys, etc. for motivation).
Reactions:
*Normal: Demonstrates no limb reaction on either side except for a mild A.T.N.R. or vestige of reaction: able to bring arms to midline with head in midline. (from 1-4 months)
Abnormal: Extension or increase in extensor tone of upper and lower extremity on face side.
           Flexion or increase in flexor tone of upper and lower extremity on skull side.
NOTE: Normal from 1-4 months; abnormal after 4 months.

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*NOTE: A strong response appearing between 1-4 months is abnormal. This is defined as the inability to bring both arms to midline with head in midline.
PRIMITIVE REFLEX

Symmetrical Tonic Neck: present from 6-8 months.

Placement: Place subject in prone position on knees. Observer places one hand on posterior surface of head and other hand cupping chin.

Stimulus: Extend head passively; then flex head passively.

Reactions:

Normal: No change in muscle tone of arms and legs. (Before 6 months and after 8 months).

Abnormal: 1. With head extended, upper extremities extend and lower extremities flex.

2. With head flex, upper extremities flex and lower extremities extend.

NOTE: Normal from 6-8 months; abnormal after 8 months.

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PRIMITIVE REFLEX

Positive Support: present from 1 months on.

Placement: Observer stands behind subject then holds subject in standing position supported under armpits.

Stimulus: Suspend subject in space, bounce soles of subject's feet 3-4 times against floor. Then suspend subject in space again.

*Reactions:

Normal: No increase in extensor tone of lower extremities; legs may flex. (after 4 months).

Abnormal: Increase extensor tone of lower extremities. Plantar flexion and inversion of foot may occur.

NOTE: Normal from 1-4 months; abnormal 4 months on.

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*NOTE: Other motor patterns of the lower extremities can occur.

A. Normal
   1. slight flexion of hips and knees., i.e., 15-20° flexion.
   2. Hip flex, externally rotated, abducted; knee flexed.

B. Abnormal
   1. Hip abducted, internally rotated, knee extended, foot plantar flexed and inverted (scissor pattern).
Tonic Labyrinthine (supine): present 1-4 months.

Placement: Subject supine; head in mid-position; arms and legs extended.

Stimulus: Supine position per se elicits extensor tone in extremities, trunk and neck. Passively flex knee and elbow to note extensor tone changes in biceps and quads (muscles).

Reactions:

Normal: No increase in extensor tone in either the trunk, legs, arms or neck when arms or legs passively flex (from 4 months on).

Abnormal: An increase in extensor tone in the trunk, legs, arms, and/or neck when arms and legs passively flexed. Able to "feel" domination of extensor tone when arms and legs are passively flexed.

NOTE: Normal from 1-4 months; abnormal from 5 months on.

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PRIMITIVE REFLEX

Tonic Labyrinthine (prone): Present from 1-4 months.

Placement: Place subject in prone; head in mid-position; legs extended, arms extended overhead (if possible).

Stimulus: Prone position per se elicits flexor tone in extremities, trunk and neck. Passively flex both knees and elbows, then extend knees to note changes in quads and biceps (muscles).

Reactions:

Normal: No increase in flexor tone seen in either the arms, legs, or hips (can be extended without resistance) from 4 months.

Abnormal: Arms, legs, and hips dominated by increase flexor tone, i.e., arms draw back into flexion position, hips flex. (Resist passive extension).

NOTE: Normal from 1-4 months; abnormal from 5 months on.

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Landau Reflex: Present from 6-24 months.

Placement: Prone position, support at thorax, hold subject in space.

Stimulus: Cup subject's chin, raise head passively.

*Reactions:

Normal: Spine and leg remain in flexed position.
(from 1-6 months; 24 months on)

Abnormal: Spine, arm and leg extends with head extended.

NOTE: Normal from 6 months to 24 months; abnormal from 24 months.

*This reflex may be masked by strong tonic labyrinthine reflexes or symmetrical tonic neck reflex. If extensor tone continues to be dominant with head flexion, assume TLR over-riding Landau. Grade this reflex abnormal severe.

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Moro Reflex: Present from 1-4 months.

Placement: Sitting position. Observer faces subject. Pass arms under armpits to support subject's head, neck and upper trunk. Recline subject to about 40 degrees to horizontal plane.

Stimulus: While maintaining head, neck, and upper trunk support, lower subject suddenly about 12 inches.

Reactions:

Normal: Minimal or no startle reaction (after 4 months).

Abnormal: Arms abduct, extend, externally rotate and/or are movements in other parts of body.

NOTE: Normal after 1-4 months, abnormal after 4 months.

