ADAPTING THE CONDITIONED EYEBLINK HEARING TEST TO THE CLINICAL SITUATION

by

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CHAPTER ONE

INTRODUCTION

The measurement of hearing usually depends on a person's voluntary response to the test tone of an audiometer. In order to establish a pure tone threshold the tester must rely on the patient's signaled or spoken indication of hearing. This method is applicable in most test situations and requires only that the patient understand and follow simple instructions. However, young children, the psychologically disturbed, or brain damaged patients, may not respond voluntarily. A more objective measure of hearing is needed in these cases and the use of a conditioned response to the test tone has provided such a measure (7) (10).

Conditioned Response Hearing Tests

Conditioning in audiometry involves the presentation of the tone, or conditioned stimulus, followed by an unconditioned stimulus which will elicit an observable response. Following a number of presentations, or conditioning trials, the tone itself will elicit the response, which is then called a conditioned response. The presence of a conditioned response indicates that the tone was heard and hearing may be measured without a signal from the patient.

The Galvanic Skin Response Test. This test is widely used as an objective measure of hearing. The galvanic skin response is a change in the electrical resistance of the skin, which may be conditioned to the tones from an audiometer by using an electric shock as the unconditioned stimulus.

Doerfler and McClure (7) used the test to measure hearing loss in adults and obtained thresholds that differed only 2½ db. from the actual pure tone threshold. The test, however, has some disadvantages. The electrical resistance of the skin is constantly fluctuating and easily altered by the extraneous stimuli present during the test. It is sometimes difficult to separate these changes from the conditioned response. Another problem stems from the use of an electric shock as the unconditioned stimulus. The shock is unpleasant and frequently makes the administration of the test difficult.

The Conditioned Eyeblink Test. The eyeblink is a stable reflex which may be elicited by a flash of light or a puff of air directed against the cornea. The eyelid response is well suited to conditioning experiments and has received considerable attention in the literature. In two of these studies it was used as a measure of hearing.

In 1936, Neet (36) compared the auditory thresholds obtained by the usual method with those found using a conditioned eyeblink test. A puff of air from a hand operated rubber bulb provided the unconditioned stimulus. He concluded that the two methods gave equivalent results.

Galloway and Butler (10) re-examined the possible usefulness of the conditioned eyeblink test. They used a pure tone as the conditioned stimulus and a flash of light as the unconditioned stimulus. The binaural thresholds differed less than 5 db. from those found by the usual method. It was concluded that the test is a potentially useful objective test of hearing. However, the practical application of the test seemed limited through the use of elaborate equipment and conditioning trials which were spaced over a three day period. These two factors provided the incentive for the present investigation.

The Design of a Practical Test

The conditioned eyeblink test has several characteristics which suggest its use as a practical clinical test. The use of a light or air puff as the unconditioned stimulus is not unpleasant, and the eyelid response is not difficult to measure. The small deviations in accuracy found by Galloway and Butler (10) seem to warrant an investigation in terms of adapting the test to the clinical situation.

Several factors are involved in the design of a practical test. The apparatus should be as simple as possible since the use of elaborate equipment will tend to limit the test to the experimental laboratory. Ideally, it should be possible to give the test in one sitting, which will require the use of a rapid and efficient conditioning procedure. The two main problems in the design of a practical test are: (1) the design of simple equipment, (2) the design of an efficient conditioning procedure.

Statement of Problem

The purpose of this study was to modify the conditioned eyeblink hearing test for clinical use. The main modifications investigated were: (1) a speeded conditioning procedure, (2) the use of simplified apparatus.

A review of the literature on eyelid conditioning, which is discussed in detail in Chapter II, provided much of the information needed to establish a suitable conditioning procedure and to form a basis for the design of simple equipment.

The present study was designed to determine whether or not these modifications are practicable in adapting the conditioned eyeblink hearing test to the clinical situation.

