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The purpose of this study was to determine the effect of a labyrinthine dysfunction, with and without visual cues, on underwater submergence. The subjects utilized were fifteen bilateral neural deaf males, nine conductive deaf males and sixteen hearing males. Following a series of pre-tests, administered to determine balancing difficulties, each subject was administered four consecutive submerging trials. An analysis of variance utilizing a multiple regression coefficient was the statistical model used to analyze the data. The results indicated that all groups, with and without visual cues, were able to maintain directional orientation underwater. The L.D. group performed in a manner comparable to the Conductive deaf group; however, the Hearing groups were significantly faster at locating the surface than were either of the deaf groups.

LABYRINTHINE DYSFUNCTION

AND

UNDERWATER SUBMERGENCE

by

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LABYRINTHINE DYSFUNCTION AND UNDERWATER SUBMERGENCE

CHAPTER I

INTRODUCTION

Statement of Purpose

The purpose of this study was to determine if subjects with auditory-vestibular nerve lesions, under varying visual conditions, would be able to orient themselves when totally submerged in water. Of further interest to the study, comparisons were made of similar performances of deaf individuals due to other causes (conductive deafness) and to hearing subjects to determine if significant differences existed between the groups.

Need for the Study

Many studies by physical educators and scientists have been concerned with human static and dynamic balancing abilities. Though the primary control center for equilibrium is located in the vestibular system of the inner ear, very few of these studies have utilized deaf subjects for balance testing.

In the studies which did utilize deaf subjects, the results indicated that not all of the deaf were able to maintain balance in skills which were easily performed by their peers and by hearing subjects. Research by these experimenters and other scientists indicate that when there is an auditory-vestibular (Cranial VIII) nerve lesion, the subject's equilibrium is precariously impaired. (18:88)

Neural impulses reflecting the positional changes required for body stability, are transmitted from the semicircular canals of the inner ear to the medulla of the brain via the auditory-vestibular nerve. A lesion of this nerve prevents the transmission of these necessary positional changes and directional disorientation is the result. The acquisition of body equilibrium and the most basic of motor skills, such as walking, are dependent upon the compensating abilities of the other sensory organs, of which the eyes and the proprioceptors appear to be the most important. If the compensating modalities are rendered ineffective, such as in the Walk-A-Line, Eyes Closed test or when the body is completely submerged in water, spatial and body disorientation occurs and the subject is unable to maintain his equilibrium. Disorientation underwater could prevent the subject from locating the water's surface.

Most researchers have selected subjects according to the etiology of deafness rather than by the type of deafness and those with a labyrinthine dysfunction have been virtually overlooked. There is a definite need to identify the neural deaf and to understand the implications that their dysfunction may have on their academic and physical world. If it is found that these subjects do indeed lose directionality when submerged in water, then it is imperative for swimming instructors and those connected with deaf programs to be cognizant of the potential hazard. If it is found that these subjects become disoriented but are also, with practice, able to find the surface then the skill of doing so should be included as a vital part of the instructional swimming program.

Delimitations

This study was limited to male high school subjects, ages 14 through 18 years, who attended a special school for the deaf and a control group of hearing subjects from a local public high school. The study was further limited to those students who received parental and school permission to participate, who were in good health and who demonstrated proficiency in swimming skills.

Assumptions and Hypotheses

Assumptions

This study was based on the following assumptions:

1. Equilibrium is maintained by the interaction of many sensory cues, of which the proprioceptors, vision and the vestibular organs of the inner ear are probably the most important.
2. When submerged in water, the proprioceptive system is ineffective due to uniform water pressure; thus the vestibular system appears to provide the main sensory cue for orienting the body since vision is blurred.

3. Sufficient non-vestibular cues of, as yet, an unknown nature will aid the individual in orientation when submerged in water.
4. Learning takes place upon repetition of a specific task and performance times will reflect the degree of learning which has occurred.

Hypotheses

The following null hypotheses were formulated to test for significant differences.

1. There will be no significant differences among the performance of all groups.
2. There will be no significant differences among groups in the ability to orient themselves when submerged in water when utilizing underwater visual cues.
3. There will be no significant differences among groups in the ability to orient themselves when submerged in water in the absence of underwater visual cues.
4. There will be no significant differences between performances of the labyrinthine dysfunction group utilizing visual cues and the labyrinthine dysfunction group not utilizing visual cues.
5. There will be no significant differences between the performances of the conductive deafness group utilizing

visual cues and the conductive group not utilizing visual cues.

6. There will be no significant differences between the performances of the hearing group utilizing visual cues and the hearing group not utilizing visual cues.

Definition of Terms

For clarity and mutual understanding, the following terms used in this study have been defined.

Adventitious Deafness

"Accidental or acquired; not hereditary." (8:48)

Central Deafness

"Deafness due to a lesion in the auditory pathway, as opposed to deafness resulting from injury to the cochlea or the auditory nerve." (8:394)

Conductive Deafness

"Deafness resulting from disordered function of the sound-conducting mechanism, which includes the ear-drum and ossicular chain." (8:394)

Labyrinth

"An interconnecting system of cavities, applied especially to the internal ear." (8:802)

Neural Deafness

"Nerve deafness due to damage or diseases of the auditory nerve." (8:395)

Nystagmus

"A condition in which the eyes are seen to move in a more or less rhythmical manner, from side to side, up and down, or in a rotary manner from the original point of fixation." (8:985-6)

Positional Nystagmus

"Nystagmus occurring only when the head is held in a certain position." (8:986)

Vestibular Nystagmus

"Nystagmus due to some disorder of the semicircular canals or their nervous connexions." (8:986)

CHAPTER II

SURVEY OF LITERATURE

INTRODUCTION

The three basic classifications of deafness are conductive, central and neural. Conductive deafness involves hearing loss attributed to faulty accoustical wave reception. Central deafness is generally associated with psychological disorders or disturbances in the neural pathways of the high auditory centers. Neural deafness is the result of a lesion or impairment within the labyrinths of the inner ear or the auditory vestibular cranial VIII nerve.

The labyrinths are located in the vestibular portion of the inner ear and are primarily concerned with positional equilibrium. The vestibular apparatus consists of three semicircular canals, a utricle and a saccule, all interconnected. The three semicircular canals have a vestibule at one end. This vestibule contains receptor cells and the terminal branches of the cranial VIII nerve. On each receptor cell there are a number of hairs which are stimulated by head movement. These hairs work in conjunction with the canal fluid. "When the head is rotated, the receptor cells move with it as they are attached to the bony canal wall, but the canal fluid lags behind due to its inertia - pushing the 'swinging door' and thereby pulling on the hairs and stimulating the receptor cells." (1:128) "The receptor cells in the utricle and saccule are arranged as a fairly flat sheet of tissue and are structurally quite similar to the receptors of the semicircular canals." (1:129) The otolithic membrane covers the hair follicles on the receptor cell sheet. The otolithic membrane is heavier than its underlying tissue and is not attached to a bony structure, therefore, it reacts to motion and gravitational forces. "The utricle, oriented in a horizontal plane, is most sensitive to horizontal linear acceleration; the saccule, oriented vertically, responds best to up-and-down motion." (1:129) The semicircular canals are affected by centrifugal force and react to rotatory movements of the head.

In terms of balance, DeWeese states:

> The utricle is concerned with static equilibrium. It regulates the sense of position in space. It is stimulated by gravity, centrifugal force, and linear movements. Stimulation of the utricle produces compensatory eye positions, the head righting reflex, and alterations in muscle tone. The semicircular canals are stimulated by rotation or acceleration in any direction. (21:279)

In regard to maintaining equilibrium Elia noted that "The delicate adjustments continuously required to balance these forces are met by the interaction of three body senses - vision, muscle and joint proprioceptors, and the vestibular system." (23:5) When a lesion or impairment exists in the vestibular system, the positional changes cannot be transmitted and body balance may be lost or may be erroneous. Corso states:

> In some instances, as in cerebral meningitis, both labyrinths may be destroyed by the bacterial invasion, but the patient can, after some weeks, control his bodily movement as in walking, running, climbing and skiing. These movements, however, would be controlled primarily by the visual and kinesthetic systems. (15:394)

Equilibrium is maintained by a set of reflexes. "The reflexes are activated by vestibular input plus input from the skin, from joints and muscle receptors, and from the eyes." (1:132)

Neural deafness may be attributed to a number of causes. "The most serious of these are measles, whooping cough, influenza and mumps." (16:388) Congenital deafness may be attributed to these same diseases if the mother developed them during her pregnancy. (19:88) Meningitis and German measles have long been considered a major contributor to neural deafness. "Perceptive deafness may also result from toxic poisoning attributable to pharmacological substances. In these cases, the onset of deafness is usually gradual, but may develop within a few days of medication with streptomycin or its derivatives." (16:388)

In situations where body orientation is imperative to safety such as when vision is impaired or when the kinesthetic sense is ineffective, the neurally deaf person's life may be endangered. In regard to the labyrinthine dysfunction person, Corso states that:

> ... if such a person were to dive into deep water, he would undoubtedly drown. The kinesthetic system would be essentially useless against the uniform water pressure and the patient would no longer know where to move to approach the surface of the water. (16:394)

Davis reported:

> It is true that children whose deafness is due to diseases or defects which have also affected the semicircular canals are inferior in balance. Therefore, a person whose deafness is due to meningitis should know that under certain conditions, such as

> when he is in the dark and cannot use visual cues or when swimming underwater, he will have difficulty in retaining his balance and sense of direction. (19:461)

Lewis (42) stated that he was sure that a deaf mute would be helpless if submerged in salt water. Felix Marti-Ibanez noted "if a person without labyrinths were thrown into water, he would drown." (43;13) Best and Taylor (6), Edwards (22), Morsh (45), and Obersteiner (47) concurred with Corso, Marti-Ibanez and Davis.

