THE FUSIMOTOR AND VESTIBULAR SYSTEMS:
AN INSTRUCTIONAL PACKAGE

A THESIS

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We hereby recommend that the thesis prepared under our supervision by Karen Young entitled The Fusimotor and Vestibular Systems: An Instructional Package

be accepted as fulfilling this part of the requirements for the Degree of Master of Science.

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INTRODUCTION

Today, the literature, workshops, and physical therapy (PT) practice reveal an interest by physical therapists (PTs) in the vestibular system and more specifically in the use of vestibular stimulation to improve motor and perceptual deficits. Recent practice trends include the use of simple diagonal activities, balance boards, and spinning as techniques for vestibular stimulation. The more vigorous techniques may frighten patients and may result in nausea and vomiting. This results in a wide spectrum of practice and controversy regarding the use of vestibular stimulation.

The literature on the vestibular system which is prepared for the physical therapist is limited. Ayres (1975) has used vestibular stimulation with children. Limited information is available on the use of this technique with adults.

Purpose of the Study

The two purposes of the study were:

1. To develop an instructional package for PT students and practitioners. The topic of fusimotor and vestibular systems was presented with the following components:

    a. an overview of the anatomy and physiology of the fusimotor system

b. the anatomy and physiology of the vestibular system

c. interrelationships between the vestibular and fusimotor systems

d. treatment techniques used by physical and occupational therapists to integrate the fusimotor and vestibular systems

2. To field test this instructional package (IP) to determine its appropriateness as an instructional tool for PTs. The field testing of this IP included the following:

a. evaluation of content of the IP by PT experts

b. distribution of the IP to sample population for completion of the IP

c. pretesting and posttesting the sample population

d. determination of test reliability

e. obtaining the students' evaluation of the IP

Research Questions

This study attempted to answer the following questions:

1. Is there a significant difference between the pretest and posttest scores of undergraduate PT students using the Fusimotor and Vestibular Systems Instructional Package?

2. Is the pretest and posttest for the Fusimotor and Vestibular Systems Instructional Package reliable?

Definitions

For the purpose of this study the following definitions are used:

1. Fusimotor system--afferent (motor) portion of muscle spindle

2. Muscle spindle--central nervous system receptor; it is unique in that it is the only receptor with both motor and sensory components

3. Vestibular system--the portion of the inner ear that assists the nervous system in maintaining equilibrium (Barr, 1972)

4. Instructional Package (IP)--"A document which lists an objective, readings and other resources, activities and feedback for students to review and utilize in order to complete an instructional module" (Frantz, 1974). Synonyms used in this study are programmed text or programmed instructions

5. Pretest--An evaluation instrument which measures the entry level of students' cognitive performance

6. Posttest--An evaluation instrument which measures the terminal performance of students after completing an instructional package

7. Undergraduate physical therapy student--Senior level student enrolled in the Texas Woman's University

School of Physical Therapy, Dallas Center--Presbyterian Campus

8. Sensory integration--The end product of an organizing process in which the brain receives isolated bits of information from any sensory receptors and processes them so a unified response may be made (Ayres, 1974)

9. Vestibular stimulation--A type of therapy used to treat sensory integrative dysfunction. This consists of various techniques to stimulate the otoliths and semicircular canals of the vestibular apparatus

10. Gain Score--The difference between the Fusimotor Vestibular Systems pretest and posttest student scores

Limitations

The limitation of this study was the small population of physical therapy undergraduate students.

Assumptions

It was assumed by the researcher that:

1. the students completed the pretest and posttest to the best of their ability

2. the students completed the instructional package as directed

3. the students completed the prerequisite instructional package as directed

Significance of Study

Physical therapy curricula include neuroanatomy and neurophysiology courses that introduce the student to both the fusimotor and vestibular systems. These courses are included in all PT curricula but emphasis varied from school to school, depending on time constraints and available personnel. A physical therapist qualified to teach neuroanatomy and neurophysiology and familiar with various neurological treatment techniques is better able to make basic course content applicable to patient treatment. Such manpower is not always available, resulting in neurologists, physiologists, doctoral students in neurology, and other non-physical therapy professionals teaching neuroanatomy and neurophysiology. The student emerges with knowledge of the basic sciences but needs more familiarity with its application to specific treatment techniques. Programmed instruction may facilitate meeting the needs of PT students and practitioners to integrate basic science with treatment techniques.

CHAPTER II

REVIEW OF LITERATURE

The review of the literature included two aspects: (a) relating current theory and practice regarding the fusimotor and vestibular systems, and (b) researching the uses of instructional packages. The Fusimotor and Vestibular Systems: An Instructional Package (see appendix A) developed by this researcher is an in-depth review of the literature relating current theory and practice regarding the fusimotor and vestibular systems. For this reason, this chapter includes only an overview of that material.

Current Theory and Practices

The text, the Neurophysiological Basis of Patient Treatment (Crutchfield & Barnes, 1975), reviewed the anatomy and physiology of the muscle spindle and related information that is clinically applicable for physical therapists. This programmed text utilized the approach to giving a concept and following the concept with a question to facilitate learning. This text provided information regarding inhibition and facilitation of the muscle spindle and its relationship to the Golgi Tendon Organ (GTO). Little information was given regarding the alpha motor innervation.

Matthews' book (1972) appears to be the most complete source of information regarding the muscle spindle. His acknowledgement of the complexity of the subject can be demonstrated by the following quote:

> The muscle spindle has been a subject of neurological studies for over 100 years and its importance was described by Ruffini in 1898 'apart from the organs of special sense (eye, ear, etc.) the body possesses no terminal organ that can compare with these in richness of nerve fibers and nerve endings.' Their historical study has been pursued for over a hundred years and has been beset with controversy and false turnings up to the very present. It would be unwise to imagine that the last word has yet been said and it still seems possible as Tower presently remarked in 1932 that their 'rich confusion of nerve fibers' . . . had not yet been thoroughly analyzed.

Matthews (1972) also gave evidence that the alpha motoneuron plays a large part in coordinated movement.

Erway (1975) correlated the fusimotor and vestibular systems in this manner,

> . . . the vestibular system, and especially the otoliths, may be uniquely important among all of the sensory organs in the development of normal, integrative functions of the brain, especially the cerebellum. On this basis, it is argued that any genetic or environmental factors which alter the normal development or maintenance of this elaborate inertial-guidance system may affect the development of early locomotor functions.

Erway also argued that deficient function in a sensory system may lead to unusual behavior patterns. This is demonstrated by abnormal responses to stimuli, nystagmus irregularity, poor separation of head and eye movements, and decreased righting responses in schizophrenic individuals. He implicated magnesium and zinc as being critical in the development of normal otoliths.

Ayres (1973) indicated that the vestibular system is a key to sensory integration. Her methods, developed for use with children, often involved vigorous stimulation of the vestibular system. These techniques included spinning and extreme challenges of balance by the use of rocker boards. She believed that "considerable opportunity exists for the vestibular system to exercise influence over all other on-going sensory experiences" (p. 119). The vestibular system plays a part in facilitating impulse flow from the muscle spindle and enhances body movement awareness.

Chapparo and Ranka (1980) gave preliminary results of attempts to standardize sensory integration tests for adults. Various vestibular stimulation techniques were widely used in their clinic. With the validation and standardization of the test battery they hope to support their treatment techniques.

Wycke (1980) deemphasized the importance of the vestibular system in its role to notify the body of its position in space. Wycke placed greater emphasis in the cervical mechanoreceptors and gives examples of what has happened to individuals who have had their necks immobilized and have attempted to walk in the dark or drive an automobile.

Instructional Packages

The concept of individualized instruction has a centuries-old history. In the United States it began in the early 1900s in the area of vocational agriculture. The concept of individualized instruction as we know it today came into vogue in the early 1960s (Tuckman, 1969).

Espich (1967) stated that the principles of behavioral psychology are applied in programmed instruction. One aspect of behavioral psychology is reinforcement which was defined and described in reference to a stimulus; positive reinforcement is thought to be a prerequisite to learning. This author described positive reinforcement as a stimulus, presented to the student after his response, that satisfies one or more of the basic human drives. "Programmed instruction takes advantage of the basic human drive for success" (Espich, 1967, p. 118).

Espich (1967) referred to Garner who stated that programmed texts were often good adjuncts to traditional teacher/class methods and are a good method of introducing new material. Garner also stated that much resistance has greeted programmed materials as a self contained course or unit. A major objection to this method is the difficulty of assigning a grade which is still seen as a need by most educators and parents.

At the present time programmed instruction is often used as a supplement. Two programmed texts used in the area of allied health are texts on medical terminology and the Neurophysiological Basis of Patient Treatment by Crutchfield and Barnes (1975). The medical terminology texts are used by physical therapy programs as the basis for learning the core material with supplemental lectures and examinations. Crutchfield and Barnes's text is used as a supplement in physical therapy neuroanatomy courses and is available to physical therapy clinicians for review and in some cases to relate previously learned theory to practice.

Friesen (1973) addressed the topic of using programmed instruction as reinforcement and remediation and suggests that if given properly can be used with all populations for almost any reason. He expressed the idea that programmed instruction is valuable as remediation but becomes defensive when some teachers list this as the only use for programmed instruction. He states these individuals feel their positions are being threatened.

Instructional packages are not as popular as they were 10 to 15 years ago but seem to be useful in some situations.

When using an instructional package, the text, population, and setting should be carefully evaluated and chosen; when these elements are considered positive results should be obtained. Although the use of programmed texts is controversial, they may be found useful by physical therapy students by physical therapy faculty, physical therapy practitioners, and other allied health faculty.

CHAPTER III

METHODOLOGY

Instructional Package

Background

During the Spring Semester 1980 as a project fulfilling the requirements of a Neuroanatomy Seminar (PT 5901), an instructional package was developed for presentation to the class. Three components of the package were: (a) an overview of the fusimotor system, (b) specific relationships between the fusimotor and vestibular systems, and (c) the physical therapist's role in affecting these two systems.

After the presentation of this instructional package the authors, Debbie Allen, Lucinda Haber and Karen Young (see appendix B) realized the need for a more sophisticated development of the text. The lack of knowledge regarding preparation of an instructional package was evident in reviewing the instructional package in its original form.

Development

The instructional package was completed in the summer of 1981 in the style described by Frantz (1974). The package has the following components: (a) the anatomy and physiology of the vestibular system, (b) interrelationships between the vestibular and fusimotor systems, and (3) treatment techniques used for sensory integration. The text developed for this study included advanced information on the fusimotor system which was condensed from the original text. More emphasis was placed on specific treatment techniques. This text was designed to include reading, references, illustrations, questions/answers, and a pretest and posttest. The order of the material was sequential and the finished product contained more illustrations than the original.

The first draft was distributed to five experts in the summer of 1981 and was returned with recommendations for modification. The experts consisted of physical therapy educators and clinicians in the Dallas-Fort Worth Metroplex who have advanced knowledge of neuroanatomy and neurophysiology and an interest in vestibular stimulation. The final draft was formulated and distributed to PT students for field testing between fall and spring semesters 1981-82.

Population and Sample

The instructional package was field tested utilizing a convenient sampling technique (Stein, 1976). This student population consisted of the senior class of physical therapy students at the Texas Woman's University, Dallas Center--Presbyterian Campus, who consented to participate in the study. Nineteen students took the pretest and 18 completed the posttest, resulting in a sample size of 18.

Instructional Package Administration

Completion of both the IP prepared for this study and its prerequisite IP were included in the behavioral objectives for the senior neuroanatomy courses. The class was given the opportunity to work through the *Neurophysiological Basis of Patient Treatment* (1975) as a prerequisite to the fusimotor and vestibular system IP. The pretest was used to determine reliability of the evaluation tool (see appendix C).

Confidentiality and Human Rights

The Human Research Committee reviewed this investigator's methodology for protection of human rights and a letter of cooperation (see appendix B) was secured from the Dean, School of Physical Therapy, at the Texas Woman's University. Voluntary consent from each participant was also secured on a prepared form (see appendix B).

The pretests and posttests were coded for anonymity for the purpose of pairing the pretests and posttests. Each participant placed his social security number on the pretest and on the posttest for the purpose of matching only. A cover letter accompanied the pretest explaining that the social security numbers would not be used in any other way (see appendix D). It was also explained in the cover letter that no individual data, only group data, would be presented.

Collection of Data

The collection of data began when five experts determined content validity of the first draft. The pretest was given at the end of the Fall Semester 1981. The students then worked through the IP over the Christmas holidays. Preceding the posttest each participant was asked to complete a form prepared by the researcher to evaluate the instructional package (see appendix E). This form was distributed with the IP for reference while working through the IP. The posttest was then given (see appendix A). It was explained that feedback would be given to all students that requested it.

Analysis of Data

Research question one was analyzed by the analysis of variance using the paired *t* test. Research question two was analyzed by using the coefficient alpha to measure reliability of the pretest (Nie & Hall, 1977). The Statistical Package for the Social Sciences (SPSS) was used to analyze the data.

CHAPTER IV

FINDINGS

Field Testing

Phase One

The findings are discussed following the sequence in which they occurred during the process of field testing. The first phase was the analysis of the IP by the five experts. The PT experts made several suggestions. The following modifications were made to the IP prior to pilot testing:

1. The IP instructions were made more detailed

2. The titles of the four major sections were changed. The modules were given subheadings

3. The illustration labels were modified

4. More illustrations were integrated into the text of the IP

5. Figure 9 was repeated as figure 12 and relabeled to change the emphasis

6. The sequence of the review test questions was changed so they did not follow sequence of material in the text

7. The matching review test was modified: (a) so that possible responses in Column B were greater than

number of terms in Column A, and (b) changing the format so there was only one correct response from Column B for each term in Column A

8. The pretest and posttest were modified to include questions that correspond with terminology in the objectives

Phase Two

The second phase of field testing was distribution to the PT student population. The following modifications to the final IP were based on students' comments given on the evaluation form which accompanied the instructional package:

1. Illustrations were relabeled
    a. The untitled illustrations were given titles
    b. The gamma efferent label on figure 3 was changed to alpha motoneuron
2. Selected portions of the text were rewritten
    a. The sentence prior to the discussion of the monosnaptic reflex (Module I, Part II) was deleted. This sentence mentioned two types of sensory endings when only Ias were discussed
    b. In Module II, Part IV the depolarization and hyperpolarization section was rewritten to clarify their relationship to firing rates and to define hyperpolarization

c. The first sentence of the second paragraph of Module II, Part V was rewritten to remove words that made the sentence difficult to understand

d. For smoother flow, some of the multiple quotes were paraphrased and narration was added to make existing quotes more readable

3. Modification of test questions were made. Questions 2 and 3 of Review Test V, Module II were renumbered to become 5 and 6 of Review Test I, Module III. The questions were erroneously placed before the portion of the text that dealt with corresponding material

Pretest and Posttest Results

The pretests and posttests were completed by 18 senior physical therapy students at the Texas Woman's University, Dallas Center--Presbyterian Campus. Research question one dealt with the significant difference between the pretest and posttest scores of undergraduate PT students using the _Fusimotor and Vestibular Systems: An Instructional Package._ This question was tested using a paired _t_ test. The pretest mean was 8.22 and the posttest mean was 19.44. The gain score of 11.22 was significant ($p < .001$). This significant difference showed the instructional package to be a valid learning tool with senior physical therapy students.

Test Reliability

A total test reliability coefficient was calculated on the Fusimotor and Vestibular Systems pretest to answer research question two: Is the pretest and posttest for the Fusimotor and Vestibular Systems: An Instructional Package reliable? Pretest questions 5, 9, 11, 12, 13, 15, 17, 19, and 27 were deleted due to zero variance. The zero variance was caused by all subjects giving the same answer to the question, be it right or wrong. The coefficient alpha (Nie & Hall, 1977) was used and found to be 0.61 which demonstrated a moderate reliability.

In summary, the findings revealed multiple recommendations from the experts and from the field test population which improved the clarity and flow of the IP. The statistical data showed the gain score to be significant and the pretest and posttest to have moderate reliability.

CHAPTER V

SUMMARY, CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

Summary

This study evolved from the premise that physical therapy students and practitioners have not had access to sufficient literature to integrate the theory and practice of vestibular stimulation. The purposes of the study were to develop and field test The Fusimotor and Vestibular Systems: An Instructional Package. The instructional package was field tested through evaluation by five physical therapists who examined the IP for content. Data were collected from pretest and posttest scores after 18 physical therapy students worked through the IP.

Two research questions were formulated as follows:

1. Is there a significant difference between the pretest and posttest scores of undergraduate PT students using The Fusimotor and Vestibular Systems: An Instructional Package?