CHAPTER TWO

REVIEW OF THE LITERATURE

A review of the many experiments on eyelid conditioning suggested the specific characteristics of an efficient conditioning procedure, and provided some information on the design of simple apparatus. This chapter will consider: (1) the conditioned stimulus, (2) the unconditioned stimulus, (3) conditioning, (4) instructions, (5) apparatus.

The Conditioned Stimulus

In order to determine a pure tone threshold of hearing, the intensity and frequency of the tone must be known. The pure tone audiometer provides these measurements and was, of course, designed for that purpose. In a conditioning experiment it is desirable to know at what intensity the tone should be used during the conditioning trials.

Meritser and Doerfler (6) compared the results obtained using constant and varied intensities of the tone in conditioning the galvanic skin response. One group was conditioned using a 1000 cycle tone at 30 db. and the other group was given intensities of 30, 50, and 70 db. They found no significant difference in the extent of conditioning between the two groups.

Carter (4) used intensities of 15, 30, 45, 75, and 90 db. at 1000 cycles and found that the intensity of the conditioned response did not vary significantly. He concluded that if the tone is above the threshold of hearing, conditioning will take place.

The Unconditioned Stimulus

A puff of air was most often used as the unconditioned stimulus in experiments on eyelid conditioning (4) (8) (24). Spence (42) compared the effects of using a weak and a strong puff, and found that the strong puff resulted in a more intense conditioned response. Spence and Taylor (45) in a similar experiment found a tendency toward better conditioning when a strong puff was used.

Spence and Norris (44) and Logan (31) used an electrode placed below the eye in order to present a shock as the unconditioned stimulus.

Grant (12) compared the results of using a light with those using a puff of air as the unconditioned stimulus. He found that the response to light was more stable from person to person than a puff of air. There was a trend toward a simplification of the response to air as the experiment progressed, and the response was variable. The intensity of the response to light also decreased; however, the decline was steady.

Conditioning

Types of Conditioning. Classical conditioning involves the presentation of the conditioned stimulus followed by the unconditioned stimulus. In instrumental conditioning, when a conditioned response occurs, the unconditioned stimulus is not presented. Kimble and Dufort (30) and Logan (31) compared the effectiveness of the two methods in conditioned eyelid experiments and found that instrumental conditioning was less effective.

Wilcott (51) found that eyelid conditioning did not occur when the intensity of the tone was below the threshold of hearing. The occurrence of sub-threshold conditioning would invalidate the results obtained with a hearing test based on eyelid conditioning.

Kimble and Dufort (30) found that the number of conditioned responses was a better indication of conditioning than the number of conditioning trials presented. This was due to individual differences in the rate of conditioning. The validity of adjusting the conditioning period to the individual is thus indicated.

The Interval Between the Conditioned and Unconditioned Stimuli. The time interval between the onset of the tone, or conditioned stimulus, and the onset of the flash of light, or unconditioned stimulus, is an important determining factor in the efficiency of a conditioning procedure.

Various intervals have been used in eyelid conditioning, depending on the experimenter and the purpose of the study. The most frequently used interval was 450 msec. This interval was used in eight of the studies reviewed (10) (17) (18) (19) (20) (35) (37) (40). The most common intervals other than 450 msec. were 400 msec. (23) (24) (50) and 500 msec. (29) (38) (43).

In a study by McAllister (33) on eyelid conditioning as a function of this interval, intervals of 100, 250, 450, 700, and 2500 msec. were used. An optimum range of 400 to 500 msec. was found; however, it was noted that an interval of 250 msec. was slightly, but not significantly, superior when a tone was used as the conditioned stimulus. McAllister (32) also noted that variations in the time interval during the experiment resulted in fewer conditioned responses.

Underwood (48) mentions that better conditioning results if the conditioned stimulus overlaps the unconditioned stimulus with both stimuli ending at the same time. This procedure is known as the simultaneous conditioned response method and is often used (10) (33) (43).