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RIGHTING REFLEX

Neck righting: present from 1-6 months.

Placement: Supine, arms and legs extended, head in mid-position.

Stimulus: Rotate head to one side passively.

Reactions:

*Normal: Body rotates as whole or like a log in same direction as head.

Abnormal: Body does not rotate; segmentally.

NOTE: Normal within 1st months; abnormal from 1 month on.

*Note: Normal from 1-6 months; abnormal after 6 months, log roll or unsegmentally. When the infant's head is turned and no reactions of the body occur, i.e., segmental rotation, this is a normal reaction for infants 6 months or older.

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Body righting acting on body: present from 6 months.

Placement: Supine, head in midposition, arms and legs extended.

Stimulus: Rotate pelvis by using one flexed leg as a crank.

Reactions:

Normal: Segmental rotation of trunk between pelvis and shoulder, i.e., pelvis turns, then shoulders, finally head (after 6 months).

Abnormal: Body rotates as whole.

NOTE: Normal from 1-6 months; abnormal after 6 months, log roll or unsegmentally. When the infant's head is turned and no reactions of the body occur, i.e., segmental rotation, this is a normal reaction for infants 6 months or older.

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RIGHTING REFLEX

Labyrinthine righting acting on head (optical): present from 6-8 months.

Placement: Subject standing/sitting. Observer places arms around pelvis from behind subject. Suspend subject in space.

Stimulus: Tilt subject to right and left to about 45° to vertical line.

Reactions:

Normal: Head rights to normal position with face vertical and mouth horizontal (from 6-8 months).

Abnormal: Head does not right to normal position. No reaction at all.

NOTE: Normal from 1-8 months. Abnormal after 9 months.

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TOTAL

*moderate-tries to hold head in vertical position, head held below midline of body.

*mild - tries to hold head in vertical position slight lateral bending of trunk towards vertical and head in midline.
PARACHUTE REFLEX
(Protective Extension; Placing Reactions)

Forward Parachute: present from 7 months.

Placement: Subject prone with arms extended overhead across observer's knee. Observer's hand grasps upper part of shoulder while other hand under subject's pelvis.

Stimulus: Raise subject's pelvis so head moves suddenly towards floor.

Reactions:

Normal: Immediate extension of arms with abduction and extension of fingers to protect head (from 7 months).

Abnormal: Arms do not protect head; may show primitive reaction as tonic neck reflexes.

NOTE: Normal before 7 months; abnormal after 7 months.

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*Moderate - some extension of upper extremity.

*Mild - touch floor, but does not support body weight.
PARACHUTE REFLEX
(Protective Extension, Placing Reactions)

Backward Parachute: present from 9 months.

Placement: Sitting. Observer stands on side of subject.

Stimulus: Place one hand behind subject in order to prevent subject from falling backward. Place other hand in subject's chest and push backward gently till subject loses balance.

Reactions:

Normal: Trunk will rotate to one side, with upper extremity on same side extending, abducting with fingers abducted, and extended to maintain balance (from 9 months).

Abnormal: Upper extremity and trunk do not react to maintaining balance.

NOTE: Normal from 1-9 months; abnormal from 9 months.

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*moderate - child rotates trunk to try to keep balance.

*mild - child rotates trunk to try to keep balance with abducting and extending arm but does not catch balance.
PARACHUTE REFLEX
(Protective Extension, Placing Reactions)

Sideward Parachute: present 6-7 months.

Placement: Subject sitting with arms on lap. Observer on side of subject.

Stimulus: Gently push subject sideward till balance is upset towards opposite side, i.e., push subject towards left, left upper extremity should abduct and extend.

Reactions:

Normal: Opposite upper extremity will abduct, extend with fingers abducted and extended (from 6 months.

Abnormal: Opposite extremity demonstrates no movements to maintain balance.

NOTE: Normal from 1-5 months; abnormal after 6 months.

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TOTAL

*moderate - head laterally flexes to opposite side to maintain balance.

*mild - head laterally flexes to opposite side and extremities begin to abduct, but does not show full reflex.
PARACHUTE REFLEX
(Protective Extension, Placing Reaction)

Downward Parachute: present from 4 months.

Placement: Observer stands behind subject. Suspend subject in space by providing support under armpits from behind.

Stimulus: Rapidly lower subject vertically towards floor.

Reactions:

Normal: Lower extremities will extend, abduct and externally rotate (after 4 months).

Abnormal: Lower extremities assume position of flexion.

NOTE: Normal from 1-4 months; abnormal after 4 months.