2. Is the pretest and posttest for The Fusimotor and Vestibular Systems: An Instructional Package reliable?

Conclusions

The conclusions for this study were as follows:

1. that <u>The Fusimotor and Vestibular Systems: An Instructional Package</u> is a valid learning tool

2. that the pretest and posttest had a moderate measure of reliability

Discussion

The first phase of field testing may have been more helpful if additional experts were used including an occupational therapist who specializes in sensory integration. The experts were very helpful in their critique but may have been more specific if an evaluation form had been developed for completion by the experts.

The experts were all practicing physical therapists or physical therapists in an educational setting. These PT experts had numerous deadlines and demands on their time that may have prevented thorough evaluation of the instructional package. It had also been one and one half to two years since the experts had worked through the prerequisite IP which may have decreased their ability to criticize information on the fusimotor system (Module I).

While planning the field test several obstacles were encountered by the researcher. Originally one instructor was planning to teach both a graduate and an undergraduate class of neuroanatomy and had offered both classes for sample populations. In summer 1981, it was announced that the graduate class could not be offered and a different instructor would teach the undergraduate class. Completion of the prerequisite instructional package was still to be included in the behavioral objectives as was the Fusimotor and Vestibular Systems: An Instructional Package. The prerequisite package, The Neurophysiological Basis of Patient Treatment (1975) was not distributed until late in the semester and the illustrations for the instructional package to be field tested were lost in the mail. For these reasons the students were given the instructional package to work through over the Christmas holidays. Since completion of the instructional package and the evaluation form was not part of coursework, the students may not have worked through it carefully. The students had just completed a rigorous semester with multiple major examinations which may have decreased the validity of this IP.

The students had most difficulty with Module II stating this was their first exposure to the material making it difficult to follow in this format. Their numerous comments regarding lack of familiarity with the vestibular system support the need for more information on the vestibular system in the physical therapy curriculum. It was also mentioned that more repetition would be helpful. Many comments were made regarding the need for further explanation in Module II but few specific suggestions were made. Student response to Module IV was in general favorable. This section was the most interesting to the students and helped integrate the previous three modules.

The field test population appreciated having the reference lists for future use, but all stated they did not use the reference lists. The timing of working through the instructional package over the Christmas break decreased the availability of the reference.

Since the reliability coefficient was only moderate, it would be hoped that this could be increased by asking more questions. The evaluation tool should be revised to ask for three responses for question 17. Question 19 would also be clearly marked to ask for five answers. The students had difficulty interpreting what was wanted in these two questions.

Recommendations

Upon reviewing comments made by experts and students and the data generated by the study, the following recommendations are made:

1. the development of additional introductory material for Module II may be helpful

2. a repeat field test should include more specific questions relating to Module II on the evaluation form

3. the final IP should be further evaluated

4. both graduate students and practicing physical therapists should be used as sample populations

5. the sample size should be increased

6. a revised evaluation tool with more questions and clearer instructions should be developed

7. for increased clarity figure 9 should be illustrated to show its relationship to the ear and head

APPENDICES

APPENDIX A

THE FUSIMOTOR AND VESTIBULAR SYSTEMS: AN INSTRUCTIONAL PACKAGE

INSTRUCTIONAL PACKAGE

INTRODUCTION AND INSTRUCTIONS

The terminal objective of this instructional package is to assist physical therapy clinicians and students in the development of a rationale for and a plan of treatment utilizing vestibular stimulation for those individuals with motor disorders. Working through The Neurophysiological Basis of Patient Treatment, Volume I, Second Edition, by Marylou Barnes and Carolyn Crutchfield, 1973, Stokesville Publishing Company, is a prerequisite for this instructional package.

The instructional package is divided into four modules:

1. An overview of the fusimotor system
2. The anatomy and physiology of the vestibular system
3. Interrelationships between the vestibular and fusimotor systems
4. Treatment techniques used by physical and occupational therapists to integrate the fusimotor and vestibular systems

Each module is preceded by behavioral objectives and followed by self-evaluation questions. The answers are found on the following page. If any item is missed, it is suggested that the student/clinician reread the module that precedes the review questions.

This instructional package is not designed for "quick flipping" as each item depends on the preceding material. A complete bibliography is provided with asterisks denoting references the author found most helpful.

INSTRUCTIONAL MODULE I

OVERVIEW OF ANATOMY AND PHYSIOLOGY OF THE FUSIMOTOR SYSTEM

OBJECTIVES:

Upon completion of this section of the instructional package, the student will be able to

1. Differentiate functions of the muscle spindle, Golgi Tendon Organ, and alpha motoneuron

2. Label the portions of the muscle spindle

3. List functions of parts of the muscle spindle

4. Differentiate reflexes related to the muscle spindle

ACTIVITIES:

Complete the following activities:

1. Read the following module

2. If you wish to read supplementary material on anatomy and physiology of the fusimotor system, see the following list:

Crutchfield, C. A., & Barnes, M. R. The neurophysiological basis of patient treatment (Vol. 1). Morgantown: Stokesville Publishing Company, 1975.

Guyton, A. C. Textbook of medical physiology. Philadelphia: W. B. Saunders Company, 1971.

Matthews, P. B. C. Mammalian muscle receptors and their central actions. London: Edward Arnold, Ltd., 1972.

Moore, J. C. The golgi tendon organ and the muscle spindle. American Journal of Occupational Therapy, 1974, 28, 415-420.

Willis, W. D., Jr., & Grossman, R. G. Medical neurobiology. St. Louis: C. V. Mosby Company, 1977.

3. There are three review tests associated with Module I.

INTRODUCTION TO THE MUSCLE SPINDLE

For years, men of science have been studying the muscle spindle. Matthews (1972) made the following comment:

> The muscle spindle has been a subject of neurological studies for over 100 years and its importance was described by Ruffini in 1898 'apart from the organs of special sense (eye, ear, etc.) the body possesses no terminal organ that can compare with these in richness of nerve fibers and nerve endings.' Their histological study has been pursued for over a hundred years and has been beset with controversy and false turnings up to the very present. It would be unwise to imagine that the last word has yet been said and it still seems possible as Tower presently remarked in 1932 that their 'rich confusion of nerve fibers' . . . had not yet been thoroughly analyzed. (Matthews, 1972, p. 10)

PART I

The essential feature of the muscle spindle is that it contains both nervous and muscular elements. The Ia nerve fiber, which is one portion of the sensory innervation, wraps around the equatorial regions of the nuclear bag and nuclear chain. Found in the polar regions are Type II afferents. The largest percentage of the Type II afferents are found in the nuclear chain.

Intrafusal fibers lie parallel within extrafusal fibers as contrasted with Golgi Tendon Organs (GTO) which lie in series within extrafusal muscle fibers (see fig. 1).

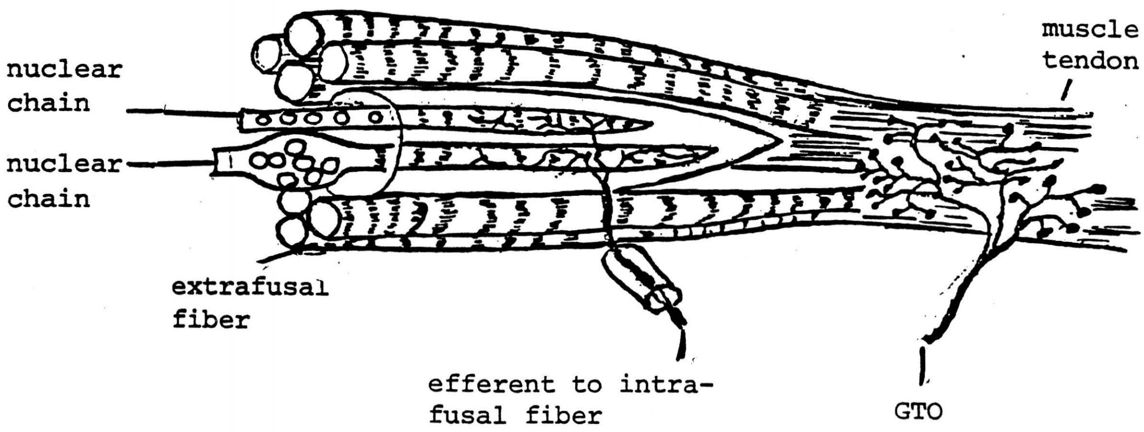


Fig. 1. Relationships of Muscle Spindle to GTO

Each intrafusal fiber was originally named for the arrangement of nuclei in their central regions. The contractile elements are found in the polar region (see fig. 2).

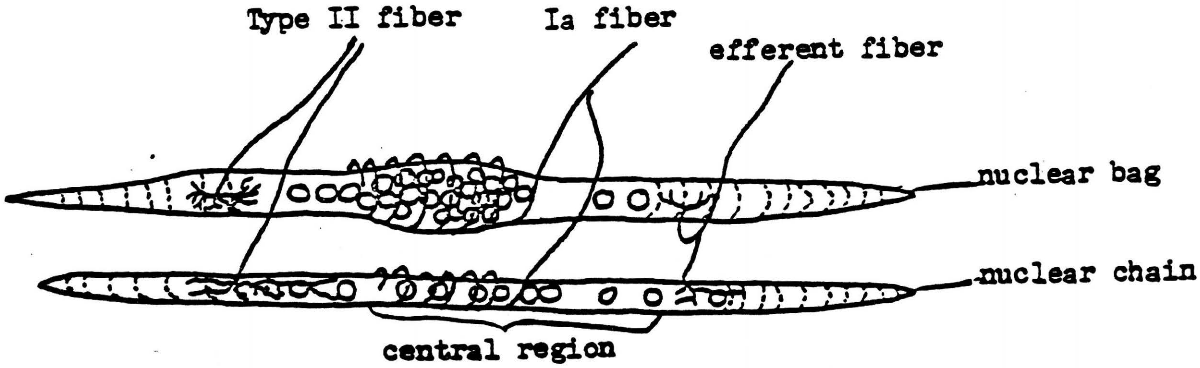


Fig. 2. The Muscle Spindle

The motor innervation to the muscle spindle is primarily from gamma motoneuron efferent; the extrafusal muscle fiber receives its innervation from the alpha motor neuron.

Each intrafusal fiber may receive terminals from several fusimotor axons, and each fusimotor axon may distribute to several intrafusal fibers. These fusimotor efferents innervate the contractile regions of the spindle.

It has been recently demonstrated in mammals that an additional motor innervation is present. Intrafusal fibers may be sporadically supplied by branches of the ordinary motor fibers as well as by specific fusimotor fibers. These branches or collaterals of the alpha motor neuron innervate extracapsular polar ends of the nuclear bag and are called Beta fibers (see fig. 3).

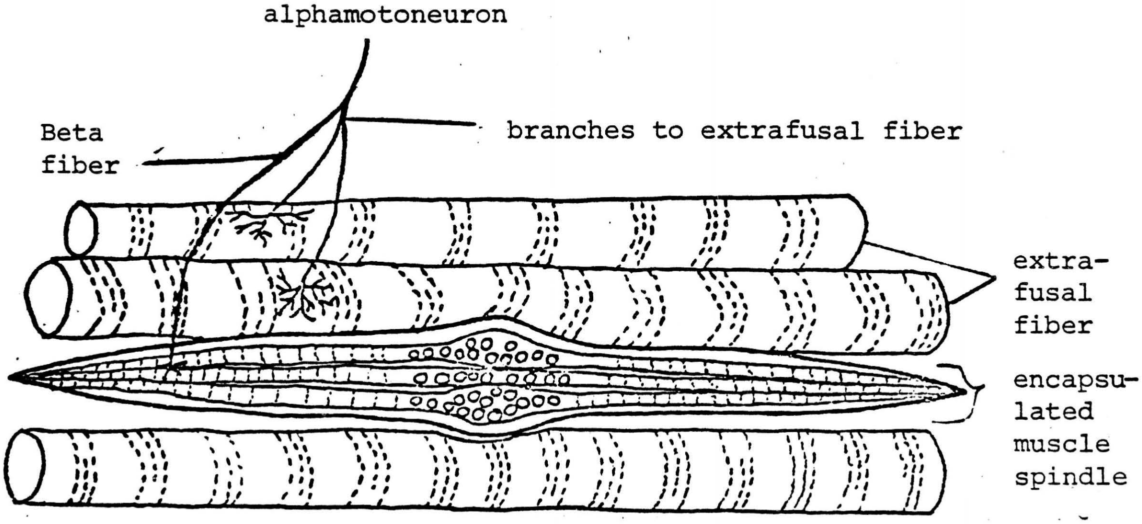


Fig. 3. Encapsulated muscle spindle with nuclear bags and chains lying in parallel with extrafusal fibers

It appears at this time there is no direct sympathetic innervation of the spindle, but there are sympathetic fibers innervating blood vessels within the spindle capsule so an intrafusal as well as a capsular sympathetic innervation would not seem finally eliminated.

The muscle spindle sends unconscious proprioceptive impulses to the cerebellum by way of dorsal and ventral spinocerebellar circuits (see fig. 4). Both the muscle spindle afferents and Golgi Tendon Organ afferents send impulses via the dorsal spinocerebellar circuit. These circuits most often terminate in the anterior lobe of the cerebellum after passing through regions of the brainstem.

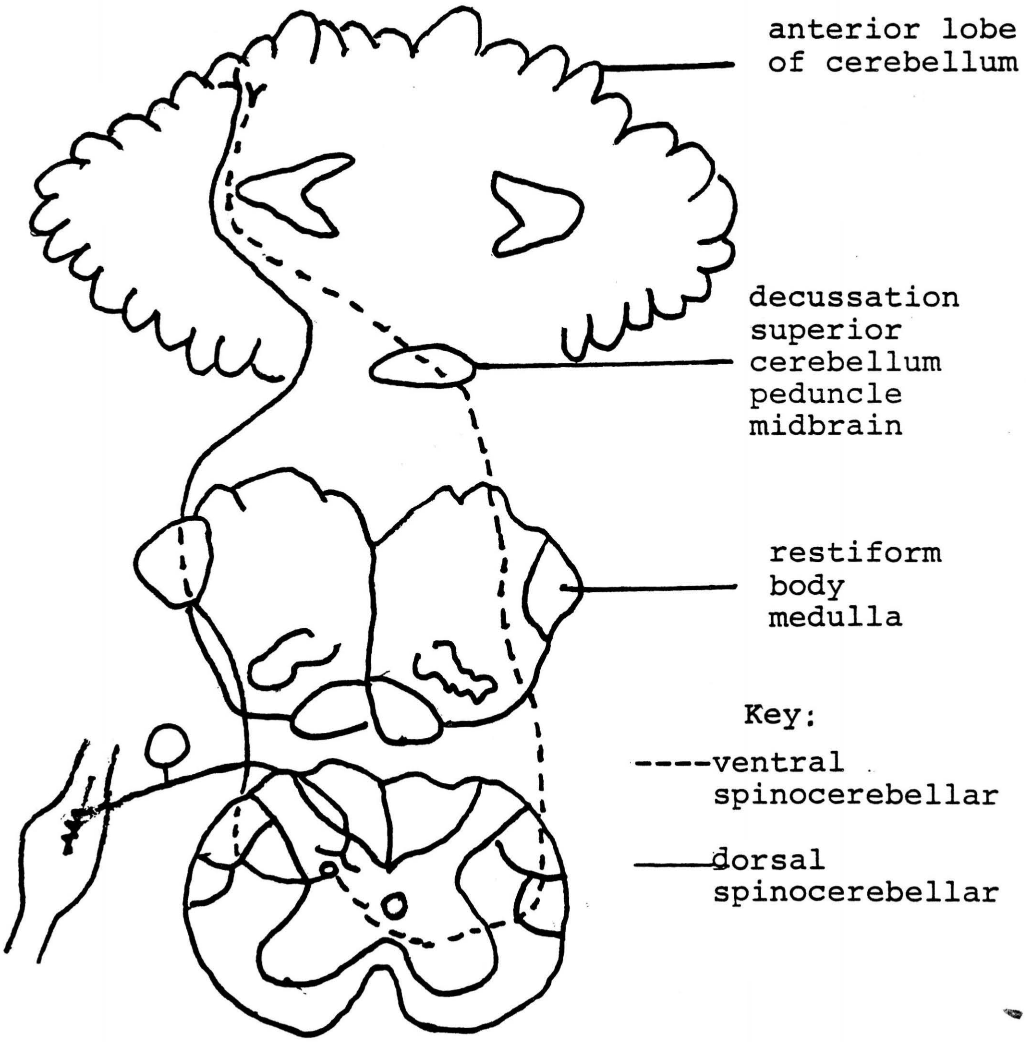


Fig. 4. Dorsal and ventral spinocerebellar circuits

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST I

OVERVIEW OF THE ANATOMY AND PHYSIOLOGY

OF THE FUSIMOTOR SYSTEM

REVIEW TEST I

DIRECTIONS: Listed below are six questions on the anatomy and physiology of the fusimotor system. Complete the following statements by providing the appropriate word in the space provided.