An exhaustive search of the literature, including a Medlar search failed to disclose any research except Padden's (48) which would substantiate or refute the opinion that the labyrinthine dysfunction deaf subject would be in danger in an underwater environment. Padden (48) speculated that perhaps experiments with animals prompted and perpetuated the theory. In her work with the deaf, Patricia Davey, who questioned the validity of the theory stated "As a matter of practical observation, all children attending the school swim and dive without accident." (20:329)

In light of the knowledge that neural deafness is accompanied by orientation difficulties, the nature of deafness should be a basic criteria for the classification of deaf subjects involved in tests utilizing balancing skills. Peripheral deafness refers to disorders within the vestibular organs and central deafness applies to conduction disorders within the Central Nervous System. Various non hearing tests including nystagmus induced and balancing tests, have been devised to locate peripheral and central deafness disorders.

For the purpose of clarity and continuity, the reviewed literature has been divided into three sections: (1) selected tests producing a nystagmus reaction, (2) selected tests requiring balancing skills, and (3) related studies utilizing various tests for identifying labyrinthine dysfunctions and studies involved with the deaf underwater.

Selected Clinical Tests of Nystagmus

Nystagmus refers to the eye movements which are produced by body motion or a vestibular disorder. Head motion stimulates the hair cells in the semicircular canals. DeWeese states:

> Distortion of the hair cells sets up a chain of reflexes which produce contractions in the eye muscles, the neck muscles and the muscles of the trunk and extremities. In normal persons these reactions restore the body position when any force throws it out of balance. (21:310)

The direction of nystagmus is dependent upon the specific nature and location of the disorder. Eye movements may be horizontal, vertical, rotatory or may oscillate at random. The speed fluctuates according to the stimulation and the location of the dysfunction. (53:395) In a normal person, the eyes look straight ahead or when the person is rotated, the eyes are reflexively directed toward the uppermost ear or in the "righting direction". Reflex tests which produce nystagmus reactions, though few in number, have been widely used for identifying vestibular disorders.

Caloric testing is the most commonly used test of nystagmus. (14, 25, 37) Its value lies in the fact that each labyrinth may be individually stimulated and examined. Caloric testing consists of stimulating the semicircular canals by introducing water into the external auditory canal.

> Water below body temperature, when directed against the tympanic membrane, causes endolymphatic fluid to flow in a downward direction. Water above body temperature sets up convection currents in the opposite direction which causes the fluid in one or more canals to rise. Motion of the endolymphatic fluid distorts the hair cells and produces the labyrinthine reactions. (21:315)

The intensity, duration and direction of visual nystagmus, as a result of caloric testing, is utilized for vestibular diagnostic examinations. (51:262)

The Dundas Grant Cold Air Test (23:31) is based on the same principle as caloric testing but uses cooled air in place of the water.

Positional nystagmus refers to the nystagmus noted in head position changes. "Nystagmus may be produced by changes in the position of the head. Testing for positional nystagmus is not difficult." (21:313) The positional test procedure is based on the method devised by Barany. (4)

> It consists of turning the seated patient's head to one side and then briskly laying him supine, so that the head is lowered over the edge of the table, some 30 degrees below the horizontal. The patient's eyes are kept open so that they may be observed for the appearance and duration of any mystagmus which may be induced. The test is then repeated with the head turned to the opposite side. (23:29)

Galvanic testing produces nystagmus through the use of electrodes. An electrode is attached to each side of the face and to each wrist. The electricity elicits a nystagmus reaction. It distinguishes peripheral and central deafness; however, its inconsistency among patients has hindered its effectiveness as a reliable clinical test. (23:31)

Rotation tests also produce nystagmus. The Barany Chair (4), one of the first such tests, requires the seated subject to be rotated 10 times in a 20 second period and then suddenly stopped. The chair has two clinical limitations; it stimulates both labyrinths simultaneously and it has a tendency, with several trials, to produce nausea. Tests of a more sophisticated nature have been devised and the Barany Chair is primarily reserved for experiments with animals. (21:314)

The Tilt Chair (44) requires the patient to identify spatial fields and planes while being rotated or tipped through them. The chair tilt is electronically recorded as is the subject's response, thus providing a measure of accuracy as to perception in space.

The Pensacola Slow Rotation Room (26:1160) is an elaborate positional testing device. It tests for nystagmus as well as spatial orientation. The large room is situated at the end of a large rotating beam. It is furnished for eating and sleeping. It has a constant rotation speed of five to ten revolutions per minute. In terms of its effectiveness, Fregley and Kennedy state:

> That postural difficulties occur in the Pensacola Slow Rotation Room and other rotating environments is well documented. They are a direct result of the gyroscopic torques and changing G forces which occur as one moves his head and body relative to these rotating platforms. (26:1160)

Selected Tests of Balance Utilized for Identifying Labyrinthine Dysfunctions

The balance tests, utilized with deaf subjects, were found to be of three basic natures: those utilizing rails or balance beams, walking a designated path, and standing in various positions.

Various rail tests have been utilized. Birren (7), Callahan (9), Cureton (17), Davey (20), Gleishman (24), Frisine (29), Goetzinger (30), Graybiel (31), Guedry (35), Heath (37), Kredl (41), Morsh (45), Mykelbust (46), Seashore (51), Vernon (56), and Whitney (58) employed tests involving rails or balance beams in their studies regarding human equilibrium.

The Heath Rail Test (37) consists of three rails, 4 in., 2 in., and 1 in. respectively in width. The first two are 9 ft. in length and the third is 6 ft. The subject, barefooted, walks each rail without support. Three trials are allowed for each rail. The test was standardized on military men and the mean score for 1013 subjects was 130.7 with a standard deviation of 19.6.

The Springfield Beam-Walking test (58) employs nine oak beams of equal length and equal heights from the floor but of varying widths. The widths of the 10 foot beams were 4, 3½, 3, 2½, 2, 1½, ½, and ¼ inches. The subjects walk heel-to-toe fashion and are required to take 10 steps on each beam. The subject begins on the 4 inch beam and progresses to the ¼ inch beam. When Whitney (58) retested for test reliability, he used 100 subjects which had an average intercorrelation of 53 for their three trials. "Using .53 and applying the Spearman-Brown formula, the coefficient of reliability was .77." (58:64)

In their work with the aerospace program, Fregley and Graybiel (27:305) utilized six rails. Four of the rails were eight feet long and had widths of 2 3/4, 2 1/4, 1 3/4, and 1 1/4 inches and were 1 inch high. Two of the rails were 3/4 and 1/2 inches wide with a height of 1 1/2 inches. The rail battery consisted of walking, with hard soled shoes on, each of the rails, standing for 60 seconds on each of the six rails, with the eyes open and then standing on each rail for 60 seconds with the eyes closed. The reliability of the "intratest correlations (r's between best trial and second best trial, of Walk H/T ranged from 0.75 to 0.92; intra-test correlation of Stand E/O and Stand E/C ranged from 0.83 to 0.96." (27:295) The short version utilized the 2¼ inch and the 3/4 inch rail. The battery consisted of walking the 3/4 inch rail, standing on the 3/4 inch rail with the eyes open and standing with the eyes closed on the 2¼ inch rail. The short version duplicated the high reliability established for the long version. The labyrinthine dysfunction subjects scored at the first percentile on each of the tests in these two batteries.

As in walking the length of a beam, the Walk-A-Line, Eyes Closed (WALEC) and the Walk on Floor, Eyes Closed (WOFEC) tests also consist of following a designated path. The subject walks, as straight as possible, a 12 foot chalk line. The position which must be maintained throughout the test is standing upright with the feet tandemly aligned, walking heel-to-toe and keeping the arms folded across the chest. The WALEC test is judged by the number of inches the closer of the two feet deviates from the line at the 12 foot mark. The WOFEC test is based on the number of steps taken without loss of the basic position. In regard to the reliability of these two tests, Fregley and Graybiel stated, "Because their sensitivity relates very well to caloric as well as to other sensitive vestibular tests, they may serve as rapid and economical procedures for screening." (25,280) None of the labyrinthine dysfunction subjects used in their study were able to complete a trial on either test.