The above studies suggest that an efficient interval between the conditioned and unconditioned stimuli is from 400 to 500 msec. It was indicated that this interval should remain fixed during the experiment and that the two stimuli should end simultaneously.

Conditioned Response Time Limits. The presence of a conditioned response may be determined by measuring the latency of the response or by establishing time limits between which the response must occur to be counted as a conditioned response.

Campbell and Hilgard (3) measured the latency of the eyelid response and found that most conditioned responses occurred between 200 and 300 msec. Grant (11) reached a similar conclusion and found the range of conditioned responses to be from 259 to 332 msec. The results obtained by Porter (39) differed slightly. He found most of the latencies to be from 205 to 435 msec. Hilgard (22) used a loud sound as the unconditioned stimulus. He found that the average latency of the conditioned response was 195 msec. Kimble and Dufort (29) used a slightly longer interval between the conditioned and unconditioned stimuli and found the average conditioned response latency to be 425 msec.

In several studies a fixed interval was used during which an eyelid movement was counted as a conditioned response. Moeller (35), in a study of the galvanic skin response test, found that a conditioned response range of 120 to 450 msec. was ample for recording most of the conditioned responses. In most of the studies reviewed on eyelid conditioning, an interval between the limits of 120 to 500 msec. was used (16) (18) (37) (43) (49). In some studies the limit was extended to 650 msec. (19), 750 msec. (17) (21), and other values (1) (31) (32) (33).

Grant and Norris (14) and (15) found that the Beta response to light may be confused with the conditioned response, since the Beta response range of 120 to 240 msec. extends into the conditioned response range. Stevens (46) made allowance for this in suggesting that a good conditioned response range, when a light was used as the conditioned stimulus, was from 250 to 450 msec.

In view of the average and range of latencies usually found and the fixed intervals most often used, an optimum and servicable range, when a light was not used as the conditioned stimulus, seemed to be between 150 and 450 msec.

The Interval Between Trials. In a study on eyelid conditioning as a function of the inter-trial interval, Humphreys (25) found that a one minute interval was more efficient than a 30 second interval. Spence and Norris (44) used intervals of 9, 15, 30, and 90 seconds. They found that conditioning improved as the length of the interval was increased. The 90 second interval was twice as efficient as the 9 second interval; however, it required ten times as long to present a given number of trials with a 90 second interval as compared to a 9 second interval.

Vandermeer (49) gave one group of subjects three trials per minute and another group nine trials per minute. He found no significant difference in the rate of conditioning.

In most of the studies reviewed it was found that a longer inter-trial interval is more efficient in terms of the number of conditioning trials. Little information was available concerning an efficient inter-trial interval in terms of time.

<u>Reinforcement</u>. If the conditioned stimulus is followed by the unconditioned stimulus on every conditioning trial, the procedure is called 100% reinforcement. Similarly, if the unconditioned stimulus is presented only half of the time, a 50% reinforcement procedure is being followed. Several studies have been made comparing the effectiveness of these two procedures.

Grant, Riopelle, and Hake (19) found that 50% random reinforcement was superior to 100% reinforcement in the acquisition of the conditioned eyeblink, and that 50% random reinforcement resulted in faster conditioning than 50% reinforcement given in a pattern of single or double alterations.

Humphreys (26) found that the difference between 100% and 50% random reinforcement during the acquisition of the conditioned eyeblink was not significant; however, he noted that 50% reinforcement was superior during extinction trials. In another study (27), he noted that 50% reinforcement was more efficient than 100% reinforcement in maintaining the galvanic skin response.

In another experiment, Grant and Hake (13) noted a trend toward slower extinction if 50% random reinforcement was used instead of 100%. They also found that the frequency of conditioned responses during the training trials was depressed when 50% reinforcement was used.

Grant and Shipper (16) studied the acquisition and extinction of the conditioned eyeblink using different percentages of reinforcement ranging from zero to 100% and found, in general, that the frequency of the conditioned responses during acquisition was a function of the percentage of reinforced trials. As the percentage of reinforced trials was increased, the percentage of conditioned responses increased.