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</tr>
<tr>
<td>*moderate</td>
<td>2</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>*mild</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL

*moderate - legs extended and abducted but do not cross at ankles.

*mild - legs extended with some abduction and external rotation.
EQUILIBRIUM REFLEX

Supine: Present from 7 months.

Placement: Supine on tilt board; arms and legs extended.

Stimulus: Tilt board to one side smoothly or in series of jerks.

Reactions:

Normal: Righting of head and spine, abduction and extension of upper and lower extremity on raised side. May have protective reactions on low side (from 7 months).

Abnormal: No righting of head or spine and/or upper and lower extremity movements. No equilibrium or protective reactions.

NOTE: Normal from 1-7 months; abnormal after 7 months.

Scoring:

<table>
<thead>
<tr>
<th>Abnormal</th>
<th>Points</th>
<th>Pretest</th>
<th>Comments</th>
<th>Post-test</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>severe</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*moderate</td>
<td>2</td>
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<td></td>
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<tr>
<td>*mild</td>
<td>3</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL —

*moderate - some trunk curvature, laterally.

*mild - movements of upper and lower extremities towards abduction. Also is lateral curvature of spine.
EQUILIBRIUM REFLEX

Prone: present from 5 months.

Placement: Subject prone on tilt board, head turned to one side, arms and legs extended.

Stimulus: Tilt board to one side smoothly or in series of jerks.

Reactions:

Normal: Righting of head and trunk (see concavity of spine towards upper edge of tilt board), is abduction and extension of upper and lower extremity on raised side (after 5 months).

Abnormal: Head and trunk do not right themselves, no protective or equilibrium reactions.

NOTE: Normal from 1-5 months; abnormal from 5 months.

Scoring:

<table>
<thead>
<tr>
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<th>Points</th>
<th>Pretest</th>
<th>Comments</th>
<th>Post-test</th>
<th>Comments</th>
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<tbody>
<tr>
<td>severe</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>*moderate</td>
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<tr>
<td>*mild</td>
<td>3</td>
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<tr>
<td>Normal</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

TOTAL

*moderate - some trunk curvature, laterally.

*mild - movements of upper and lower extremities towards abduction.
Also is lateral curvature of spine.
EQUILIBRIUM REFLEX

Sitting: present from 10-12 months.

Placement: Sitting on chair, observer grasps one upper extremity by the wrist and elbow. Observer stands to side of subject.

Stimulus: Gently pull subject to one side.

Reactions:

Normal: Righting of head and trunk, upper and lower extremity abduct and extend on opposite side. i.e., leans away from observer (from 10-12 months).

Abnormal: No righting of head and trunk and/or movements of upper and lower extremity in protective or equilibrium pattern.

NOTE: Normal from 1-12 months; abnormal after 12 months.

Scoring:

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<th>Pretest</th>
<th>Comments</th>
<th>Post-test</th>
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<td>no response</td>
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<td>*mild</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>*moderate</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>4</td>
<td></td>
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<tr>
<td>TOTAL</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*mild - movements of upper and lower extremities towards abduction. Also is lateral curvature of spine.

*moderate - some trunk curvature, laterally.
APPENDIX C

199
**POST ROTATORY NYSTAGMUS**

*With Impulsive Stops*

<table>
<thead>
<tr>
<th>Date</th>
<th>I.D.</th>
<th>Age</th>
<th>Chron.</th>
<th>Devel.</th>
</tr>
</thead>
</table>

**Pretest at 150°; 100°; 50°; 30°; 20°**

| Counter | Clockwise | Clockwise | *Comments *
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>150°</td>
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<td>Side</td>
<td>Lying</td>
</tr>
<tr>
<td>100°</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
</tr>
<tr>
<td>50°</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
</tr>
<tr>
<td>30°</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
</tr>
<tr>
<td>20°</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
</tr>
</tbody>
</table>

*Positive Reactions*
1. Calm
2. Relax
3. Quietly alert
4. Smiling
5. Laughs
6. Drowsy, sleepy
7. Excited (Happy)
8. Other (explain)

*Negative Reactions*
1. Clings to therapist
2. Withdraws from examiner
3. Cries
4. Vocal protest
5. Trembles
6. Body tense
7. Physical protest
8. Other (explain)
APPENDIX D
Post-Rotatory Nystagmus with Impulsive Stops
Treatment at 100° Angular Velocity