The Classical Romberg (CR) test (49) is a static testing device for vestibular function. The subject stands with feet together; the eyes are closed. The arms are folded across the chest with each hand clasping the opposite elbow. This position should be maintained for 60 seconds. The Sharpened Romberg (50) requires the subject to stand with the feet tandemly aligned, heel-to-toe. The arms and body position are the same as in the Classical Romberg.

The Stand on One Leg, Eyes Closed (SOLEC) test (25:280) is commonly used for testing balancing abilities. The subject stands on one foot with the arms folded across the chest. The test is reported four times with two trials on each leg. Maintaining balance for a 30 second time period is considered normal. There is a question as to whether a one foot support test is a true measure of a vestibular disorder or a measure of nonvestibular influences such as orthopedic adaptations. (25:278)

Related Research

The deaf subject has been virtually overlooked in the quest for understanding human equilibrium. Relatively few studies have utilized deaf subjects and of these only a limited number have been concerned with the type of deafness involved. Of interest to this study is the research which is directly related to the identification of vestibular disorders and to those studies which are involved with balancing skills of labyrinthine dysfunction subjects. Etiology of deafness appears to be the criteria for classification of deaf subjects rather than the nature of deafness; therefore, test results in studies based upon etiology may be reflective of the classification criteria.

In an attempt to examine equilibrium in relation to the etiology of deafness, Myklebust (46:249) used five groups of deaf subjects. These groups were "presumely endogenous, endogenous, exogenous, meningitis and undetermined." The subjects were administered the Heath Rail test (37) and the mean performance scores of all subjects were compared. The study revealed that the meningitis group scored significantly lower than did the other group, undetermined, which had a mean score of 63.2. Mykelbust then administered the Barany Chair (4) test and caloric testing (20°) to the meningitis group and found that all three tests revealed significant etiological information. (46:258)

Davey (20:329) utilized the Heath Rail test (37), caloric testing (30°), audiograms and opthamologic testing to determine the relationship of rubella to deafness and labyrinthine function. She also attempted to determine "if there were any relevant constant factors affecting eye, muscles, and labyrinthine control." (20:329) The test was administered to 18 deaf subjects whose deafness was attributed to rubella. As a result of the study she noted "The relationship of vision is very significant and visual incompetence in a co-ordinated test such as the Rail test appears to be of more importance than labyrinthine integrity." (20:329) Two factors should be noted, first, the homogeneous classification was based on the etiology of deafness and secondly, the test utilized visual cues which would probably allow the labyrinthine dysfunction group to perform equal to any other deaf group.

In 1950 Worchel and Dallenbach (61:161) attempted to discover if the degree of deafness influenced sensitivity to rotation and its relationship to standing on one foot and, secondly, to determine whether loss of macular and semicircular function is correlated with the degree of deafness. The 59 subjects were administered a rotational chair test and a standing, eyes closed test. The first standing, eyes closed test utilized the support of both feet for 25 seconds and the second required them to stand on one foot for 25 seconds. Their conclusions were:

1. The rotation and standing tests involve different physiological mechanisms.

2. The rotation test involves the semicircular canals -- normal functioning of which is neither sufficient nor necessary for success in the standing test.

3. The standing test involves the macular organs of the utricle and saccule. Success and failure in this test is not dependent upon the functioning of the semicircular canals.

4. Deafness correlates highly with the performance of the rotation and standing tests but the correlation is not absolute in that even people suffering partial or total deafness may show all the effects of rotation and stand on one leg 25 seconds -- the criterion of normal performance. The differences among the results with different subjects are due to differential damage to the organs of the inner ear.

5. The discrepancies among the results of different investigators are due in sampling and to the fallacy of basing conclusions upon gross classifications of the subjects' experiences and behavior. (61:175)

The onset of celestial exploration prompted a need to understand the equilibrium of man in a weightless and visually obscured environment. Fregley, director of research at the Naval Aerospace Medical Institute in Pensacola, Florida, collaborated with Graybiel and devised two ataxia test batteries which could be utilized to identify vestibular disorders. In 1961 they developed "A New Quantitative Ataxia Test Battery." (27). The long version consisted of walking with the eyes open the length of six rails of varying widths, standing with the eyes open on each of the six rails and standing with the eyes closed on each rail. The Classical Romberg and the Sharpened Romberg tests were also included in their testing. The long version was administered to 550 normal males, 11 labyrinthine defective males and 158 normal females. The sample represented various occupations and an age range from 13 years through 67 years. The results showed "that each test comprising the test battery relates only moderately to each other test and thereby, suggests a nearly ideal distinctness desired in a battery or test designed to measure complex performances referred to singularly as ataxia, or postural equilibrium," (27:295) The labyrinthine defective group scored at the first percentile on each of the tests. They showed improvement after practice on the rail test and standing with the eyes open test but no improvement was noted for the standing with eyes closed test.

The short version eliminated three of the rails. The test results were also identical to those found in the long version.

In 1968, Fregley and Graybiel developed an "Ataxia Test Battery Not Requiring Rails." (25) This battery was composed of the Sharpened Romberg (SR), Stand On One Leg, Eyes Closed (SOLEC), Walk-a-Line, Eyes Closed (WALEC), Walk on Floor, Eyes Closed (WOFEC), and the Classical Romberg (CR). In order to validate the test results, these tests were also administered with the eyes open. The subjects utilized were 87 males and 53 females from ages 20 through 70 years. The testing results indicated that all of the tests, except the Classical Romberg, were highly discriminate measures of vestibular disorders. None of the labyrinthine dysfunction group were able to perform a single scorable trial on the WALEC or the WOFEC tests. All subjects scored high on the tests when visual cues were allowed. In terms of the test results as they applied to the labyrinthine dysfunction group, the scientists stated "The WALEC and WOFEC procedures alone, when employed with such individuals, appear to be sufficient to establish clinically significant performance deviations from the quantitative normative standards set forth." (25:280)

The study conducted by Padden (48) was the only research found that actually examined the equilibrium abilities of deaf subjects in an underwater environment. Padden used 105 deaf and hard of hearing males and 23 hearing males in his study. The ages ranged from 15 to 30 years of age. He grouped the subjects into five categories which were congenital deaf, meningitis, adventitiously deaf, deaf due to unknown causes and normals. The grouping was based on data secured from the health records. A second grouping, based on balancing abilities, was then made. Subjects were rated as "good" or "poor" in balance as determined by subjectively watching them maintain balance while sitting on a rotating disc. All subjects were able to swim. Subjects were projected into the water from a two foot height. Each subject was administered 20 trials with the eyes open and 20 trials with the eyes blindfolded.

The results of his study showed that the meningitis group and those with "balancing" difficulties had scores which were significantly slower than the other groups at the 5% level of confidence both on the eyes open and the eyes blindfolded test. Several of the subjects, in the meningitis group, did lose total orientation and swam to the bottom or sides rather than to the surface. However, not all subjects in the meningitis group or "poor" balancing group had difficulties in locating the surface.

No conclusions from Padden's study could be made regarding neural deafness and the ability to maintain body and directional orientation when submerged in water. Though Padden's subjects were grouped according to the probable cause of deafness, they were not screened for labyrinthine dysfunctions and certainly no distinction was made between unilateral and bilateral deafness. Health records of deaf subjects, as pointed out by Shearer (51:42), are seldom complete or accurate. The cause of deafness is often a guess rather than the diagnosis of a physician; therefore, it would be difficult to use health records as a reliable criteria for grouping of subjects.

CHAPTER III

RESEARCH PROCEDURES

When the labyrinths have been destroyed or when an auditory-vestibular nerve lesion exists there is a distinct equilibrium deficiency. When the body is submerged in water a labyrinthine dysfunction could result in directional disorientation which would prevent the swimmer from locating the surface. For this reason and the fact that only a minimum number of deaf subjects have been tested underwater, careful consideration was given to safety factors, testing procedures and evaluative techniques.

Pilot Study

Prior to the present study, a pilot experimental study was conducted to determine the feasibility and to refine the procedures and evaluative techniques employed.

Subjects

The subjects for the study were 15 volunteer males, ages 14-18, from a state school for the deaf and six hearing subjects from a local high school. All were in good health and received parental and school permission to participate in the study.

Pre-Tests

Each subject was administered the WALEC, WOFEC and the 2¼ inch rail test. These tests were utilized to distinguish subjects with labyrinthine dysfunctions and those subjects with unusual balancing difficulties. As a result of these pre-tests it was found that positional testing was needed to determine bilateral labyrinthine dysfunctions.

Submerging Test

Each subject was projected into the water eight times, twice forward, twice on the left side, twice on the right side and two times backward. In that the performance times were not significantly influenced by the direction of the body's entry position, the forward, head first entry was selected for use in the final study. Improvement in performance times were not noted in the trials beyond the first four.

Equipment

In anticipation of extensive disorientation, it was decided that the dimensions of the testing area should be limited. A plastic tarpaulin, nine feet wide and 22 feet long, was secured. It extended across the width of the pool's deep end and was secured to the pool bottom by weights. It was secured to the side of the pool by means of anchored metal poles. It was found, however, that the tarpaulin was neither necessary nor effective and was eliminated from use in the present study.