Grant, Shipper, and Ross (20) used 50% and 100% reinforcement in various combinations with massed and spaced trials during acquisition and extinction. They found that 100% reinforcement was most effective in acquisition when the conditioning trials were massed (ten seconds apart) and that 100% reinforcement was most effective in extinction when both the acquisition and extinction trials were massed.

Jenkins and Stanley (28), in a review and critique of partial reinforcement, suggest the use of 100% reinforcement to establish the desired behavior initially and then to use partial reinforcement to maintain the conditioned response.

In view of these studies a procedure of 100% reinforcement should provide the most rapid conditioning, and a procedure of 50% reinforcement prove ample to maintain the conditioned response.

Apparatus

The apparatus for a conditioned eyelid experiment must perform two basic functions: (1) detect the conditioned response, (2) time the presentation of the stimuli. Several different devices have been used for this purpose. One of the earliest experimenters used a thread fastened to the eyelid. The thread was connected to a lever system which moved the recording pen.

A pendulum chronograph was often used in eyelid experiments to time the stimuli. The chronograph utilized the constant motion of a pendulum which tripped the switches as it was swung (50).

Spence and Taylor (45) and McAllister (33) used a microtorque potentiometer actuated by a thread or wire attached to the eyelid. The alterations in the resistance of the potentiometer as the eyelid moved, changed the frequency of an oscillator which was connected to an amplifier, rectifier, and pen motor.

Kimble, Mann, and Dufort (30) attached a foil eyelash to the subject's eyelid. The shadow cast by the eyelash actuated a photoelectric cell indicating the occurrence of a conditioned response.

Galambos, Rosenberg, and Glorig (9) detected the movement of the eyelid by using a phonograph cartridge with a wire, in place of the needle, touching the eyelid. The output of the cartridge was amplified and viewed on an oscilloscope.

Galloway and Butler (10) studied the use of the conditioned eyelid response to tone as an objective test of hearing. A beat frequency oscillator, amplifier, attenuator, and headphones were used to present the tones. In order to detect and record the conditioned response, a phonograph cartridge, amplifier, oscillator, and electroencephalograph were used. A spot lamp provided the unconditioned stimulus and a photoelectric cell detected the flash of light which was recorded on the electroencephalograph. The timing of the stimulus presentations was accomplished by using two electronic interval timers.

Instructions

Grant (11), in a study on the effect of attitudes on eyelid conditioning, compared the effects of using passive and active instructions. One group was told to adopt an attentive attitude, to watch for the conditioned stimulus and respond by quickly tapping a finger when it appeared. A second group was told to remain passive toward the experiment. He found that the first group gave a higher percentage and greater amplitude of conditioned responses.

Miller (34) compared facilitory and inhibitory instructions. He obtained conditioned responses on 71% of the trials when facilitory instructions were given and 26% when inhibitory instructions were given.

Campbell (2) controlled random blinks by asking the subject to blink before each trial.

CHAPTER III

INSTRUMENTATION AND PROCEDURE

The problem in the present study was to determine the practicability of two basic modifications of the conditioned eyeblink hearing test which were designed to adapt the test to the clinical situation. The modifications investigated were: (1) a speeded conditioning procedure, (2) the use of simple apparatus. A review of the literature on eyelid conditioning provided the essential information needed to design the apparatus and set up an efficient conditioning procedure. In order to test the practicability of these modifications, the thresholds obtained with the modified conditioned eyeblink test were compared with those found using the standard test of hearing. This measure of validity and the length of time required to administer the test, served to indicate the effect of the modifications.

Apparatus

Design. A device was needed for this experiment which would perform the following functions: (1) detect and record slight movements of the eyelid, (2) present the conditioned and unconditioned stimuli, (3) time these functions accurately. The design of this equipment was influenced by the choice of conditioning procedure, the apparatus used in previous studies, and the writer's intention to use a simple device.