<table>
<thead>
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<th>Date</th>
<th>Time</th>
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<th>Counter Clockwise</th>
<th>Counter Clockwise</th>
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<tbody>
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<td>Sitting</td>
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<td></td>
<td></td>
<td>L Side</td>
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<td></td>
<td></td>
<td>Lying</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R Side</td>
<td></td>
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</tr>
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<td></td>
<td></td>
<td>Lying</td>
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<tr>
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<td>Sitting</td>
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<td></td>
<td>L Side</td>
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<tr>
<td></td>
<td></td>
<td>Lying</td>
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<tr>
<td></td>
<td></td>
<td>R Side</td>
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<td></td>
<td></td>
<td>Lying</td>
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<td></td>
<td>Sitting</td>
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<td></td>
<td>L Side</td>
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<tr>
<td></td>
<td></td>
<td>Lying</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Positive Reactions
1. Calm
2. Relax
3. Quietly alert
4. Smiling
5. Laughs
6. Drowsy, sleepy
7. Excited (happy)
8. Others (explain)

*Negative Reactions
1. Clings to therapist
2. Withdraws from examiner
3. Cries
4. Vocal protest
5. Trembles
6. Body tense
7. Physical protest
8. Others (explain)

*Comments Continued
**POST ROTATORY NYSTAGMUS**

**With Impulsive Stops**

<table>
<thead>
<tr>
<th>Date</th>
<th>I.D.</th>
<th>Age</th>
<th>Chron.</th>
<th>Devel.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Post-test at $150^\circ$; $100^\circ$; $50^\circ$; $30^\circ$; $20^\circ$</th>
<th>Counter</th>
<th>Clockwise</th>
<th>Clockwise</th>
<th>*Comments</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>$150^\circ$</th>
<th>Sitting</th>
<th>Side</th>
<th>Lying</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$100^\circ$</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
<td></td>
</tr>
<tr>
<td>$50^\circ$</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
<td></td>
</tr>
<tr>
<td>$30^\circ$</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
<td></td>
</tr>
<tr>
<td>$20^\circ$</td>
<td>Sitting</td>
<td>Side</td>
<td>Lying</td>
<td></td>
</tr>
</tbody>
</table>

*Positive Reactions*
1. Calm
2. Relax
3. Quietly alert
4. Smiling
5. Laughs
6. Drowsy, sleepy
7. Excited (happy)
8. Other (explain)

*Negative Reactions*
1. Clings to therapist
2. withdraws from examiner.
3. Cries
4. Vocal protest
5. Trembles
6. Body tense
7. Physical protest
8. Other (explain)
### POST ROTATORY NYSTAGMUS QUESTIONNAIRE

**Areas of Observation:**
1. Bathing  
2. Dressing  
3. Carrying  
4. Feeding  
5. Sitting  
6. Sleeping  
7. Playing  
8. Locomotion  
9. General (motor, emotional, etc.)

<table>
<thead>
<tr>
<th>AREAS</th>
<th>ITEMS</th>
<th>CHANGES</th>
<th>YES</th>
<th>NO</th>
<th>COMMENTS</th>
</tr>
</thead>
</table>
| 1. Bathing | Position (sit/lie)  
|          | Balance (head, trunk control)                                         |         |     |    |          |
|          | Relaxed or tense                                                      |         |     |    |          |
| 2. Carrying | Position (sit/lie)  
|          | Balance (head, trunk control)                                         |         |     |    |          |
|          | Body rigid or relaxed                                                |         |     |    |          |
|          | Able to rotate head                                                  |         |     |    |          |
| 3. Dressing | Position (sit/lie)  
|          | Balance (head, trunk control)                                         |         |     |    |          |
|          | Assist getting on garment                                            |         |     |    |          |
|          | Pull head up                                                          |         |     |    |          |
| 4. Feeding | Position (sit/lie)  
<p>|          | Balance (head, trunk control)                                         |         |     |    |          |
|          | Head rotate (follow spoon)                                            |         |     |    |          |
|          | Areas of a) swallowing b) chewing c) biting d) drinking e) gagging |         |     |    |          |
|          | Help feed self (hold cup)                                             |         |     |    |          |
|          | Feeding habits (relaxed/tensed)                                       |         |     |    |          |
| 5. Sitting | Balanced a) head control b) trunk control                             |         |     |    |          |
|          | Relaxed                                                               |         |     |    |          |</p>
<table>
<thead>
<tr>
<th>AREAS</th>
<th>ITEMS</th>
<th>CHANGES</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Sleeping</td>
<td>Time (longer/shorter)</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Position</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>7. Playing</td>
<td>Position (sitting, stomach supine, reclining)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active/passive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alert/curious</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Locomotion</td>
<td>Attempts to move/change position</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Head control</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(lifts head more)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rolls, crawl, creep, scoot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. General</td>
<td>Alert</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active/passive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vocalization</td>
<td></td>
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<tr>
<td></td>
<td>Activities (any new)</td>
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<td></td>
<td>Attitude toward strangers</td>
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<td>Attention span longer</td>
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</tr>
<tr>
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<td>V/E's less/more tense</td>
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</tr>
<tr>
<td></td>
<td>L/E's less/more tense</td>
<td></td>
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</tr>
</tbody>
</table>

Comments:
POST ROTATORY NYSTAGMUS

With Impulsive Stops

Date ___________ I.D. ___________ Age ___________

Chron. Devel.