1. Type II afferents are found in the ____________________ of the muscle spindle.
2. The muscle spindle lies in ___________ with the extrafusal muscle fibers, and the Golgi Tendon Organ lies in _______________________ with extrafusal fibers.
3. The equatorial region of the nuclear chain contains ____________ fibers.
4. The _______________________ system is the efferent innervation of the muscle spindle.
5. Beta fibers are collaterals of the ___________________.
6. The ascending circuits for the muscle spindle terminate in the ___________________________.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. polar regions
2. parallel

   series
3. Ia efferent
4. fusimotor
5. alpha motoneuron
6. cerebellum

REFERENCES:

Crutchfield, C. A., & Barnes, M. R. The neurophysiological basis of patient treatment (Vol. 1). Morgantown: Stokesville Publishing Co., 1975.

Matthews, P. B. C. Mammalian muscle receptors and their central actions. London: Edward Arnold, Ltd., 1972.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional module Part I on pages 31-34. When you complete this activity, retake Review Test I. When you have answered all questions correctly, proceed to Part II.

TURN TO NEXT PAGE

PART II

The sensory and motor nerve fibers have a tonic and/or phasic component. The phasic or dynamic component relates to the rate of change of length of the extrafusal muscle fiber responding to quick stretch. The tonic or static component of the muscle spindle relates to changes in length of the extrafusal fibers and responds to a maintained stretch.

As previously mentioned, muscle spindles are arranged in parallel with the extrafusal muscle fibers. A stretch of the whole muscle will increase the tension in the spindle. A contraction will cause the tension in the spindle to decrease. This response to muscle contraction is known as spindle unloading (see fig. 5).

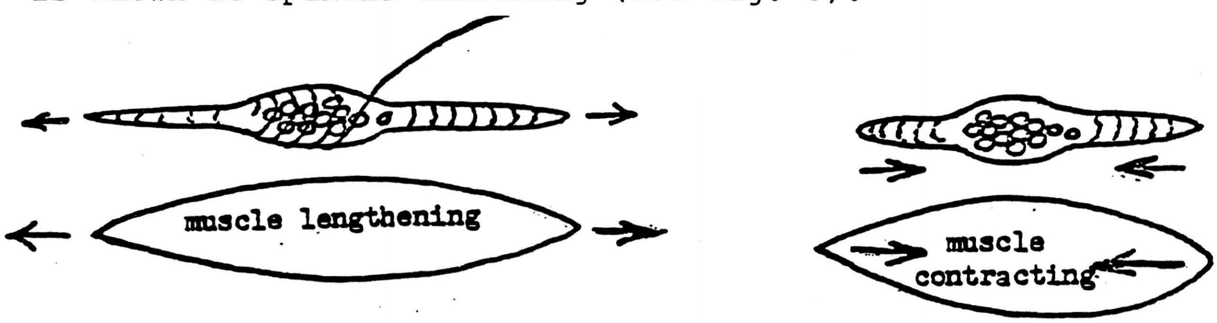


Fig. 5. Effect of Muscle Contraction on Muscle Spindle

Muscle spindles function to monitor changes in length and rate of change in length:

> If a rapid stretch is applied and then maintained at a constant level a biphasic response will

> occur. The dynamic response will be an initial burst of impulses followed by a steady discharge at a lower rate, which is the static response. (Willis, 1977, p. 50)

Thus, both Group Ia and Group II afferents have an increase in their activity. The following illustration demonstrates the typical effects different stimuli have on muscle spindle afferent activity (see fig. 6).

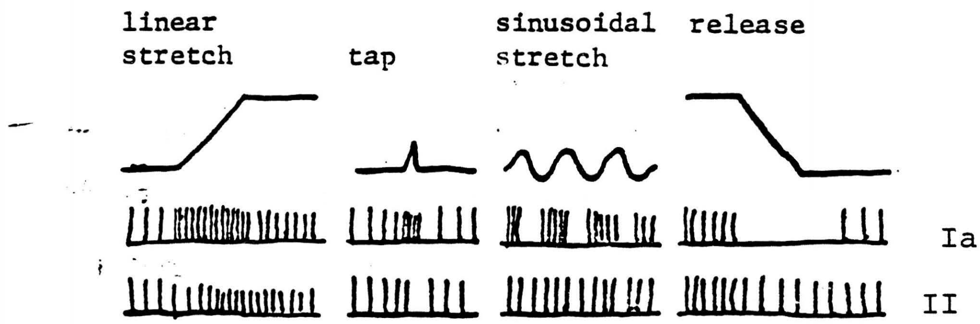


Fig. 6. Effects of Varying Stimuli on the Muscle Spindle

Golgi Tendon Organs lie in series. When tension is increased either by stretch of the muscle or by contraction of the muscle against resistance, the Golgi Tendon Organ terminals are distorted and an afferent discharge is produced. Thus, an effective stimulus might be a combination of stretch and contraction.

A quick stretch to a muscle and its spindle will activate the monosynaptic reflex. This distortion of the primary ending on the nuclear bag causes an increase in the rate of Group Ia afferents. Group Ia afferent fibers produce monosynaptic excitatory post synaptic potential

(EPSPs) in motoneurons supplying their own muscle or its synergists. The motor neuronal discharge is detected by observing the phasic contraction of the extrafusal muscle fibers. As well as being excitatory to its own muscle, these Ia fibers cause an inhibitory post synaptic potential (IPSPs) in the antagonist muscle's motor neuron. Evidence demonstrates the inhibitory pathway to be disynaptic. The myotatic reflex arc (see fig. 7) is thus characterized by reciprocal innervation of muscles opposing each other at a joint. This pathway is of great clinical importance since it is often used in testing reflex activity.

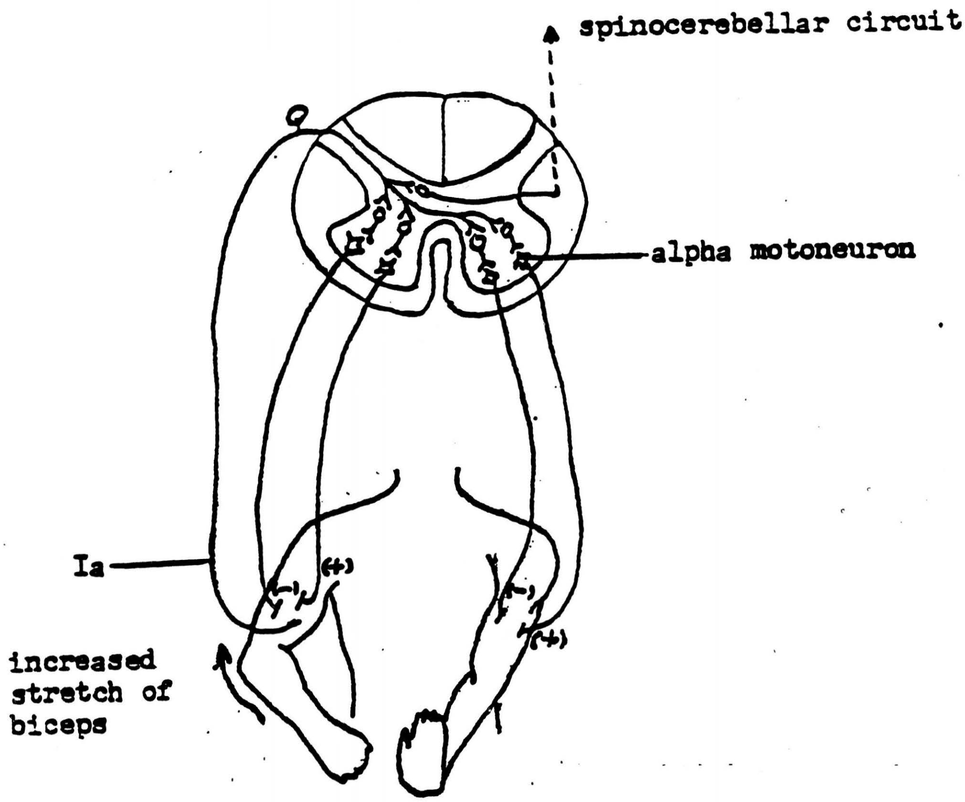


Fig. 7. The Myotatic Reflex Arc

TURN TO NEXT PAGE AND ANSWER REVIEW TEST II

OVERVIEW OF ANATOMY AND PHYSIOLOGY OF THE FUSIMOTOR SYSTEM

REVIEW TEST II

DIRECTIONS: Listed below are seven questions on the anatomy and physiology of the fusimotor system. Complete statements 1 through 6 by providing the appropriate word in the space provided. Circle the appropriate word in parentheses in statement 7.

1. A quick stretch will activate the ____________________ receptors of the muscle spindle.
2. A maintained stretch will activate the ______________ receptors of the muscle spindle.
3. Contraction of the muscle causes a __________________ in the tension in the muscle spindle.
4. Applying a rapid stretch and then maintaining the stretch produces a __________________ response.
5. Ia fibers are _______________ to their own motoneuron.
6. The patellar reflex is an example of a _______________ reflex.
7. The muscle spindle has a (low, high) threshold to stretch and the Golgi Tendon Organ has a (low, high) threshold to stretch.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. phasic
2. tonic
3. decrease
4. biphasic
5. excitatory
6. myotatic
7. low

   high

REFERENCES:

Matthew, P. B. Mammalian muscle receptors and their central actions. London: Edward Arnold, Ltd., 1972.

Willis, W. D., & Grossman, R. G. Medical neurobiology. St. Louis: C. V. Mosby Company, 1977.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional module Part II on pages 37-39. When you complete this activity, retake Review Test II. When you have answered all questions correctly, proceed to Part III.

TURN TO THE NEXT PAGE

PART III

Another mechanism of inhibition is called presynaptic inhibition. By depolarizing the presynaptic terminals, a decrease in the amount of transmitter substance released by the nerve is produced.

> This polysynaptic mechanism of inhibition is likely to be of considerable physiological interest because it lasts longer than the spinal cord mechanism of postsynaptic inhibition. Presynaptic inhibition may be a switching mechanism. (Matthews, 1972, p. 383)

For example, if the Group Ia myotatic reflex is considered, presynaptic inhibition would allow the motor neuron to be free to respond to other pathways.

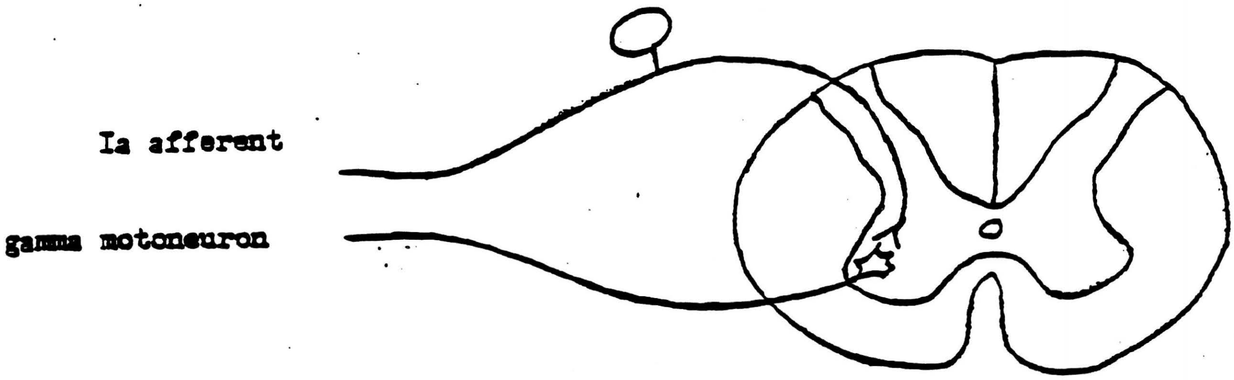
Activation of the secondary afferent endings has been said to evoke flexor reflexes: i.e., they are <u>always</u> facilitory to flexor motoneurons and inhibitory to extensor motoneurons (ipsilaterally) regardless of where the II ending is located. Caution, however, should be exercised when making such an implication. Indeed, Wilson and Mikato (1965) showed that stimulation of Group II and Group III afferents evoked IPSPs in flexor motoneurons. Inhibition of extensors still appears to be the dominant effect of activation of Group II endings. The heterogeneity of these fibers needs to be studied more extensively before any final conclusions are drawn as to their functional nature.

The response elicited by the Golgi Tendon Organ is known as autogenic inhibition. Always acting as inhibitors to their own muscle synergists, the antagonistic muscles are then facilitated. The opposite response is observed on the contralateral musculature. The response to the Golgi Tendon Organ will spread to nearby joints as well, making this a diffuse response. Clinically, Golgi Tendon Organ effects are seen as the clasped knife phenomenon. Functionally, it is known to contribute to fine control of movement as well as a protective mechanism. The intrafusal muscles are innervated by the fusimotor neurons. The Golgi Tendon Organ has no motor innervation.

Movements may be initiated by one of three circuits. The direct circuit is via excitatory effects on the alpha motor neuron by descending circuits (particularly corticorubrospinal) or by the spinal level circuitry elicited by stretch of the muscle.

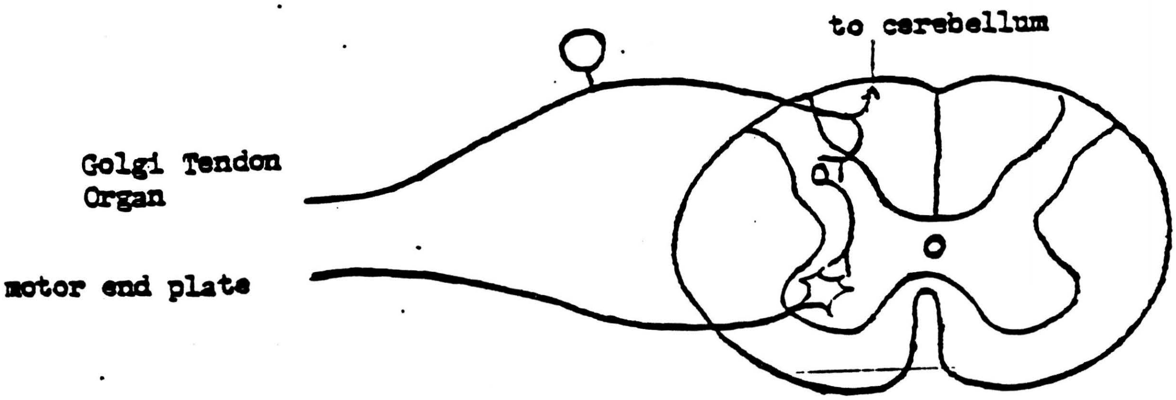
The indirect circuit would be via the gamma loop. If the fusimotor neuron is facilitated enough to discharge, it will cause a contraction of the polar portion of the intrafusal muscle (shortening of the spindle). This causes

TURN TO NEXT PAGE FOR ILLUSTRATION



PHASE I

Excitatory Effect



PHASE II

Autogenic Inhibition

Fig. 8. Clasped Knife Phenomenon

stretching of the equatorial region creating an increase in the discharge rate of Group Ia afferent fibers and therefore excite the alpha motoneurons of the same muscle.

In reading, there is much reference to the gamma motoneuron. More current terminology in reference to humans is the fusimotor system whereas gamma is appropriate for animals.

The third circuit is characterized by coactivation of both the alpha and fusimotor fibers. These fibers often fire in parallel (even with the dorsal roots cut). This simultaneous activation allows for controlled regulation of muscle tone, reflex activity, and coordinated movement. In terms of feedback circuits, the occurrence of alpha-fusimotor coactivation could be considered as servo-assistance mechanism for controlling movement. All of this emphasizes again the functioning of the spindle, and its input is a more complex chain than was previously realized. The muscle spindle is not only a sensor device playing a passive role in a feedback (servo) system but also serves as a powerful influence to its alpha motoneurons due to monosynaptic contacts. Thus, when appropriately stimulated by central fusimotor command, the spindle primaries may act as excitatory or trigger organs for centrally induced motor activities.

Harris notes that "light, sound, smell, cutaneous stimuli over the muscle belly excite the alpha motoneurons by influence on the gamma system" (1969, p. 398). Touch-temperature modalities--hearing, balance and vision--also activate the reticular formation. These impulses in concert with the limbic system's effect on emotions, adding input to the reticular formation, may help to keep it primed for action. Descending input from the reticular formation affects the alpha motoneuron via the indirect circuit; e.g., vestibular, visual, etc. The complexities of descending control are too numerous to pursue at this time but should be brought to the reader's attention in an effort to avoid oversimplification.