The other equipment used in the pilot study was found to be accurate, effective and workable. The Data Time Automatic Multipurpose Timer, was found to be an excellent timing device.

As a result of the pilot study, the methodology for the present study was determined.

The Present Study

Subjects

The subjects selected for the study had not previously participated in a research study of this nature. Due to their familiarity with test items, subjects used in the pilot study were not included in the present study. The subjects were basically mesomorphic in body build, without extremes in size, height or weight.

Deaf Subjects. The 24 bilateral neural and the conductive deaf subjects were selected from volunteer high school students at a special school for the deaf. They ranged in ages from 14 to 18 years. All subjects were in good health as determined by the school health authorities. Subjects with multiple handicaps, blind as well as deaf, were omitted from the study. Each subject had been given parental and school permission to participate in the study.

Hearing Subjects. The 16 hearing subjects were selected from volunteers in physical education classes at two local high schools. All subjects were in good health and free of any known vestibular dysfunction. Each subject received parental permission to participate in the study.

Test Selection and Administration

The following tests were selected and utilized in the study. They are noted in the sequence of administration:

Pre-Test Battery. The pre-tests were utilized to identify the labyrinthine dysfunction subjects and those hearing subjects with extreme balancing difficulties due to other than vestibular causes.

1. Walk-A-Line, Eyes Closed. (WALEC) The subject walks, as straight as possible, at a normal pace, a 12 foot chalk line. The feet are tandemly aligned, heel-to-toe. The body is as erect as possible with the arms folded across the chest. The subject is blindfolded. (25)

2. Walk on Floor, Eyes Closed. (WOFEC) The WOFEC and the WALEC tests are administered simultaneously. The WOFEC test is virtually the same as the WALEC but scored differently. The test measures the number of steps that the subject takes. It is used for testing subjects who are unable to walk a straight chalk line. (25)

3. Standing With Eyes Closed, 2¼" Rail. (SEC, 2¼") The 2¼" rail test measured the ability to maintain equilibrium under varying gravitational forces. Subjects are timed on the number of seconds that they remain balanced on the rail.

The subject stands as erect as possible with the feet tandemly aligned, heel and toe touching. The arms are folded across the chest. Subjects are blindfolded. (27)

4. Positional Testing. Positional testing is used to differentiate between unilateral and bilateral neural deafness. It should be noted that caloric testing, (21:315) a highly reliable test for the purpose, (24) was not approved by the deaf school authorities for use in this study.

The procedure for administering positional testing was explained and demonstrated by a local physician. In a back prone position, the subject's head and neck are extended beyond the end of the bench. With the head and neck hyper-extended to a 30° angle, the examiner turns the head to the side and watches the eyes for nystagmus reactions. The test is repeated with the head turned to the opposite side. (21)

Pre-Test Scoring

Each of the tests were scored individually.

1. Walk-A-Line, Eyes Closed. The score was determined by the number of inches the center of the foot was from the line at the 12 foot mark. The best two-out-of-three trials constituted the score. A maximum of five unscorable trials were allowed. Obvious false starts did not count as trials. Subjects who violated the tandem alignment, altered their speed or arm position, or removed their blindfolds were marked as "Unable to Perform" (UTP).

2. Walk on Floor, Eyes Closed. The number of steps, after the initial two, that were taken determined the score. Ten was the maximum number of steps allowed in each trial. The best three-out-

of-five trials were recorded as the test score. The maximum score would be 30 (ten steps times three trials). Obvious false starts did not count as trials. Subjects were marked as "Unable to Perform" (UTP) if they violated the tandem alignment, altered their speed or arm position, or removed their blindfold prior to their third step. (25)

3. Standing with Eyes Closed, 2¼" Rail. Sixty seconds was the maximum time allowed on each trial. The best three-out-of-five trials constituted the test score. The maximum test score was 180 (three times sixty seconds). Obvious false starts did not count as trials. Time was stopped at the end of 60 seconds, when the subject violated the tandem alighment, altered the arm position, lifted the heels or toes, or if the blindfold was removed. (27)

4. Positional Testing. Nystagmus is present if, when the head is turned laterally, there is a rapid component of the eyes. These movements may be lateral, up and down, or rotatory. The duration of nystagmus varies with the nature of the disorder. In the absence of a vestibular disorder, the eyes focus straight ahead or toward the uppermost ear. If nystagmus occurs when the head is turned to both sides, a bilateral vestibular dysfunction is present. (21)

An "OK" was placed on the score card if there was an absence of nystagmus and a "X" was marked on the card if nystagmus was present.

Swimming Proficiency Test

A swimming test was administered to all hearing subjects and to those deaf subjects who, according to the school authorities, had not completed the intermediate swimming class or who were newly enrolled in the school.

The test involved diving into the deep end of the pool and swimming one length of either a front crawl or the breast stroke. Subjects who could not dive or complete the pool length swim without struggling or stopping were eliminated from the study.

Submerging Test

The submerging test measured the time lapse between total body submergence and surfacing. Timing began when the subject was totally submerged and ended when the head broke the water surface. The subject entered the nine foot deep water in a forward, head first, tucked position. This position was held until the body was completely submerged. Upon total submergence, the subject was to swim directly to the surface.

Body Position. Water entries were from a platform disc, approximately two feet above the water surface. Subjects sat on the disc with the chin tucked tightly to the chest. The legs were tucked toward the chest with the knees almost touching the head. The knees were together with the arms clasping them. When the correct position was assumed the disc was tipped and the subject was projected head first into the water. As a result of the pilot study and Padden's (48) findings, the forward, head first entry was utilized. This position, in contrast to the lateral and backward entries, allowed the subject to remain tucked and offered a minimum amount of the body surface to contact the water. Complete submerging was possible and the sting associated with "hitting" the water, as in the backward and side entries, was eliminated.

Trials. Four scorable trials were administered. A trial was not scored if the tucked position was not held until complete submergence occurred, if swimming did not commence immediately, or if those wearing blindfolds removed them prior to surfacing. A maximum of six unscorable trials were allowed. The life guards were directed to stay near the swimmer but not to touch or interfere with his progress unless signaled by the researcher to do so. To interfere would void the trial.

Blindfolded Subjects. Subjects to be blindfolded were randomly selected from within groups. The blindfold was fitted into place when the subject was positioned on the disc. Blindfolds were not to be removed before surfacing unless visual cues were absolutely vital to their locating the surface.

Scoring. Three examiners timed each trial and an average of the three constituted the trial score. Subjects who, after six unscorable trials, were unable to complete the test were omitted from the study.

Facilities

A local country club recreation center was used for the testing.

Swimming Pool. The indoor rectangular pool was 34 feet wide and 60 feet long. The water depth ranged from three feet in the shallow end to nine feet in the deepest section. The submerging test was performed in the deep end, eight feet from the side wall. Side ladders, 10 feet from the surface area, were available for water exits.

Testing Rooms. The lobby, approximately 25 feet wide and 40 feet long, served as the WALEC and WOFEC testing station. The 10 by 12 foot administration office was used for administering the 2¼" rail test. Positional testing was performed on the pool deck.

The two dressing rooms served as waiting areas for the subjects.

Apparatus and Equipment

2¼" Rail. A wooden rail, 2¼ inches wide, 1 inch high and 36 inches long was used for the SEC, 2¼" rail test. This small rail was securely attached to a wooden base that was 36 inches long, 8 inches wide and 1 inch high. (Plate I)

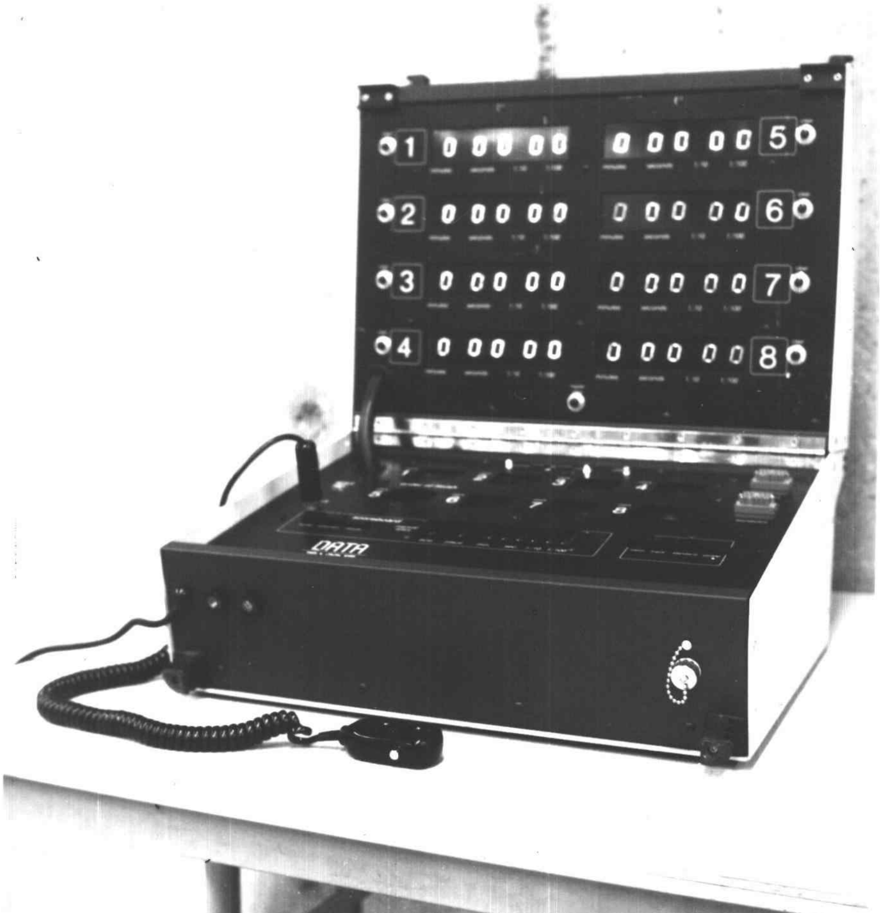
Timer. The Automatic Multipurpose Timer (Plate II) designed and owned by Data Time Company of Portland, Oregon, was utilized for all timed trials. It was selected for use over methods which required objects to be placed on or attached to the person or suit