The review of the literature indicated that classical conditioning was best suited to the present study. This involves the presentation of the conditioned stimulus followed by the unconditioned stimulus. Since the threshold of hearing was to be determined, the use of a pure tone audiometer was indicated as a practical source for the conditioned stimulus.

The unconditioned stimulus must be capable of eliciting an eyeblink. Of the three possibilities suggested in the literature, an electric shock, a puff of air, or a flash of light; the choice of a light as the unconditioned stimulus for the present study seemed most satisfactory. A light is probably the least irritating of these three. The eyelid response to light is relatively stable; and, mechanically, it is simpler to switch on a light for a brief period than to release a puff of air.

The experiments on eyelid conditioning suggested that an efficient interval between the conditioned and unconditioned stimuli was from 400 to 500 msec. The choice of an interval for the present study was also influenced by the latency of conditioned responses and the use of reinforcement during the test trials. In order to record the conditioned responses occuring on reinforced trials, the conditioned response had to be measured before the onset of the unconditioned stimulus; therefore, it was necessary that the time interval be long enough to include the interval during which a conditioned response could be recorded, excluding blinks caused by the unconditioned stimulus. If, for example, an interval of 250 msec. were used, it would be impossible to record a conditioned response on reinforced trials which had a latency greater than 250 msec. If such recordings were made, the blink elicited by the unconditioned stimulus would be counted as a conditioned response. Since it was desirable to record conditioned responses with latencies up to 450 msec., a 450 msec interval was chosen for this study.

Another problem in the design of an efficient conditioning procedure was the choice of conditioned response time limits. These limits were established by noting the average and range of conditioned response latencies in studies where latency was measured, and by noting the conditioned response time limits used in other studies. The choice of time limits for this study was also influenced by the use of sound as the conditioned stimulus which made it possible to extend the upper time limit to 150 msec. In most of the studies reviewed it was found that a lower limit of 450 msec. was ample for recording conditioned responses. An interval of 150 to 450 msec. was chosen for this experiment.

Construction. The main considerations in the construction of the apparatus were: (1) simplicity, (2) accuracy, (3) sensitivity, (4) quiet operation. Essentially, the equipment constructed for this study was found to satisfy these requirements. It was not difficult to build and the parts were easily obtainable and inexpensive.

The movement of the eyelid was detected by a model 30 Astatic phonograph cartridge. The needle was replaced by a 2" length of 1/16" piano wire tipped with a 3/16" plastic ball. A paper eyelash ½" x 1" was attached to the eyelid with a tiny strip of adhesive tape so as to slope upward at about a 45 degree angle. The plastic ball was placed against the paper eyelash with enough pressure to bend the paper to a nearly vertical position. This was accomplished by adjusting the swivel mount of the cartridge which was attached to an oto-scopic headband. An eyeblink moved the paper eyelash across the plastic tip which generated a current in the cartridge. The output of the cartridge was amplified by a VM model 985 amplifier which uses a 35Z5, a 12SQ7, and a 50L6 tube. The amplifier output was connected through an inter-stage transformer, which had an impedance of 10,000 to 100,000 ohms, to a sensitive relay circuit utilizing an OA4 thyratron (41). An 8000 ohm relay was connected in the plate circuit and its contacts used to turn on an NE-2 neon lamp. This circuit is shown in Figure 1. The OA4 tube was painted black to avoid false triggering from changes in illumination and the neon lamp used to indicate the conditioned response. The maximum output of the VM amplifier was used and the voltage on the OA4 adjusted to a point just below firing. A very slight movement of the eyelid was sufficient to cause the tube to conduct and turn on the neon lamp.

A Maico D-9 audiometer was used to provide the test tones and regulate their frequency and intensity. Provided with the audiometer were Permoflux P.D.R. 1 headphones with MX-41/AR covers.