It is important to note at the end of the discussion concerning the muscle spindle that several researchers have questioned the existence of spindles in all muscles. Gonyea and Ericson (1977) found that the

> muscle spindle associated with the slow-twitch and fast twitch regions might allow these regions to function independently of one another when called upon to perform complex behavioral tasks. (p. 340)

TURN TO NEXT PAGE AND ANSWER REVIEW TEST III

OVERVIEW OF THE ANATOMY AND PHYSIOLOGY

OF THE FUSIMOTOR SYSTEM

REVIEW TEST III

DIRECTIONS: Listed below are five questions on the anatomy and physiology of the fusimotor system. Complete statements 1 through 4 by providing the appropriate word in the space provided. Complete number 5 by listing the requested information.

1. Secondary afferent endings are facilitory to _________ motoneurons and inhibitory to ___________ motoneurons.
2. The muscle spindle has strong ______________ functions and activates ________________ functions.
3. The ________ ________ exerts a major descending influence on the alpha motoneuron via the gamma loop.
4. The reticulospinal, corticospinal, and vestibulospinal circuits are descending circuits that influence the

   ____________________ ____________________.
5. List three (3) circuits for initiating movement.

   (1)

   (2)

   (3)

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. Flexor

   extensor

2. sensory

   motor

3. reticular formation

4. muscle spindle

5. (1) direct stimulation of the alpha

   (2) indirect stimulation of the alpha via gamma loop

   (3) coactivation of alpha and fusimotor

REFERENCES:

Gonyea, W. J., & Ericson, G. C. Morphological and historical organization of the flexor carpi radialis muscle in the cat. American Journal of Anatomy, 1977, 148, 329-344.

Harris, F. A. Control of gamma efferents through the reticular activating system. American Journal of Occupational Therapy, 1969, 23, 397-409.

Matthews, P. B. C. Mammalian muscle receptors and their central actions. London: Edward Arnold, Ltd., 1972.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional module Part III on pages 42-46. When you complete this activity, retake review Test III. When you have answered all questions correctly, proceed to Module II.

TURN TO THE NEXT PAGE

INSTRUCTIONAL MODULE II

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

OBJECTIVES:

Upon completion of this section of the instructional package, the student will be able to

1. List the components of the vestibular apparatus and their locations

2. List innervations to the vestibular apparatus

3. List the function of the components of the vestibular apparatus

4. Discuss relationships between components of the vestibular apparatus

5. Differentiate functions of the vestibular appara- apparatus

ACTIVITIES:

Complete the following activities:

1. Read the following module

2. If you wish to read supplementary material on the anatomy and physiology of the vestibular system, see the following list:

Guyton, A. C. Textbook of medical physiology. Philadelphia: W. B. Saunders Company, 1971.

Kilday, B. The vestibular system. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Kilday, B. The tactual and kinesthetic systems. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Kornhuber, H. H. The vestibular system and the general motor system. The holding function of the vestibular system. Handbook of Sensory Physiology, 1968, 6(1), 583-585.

Parker, D. E. The vestibular apparatus. Scientific American, 1980, 243(5), 118-132.

Weeks, Z. R. Effects of vestibular system on human development, Part I. Overview of functions and effects of stimulation. American Journal of Occupational Therapy, 1979, 33(2), 376-381.

Weeks, Z. R. Effects of vestibular system on human development, Part II. American Journal of Occupational Therapy, 1979, 33(7), 450-457.

Willis, W. D., Jr., & Grossman, R. G. Medical Neurobiology. St. Louis: C. V. Mosby Company, 1977.

3. There are five review tests associated with Module II.

PART I

The vestibular apparatus is contained within the temporal bone in a cavity known as the bony labyrinth (see fig. 8). The space between the bony and membranous labyrinths is filled with a fluid called perilymph. Endolymph is the fluid which fills the membranous labyrinth. The otolith and semicircular ducts comprise the sensory organs of the vestibular apparatus.

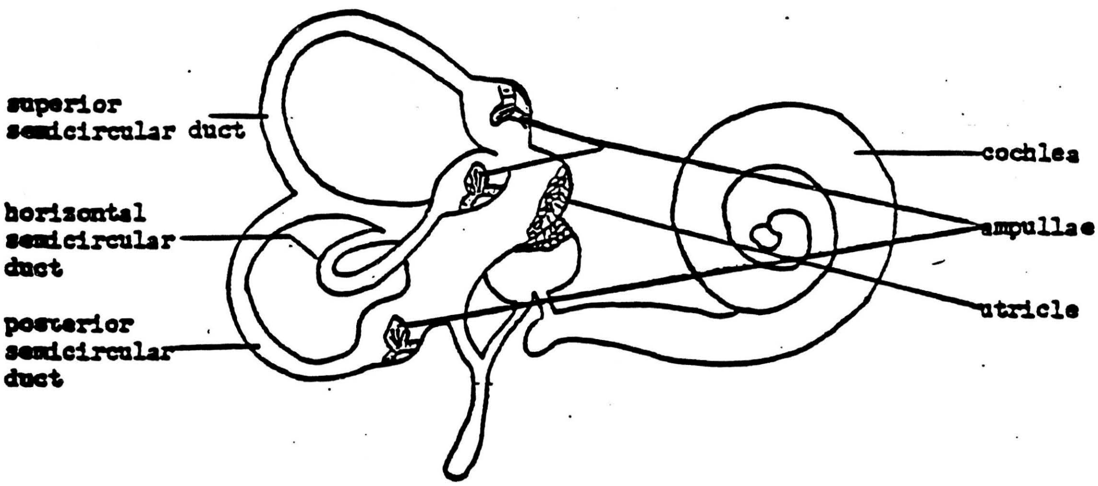


Fig. 9. The Vestibular Apparatus

There are two otolith organs, the utricle and saccule. Each consists of a macula or sensory epithelium. The utricular cavity has continuity with the semicircular canals and is also connected to the saccule.

The sensory epithelium of the utricle is called the utricular macula and is parallel to the ground when the head is upright. Covering the utricule is a membrane in which otoliths or calcite granules are embedded.

The sensory epithelium of the utricle is composed of supporting cells and sensory hair cells. Supporting cells are found throughout the epithelium, and hair cells are found in the superficial portion. There are two types of hair cells (see fig. 10). Type I cells are pear-shaped and are engulfed by a chalice-like sensory nerve ending. Type II cells are cylindrical.

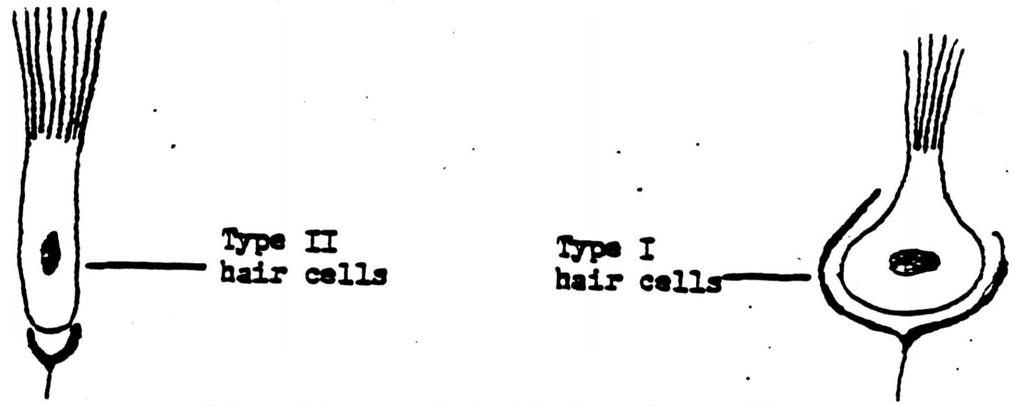


Fig. 10. Epithelial Hair Cells

There are more Type I cells in the striola, located at the center of the epithelium. The majority of Type II cells are found in the periphery.

The otolithic membrane (statoconial membrane) overlies the sensory epithelium of the utricular macula (see fig. 11). This membrane is made of a gelatinous substance in which calcite crystals are found. The sensory hairs project into the gelatinous material. The nerve fibers supplying the utricular macula include afferents and efferents. With movement of the head, the calcite crystals stimulate the sensory hairs.

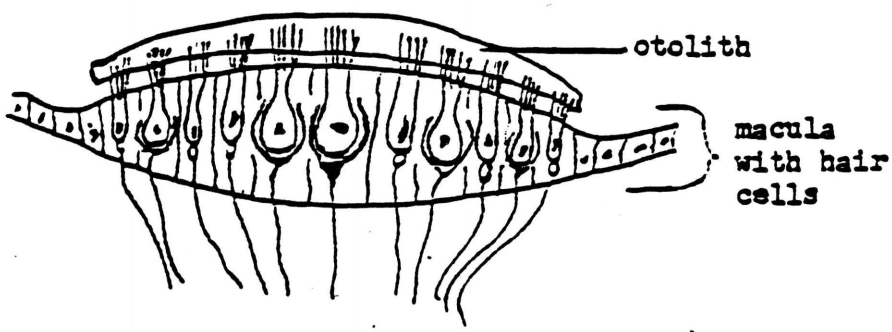


Fig. 11. Relationship of Otolithic Membrane to Utricular Macula

Cell bodies of the afferent fibers are found in the vestibular ganglion, which is located in the internal auditory meatus. These afferent neurons are bipolar; one process is sent to the vestibular apparatus and one to the VIII (auditory) nerve in the brain stem.

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST I

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

REVIEW TEST I

DIRECTIONS: Listed below are questions on the anatomy and physiology of the vestibular system. Complete the statements by providing the appropriate word in the space provided.

1. The sensory organs of the vestibular system are comprised of ________________ and _______ ______.
2. The otolith is comprised of the _______________ and the _____________________.
3. The macula of the utricle is ____________________ to the ground when the head is upright.
4. Hair cells are found in two shapes: ______________ and _____________________.
5. The ____________________ shaped or Type II hair cells are found in the periphery of the epithelium.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. otoliths

   semicircular ducts

2. utricle

   saccule

3. parallel

4. pear-shaped

   cylindrical

5. cylindrically

REFERENCES:

Kilday, B. The vestibular system. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Willis, W. D., Jr., & Grossman, R. G. Medical neurobiology. St. Louis: C. V. Mosby Company, 1977.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional module II, Part I on pages 51-53. When you complete this activity, retake Review Test I. When you have answered all questions correctly, proceed to Part II.

TURN TO THE NEXT PAGE

PART II

The saccule (one of the otolith organs) is a flattened, irregular structure located in the vestibule below the utricle. The sensory epithelium of the saccule is the saccular macula, and it is found to be vertical in the human. The saccule is innervated by two branches of the VIII nerve. The part of the membranous labyrinth concerned in hearing is the cochlear duct found within the bony cochlea and is in open communication with the saccule (see fig. 12).

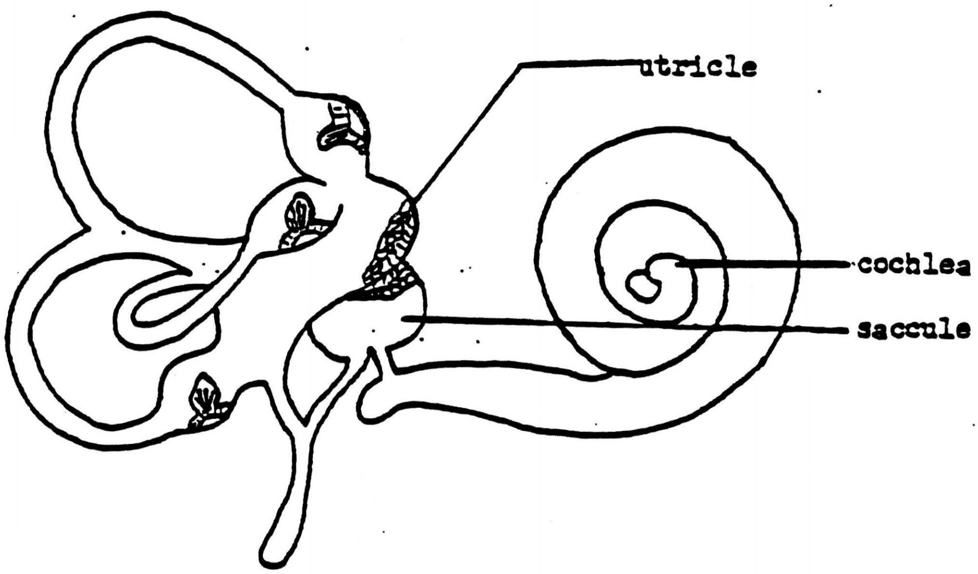


Fig. 12. The Vestibular Apparatus

There are three semicircular ducts in each labyrinth and are oriented in planes approximately perpendicular (at right angle) to one another.

The lumina of the semicircular ducts connect with the lumen of the utricle. Near this connection is a dilatation called the ampulla (see fig. 9). In the sensory epithelia of the semicircular ducts are located specialized receptors, the cristae ampullares. Each crista contains hair cells and supporting cells similar to those of the otolith organ (see fig. 13). A separate branch of the vestibular nerve supplies each crista.

The cupula is a gelatinous structure into which hair cells of the crista project (see fig. 13). The cupula divides the ampulle. A cupula can be found in each semicircular canal.

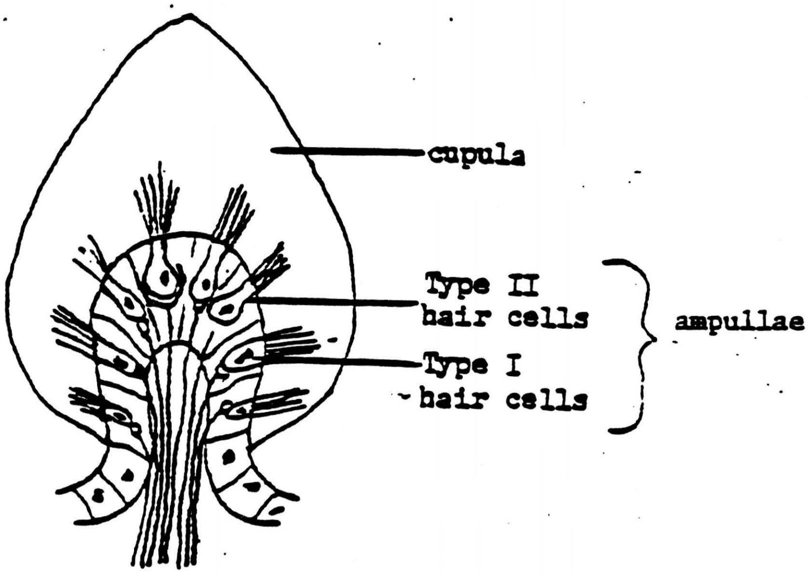


Fig. 13. Cristae Ampullares

Vestibular afferents have their cell bodies in the vestibular ganglion located in the internal auditory meatus (see fig. 14b). Their axons travel via the VIII nerve to the brain stem. The vestibular portion of the VIII nerve enters between the restiform body and the spinal tract of the trigeminal nerve. It then terminates in vestibular nuclei which are located beneath the floor of the fourth ventricle.

There are four vestibular nuclei: lateral (Deiter's), medial, superior, and descending.

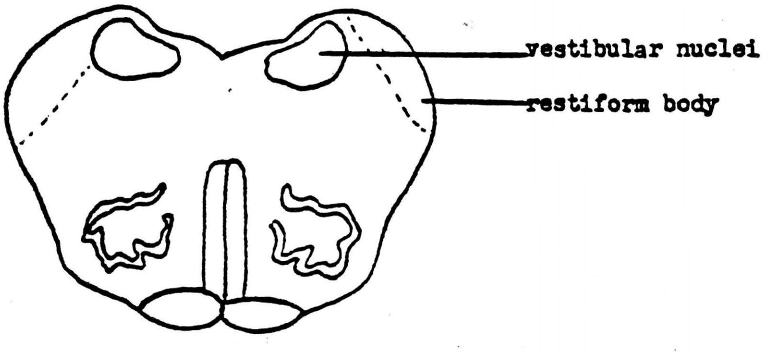


Fig. 14a. Cross-section Medulla.