Delayed Post-test at 150°; 100°; 50°; 30°; 20°

<table>
<thead>
<tr>
<th>Counter Clockwise</th>
<th>Clockwise</th>
<th>*Comments</th>
</tr>
</thead>
</table>

| 150° Sitting Side |             |           |
| Lying            |             |           |

| 100° Sitting Side |             |           |
| Lying            |             |           |

| 50° Sitting Side |             |           |
| Lying            |             |           |

| 30° Sitting Side |             |           |
| Lying            |             |           |

| 20° Sitting Side |             |           |
| Lying            |             |           |

*Positive Reactions

1. Calm
2. Relax
3. Quietly alert
4. Smiling
5. Laughs
6. Drowsy, sleepy
7. Excited (happy)
8. Other (explain)

*Negative Reactions

1. Clings to therapist
2. Withdraws from examiner
3. Cries
4. Vocal protest
5. Trembles
6. Body tense
7. Physical protest
8. Other (explain)
APPENDIX H
Dear Parents:

My name is Jeffrey R. Kreutzberg, R.P.T. (Registered Physical Therapist), and I am presently a Doctoral Candidate with the Department of Anatomy, College of Medicine, The Ohio State University. My colleague, Francis K.W. Chee, R.P.T., is also a graduate student in anatomy and a physical therapist.

Our present goal is to investigate possible avenues of treatment procedures that could be utilized in treating developmentally delayed children (cerebral palsy) in a clinical setting, as well as increasing motor development of normal children.

We are requesting your consent to allow your child to participate in a study we are doing entitled: Effects of Vestibular Stimulation on Motor Development in Normal and Developmentally Delayed Children Due to Cerebral Palsy.

The "vestibular" system refers to that part of the inner ear that helps us maintain our balance and posture. In normal children, it is our belief that this is the system, when appropriately stimulated, enhances normal motor development. Many cerebral palsy children have some type of balance and postural problems, in crawling, sitting, or standing. The "vestibular" system may or may not be involved in these balance problems - it may only be a part of the answer or none at all.

Basically, this study is designed to uncover more clues to this problem. Will stimulating this balance (vestibular) mechanism cause an increase in balance or motor activity in the normal infant and in the developmentally delayed infant?

In order to provide the balance (vestibular) stimulation, either I or an assistant will hold your child (placed in an infant seat) in our arms while being rotated in a "swivel" chair. Each rotation will last one to two minutes depending on the child's position. Three different positions will be used: side lying on right side, then left side and finally in the sitting position. The position changes are necessary in order to stimulate specific areas of the balance mechanism. Please note that
research indicates no harmful side effects, and in many cases beneficial gains have been noted.

This study will be conducted for four weeks, two times a week plus one or two sessions before so we can evaluate your child’s motor development. Each session of balance stimulation will require 20 minutes.

Please keep in mind (1) that this is not a "treatment", rather a study in hopes of finding an avenue to better treat cerebral palsy and other developmentally delayed children; (2) that this study will hope to show increased motor development of normal children; (3) that you may remove your child from the study at any time; (4) that you are welcome to observe your child at any time.

Your time and cooperation in this matter is greatly appreciated. If you have any questions, please contact either Frank or myself.

Jeffrey R. Kreutzberg, R.P.T.
422-5521 (O.S.U.)
486-4601 (home)

Francis K.W. Chee, R.P.T.
422-5521 (O.S.U.)
875-3947 (home)

Sincerely,

Jeffrey R. Kreutzberg, R.P.T.
Department of Anatomy

(circle)

Yes I (we) am/are willing to participate in this study.

No I (we) am/are not willing to participate in this study.

Yes I (we) would like to know more about this study before I (we) decide. Please list your:

NAME
ADDRESS
PHONE NUMBER

A reply within 3 days would be greatly appreciated.
BIBLIOGRAPHY


Rood, M. Concept of muscle actions through the stimulation of sensory receptors. Unpublished notes from University of Southern California, P.T. 5M, 1963.