PLATE I

2¼" Inch Rail

PLATE II

AUTOMATIC MULTIPURPOSE TIMER



of the swimmer, those that required surfacing in an exact spot or any device, such as a light beam, which would be activated by foreign movement such as a water splash. It was the consensus of three college swimming coaches and an electronic engineer that the AMT console was the most functional and reliable tool presently available.

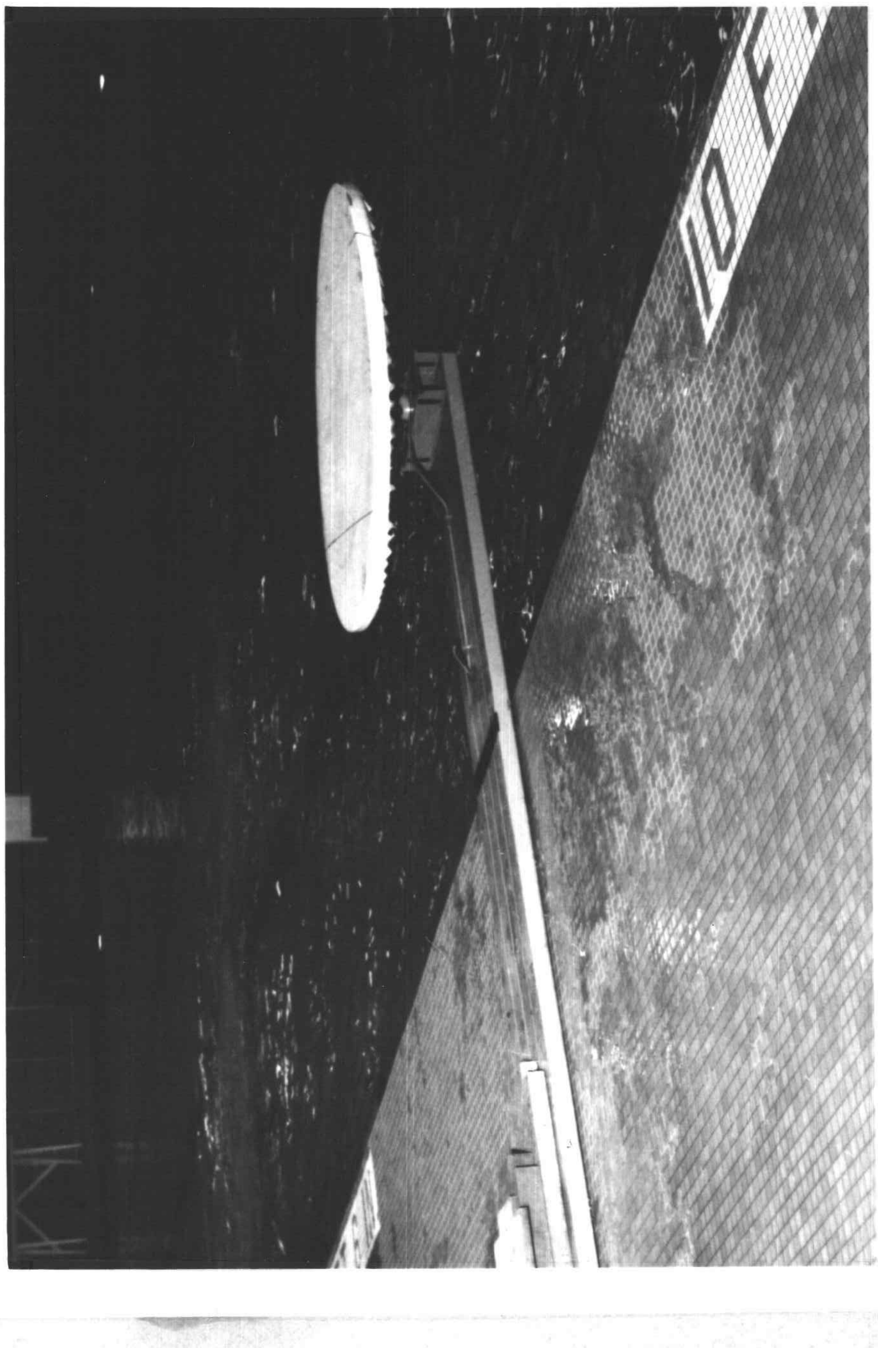
The AMT measured to one hundredth of a second. It allowed for a maximum of eight scorers at one time. The timer contained a master switch which started all clocks at the same time but allowed each to be stopped independently. As a result of the pilot study, it was found that times were more accurate when one conscientious and experienced person started all trials with the master switch.

Submerging Test Apparatus. Water entries were from a vinyl covered wooden disc which was 37 inches in diameter and 1 inch thick. (Plate III) It was mounted on a metal plank by means of a 3 3/4 inch long pipe in the middle of the disc's underside. This 2½ inch diameter pipe fitted into a 3 inch metal sleeve which was mounted on a box on the plank.

The metal plank was 96 inches long, 10½ inches wide and 1½ inches high. A metal box, 8½ x 4 x 1½ inches, was placed on the top of the plank, flush with the end. An eight inch "T" hinge, at the butt end of the plank, attached the box to the plank. A metal pipe, 4 inches in length and 3 inches in diameter was welded on top of the box. This pipe served as the sleeve for the

PLATE III

SUBMERGING TEST APPARATUS



disc's mounting. This design allowed the disc to be rotated freely in either direction and the box to be tipped to a 290° angle. The surface of the disc was two feet above the water surface and was three feet from the pool edge.

A safety catch was installed on the plank mount which prevented the disc from tipping accidently. A hole was drilled into the front of the metal box through which a metal rod could be slipped. The disc could be rotated but not tipped. When the subject was positioned, the rod was pulled by the researcher and the disc was ready to be tipped.

Five, one hundred pound elevator counter-weights were used to secure the plank to the pool deck. These weights were 26 inches long, 14 inches wide and 1 inch thick. They were placed, one on top of the other, on the end of the plank situated on the deck.

Blindfolds. A dark green, ribbed corduroy material, 4 inches wide and 32 inches long was used for the blindfold. When the subject was positioned on the disc the blindfold was fitted over the eyes and securely tied in the back.

Administrative Procedures

The following procedures were followed in securing the data for the study:

Neurological Screening of the Labyrinthine Dysfunction Subjects. Each subject was administered a series of pre-tests which were used to identify labyrinthine dysfunctions.

Each of the deaf subjects were enrolled in a special school for the deaf and medical records and case histories were available for examination. These records were examined in terms of congenital birth defects, age at which deafness was detected, childhood illnesses and hereditary factors which may have influenced deafness. It must be noted that the majority of the records were incomplete and vague. In most cases, the actual cause of deafness was not known and the parents offered a presumed cause. Audiometric testing had been done by the medical authorities at the school but no tests such as positional or caloric testing has been administered.

Subjects who were found to be in good health as indicated by their yearly physical examination, were included in the study.

Subjects who were deaf due to rubella and meningitis were tentatively placed in the L.D. group.

The final grouping of L.D. subjects was determined after the pre-tests were completed.

Neurological Screening of Hearing Subjects. Each of the hearing subjects was administered the pre-tests. These were given to detect equilibrium problems, due to colds, flu or recent illnesses, which may have influenced their testing performances.

All subjects were in good health as noted by their school health records. Each subject was questioned about a family history of deafness. None indicated a history of deafness in the family.