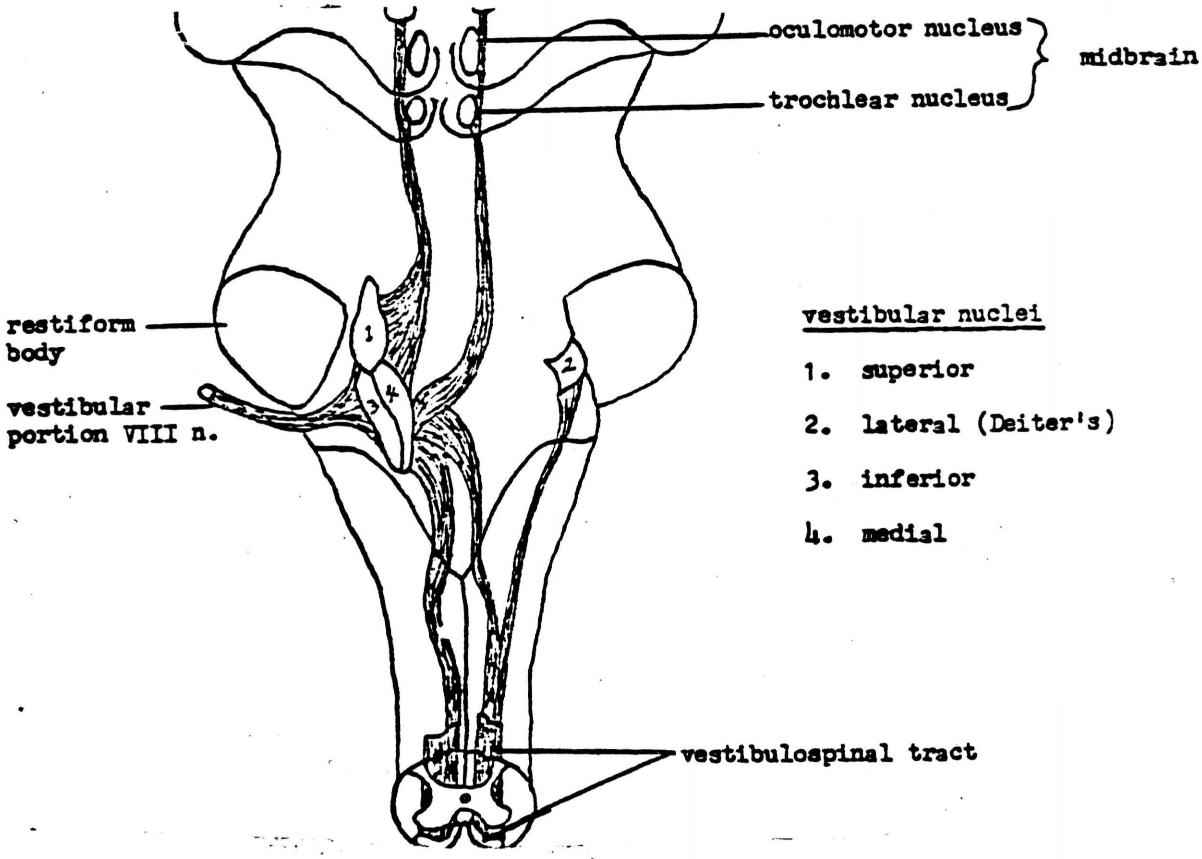


Fig. 14b. Vestibular Afferents

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST I

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

REVIEW TEST II

DIRECTIONS: Select the correct answer from Column B. Place the letter of the correct response on the appropriate line under Column A.

COLUMN A	COLUMN B
1. ___cristae	A. located on the floor of the 4th ventricle
2. ___vestibular apparatus	B. pear shaped nerve
3. ___supula	C. sensory epithelium
4. ___utricular macula	D. receptor in semicircular duct
5. ___Type I hair cells	E. located below the utricle
6. ___endolymph	F. located in temporal bone
7. ___otolith	G. sensory portion of the vestibular apparatus
8. ___vestibular nuclei	H. parallel to ground
9. ___saccule	I. concerned with hearing
10. ___Type II hair cells	J. fluid within vestibular apparatus
11. ___macula	K. contains hair cells from cristae
12. ___semicircular ducts	L. cylindrical-shaped
	M. defined as rock-like crystals

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. D
2. F
3. K
4. H
5. B
6. J
7. G
8. A
9. E
10. L
11. C
12. G

REFERENCES:

Guyton, A. C. Textbook of medical physiology. Philadelphia: W. B. Saunders Company, 1971.

Kilday, B. The vestibular system. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instruction Module II, Part II on pages 56-59. When you complete this activity, retake Review Test II. When you have answered all questions correctly, proceed to Part III.

TURN TO THE NEXT PAGE

PART III

The vestibular afferents enter specific regions of each of the vestibular nuclei. Some vestibular afferents bypass these nuclei and terminate in the cerebellum. The afferents from the utricle project to the lateral (Deiter's) and descending vestibular nuclei, while those from the semicircular ducts project to the superior and medial nuclei.

Vestibular nuclei receive numerous other afferent projections from mesencephalon, cerebellar nuclei, spinovestibular fibers, cerebelloreticular fibers and joint afferents primarily from upper cervical and proximal limbs (see fig. 15). The joint afferents are not mediated by the cerebellum and probably not by the reticular formation:

> The absence of Ia muscle afferents in the vestibular nuclei (in contrast to the presence of joint afferents) has been confirmed. (Willis, 1977, p. 251)

The vestibular nuclei project to the spinal cord, cerebellum, extrinsic eye muscles, reticular formation, contralateral vestibular nuclei and the cerebral cortex. This connection with the extrinsic eye muscles has been important in observing the function of the vestibular apparatus.

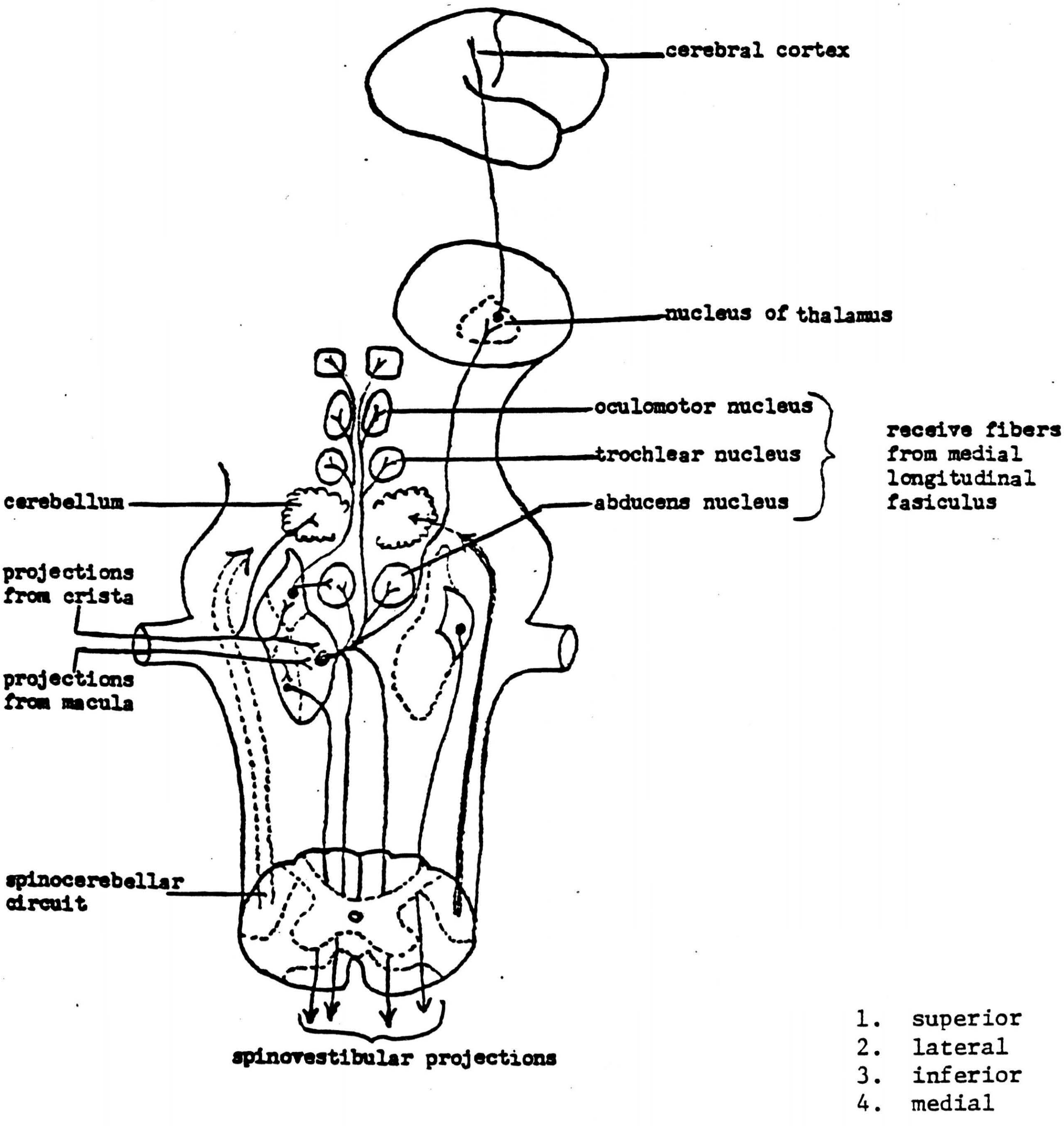


Fig. 15. Vestibular Afferents

The three major descending circuits from the vestibular complex are vestibulospinal, reticulospinal and medial longitudinal fasiculus (MLF) (see fig. 16b). These descending circuits have both crossed and uncrossed components: spinal termination of these tracts is predominantly on interneurons. Studies indicate there are stronger connections from the vestibular complex influencing the cervical area as compared to other regions of the cord.

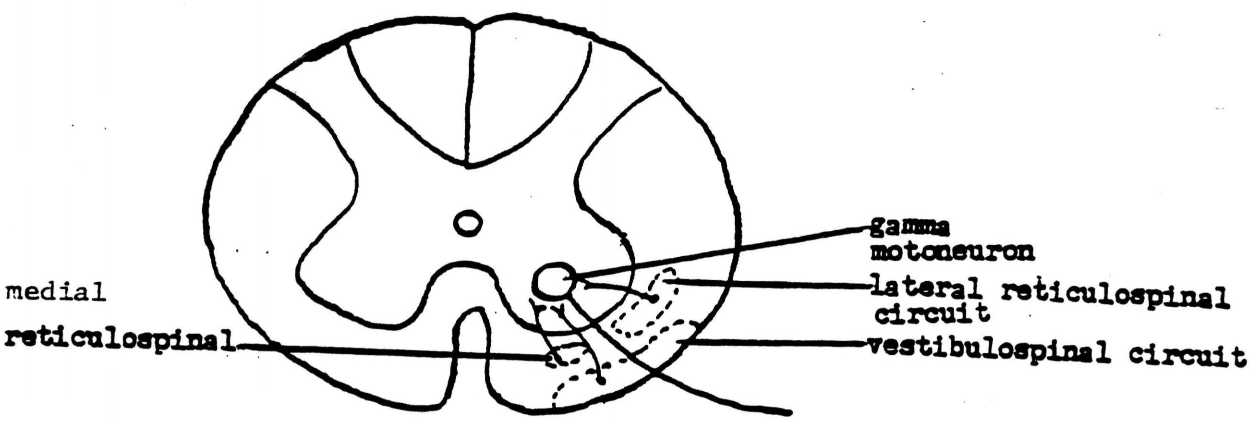


Fig. 16a. Cross-Section
Lumosacral Enlargement

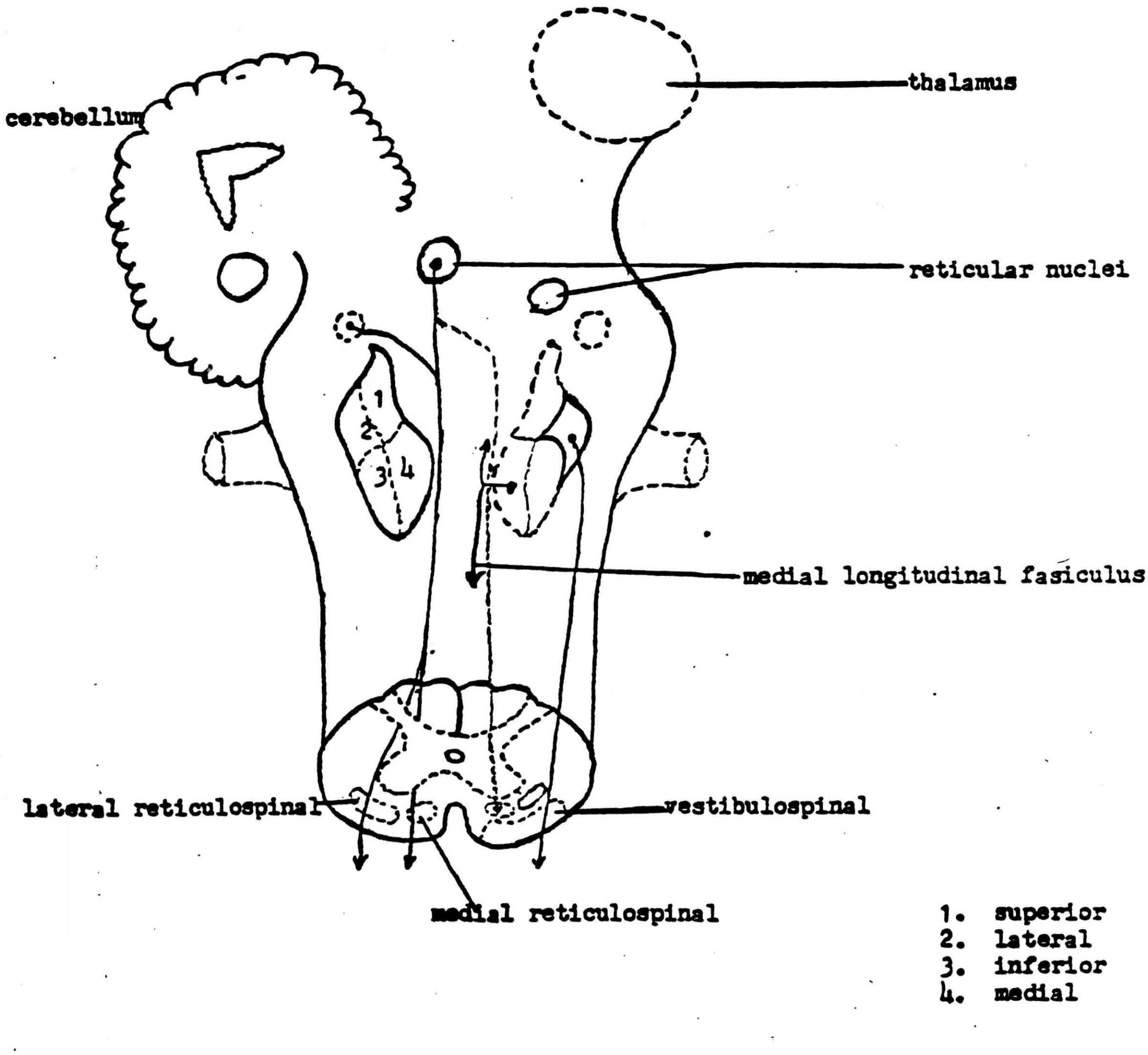


Fig. 16b. Three Major Descending Circuits

> Ontogenetically, vestibular function is said to be the second earliest appearing sensory perception, just after oral tactile function. (Weeks, 1979, p. 376)

This prenatal development of the vestibular system enables the infant to prepare to orient himself in space and overcome the effects of gravity postnatally. The vestibular system, and especially the otoliths, may be uniquely important among all of the sensory organs in the development of normal integrative functions of the brain, especially the cerebellum. On this basis, it is argued that any genetic or environmental factors which alter the normal development or maintenance of this elaborate internal guidance system may affect the development of early locomotor functions.

The function of the vestibular apparatus is defined by Willis (1977) as "a sensory receptor that detects the position of the head and changes in the position of the head in space" (p. 247). The vestibular apparatus monitors both position and changes in position of the head. Changes in static position are monitored by the otoliths and acceleration is detected by the semicircular canals.

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST III

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

REVIEW TEST III

DIRECTIONS: Listed below are questions on the physiology of the vestibular system. Complete the following statements by providing the appropriate word in the space provided.

1. Afferents from the utricle project to the ____________ and ________________ vestibular nuclei.
2. The vestibular nuclei's projection to the ____________ ________________ has been important in observing the function of the vestibular system.
3. Interruption in the development of the vestibular system may result in delayed ______________________________ development.
4. Changes in static position of the head are monitored by the __________________________.
5. Changes in acceleration of the head are monitored by the ___________ _____________.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. lateral

   descending

2. extrinsic eye muscles

3. motor

4. otoliths

5. semicircular canals

REFERENCES:

Kilday, B. The vestibular system. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Kornhuber, H. H. The vestibular system and the general motor system. The holding function of the vestibular system. Handbook of Sensory Physiology, 1968, 6(1), 583-585.