The unconditioned stimulus was provided by a Champion 150 watt reflector spot lamp mounted on an adjustable stand. The spot lamp was connected in series with a 75 watt light bulb which kept the spot lamp lighted to a dull red, allowing the flash of illumination to be more brilliant since less time was spent in warming the bulb.

The automatic switching device, used to present and time the stimuli and to set the time limits for the conditioned response, was built around a small electric motor. The device, when started with a push button, turned on the tone for 450 msec., turned on the light for 100 msec., and then disconnected both. Contacts were also used to make it possible to record the conditioned response during the interval between 150 and 450 msec. as measured from the onset of the tone. After performing these switching operations, the mechanism was ready for the next trial.

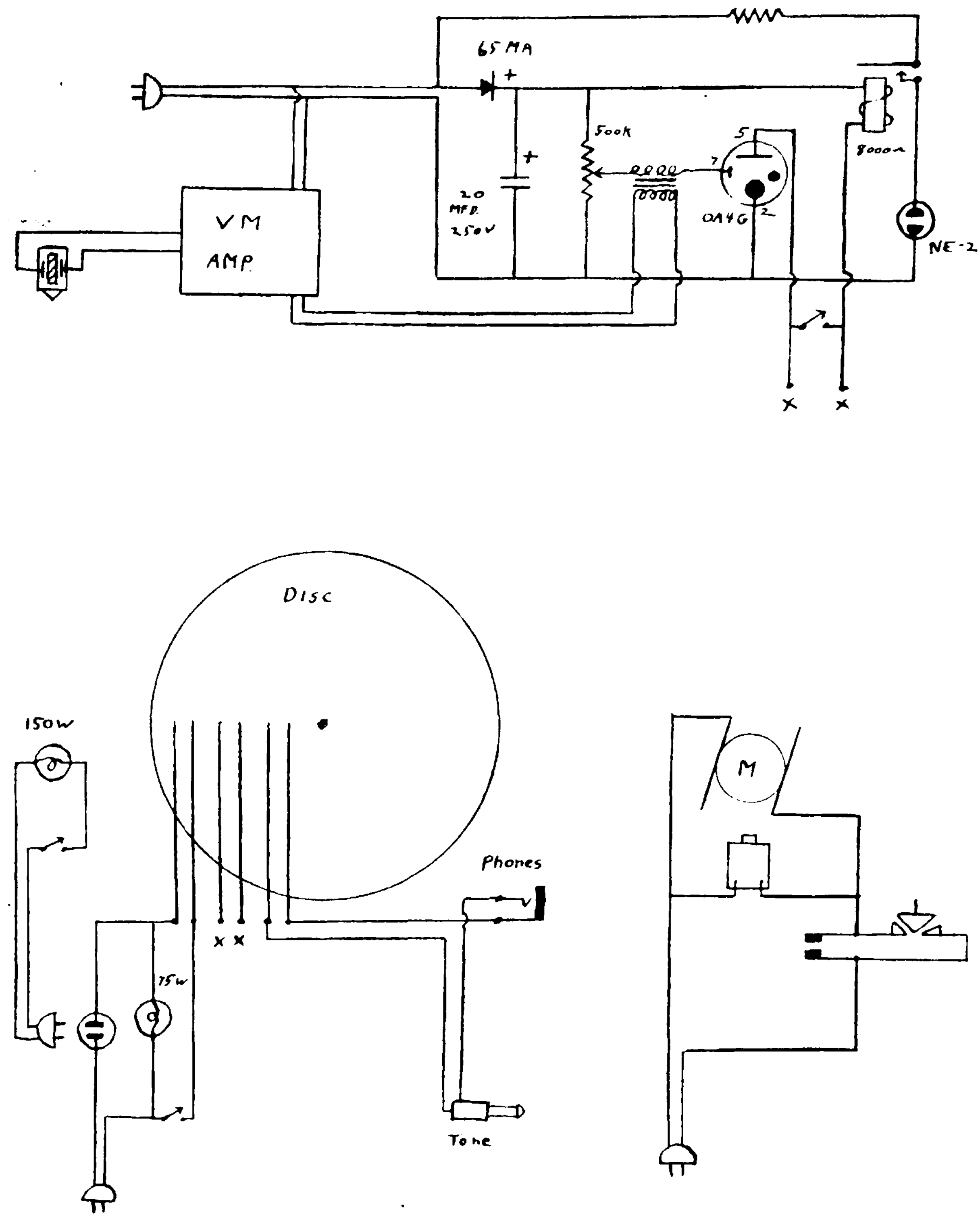

Fig. 1. Wiring Diagram

A small synchronous motor was geared down with two rubber phonograph drive wheels and used to turn a shaft at the speed of one revolution per second. A $\frac{1}{4}$" x $3\frac{1}{2}$" plexiglass disc was fastened to the end of the shaft and three pairs of curved wire contacts were attached to the face of the plexiglass disc. The first wire was located 5/8" from the center of the disc and the rest of the wires were spaced at 3/16" intervals. The curvature of each wire followed a circle scribed at its distance from the center of the disc and, as the disc turned, the contact remained in a fixed position relative to the center. The disc and contacts are drawn in Figure 2.

Since the disc completed one revolution per second, the circle's 360 degrees passed a given point in that period of time. Similarly, an area of 36 degrees passed a given point in one tenth of a second or 100 msec. On this basis, the wire contacts used to switch on the light, for example, were long enough to cover an area of 36 degrees at their particular radiuses. The contacts were arranged on the disc in order that the pair used to switch on the tone were first to pass the brass contacts located along the horizontal radius of the disc. The number of degrees between the pairs of wires on the disc was determined in the same manner as the length of the wires. The brass contacts pressing against the face of the disc were connected for the required number of milliseconds as the wire contacts passed.