Testing Procedures

The pre-tests were administered in isolated rooms so that subjects remained naive until it was their turn to perform. Prior to the WALEC and WOFEC tests, subjects waited in the women's locker room. Upon completion of the WALEC and WOFEC tests, the subjects moved to the end of the lobby and waited to be called into the administrative office for the 2¼" rail test. The subject exited from the office to the pool deck where positional testing was being administered. Following the completion of the pre-tests, the subject went into the men's locker room and changed into his swimming suit. Each subject waited there until he was called for the proficiency swim or submerging test. Due to the limited time availability of the pool, one subject was swimming the proficiency test while one was taking the submerging test. Upon completion of the submerging test, subjects were allowed to swim in the shallow end of the pool.

Score Cards. Each subject had an individual score card (Appendix C) on which he wrote his own name, birthday, height and weight. This data was later matched against health records. The score card went from station to station with the subject and was collected prior to his entering the water. A tester at each station recorded each performance trial and returned the card to the subject upon completion of the test.

Instruction Cards. Test instructions were printed on cards (Appendix C) and were given to each subject when he was ready to perform the test.

Testing Personnel. Fourteen testers were utilized in administering the tests. Each person was thoroughly trained in his or her particular task. All but two had worked on the pilot study and were familiar with the testing duties. The two newcomers were used as timers.

A sign interpreter was present at all times. During the pretests she circulated among the stations so that she was available to answer any questions. During the submerging test, she positioned herself next to the disc so that she was available for giving any additional directions that were necessary.

Three testers were assigned to the WALEC and WOFEC tests. The head tester gave the direction card to the subject, determined successful and unsuccessful attempts and recorded the scores. The second tester measured for the WALEC test and the third tester counted the steps for the WOFEC test.

Three testers were assigned to the 2¼" rail test. The head tester gave the subjects the direction card, applied the blindfold and recorded the scores. The other two people were timers.

The researcher administered the positional testing. The results were recorded by a designated scorer.

Five testers and three life guards were utilized in the submerging test. Two life guards were in the water, five feet on either side of the disc and one guard was on the deck. Three timers were used, with one person designated as the head timer. The head timer was responsible for alerting the other timers when a trial was ready to start and for starting the master switch.

One scorer recorded each of the timed trials. The researcher positioned the subjects on the disc, applied the blindfold, alerted the head timer, projected the subject into the water and made all decisions relevant to the success of the trial.

Statistical Analysis

The submerging test consisted of four consecutive trials with each trial score recorded. The time began when the subject was completely submerged in water and stopped when the subject's head broke the water's surface. The average of the three timer's time constituted the trial score.

In order to test the null hypotheses, an analysis of variance was the statistical tool employed. The sample size was small and fourteen comparisons were needed, thus, a multiple regression coefficient was used for the analysis of variance.

Statistical comparisons were made between the performance times of the L.D. and Conductive groups, between L.D. and Hearing groups, and between the Conductive and Hearing groups. In order to determine the influence of vision on performance times, comparisons were made between all subjects using visual cues and all subjects blindfolded, between L.D. subjects using visual cues and the L.D. subjects blindfolded, between Conductive deaf using visual cues and the Conductive deaf that were blindfolded, and finally between the Hearing subjects who were using visual cues and those blindfolded. The influence that trials would have on performance times was determined by comparing the individual scores of each group to each other group's individual scores.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine the effect of a bilateral labyrinthine dysfunction on body orientation when subjects were submerged in water. It was further a purpose to determine if visual cues would influence performance. Six groups were utilized in the study, L.D.'s, Conductive deaf and Hearing subjects utilizing visual cues, and L.D.'s, Conductive deaf and Hearing subjects blindfolded. A battery of pre-tests were administered prior to the submerging test.

Analysis of Results

Pre-Tests

The pre-tests were administered to the deaf subjects to identify those with a bilateral labyrinthine dysfunction and were given to the hearing subjects to identify any unusual balancing difficulties which may have influenced their performance.

The WALEC and WOFEC tests were administered simultaneously and were the first tests performed. Subjects who were unable to perform (UTP) on the WALEC test and were not able to take more than two steps on the WOFEC test were tentatively placed in the L.D. group. Grouping was finalized by the results of the 2¼" rail test and positional testing. Positional testing was utilized to isolate those subjects with bilateral auditory-vestibular nerve lesions.

As noted in Table 1, the groups were easily distinguished by composites of the pre-test scores. The groups were composed of fifteen L.D. subjects, nine Conductive deaf subjects and sixteen Hearing subjects.

TABLE 1. Pre-Test Mean Scores

Groups	Number of Subjects	WALEC	WOFEC	2¼" Rail
L.D.	15	UTP	.3	6.7
Conductive	9	6.7	15.2	11.8
Hearing	16	10.9	27.6	27.8

Walk-A-Line, Eyes Closed. The L.D. subjects were unable to maintain, at a minimal level, the initial balancing position for performing the WALEC test which resulted in a UTP score. The Conductive deaf were not only able to maintain their balance but scored better than did the Hearing group. All of the Conductive and Hearing subjects were able to complete the test in at least four of their five trials, whereas, none of those placed in the L.D. group were able to perform the WALEC test one time out of five trials.

Walk on Floor, Eyes Closed. Subjects who were unable to perform on the WALEC test were likewise unable to perform on the WOFEC test. Though a straight line was not necessary, L.D. subjects were unable to take more than one step in any direction without losing their body balance. Hearing subjects had little difficulty with the test, scoring 27.6 out of a possible 30 points. The Conductive deaf group was able to perform on at least two out of the five trials, averaging 15.2 steps out of a possible 30.

Standing With Eyes Closed, 2¼" Rail. The 2¼" Rail test substantiated the WALEC and WOFEC test findings. Though the L.D. group performed considerably better on the Rail test than on the previous two tests, their performance was appreciably less than either the Conductive or the Hearing group. The mean for the L.D. group was 6.7 seconds, for the Conductive deaf it was 11.8 seconds and the Hearing group balanced for an average of 27.8 seconds.

Positional Testing. Positional testing was administered to all subjects. As Table 2 indicates, bilateral nystagmus characterized the L.D. group. Four of the Conductive deaf subjects were found to have a vestibular dysfunction on one side. Both labyrinths work together to maintain body balance. When one does not function, the other one provides the vestibular cues needed for maintaining equilibrium. The adjustments are not always immediate and several task repititions may be necessary; however, the compensation does occur and directional orientation is maintained. None of the Hearing group displayed nystagmus.

As a result of these tests the subjects were classified into their respective groups. Blindfolded and visual cue subjects were randomly selected from within the three groups.

TABLE 2. Number of Unilateral and Bilateral Subjects as Determined by Positional Testing

Groups	Bilateral	Unilateral
L.D.	15	0
Conductive	0	4
Hearing	0	0

Proficiency Swim

The proficiency swimming test was administered to six deaf subjects and to all of the hearing subjects. All of these subjects displayed swimming proficiencies and were included in the study. Four deaf subjects, categorized as L.D.'s refused to take the test and were excused from the study.

Submerging Test

The submerging test consisted of four consecutive trials for each subject with each trial score being the average time of the three timers. (Table 3) An analysis of variance, utilizing a multiple regression coefficient, was the statistical method employed for computing and analyzing the test scores.

TABLE 3. Average Mean Trial Times in Seconds

Groups	N	Trials 1	2	3	4	Average Mean
L.D. - Vision	8	.456	.328	.259	.275	.330
L.D. - Blindfolded	7	.267	.294	.336	.338	.309
Conductive - Vision	5	.315	.353	.380	.362	.352
Conductive - Blindfolded	4	.347	.368	.288	.279	.321
Hearing - Vision	8	.121	.115	.120	.112	.117 *
Hearing - Blindfolded	8	.100	.105	.116	.103	.106 *

* Significant at the 1% level of confidence (2.16)

Between Groups. The six groups of subjects tested were eight L.D.'s utilizing visual cues, seven L.D.'s blindfolded, five Conductive deaf utilizing visual cues, four Conductive deaf blindfolded, eight Hearing subjects utilizing visual cues and eight Hearing subjects blindfolded. The average mean for the L.D. group utilizing vision was .330 and for the L.D. group which was blindfolded it was .309. The average mean for the Conductive deaf group utilizing visual cues was .352 and for the Conductive deaf group which was blindfolded, it was .321. The Hearing group which utilized visual cues had a mean score of .117 which was significant at the 1% level of confidence. The Hearing group which was blindfolded had an average mean score of .106 which was significant at the 1% level of confidence.

The test results indicated that there was a significant difference, an F ratio of 15.67 (Appendix A) between the Hearing groups and the four deaf groups. There was no significant difference between the performance times of the L.D. groups and the Conductive deaf groups. The null hypothesis that there will be no significant difference among the performances of all groups was rejected.

There was no significant difference in performance times between any groups utilizing visual cues and groups which were blindfolded. (Appendix B) The null hypothesis that stated that there will be no significant differences among groups in the ability to orient themselves when submerged in water when utilizing underwater visual cues was accepted.

There was no significant difference in the performance improvement between any groups in accordance with the number of trials.