Willis, W. D., Jr., & Grossman, R. G. Medical neurobiology. St. Louis: C. V. Mosby Company, 1977.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional Module II, Part III on pages 62-66. When you have answered all questions correctly, proceed to Part IV.

TURN TO THE NEXT PAGE

PART IV

> Erway postulates that genetic, nutritional and other environmental factors affecting the development and maintenance of otoliths may be critical to brain development and sensory perception. Normally functioning otoliths provide reference to gravity and a system for monitoring movement which make them important in spatial perception development. (Weeks, 1979, p. 376).

". . . adequate vestibular function may be basic to emotional stability" (Weeks, 1979, p. 452). Studies have been done by Fish, Hagin, and Erway to demonstrate a relationship between vestibular functioning and schizophrenia. Abnormal responses to vestibular stimulation include: nystagmus irregularities, poor ability to dissociate head and eye movements and defective righting reflexes.

Magnesium and zinc relate to otolith development and show therapeutic effects on the behavior of schizophrenic persons. "Erway proposes that such magnesium and zinc elements might be essential for normal formation and function of human otoliths" (Weeks, 1971, p. 453).

The utricle and saccule function in detecting the position of the head in space and respond to linear movement as opposed to the semicircular canals which respond to angular acceleration. The utricle detects horizontal movements and the saccule vertical ones such as jogging.

The saccule is also thought to monitor low frequency vibrations. "The afferent fibers of the utricular macula are stimulated whenever the otolithic membrane is shifted with respect to the sensory epithelium" (Willis, 1977, p. 249). Most of the afferents spontaneously discharge when the head is in an upright position. Any change in head position will cause some utricular afferents to increase and others to decrease their firing rates. Hyperpolarization occurs when vestibular hairs move causing axons of neighboring neurons to be more negative. This decreases the firing rate. When the hairs move in the opposite direction the axons become less negative resulting in depolarization and increased firing rate (Parker, 1980).

The semicircular ducts detect angular acceleration of the head. When the head rotates, the inertia of the endolymph withing one or more pairs of semicircular ducts causes a relative movement of the endolymph in the direction opposite that of the head. The afferents from a given semicircular duct are most sensitive to movements in the plane of the duct.

> The vestibular system tells you whether any sensory input, visual, tactile, or proprioceptive is associated with movement of the body or a function of the external environment, i.e., are you spinning, or is the room spinning? (Kilday, 1980, p. 19)

In addition to providing information regarding the position of the head in space, the vestibular system functions through reflex activity to stabilize eyes, head and body in space.

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST IV

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

REVIEW TEST IV

DIRECTIONS: Listed below are five questions on the physiology of the fusimotor system. Complete statement 1 through 4 by providing the appropriate word in the space provided. Complete statement 5 by circling the appropriate response.

1. The elements ____________________ and ________________ are thought to relate to normal development of the vestibular system.

2. The two vestibular receptors that detect position of the head in space are the ____________________ and the ____________________.

3. A maintained change in position is monitored by the ____________________.

4. Angular acceleration of the head is detected by movement of _________________ in the semicircular canals.

5. The afferent fibers of the utricle are slowly or rapidly adapting.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. magnesium

   zinc

2. otolity

   utricle

3. utricle

4. endolymph

5. slowly

REFERENCES:

Kilday, B. The vestibular system. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Parker, D. E. The vestibular apparatus. Scientific American, 1980, 243(5), 118-132.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional module II, Part IV on pages 69-71. When you complete this activity, retake Review Test IV. When you have answered all questions correctly, proceed to Part V.

TURN TO THE NEXT PAGE

PART V

The kinetic labyrinth signals movement of the head and has special relation to ocular movements for maintenance of visual orientation. The static labyrinth signals the position of the head in space, influencing muscle tone throughout the body in relation to balance.

Nystagmus is an involuntary movement of the eyeballs slowly in one direction and rapidly in the opposite direction. This phenomenon is observed following rotation of the head and results from: stimulation of the semicircular canals, visual input, or brain disorder (Ayres, 1975). This reflects function of the extraocular muscles which is critical in perceiving the accurate relationship between bodily motion and the visual fields (Ayres, 1975). The analysis of this vestibulo-ocular reflex arc (nystagmus) is used to assess the functioning of the vestibular system.

> The postrotatory nystagmus reflex (vestibulo-ocular reflex) response reflects the effects of any CNS inhibitory mechanism such as that active in producing vestibular habituation. (Kanter, 1976, p. 416)

Ayres (1975) has developed a standardized test called the Southern California Post Rotatory Nystagmus Test, which is only standardized for boys and girls ages 5 through 9. Although no standardization has been done with adults, a study was reported by Van Der Laan and Oosterveld (1974) which showed increased frequency of nystagmus from young to middle age and a sudden decrease in frequency in the geriatric population.

Nystagmus accommodates rapidly upon stimulation; this phenomenon is called inhibition. Studies have shown this inhibition in proficient figure skaters as compared to ballet dancers who are dependent on using ocular fixation. "It appears that the lack of ocular fixation in the skaters while spinning led to more complete vestibular suppression than in dancers who fixated" (Weeks, 1979, p. 378).

Associated with nystagmus may be dizziness, which is caused by stimulation of inner ear hair receptors by slanting of endolymph in the semicircular canals. Nausea may also be associated with nystagmus and is explained by disordered sensory input affecting the autonomic nervous system. Other associated reactions may include: altered gait, decreased head control, vertigo, alarm, and palor or flushing. These may occur in varied degrees from subject to subject.

It is important to note at the end of this discussion that there is also controversy regarding the importance of the vestibular system in detecting the position of the head in space. Wycke (1980) states that in quadripeds the system is dominant, but in bipeds the cervical joints override the vestibular system. He cites experiments in which the cervical epophyseal joints were infiltrated with local anesthetic resulting in nystagmus, nausea, vomiting, and altered gait.

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST V

THE ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

REVIEW TEST V

DIRECTIONS: Listed below are four questions on the physiology of the vestibular system. Complete the following statements by providing the appropriate word in the space provided.

1. The _________________ system functions to tell whether sensory input is associated with movement of the body or a function of the external environment.
2. The vestibulo-ocular reflex (nystagmus) is commonly used to assess _________ _________.
3. The ____________________ in the horizontal semicircular canal is the receptor responsible for nystagmus.
4. Overstimulation of the vestibular system may result in nausea and vomiting which demonstrates the effect of the vestibular system on the _________________ system.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. vestibular
2. vestibular functioning
3. cupula
4. autonomic nervous

REFERENCES:

Ayres, A. J. Southern California postrotatory nystagmus test. Los Angeles: Western Psychological Services, 1975.

Kanter, R. M., Clar, D. L., Allen, L. C., & Chase, M. F. Effects of vestibular stimulation on nystagmus response and motor performance in the developmentally delayed infant. Physical Therapy, 1976, 56, 414-421.

Van Der Laan, F., & Oosterveld, W. Age and vestibular function. Aerospace Medicine, 1974, 45, 540-547.

Weeks, Z. R. Effect of vestibular system on human development, Part I. Overview of functions and effects of stimulation. American Journal of Occupational Therapy, 1979, 33(6), 376-381.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing the instructional Module II, Part V on pages 74 and 75. When you complete this activity, retake Review Test V. When you have answered all questions correctly, proceed to Module III.

TURN TO THE NEXT PAGE

INSTRUCTIONAL MODULE III

INTERRELATIONSHIPS BETWEEN THE VESTIBULAR AND FUSIMOTOR SYSTEMS

OBJECTIVES:

Upon completion of this section of the instructional package, the student will be able to

1. Contrast reflexes mediated by the fusimotor system with those mediated by the vestibular system

2. List vestibular pathways that influence the fusimotor system

3. List the roles of vestibular versus fusimotor sys- systems

ACTIVITIES:

Complete the following activities:

1. Read the following module

2. If you wish to read supplementary material on the interrelationships between the vestibular and fusimotor systems, see the following list:

Gernandt, B. E. Vestibulo-spinal mechanisms. _Handbook of Sensory Physiology_, 1968, _6_(1), 541-564.

Kilday, B. _The vestibular system_. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Kornhuber, H. H. The vestibular system and the general motor system II. The holding function of the vestibular system. Handbook of Sensory Physiology, 1968, 2(1), 583-585.

Pompeiano, D. Spinovestibular relations: anatomical and physiological aspects. Progressive Brain Research, 1972, 37, 601-618.

Weeks, Z. R. Effect of vestibular system on human development, Part I. Overview of functions and effects of stimulation. American Journal of Occupational Therapy, 1979, 3396), 376-381.

Willis, W. D., Jr., & Grossman, R. G. Medical neurobiology. St. Louis: C. V. Mosby Company, 1977.

3. There are four review tests associated with Module III.

TURN TO THE NEXT PAGE AND BEGIN MODULE III, PART I

PART I

The receptors for tonic neck reflexes are located in the joints of the neck. The asymmetrical reflex is activated when the head is turned, eliciting increased extensor tone in the ipsilateral arm and increased flexor tone in the contralateral arm. The symmetrical tonic neck reflex is activated by flexion and extension of the head. When the head is flexed, flexor tone is increased in arms and extensor tone is increased in the legs. When the head is extended, the opposite reaction is elicited.

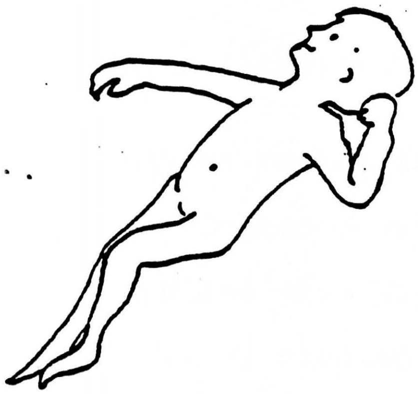


Fig. 17a. Asymmetrical Tonic Neck Reflex

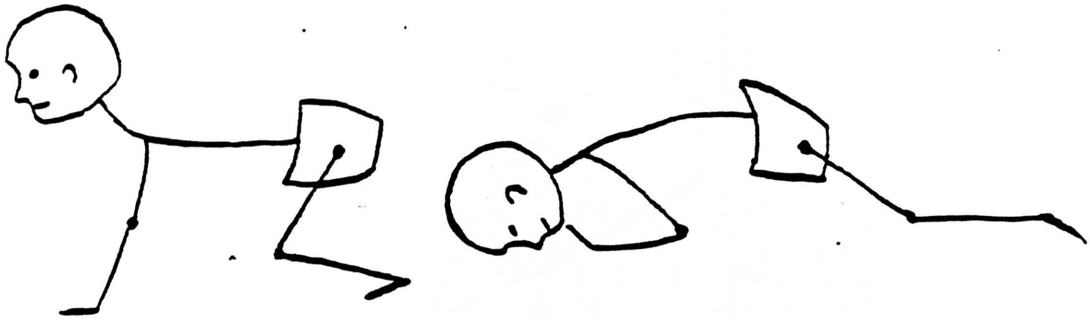


Fig. 17b. Symmetrical Tonic Neck Reflex

In response to the earth's gravitational pull, the tonic labyrinthine reflex is elicited. This is demonstrated by increased flexor tone when the head is prone and increased extensor tone when the head is supine.

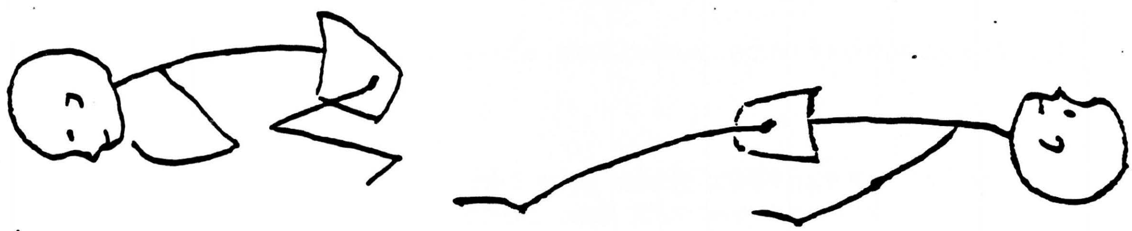


Fig. 18. Tonic Labyrinthine Reflex

Another important labrinthine reflex is the tilting or tipping reflex. This is elicited by way of the labyrinth through propriceptive impulses when the subject is suddenly taken off his balance by tipping or tilting the object on which the subject is seated.

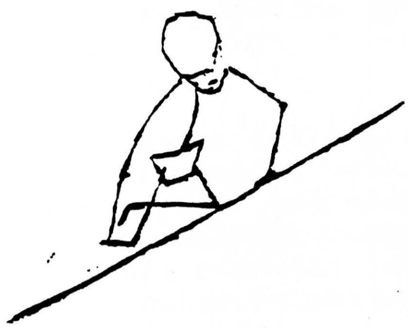


Fig. 19. Tilting Reflex

> In higher vertebrates that have a freely moving head, the labyrinths indicate body position only in conjunction with the afferents from the neck receptors. Therefore the vestibular afferents cannot be used as a stabilizing feedback signal for body position unless the position of the head relative to the body is taken into account. (Kornhuber, 1973, p. 584)

The neck reflexes are the exact opposite of the labyrinthine tilting reflexes which depend on the vertical channels and otoliths. The neck reflexes are independent of the cerebellum:

> Magnus, who discovered the neck reflexes, failed to appreciate this fact and his erroneous functional interpretations of the neck reflexes persist in physiological textbooks up to the present. (Kornhuber, 1973, p. 583)

Righting reactions enable the development of postural responses in order for an organism to master gravity. These reactions serve to align the head and body with the earth's surface so the organism is in a position for locomotion. The labyrinthine component of the righting reflexes is a function of the semicircular ducts and the otoliths (Willis, 1977).

The following statement relates the vestibular apparatus to motor pathways:

> The vestibular organs can influence spinal motor outflow via direct descending vestibulofugal circuits, the vestibulospinal and medial longitudinal fasiculas (MLF); via indirect channels the reticulospinal and pyramidal circuits including the cerebellum, the reticular formation, and some

> unidentified subcortical relay stations. (Gernandt, 1973, p. 479)

Outflow from the vestibular mechanism is influenced by the position of the head influencing eye coordination. These vestibular impulses also reach alpha directly via vestibulospinal circuits. They also impinge on the fusimotor system because their outflow also goes through the reticular formation (Gernandt, 1968). This impingement on alpha and gammas is a postural control mechanism.

RELATIONSHIPS BETWEEN THE VESTIBULAR

AND FUSIMOTOR SYSTEMS

REVIEW TEST I

DIRECTIONS: Listed below are five questions on the relationships between the vestibular and fusimotor systems. Complete statements 1 through 3 by providing the appropriate word in the space provided. List the requested information for question 5.

1. The stimulus for the tonic labyrinthine reflex is ________________.

2. Because of the ________________ reflexes, head position must be considered for the labyrinths to stabilize body position.

3. The ________________ and ________ ________ are responsible for the labyrinthine component of the righting reflexes.

4. Name the vestibulofugal circuits.

5. The _______ _______ and ________________ reflexes are mediated by the vestibular nuclei.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. gravity
2. neck
3. otoliths

   semicircular ducts
4. MLF

   vestibulospinal
5. vestibular labyrinthine

   tonic neck

REFERENCES:

Kornhuber, H. H. The vestibular system and the general motor system II. The holding function of the vestibular system. _Handbook of Sensory Physiology_, 1968, _2_(1), 583-585.

Willis, W. D., Jr., & Grossman, R. G. _Medical neurobiology_. St. Louis: C. V. Mosby Company, 1977.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing instructional Module III, Part I on pages 80-83. When you have completed this activity, retake Review Test I. When you have answered all questions correctly, proceed to Part II.

TURN TO THE NEXT PAGE

PART II

The vestibular mechanism influences or excites the reticular formation via the semicircular canals. Vestibular stimulation leads to gross activation of the bulbar reticular formation that is known to control not only the amplitude and pattern of motor reflex phenomenon but also to regulate incoming sensory activity.

The reticulospinal tract descends both ipsilaterally and contralaterally. In general, the major effect of this tract is facilitation of extensor motoneurons. High extension tone, such as that seen in decerebrate rigidity, may result if this tract is not sufficiently inhibited.

The MLF originates in the medial vestibular nucleus and terminates at midthoracic level. No monosynaptic connection has been found between the MLF and spinal motoneuron. This tract evokes a much weaker effect on the spinal cord than do the reticulospinal and vestibulospinal tracts.