Within Groups. There was no significant difference between the performance time of the L.D.'s utilizing visual cues and the L.D.'s blindfolded. (Appendix B) The null hypothesis that there will be no significant difference between performances of the L.D. group utilizing visual cues and the L.D. group not utilizing visual cues was accepted.

There was no significant difference between the performance time of the Conductive deaf group utilizing visual cues and the Conductive deaf group blindfolded. (Appendix B) The null hypothesis that there will be no significant differences between the performances of the Conductive deafness group utilizing visual cues and the Conductive deaf group not utilizing visual cues was accepted.

There was no significant difference between the performance time of Hearing groups utilizing visual cues and the Hearing group blindfolded. (Appendix B) The null hypothesis that there will be no significant differences between the performances of the Hearing group utilizing visual cues and Hearing group not utilizing visual cues was accepted.

Discussion

Pre-Tests

The pre-tests were used to distinguish groups prior to the submerging test.

Walk-A-Line, Eyes Closed. The WALEC test was found to be a highly discriminating test that isolated subjects with an auditory-vestibular nerve dysfunction. Subjects who had a labyrinthine dysfunction were able to assume the basic starting position but when the blindfold was applied they immediately experienced an upper trunk body sway which prevented them from taking the first step. Several, on the third trial, were able to take one step but none were able to take more. When the body sway began it was virtually impossible for them to hold the arm position or to maintain the tandem foot alignment. The Conductive deaf subjects and the Hearing group had little difficulty with the test and did not experience the body sway. The Conductive deaf group performed better on their second and third trial than on their first.

Walk on Floor, Eyes Closed. As in the WALEC test subjects with an auditory-vestibular nerve lesion were unable to perform on the WOFEC test. The subjects were unable, when blindfolded, to maintain the basic body position and consequently were unable to take more than one or two steps before violating the required body position. The hearing subjects performed the test without difficulty and without much deviation from the line. The conductive deaf subjects were basically able to maintain their body position but did not consistantly do so on every trial.

Standing With Eyes Closed, 2¼" Rail. The L.D. group performed better on the 2¼" rail test than on either of the two previous tests. However, their performance times were considerably shorter than the subjects in the Conductive deaf or Hearing groups. As in the previous tests, the upper trunk sway prevented them from maintaining the upright position. The conductive deaf and the hearing subjects also experienced body sway but were able to compensate, for a longer period of time than the L.D.'s, with ankle and leg adjustments. The L.D. group struggled to stay on the rail and literally fell off the rail in their attempt to maintain the body position. When the hearing and conductive subjects experienced extreme body sway, they merely stepped off the rail.

Positional Testing. All of the subjects which had tentatively been classified in the L.D. group were found to have a bilateral vestibular disturbance. All four of the "non-swimmers" excused from the study displayed bilateral nystagmus.

Submerging Test

All of the subjects in this study were able to locate the water's surface without extreme difficulty. The hearing subjects performed significantly better than did either deaf group. The hearing subjects did not have to repeat a trial and they swam directly to the surface after being completely submerged. Five of the L.D. group had to repeat their first trial and in general, the deaf subjects held their tuck position longer than necessary and tended to be slower in reacting when totally submerged.

This study indicated that there was no significant difference in the performance times between the conductive deaf subjects and the L.D. group. In analyzing the testing results of these two groups, two factors emerged which need to be considered as relevant to the findings. The first factor was that all but seven of the deaf subjects learned to swim through the deaf school's swimming program and were exposed to the same swimming instructor and teaching method. Upon completion of their four trials, each subject was asked by the interpreter how he located the water's surface. The majority, both L.D. and conductive, stated that they had been taught, in their swimming classes, to lift their head whenever they were underwater. This would provide the body with a direct pathway to the surface. As noted in diving or tumbling stunts, the body reacts to and follows the pathway established by the neck and head. It would seem that these subjects may have been taught a method which would allow them to compensate for the lack of visual cues and the cues normally afforded by the kinesthetic sense. In the pilot study, using subjects from a different school and with a different swimming background, the L.D. group had a more difficult time in maintaining their equilibrium while underwater. One subject did become completely disoriented and swam to the side wall mistaking it for the surface. He tore off the blindfold and subsequently found the surface. The fact that the deaf subjects tended to hold the tuck position longer than the hearing subjects gives rise to the speculation that they were actually, consciously or unconsciously, waiting for a bouyancy cue to assist them.

The second contributing factor was the exclusion, by the design of the study, of L.D. subjects who may indeed have become disoriented. Subjects volunteered to participate and those with known orientation problems were not apt to volunteer. The four who refused to perform the proficiency swim test and were, therefore, eliminated from the study were all classified in the L.D. group. Though these four demonstrated proficient swimming skills in the shallow end of the pool, they would not try to test in the deep water. Though none of them had previously experienced disorientation in the water and they cound not recall being told that they would drown, they were positive that they would not be able to find the surface. No amount of reassurance, bribery or peer pressure would change their minds.

The use of visual cues did not enhance performance times. This may also have been influenced by the method that the L.D. subjects utilized in locating the surface. It appeared obvious that some factor or factors, of an undetermined nature, other than vision were successfully employed by the L.D. subject.

Five of the L.D. subjects had to repeat their first trial, whereas, none of the other subjects in the study had a trial disqualified. These five released their legs and extended their arms prior to entering the water. They maintained the tuck position on all subsequent trials.

Though some of the deaf students appeared to be tense on their first trial, as indicated by their inability to maintain the tuck position, fear did not appear to be an influencing factor. Except for the four who were eliminated from the study, all of the subjects were eager to perform the test over and over again.

CHAPTER V

SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

Summary

The Purpose

The purpose of this study was to determine if subjects with auditory-vestibular nerve lesions, under varying visual conditions, would be able to orient themselves when totally submerged in water. Of further interest to the study, comparisons were made of similar performances of deaf individuals due to other causes (conductive deafness) and to hearing subjects to determine if significant differences existed between the groups

Procedures

The following sequential procedures were utilized for securing and analyzing the study's data:

1. The assumptions on which the study was established were defined and the hypotheses to be tested were formulated.

2. A pilot study was designed and administered and as a result, the methodology for the present study was refined and employed.

3. The subjects for the present study were selected. The L.D. group was composed of fifteen bilateral neural deaf, nine

Conductive deaf subjects were used, and there were sixteen Hearing subjects in the study. Both deaf groups were students at a special school for the deaf and the hearing subjects were from nearby high schools. The deaf groups were determined by a series of pre-tests and the school health records.

4. The submerging test was administered and the testing results were statistically treated and analyzed.

5. The study's results were presented and the findings discussed.

Hypothesis

The following hypotheses were tested:

1. There will be no significant differences among the performances of all groups.

2. There will be no significant differences among groups in the ability to orient themselves when submerged in water when utilizing underwater visual cues.

3. There will be no significant differences among groups in the ability to orient themselves when submerged in water in the absence of underwater visual cues.

4. There will be no significant differences between performances of the labyrinthine dysfunction group utilizing visual cues and the labyrinthine dysfunction group not utilizing visual cues.

5. There will be no significant differences between the performances of the conductive deafness group utilizing visual cues and the conductive group not utilizing visual cues.

6. There will be no significant differences between the performances of the hearing group utilizing visual cues and the hearing group not utilizing visual cues.

The null hypothesis which stated that there will be no significant differences among the performances of all groups was tenable. The remaining null hypotheses stated after the analysis of data were not tenable.

Results

The ability to maintain directional orientation when under water was accomplished by the L.D. group with equal proficiency to those in the conductive deaf group. Though the hearing subjects demonstrated faster times, directional disorientation did not occur with any of the subjects used in the study.

The use of visual cues did not have a significant influence on the performance times with any of the six groups.

The repetition of the task four times did not improve the performance times.

Conclusions

The results of this study did not support the opinion of authors who stated that subjects with a bilateral auditory-vestibular nerve dysfunction would drown or be completely disoriented when submerged in deep water. Though the L.D. group utilized in this study were slower in finding the water's surface when submerged than the hearing subjects, their performance was equal to that of the non-neural deaf group. None became disoriented nor did their lives appear to be in danger. It would appear that not all bilateral neural deaf subjects drown or become disoriented when submerged in deep water.

It was apparent that vision, as utilized in this study, was not the sense organ that the L.D. subjects utilized to locate the water's surface. The method of maintaining directional orientation appeared to be due to, as of yet, an undetermined factor.

Limitations

The nature of the study allowed for several possible limitations which may be reflected in the data.

The safety design of the study, utilizing volunteers who possessed swimming skills, may have excluded those labyrinthine dysfunction subjects who might have experienced total disorientation when submerged in water. The swimming skills of these particular labyrinthine dysfunction subjects had prepared them to cope with an underwater situation.

The sampling was relatively small and may not have been representative of the deaf or hearing population. Therefore, any implications derived from or conclusions made from this study should pertain only to the subjects studied.

Recommendations

The labyrinthine dysfunction individual has been virtually overlooked in the search for understanding human equilibrium and there appears to be a dire need for the limited hypothetical research to be enhanced and documented by additional experimental studies.

There is a need to fully understand the sensory modalities which are employed by labyrinthine dysfunction individuals in their attempt to maintain their equilibrium when underwater. The exact nature of the employed modalities needs to be understood as well as the defining of their potentials and limitations.

The method of water entry utilized in this study was in keeping with the premise that a neurally deaf subject would experience disorientation "if thrown" or if he "dived" into deep water, the method used has obvious limitations. A method of rotating and releasing a person while he is submerged in water would appear to be a more reliable means of determining the degree, if any, of disorientation which might result.

The 14 to 18 year old males utilized in this study may or may not have demonstrated skills representative of the total labyrinthine dysfunction population. Further studies, employing various age groups and both sexes would provide a greater understanding of neural deafness in an underwater setting.

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APPENDICES

APPENDIX A

STATISTICAL COMPUTATIONS

Table 4. Submergence Test-Multiple Regression Computations Utilizing Hearing, Vision and Trials. Selection 1.

Variables	Variable No.	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Ref. Coef.	Computed T Value
Hearing Contrasts	1	-0.17500	0.77337	0.57128	127.88911	15.79705	8.09575
	2	-0.12500	1.45692	-0.29547	-26.63426	8.37660	-3.17960
Vision Cont.	3	0.05000	1.00188	0.11357	20.76065	12.38345	1.67648
Interaction of hearing by vision	4	0.02500	0.79265	0.7536	20.38940	15.79706	1.29070
	5	-0.02500	1.46209	0.01557	5.17513	8.37660	0.61780
Trial No.	6	2.50000	1.12153	0.00294	0.49510	10.68081	0.04635
	Dependent						
	7	248.68753	188.27758				

Intercept 265.08270

Multiple Correlation 0.61697

Std. Error of Estimate 151.04879

Table 5. Submergence Test - Analysis of Variance for the Regression Utilizing Hearing, Vision and Trials. Selection I

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	6	2145495.00585	357582.43835	15.67262*
Deviation from Regression	153	3490809.00683	22815.74223	
Total	159	5636304.01367		

* Significant at the 1% level of confidence (2.16)

Table 6. Submergence Test - Multiple Regression Computations Utilizing Hearing and Trials. Selection II

Variable No.	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Ref. Coef.	Computed T Value
1	-0.17500	0.77337	0.57128	129.54763	15.73913	8.23092
2	-0.12500	1.45692	-0.29547	-25.94672	8.34743	-3.10834
3	0.05000	1.00188	0.11357	16.47280	11.96112	1.37719
6	2.50000	1.12153	0.00294	0.49510	10.67460	0.04638
Dependent						
7	248.68753	188.27758				

Intercept	266.05358
Multiple Correlation	0.61097
Std. Error of Estimate	150.96099

Table 7. Submergence Test - Analysis of Variance for the Regression of Hearing and Trials. Selection II.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	4	2103974.00683	525993.50190	23.08079*
Deviation from Regression	155	3532330.00683	22789.22270	
Total	159	5636304.01367		

* Significant at the 5% level of confidence (2.43)

Table 8. Submergence Test - Multiple Regression Computations Utilizing Hearing and Vision. Selection III

Variable No.	Mean	Standard Deviation	Correlation X vs Y	Regression Coefficient	Std. Error of Ref. Coef.	Computed T Value
1	-0.17500	0.77337	0.57128	127.88194	15.74579	8.12211
2	-0.12500	1.45692	-0.29547	-26.63426	8.34941	-3.18995
3	0.05000	1.00188	0.11357	20.76065	12.34326	1.68194
4	0.02500	0.79265	0.07536	20.38940	15.74579	1.29491
5	-0.02500	1.46209	0.01557	5.17513	8.34941	0.61981
Dependent						
7	248.68753	188.27758				

Intercept 266.32043

Multiple Correlation 0.61696

Std. Error of Estimate 150.55862

Table 9. Submergence Test - Analysis of Variance for the Regression of Hearing and Vision. Selection III

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Value
Attributable to Regression	5	2145447.00683	429089.31323	18.92938 *
Deviation from Regression	154	3490857.00683	22667.90239	
Total	159	5636304.01367		

* Significant at the 5% level of confidence (2.27)

APPENDIX B

Test Scores

Table 10. Submerging Test - Individual Time Trials
L.D. Vision Group.

Subjects	Trials				AVERAGE
	1	2	3	4	
1	.389	.377	.289	.310	.341
2	1.105	.348	.232	.182	.466
3	.598	.187	.151	.121	.264
4	.494	.586	.303	.373	.439
5	.168	.123	.143	.135	.142
6	.090	.065	.141	.230	.131
7	.248	.434	.372	.320	.343
8	.562	.504	.445	.535	.511

Table 11. Submerging Test - Individual Time Trials
L.D. Blindfolded Group.

Subjects	Trials				Average
	1	2	3	4	
1	.258	.297	.279	.273	.276
2	.268	.386	.504	.432	.397
3	.292	.316	.371	.365	.336
4	.205	.271	.246	.225	.236
5	.217	.151	.201	.139	.177
6	.336	.344	.452	.632	.441
7	.299	.336	.301	.300	.309

Table 12. Submerging Test - Individual Time Trials
Conductive Vision Group

Subjects	Trials				Average
	1	2	3	4	
1	.349	.491	.543	.357	.324
2	.315	.331	.359	.315	.335
3	.475	.340	.298	.371	.371
4	.263	.312	.367	.442	.346
5	.176	.293	.335	.329	.283

Table 13. Submerging Test - Individual Time Trials
Conductive Blindfolded Group

Subjects	Trials				Average
	1	2	3	4	
1	.345	.444	.168	.252	.302
2	.534	.410	.353	.371	.417
3	.380	.386	.378	.284	.357
4	.132	.235	.256	.212	.209

Table 14. Submerging Test - Individual Time Trials
Hearing Vision Group

Subjects	Trials				Average
	1	2	3	4	
1	.169	.138	.145	.155	.151
2	.101	.060	.071	.077	.077
3	.133	.156	.156	.120	.141
4	.134	.147	.136	.136	.138
5	.144	.165	.132	.165	.151
6	.083	.093	.149	.085	.102
7	.085	.095	.085	.082	.086
8	.124	.071	.086	.077	.089

Table 15. Submerging Test - Individual Time Trials
Hearing Blindfolded Group

Subjects	Trials				Average
	1	2	3	4	
1	.080	.065	.097	.065	.076
2	.065	.070	.069	.070	.070
3	.103	.081	.113	.090	.096
4	.129	.123	.128	.121	.125
5	.113	.107	.167	.134	.130
6	.126	.111	.096	.112	.111
7	.085	.116	.128	.122	.112
8	.100	.169	.135	.110	.128

APPENDIX C

Score Card

SCORE CARD

Name ______________________ Birthdate ______________________

Weight ______________________ Height ______________________

Comments:

WALEC - WOFEC

	1	2	3	4	5
Inches					
Steps					

2¼" Rail - Eyes Closed

1	2	3	4	5

Positional Testing

Left	Right

Submerging

	1	2	3	4	5
Timer 1					
Timer 2					
Timer 3					
Average					

Walk-A-Line, Eyes Closed
Walk-On-Floor, Eyes Closed

WALEC - WOFEC

Please read the directions carefully and then proceed to the starting place.

1. The purpose of this test is to walk the chalk line, keeping as straight a line as possible.

2. Go to the X marked on the floor.

3. Place one foot on the X and the other foot directly in front of it.

4. The heel of your front foot must always touch the toe of the back foot.

5. A blindfold will be placed over your eyes.

6. When blindfolded, cross your arms and clasp your elbows with your hands. Do not release your arms.

7. Walk as straight a line as possible and continue until stopped by one of the examiners.

Thank you.

Standing, Eyes Closed - 2¼" Rail

2¼" Rail - SEC

Please read the directions carefully and then signal when ready.

1. The idea of the test is to stand on the rail as long as possible.

2. A blindfold will be placed over your eyes.

3. Step on the rail with one foot and then place your other foot in front of the first one.

4. The heel of your front foot must touch the toe of the back foot.

5. Keep this position as long as possible or until touched by one of the examiners.

Thank you

Positional Testing

Please read the directions before assuming the starting position.

1. The purpose of this test is to check the movement of your eyes.

2. Lie down on the bench with your head, neck and shoulders extended over the end.

3. Relax

4. The examiner will be turning your head to the left and to the right.

That's all there is to the test.

Thank you

Submerging Test

Submerging Test

Please read all the directions before getting on the disc.

1. The purpose of this test is to see how quickly you can surface once you are underwater. You will be tipped into the water from the disc.

2. Sit in the middle of the disc.

3. Fold your knees to your chest.

4. Clasp your arms around your knees. Do not let go until you are completely underwater.

5. Tuck your head to your chest.

6. Some of you will be blindfolded. Do not remove the blindfold until you surface.

7. Stay tucked until you are completely submerged.

8. When you are completely submerged, swim directly to the surface.

9. Remove your blindfold.

10. You will try the test four times.

Thank you