Experiments by Anderson and Gernandt (1956) have indicated that the muscles are activated prior to stronger stimulation (descending from vestibular volleys) evoking coactivation of alpha and fusimotor discharge. It has been concluded from these studies that vestibular stimulation effects on the gamma loop do not provide the alpha motoneuron with an input that is essential for extrafusal contraction. However, it is often the case that the nervous system solves problems by both approaches and does not rely on either circuit exclusively:

> The gamma loop seems to function as a sensitizing or priming device in concert with the direct monosynaptic vestibular coupling and not as a triggering device. Alpha control is probably employed when speed is essential whereas gamma signals a smooth, continuous control. (Gernandt, 1968, p. 542)

Kempinsky and Word (Gernandt, 1968) concluded that

> afferent impulses from the vestibular system help to maintain facilitory background activity. It is known that some afferent support is needed for the central nervous system to produce movement. It is thought this afferent support comes from the vestibular system. (p. 542)

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST II

RELATIONSHIPS BETWEEN THE VESTIBULAR

AND FUSIMOTOR SYSTEMS

REVIEW TEST II

DIRECTIONS: Listed below are five questions on the relationships between the vestibular and fusimotor systems. Complete statements 1 through 4 by providing the appropriate word in the space provided. Circle the appropriate word in parentheses in statement 5.

1. The bulbar reticular formation may be activated by

   ______________ ________________.

2. The vestibulospinal tract originates in the _________ ________________ nucleus.

3. The reticulospinal tract is facilitory to __________.

4. The MLF terminates at the ____________________ level.

5. (Speed or control) is the responsibility of the alpha system whereas the fusimotor system is responsible for (speed or control).

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. vestibular stimulation
2. lateral vestibular
3. extension
4. mid-thoracic
5. speed

   control

REFERENCES:

Gernandt, B. E. Vestibulo-spinal mechansims. _Handbook of Sensory Physiology_, 1968, _6_(1), 541-564.

Pompeiano, D. Spinovestibular relations; anatomical and physiological aspects. _Progressive Brain Research_, 1972, _37_, 601-618.

RESEARCH:

Note your incorrect responses and clarify your responses by reviewing instructional Module III, Part II on pages 86 and 87. When you have completed this activity, retake Review Test II. When you have answered all questions correctly, proceed to Part III.

TURN TO THE NEXT PAGE

PART III

The labyrinth has no sensation of its own but effect other modalities. This is exemplified by inner ear infections which cause dizziness, nausea, and decreased equilibrium. Injury to the labyrinth causes hypotonia in the neck, limb and trunk musculature, disturbed action of the eye muscles, disordered movements, equilibrium problems, and emotional and autonomic disturbances.

It has been noted in patients with idiopathic scoliosis that there is a tendency for altered nystagmus response including spontaneous nytagmus and elicitation of nystagmus response with change in head position alone. "Postural control information is transferred to the spinal cord through the vestibulospinal and reticulospinal tracts" (Pompeiano, 1972, p. 616). Skeletal muscle tone can be changed through vestibular stimulation or pathology through these tracts.

Gellhorn (1964) cites evidence for relating emotional state and the activity of striated muscle. Emotions cause changes in tonic and phasic muscle activity, the tonic activity appearing as postural changes and phasic activity as facial muscle contraction.

Tests done for vestibular integrity include the balancing test (Rhomberg's sign), cupulogram of postrotatory nystagmus (Barany test), caloric test, and reflex testing. The balancing test is done by having the subject stand still with his eyes closed. If the utricles are not intact, he will waiver or fall.

The cupulogram of postrotatory nystagmus or Barany Test is done by rapidly rotating the subject while his head is placed in various planes. When the rotation of the chair is stopped, the endolymph continues to rotate causing the cupula to bend, resulting in nystagmus.

Ayres (1975) has developed a standardized postrotatory nystagmus test for children aged five through nine. This test uses a scooter board and observes nystagmus time after spinning 10 times in 20 seconds. Other observations noted while testing include balance while turning, head control, vertigo, dizziness, nausea, alarm or threat, pain, flushing, and pleasure from rotation.

Following irrigation of the right ear with cold water (up to 10° C) with the subject seated and the head tilted back to 60°, the responses of nausea, horizontal nystagmus, past pointing to the left and falling to the right will occur in normals. Absence of reaction of diminished response is indicative of vestibular nerve injury. This is known as the Caloric Test:

> The difference between the two forms of stimulation-rotational and caloric are: rotation suddenly stimulates both labyrinths, whereas in the caloric test there is a gradual stimulation of only one labyrinth. Thus, caloric stimulation permits determination of which labyrinth is affected and estimates from the duration of the nystagmus the degrees of impairment. (Kilday, 1980, p. 2)

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST III

RELATIONSHIPS BETWEEN THE VESTIBULAR AND FUSIMOTOR SYSTEMS

REVIEW TEST III

DIRECTIONS: Listed below are six questions on the relationships between the vestibular and fusimotor systems. Complete statements 1 and 2 by providing the appropriate word in the space provided. List the requested information for questions 3 through 6.

1. The Rhomberg or balancing test measures integrity of the ________________________.

2. The Caloric or irrigation test is used to detect injury to the ____________________ ____________________.

3. List three (3) symptoms of injury to the labyrinth.

   (1)

   (2)

   (3)

4. How is the Rhomberg or balancing test performed?

5. Give the normal responses of the Caloric test.

6. What is the advantage of caloric testing over rotary testing?

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. utricles

2. vestibular nerve

3. Any three of the following:

   hypotonia (neck, limb, trunk)

   nystagmus

   disordered movements

   equilibrium disturbances

   emotional disturbances

   autonomic disturbances

4. The subject is asked to stand with eyes closed

5. nausea

   nystagmus

   past pointing

   falling to ipsilateral side

6. isolates damage to one labyrinth (right versus left)

REFERENCES:

Ayres, A. J. Southern California postrotatory nystagmus test. Log Angeles: Western Psychological Services, 1975.

Kilday, Betsy. The tactual and kinesthetic systems. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Pompeiano, D. Spinovestibular relations: Anatomical and physiological aspects. Progressive Brain Research, 1972, 37, 601-618.

Weeks, Z. R. Effect of vestibular system on human development, Part I. Overview of functions and effects of stimulation. American Journal of Occupational Therapy, 1979, 33(6), 376-381.

RECHECK:

Note your incorrect responses and clarify your responses in reviewing instructional module III, Part III on pages 90-92. When you complete this activity, retake Review Test III. When you have answered all questions correctly, proceed to Part IV.

TURN TO THE NEXT PAGE

PART IV

The reflex portion of vestibular testing looks at the maturation of primitive reflexes, notes postural mechanisms, and is based on the developmental sequence. The subject is placed in positions that attempt to elicit the asymmetrical tonic neck reflex (ATNR), symmetrical tonic neck reflex (STNR), and tonic labyrinthine reflex (TLR). The observer should take into account the subject's position in relation to gravity and should note whether or not these reflexes are overriding his nervous system. The inability to inhibit these primitive reflexes demonstrates a lack of central integration. Even if the reflexes are not obligatory, discrete changes in tone should be noted.

The past pointing test for vestibular influence on muscle tone is performed by asking the subject to close his eyes and lift the arm up and down, pointing to the same spot each time. An abnormal response is observed when the arm moves from side to side.

Another observation that should be made is how the subject reacts to moving through space, i.e., is the subject afraid to move backward? Frequently, when there is vestibular damage, the subject will rely on higher cortical areas of vision to compensate for not having the vestibular input informing him of where his body is in space.

There are several clinical manifestations that are known to be effected by vestibular stimulation. The clinical effects on eye movement disorders and disturbed visual perception are: normalizing visual processing, improving postural base for eye movements, normalizing proprioceptive feedback, and improving strength/coordination of skeletal muscles. Vestibular stimulation is used to enhance auditory discrimination, facilitate vocalization and lateralization in auditory-language learning disabilities. These disabilities may be a major contributor to inadequate hemispheral specialization.

> Fish (1965), Fish and Hagin (1973) and Erway (1975) have done studies relating vestibular influences in emotional disturbances. Most work in this area has dealt with schizophrenia. It is thought that adequate vestibular function may be needed for emotional stability. It has been reported (Fish, 1965), that children later diagnosed as schizophrenic demonstrated early delayed postural development and poor neurologic integration. Schizophrenic and pre-schizophrenic individuals have also been reported to have visual-motor disturbances. Erway (1975) uses abnormal response to vestibular stimulation in schizophrenic individuals to support the theory of impaired vestibular function in these individuals. (Weeks, 1979, p. 380)

Numerous research studies are being performed on vestibular stimulation of normal and high-risk infants. The effects known to date are changes in muscle tone, facilitation of hand-to-mouth behavior, facilitation of oral functions, decreased frequency of apnea, and facilitation of visual focus and tracking.

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST IV

RELATIONSHIPS BETWEEN THE VESTIBULAR

AND FUSIMOTOR SYSTEMS

REVIEW TEST IV

DIRECTIONS: Listed below are five questions on the relationships between the vestibular and fusimotor systems. Complete statements 1 through 3 by providing the appropriate work in the space provided. List the requested information for questions 4 and 5.

1. The inability to inhibit primitive reflexes shows a lack of __________ __________.

2. ______________________________ is used to compensate for lack of vestibular input.

3. Work with schizophrenic patients indicates a strong relationship between the vestibular system and ____________________________.

4. Name the three (3) reflexes observed for overriding of the nervous system.

   (1)

   (2)

   (3)

5. Describe the test used to examine vestibular influence on muscle tone.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. central integration
2. vision
3. emotions
4. ATNR

   STNR

   TLR
5. Pointing with eyes closed to the same spot.

REFERENCES:

Ayres, A. J. Sensory integration and learning disorders. Western Psychological Services, 1973.

Kilday, B. The tactual and kinesthetic systems. Unpublished paper received in Advanced Neuroanatomy, Texas Woman's University, Dallas, Texas, Spring, 1980.

Weeks, Z. R. Effect of vestibular system on human development, Part II. Effect of vestibular system on mentally retarded, emotionally disturbed and learning disabled individuals. American Journal of Occupational Therapy, 1979, 33(7), 450-457.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing instructional Module III, Part IV on pages 96 and 97. When you complete this activity, retake Review Test IV. When you have answered all questions correctly, proceed to Module IV.

TURN TO THE NEXT PAGE

INSTRUCTIONAL MODULE IV

TREATMENT TECHNIQUES USED BY PHYSICAL AND OCCUPATIONAL THERAPISTS TO INTEGRATE THE FUSIMOTOR AND VESTIBULAR SYSTEMS

OBJECTIVES:

Upon completion of this section of the instructional package, the student will be able to

1. List indications for vestibular stimulation

2. List contraindications for vestibular stimulation

3. Document the need for further study regarding the use of vestibular stimulation with adults

4. Select methods of vestibular stimulation for selected cases

ACTIVITIES:

Complete the following:

1. Read the following module

2. If you wish to read supplementary material on treatment techniques which might suggest the integration of the fusimotor and vestibular systems, see the following list:

Ayres, A. J. Sensory integration and learning disorders. Los Angeles: Western Psychological Services, 1973.

Kanter, R. M., Char, D. L., Allen, L. C., & Chase, M. F. Effects of vestibular stimulation on nystagmus response and motor performance in the developmentally delayed infant. *Physical Therapy*, 1976, *56*, 414-421.

Montgomery, P. *The vestibular system, instruction syllabus clinical implications for the occupational therapy and physical therapy workshop*: The Vestibular System: April 12 and 13, 1980.

3. There is one review test associated with Module IV.

TURN TO THE NEXT PAGE AND BEGIN MODULE IV, PART I

PART I

One of the most frequent uses of vestibular stimulation is directed at the "normalization of postural mechanism by inhibition of primitive postural reflexes and activation of righting and equilibrium reactions" (Weeks, 1971, p. 433). Normalization of muscle tone and postural reflexes is often a treatment objective in patients sustaining cerebral vascular accidents (CVAs). This is necessary to achieve improved functional gait. In a group of patients sustaining cerebral vascular accidents (CVAs), Fiebert and Brown have noted greater functional gait after the use of vestibular stimulation.

> Muscle tone is enhanced and the increased facilitory effect on the intrafusal fibers of the muscle spindle prepares the nervous system for easier activation in subsequent activity. (Fiebert, 1979, p. 423)

Sensory integrative therapy is based on the following principles:

> Therapy consists of experience specifically planned to control sensory input and elicit output that will bring about more normal function, especially at the brain stem level. Response to primitive reflex inhibition is not immediate and may take three weeks for permanent change to occur. The two basic principles employed are recapitulation of the pertinent ontogenetic sequence and control of sensory input in a situation conducive to its integration and adaptive responses to it. (Ayres, 1974, p. 10)

Reflex inhibiting activities should be preceded by activities to normalize muscle tone. Normal tone is a prerequisite for appropriate motor response. It is necessary to decrease muscle tone in muscles receiving excess innervation because of the tonic labyrinthine reflex.

The following technique can be used to normalize muscle tone:

> When a muscle is placed in its lengthened position for several seconds, it tends to reduce its tension. At the same time, the muscle spindles in that muscle will be "re-set" or biased so that there will be less sensory flow over the primary afferent from the spindle and therefore less sensory facilitation of contraction of the muscle. (Ayres, 1973, p. 147)

The technique of spinning is used by Ayres (1973):

> Passive vestibular stimulation is most effectively given by swinging or spinning a child while he is lying or sitting in a net hammock. Active involvement develops adaptive responses which in turn organize the sensory stimuli. Children with diminished response to vestibular stimuli generally should start treatment with as much rapid spinning as they desire and as the brain can tolerate. (p. 119)

The benefits of such vigorous stimulation can be explained as follows:

> The vestibular input resulting from rapid spinning might influence the body in the following ways. Synapses which normally are made as a result of vestibular input and are not being made in the child with dysfunction are activated. Muscle tone is enhanced and the increased facilitory effect on the intrafusal fiber to the muscle spindle prepares the nervous system for easier

> activation of the alpha motoneuron supply in the skeletal muscles in subsequent activity. (Ayres, 1973, p. 121)

There are several ways to inhibit the TLR. Use the prone position in the hammock with shoulders, hips and extended legs in a supported position. To incorporate the vestibular stimulation in inhibiting the flexor muscles further, have the person swing in the hammock. Another procedure to inhibit the TLR is the use of a scooter board and a ramp:

> The accelerated motion resulting from going down the ramp apparently stimulates the vestibular system which in turn reflexly facilitates an arched back position. The excitement of the task and its purposefulness encourage emotional involvement which seems to enhance the desired response. (Ayres, 1973, p. 148)

A suspended net hammock can be used to integrate the TLR:

> Spinning a child who is lying supine in the suspended net hammock, head and legs extending beyond the net, will reflexly activate a flexor position in neck and extremities, the arms flexing to hold onto the net. Centrifugal force increases resistance to flexion. Holding the head up for a prolonged period of time while in the supine position requires much more effort than in the prone position. (Ayres, 1973, p. 146)

A large inner tube can be hung with the hole in a vertical position.

> The prone extensor posture is facilitated through motion and in connection with activating equilibrium reactions when the child lies across and

> through the hole of the inner tube. Turning the inner tube so that it winds up and letting it unwind provides the motion to stimulate the vestibular system. (Ayres, 1973, p. 149)

Another children's activity is to have the child sit on a scooter board:

> Which is a pretend canoe and pushes himself with a plumber's helper. The child looks away from the stick which is held to the side of the canoe and in the direction toward which he is rowing, thereby rotating the head and eliciting the TNR which is integrated through extension in the arm in which flexion is reflexly facilitated. (Ayres, 1973, p. 152)

Rolling in several inner tubes tied or taped together is effective in using the neck righting reflex. It also generates greater vestibular stimulation than the hammock or the scooter board.

The vestibular sensations evoked by the use of a large therapeutic ball contribute to the promotion of equilibrium reactions in the prone or supine position; a barrel could be substituted for the ball. It should be mentioned during the discussion of Ayres' techniques that these are used with children. Care should be taken in applying these techniques to all ages but increased caution should be taken with neurologically involved adults whose previous memory of movement can cause complete "shutdown" or extremely high tone when these vigorous techniques are used. Due to decreased plasticity of the nervous system with increased age, vestibular stimulation may not be as effective with adults.

Rocking contributes to postural development both in equilibrium reactions and muscle tone. Slow rocking encourages relaxation. Vertical rocking has been found to be more effective than horizontal rocking. Fast rocking in the various developmental patterns excites the vestibular system, producing facilitory effects. Slow to moderate rocking is a helpful technique with adults.

As in any other treatment modality, precautions must be a major concern. Be aware that equipment and/or the treatment situation can be threatening to the individual, especially to the adult. Fear should be decreased by using slow, non-threatening approaches to vestibular stimulation:

> Movement, especially in rapid acceleration that activates the vestibular system, is generally exciatory. When the excitement that comes from vestibular arousal of the ascending reticular system is added to the excitement arising from emotional reaction to the activity, a labile nervous system may become so excited that it can no longer handle the immediate situation and behavior control breaks down. If behavior cannot be brought to an acceptable level within a few minutes after termination of the treatment period, the last of the therapeutic session should be devoted to inhibitory stimulation. (Ayres, 1973, p. 120)

TURN TO THE NEXT PAGE AND ANSWER REVIEW TEST I

TREATMENT TECHNIQUES USED BY PHYSICAL AND OCCUPATIONAL THERAPISTS TO INTEGRATE THE FUSIMOTOR AND VESTIBULAR SYSTEMS

REVIEW TEST I

DIRECTIONS: Listed below are five questions on the clinical application of vestibular stimulation. Complete statements 1 through 4 by providing the appropriate word in the space provided. List the requested information for questions 4 and 5.

1. In motor disorders, vestibular stimulation is used to normalize ____________ ____________.
2. Swinging a prone individual in a hammock facilitates ______________________________.
3. At what level of the nervous system are Ayres' methods of vestibular stimulation primarily aimed? ___________
4. Using a "pretend canoe" can aid in integrating which reflex?
5. Name a technique for decreasing muscle tone by biasing the muscle spindle.

FEEDBACK: Check your responses with the answers on the next page.

CHECK

1. muscle tone
2. extension
3. brainstem
4. TNR
5. Placing the muscle in its lengthened position for a few seconds

REFERENCES:

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Weeks, Z. R. Effects of vestibular system on human development, Part II. Effect of vestibular system on mentally retarded, emotionally disturbed and learning disabled individuals. American Journal of Occupational Therapy, 1979, 33(7), 450-457.

RECHECK:

Note your incorrect responses and clarify your responses by reviewing instructional Module IV, Part I on pages 102-106. When you have answered all questions correctly, proceed to Clinical Suggestions.

TURN TO THE NEXT PAGE

CLINICAL SUGGESTIONS

Spinning should be done with close monitoring if a child is prone to seizures. Spinning should be avoided with adults prone to seizures or having cardiac involvement. Autonomic nervous system reactions from overstimulation are flushing, blanching of the face, unusual perspiring, nausea, and yawning.

There are reports of over-inhibition of the brainstem: in one case, the child became cyanotic (Ayres, 1973). Another became unconscious. If such a reaction should occur, a more normal excitatory state can be achieved through excitatory stimuli such as light touch stimuli to feel and face or ice to hands:

> A nervous system which has maintained one organization for many years and then is encouraged to assume a more mature organization will have a tendency to revert back to its previous organization. (Ayres, 1973, p. 127)

There should be periodic evaluation of the primitive postural reflexes and righting and equilibrium reactions to ascertain if these reflexes have remained integrated.

Equipment that can be utilized in vestibular treatment not mentioned previously includes: rocking horse, rocking chair, wedges to lift the head up encouraging the prone extensor posture, playground equipment requiring swinging, rocking, and spinning. The basket chair can be used for individuals who need maximum support.

The Swiss gynmastic ball has many uses with adults. Care should be taken to give the patient either proximal or distal fixation to prevent anxiety.

A group of occupational therapists at the Rehabilitation Institute of Chicago is in the process of standardizing sensory integration tests for adults (Chapparo & Ranka, 1980). Those standardized by Ayres for children are not valid for use with adults.

Chaparro and Ranka (1980) give suggestions for use with adults. The techniques involve moving objects such as checkers from a lower level to the checkerboard at a higher level and on the other side of the body. The same concept can be applied to more active games such as darts. To increase weight bearing on the affected hip, if the patient has sufficient balance, the side sitting position may be used.

The previous treatment techniques are helpful to any therapist interested in vestibular stimulation. Care and creativity need to be taken as with any unfamiliar treatment technique.

IT SHOULD BE MENTIONED THAT CAUTION SHOULD BE EXERCISED IN APPLYING THEORETICAL INFORMATION. THIS CAUTION IS GIVEN DUE TO THE LACK OF CLINICAL

RESEARCH. STUDIES ARE NECESSARY TO CONFIRM THE POSITIVE IMPRESSIONS OF USING VESTIBULAR STIMULATION AS A TREATMENT MODALITY. THE SHORT TERM AND LONG TERM EFFECTS ARE ONLY PARTIALLY KNOWN.

CONGRATULATE YOURSELF! YOU HAVE COMPLETED THE INSTRUCTIONAL PACKAGE AND MAY PROCEED TO THE COMPREHENSIVE POSTTEST.

FUSIMOTOR AND VESTIBULAR SYSTEMS

POSTTEST

DIRECTIONS: Complete the following statement by filling in the blank(s) for questions 1 through 15. List the requested information for questions 16 and 17. Circle the appropriate word in parenthesis in statement 18. Label the illustration in question 19.

1. The ____________________ system is the efferent innervation of the muscle spindle
2. The ascending circuits for the muscle spindle terminate in the ____________________.
3. Applying a rapid stretch and then maintaining the stretch produces a ____________________ response.
4. The patellar reflex is an example of a ____________ reflex.
5. A sensory epithelium is called a ____________________.
6. The ____________________ and ____________________ comprise the sensory organs of the vestibular system.
7. The ____________________ is the part of the vestibular system responsible for hearing.
8. Changes in static position of the head are monitored by the ____________________.

9. Changes in acceleration of the head are monitored by the ________________________.

10. The elements ______________________ and _____________ are thought to relate to normal development of the vestibular system.

11. The __________________ in the horizontal semicircular canal is the receptor responsible for nystagmus.

12. Because of the ___________________ reflexes, head position must be considered for the labyrinths to stabilize body position.

13. The Rhomberg of balancing test measures integrity of the ____________________.

14. _______________________ is used to compensate for lack of vestibular input.

15. In motor disorders, vestibular stimulation is used to normalize ________________________.

16. Give three (3) circuits for initiation of movement.

(1)

(2)

(3)

17. List three (3) adverse affects of overstimulation of the vestibular system.

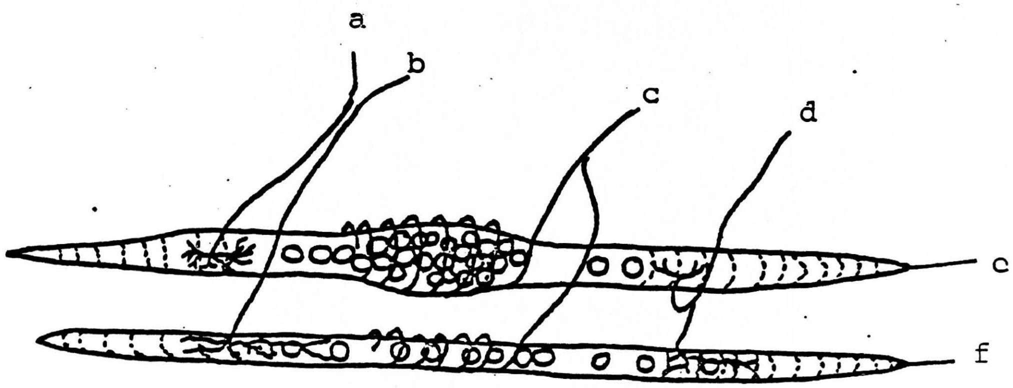
(1)

(2)

(3)

18. (Speed or control) is the responsibility of the alpha system whereas the fusimotor system is responsible for (speed or control).

19. Label the following illustration.



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APPENDIX B

LETTERS OF CONSENT

TEXAS WOMAN'S UNIVERSITY

SCHOOL OF HEALTH CARE SERVICES

DENTON, TEXAS 76204

CO-AUTHOR PERMISSION FOR CONDUCTING STUDY

Mrs. Karen L. Young, a coauthor, has permission to use the material in the manual <u>The Gamma and Vestibular Systems: A Neglected Kinship</u>. Further, Mrs. Karen L. Young has exclusive rights to the final product that she is developing for her thesis. The co-authors will be credited in the text for their part in the original project.

Debbie Allen
Signature of Co-author
6-5-81
Date

Lucinda G. Haber (Cindy
Signature of Co-author
7-15-81
Date

TEXAS WOMAN'S UNIVERSITY
SCHOOL OF HEALTH CARE SERVICES
DENTON, TEXAS 76204

AGENCY PERMISSION FOR CONDUCTING STUDY*

THE Texas Woman's University School of Physical Therapy

GRANTS TO Karen S. Young
a student enrolled in the School of Health Care Services leading to a Master's Degree in X Health Sciences Instruction ____ Health Care Administration at the Texas Woman's University, the privilege of its facilities/data in order to study the following problem:

Field testing of fusimotor and vestibular systems instructional package using undergraduate and graduate students enrolled in neuroanatomy in the fall of 1981 at Texas Woman's University School of Physical Therapy, Dallas Presbyterian Campus.

The conditions mutually agreed upon are as follows:

1. The agency (may) (may not) be identified in the final report.
2. The names of consultative or administrative personnel in the agency (may) (may not) be identified in the final report.
3. The agency (wants) (does not want) a conference with the student when the report is completed.
4. The agency is (willing) (unwilling) to allow the completed report to be circulated through interlibrary loan.
5. Other ______________________________

Date: ______________________ Carolyn K Pezzi
Signature of Agency Personnel

Karen Young
Signature of Student

Barbara Tramel
Signature of Faculty Advisor

*Fill out and sign three copies to be distributed as follows: Original-Student; First copy - agency; Second copy - SCHOOL OF HEALTH CARE SERVICES.

7/79

Consent Form
TEXAS WOMAN'S UNIVERSITY
HUMAN SUBJECTS REVIEW COMMITTEE

(Form B)

Title of Project: Fusimotor and Vestibular Systems Instructional Package

Consent to Act as A Subject for Research and Investigation:

I have received a written description of this study, including a fair explanation of the procedures and their purpose, any associated discomforts or risks, and a description of the possible benefits. An offer has been made to me to answer all questions about the study. I understand that my name will not be used in any release of the data and that I am free to withdraw at any time. I further understand that no medical service or compensation is provided to subjects by the university as a result of injury from participation in research.

Signature Date

Witness Date

Certification by Person Explaining the Study:

This is to certify that I have fully informed and explained to the above named person a description of the listed elements of informed consent.

Signature Date

Position

Witness Date

One copy of this form, signed and witnessed, must be given to each subject. A second copy must be retained by the investigator for filing with the Chariman of the Human Subjects Review Committee. A third copy may be made for the investigator's files.

APPLICATION TO HUMAN SUBJECTS REVIEW COMMITTEE

Subject: Research and Investigation Involving Humans

Statement by Program Director and Approved by Department Chairman

This abbreviated form is designed for describing proposed programs in which the investigators consider there will be justifiable minimal risk to human participants. If any member of the Human Subjects Review Committee should require additional information, the investigator will be so notified.

Five copies of this Statement and a specimen Statement of Informed Consent should be submitted at least two weeks before the planned starting date to the chairman or vice chairman on the appropriate campus.

Title of Study: Fusimotor and Vestibular Systems Instructional Package

Program Director (s): Dr. Barbara Cramer

Graduate Student: Karen S. Young

Estimated beginning date of study: August 1981

Estimated duration: To be completed in May 1982

Address where approval letter is to be sent:

7115 Lost Canyon Drive

Dallas Texas 75249

Is this research being conducted for the thesis or professional paper? Y X N ____; for the dissertation? Y ____ N ____.

APPENDIX C

PRETEST

FUSIMOTOR AND VESTIBULAR SYSTEMS

PRETEST

DIRECTIONS: Complete the following statements by filling in the blank(s) for questions 1 through 15. List the requested information for questions 16 and 17. Circle the appropriate word in parenthesis in statement 18. Label the illustration in question 19.

1. The ________________ system is the efferent innervation of the muscle spindle.

2. The ascending circuits for the muscle spindle terminate in the _________________________.

3. Applying a rapid stretch and then maintaining the stretch produces a ________________________ response.

4. The patellar reflex is an example of a _________________ reflex.

5. A sensory epithelium is called a _____________________.

6. The ___________________ and _____________________ comprise the sensory organs of the vestibular system.

7. The __________________ is the part of the vestibular system responsible for hearing.

8. Changes in static position of the head are monitored by the _________________________.

9. Changes in acceleration of the head are monitored by the ___________________________.

10. The elements ____________________ and ______________ are thought to relate to normal development of the vestibular system.

11. The ____________________ in the horizontal semicircular canal is the receptor responsible for nystagmus.

12. Because of the ________________ reflexes, head position must be considered for the labyrinths to stabilize body position.

13. The Rhomberg or balancing test measures integrity of the ________________________.

14. __________________________ is used to compensate for lack of vestibular input.

15. In motor disorders, vestibular stimulation is used to normalize ____.

16. Give three (3) circuits for initiation of movement.

    (1)

    (2)

    (3)

17. List three (3) adverse affects of overstimulation of the vestibular system.

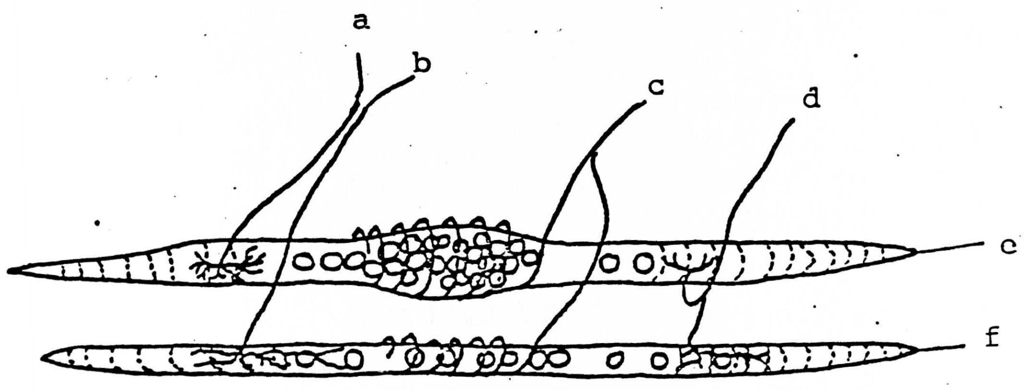
    (1)

    (2)

    (3)

18. (Speed or control) is the responsibility of the alpha system whereas the fusimotor system is responsible for (speed or control).

19. Label the following illustration.



APPENDIX D

COVER LETTER

COVER LETTER

FUSIMOTOR AND VESTIBULAR SYSTEMS:

AN INSTRUCTIONAL PACKAGE

Thank you for your consent to participate in this study. The purpose of this study is to provide clinically applicable information regarding vestibular stimulation. In order to do this effectively, it is felt by the researcher that information relating the vestibular system to the fusimotor system is needed.

Your participation in the study will entail:

1. Completion of the pretest

2. Working through the instructional package as directed

3. Completion of the posttest

4. Completion of an evaluation form to determine the usefulness of the package to the participants.

Data will be collected by scoring the pretests and posttests. For this reason it will be necessary to place your social security number on both the pretest and posttest. At no time will a name be associated with your pretest or posttest. Social security numbers will be used for the purpose of matching your pretest and posttests only.

I will be available at the time of administration of the pretest and posttest to answer questions. If you have any questions while working through the instructional package, I can be reached at work at (214) 944-8442 and at home at (214) 298-1651.

Feedback will be given to any participant who requests it. The course instructor will determine if there is sufficient time for the researcher to return or if the feedback will be done in writing. Participation in the study will have no effect on your Neuroanatomy grade.

APPENDIX E

EVALUATION FORM

EVALUATION

THE FUSIMOTOR AND VESTIBULAR SYSTEMS:

AN INSTRUCTIONAL PACKAGE

Please consider the following questions as your complete each module of the instructional package.

1. Was the length of text between review tests appropriate?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

2. Did the review questions test the material which preceded them?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

3. Were the suggested references helpful?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

4. Were the review tests helpful in understanding the information?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

5. Were there an adequate number of illustrations?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

6. Were the illustrations sufficiently labeled?

	Yes	No
Module I		
Module II		
Module III		
Module IV		

If you answered no to any of the above, list specifics.

7. Do you feel you can apply the clinical application from Module IV?

Yes No

Please comment.

8. Please comment on your overall evaluation of the instructional package.

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