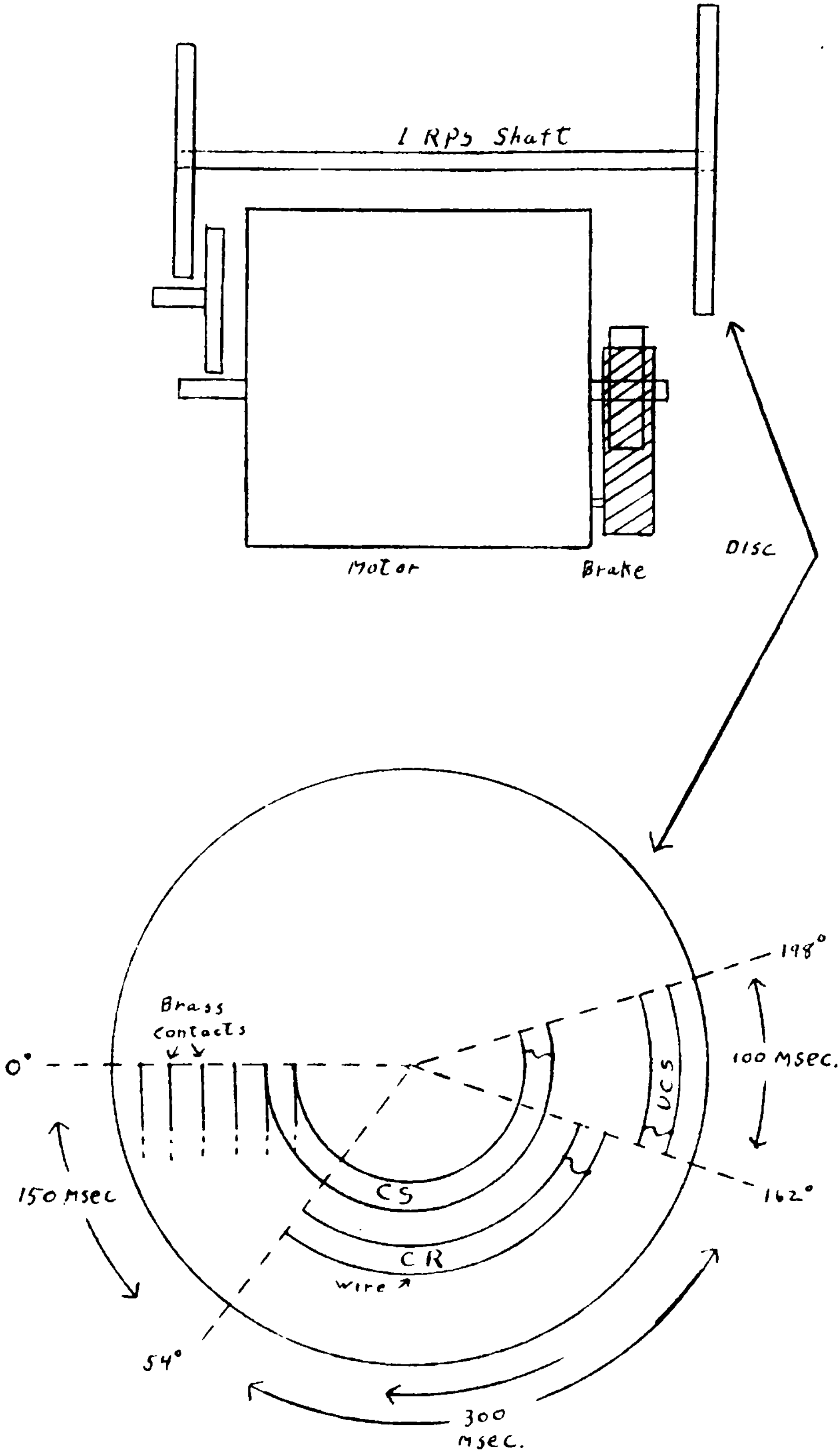

Fig. 2. Mechanical Diagram

Following the switching operation, a lever attached to the one rps. shaft opened a pair of contacts which disconnected the motor. The switching operation could be repeated by pressing the start button which was connected across the motor switch. Since the motor required about 250 msec., from the time the current was turned on, to reach its peak speed; it was necessary to stop the motor immediately following the switching operation. An electric brake was added. With this addition the motor had nearly 500 msec. to reach its maximum speed before the switching operation was begun. This insured the accuracy of the stimulus presentation. By holding in the start button and comparing the click of the motor switch to the one second markings on a watch, no variation was visible over a period of 60 seconds. The accuracy of the device seemed ample.

With the exception of the audiometer and spot lamp, the apparatus was housed in a cabinet measuring 11" x $8\frac{1}{2}$" x 7".

Test Procedure

Although little evidence was available for the following belief, the writer felt that the procedure used in the test trials should not be foreign to the procedure used in the conditioning trials. It seemed that transfer of training would most likely occur if the situations were similar. It was decided that training and test trials should be made more nearly alike by presenting the intensities and frequencies in the same general order during both periods.

Conditioning Trials. A conditioning trial consisted of presenting the tone or conditioned stimulus to the subject's right ear for 450 msec. followed immediately by the flash of light, or unconditioned stimulus, lasting 100 msec. The tone was continued during the presentation of the light and both stimuli ended at 550 msec. as measured from the onset of the tone. The interval between trials was arbitrarily chosen and ranged from two to twenty seconds; however, the most frequently used intervals were from five to ten seconds and averaged approximately eight seconds.

For the presentation of the first conditioning trial, the frequency dial of the audiometer was set at 512 cycles and the intensity dial set at 70 db. One conditioning trial was given at that setting and the intensity reduced to 60 db. A conditioning trial was given at 60 db. and then at each 10 db. step until the intensity was reduced to 30 db. The frequency dial was then changed to 1024 cycles and the various intensities were presented in the same order. Following the conditioning trials given at 1024 cycles, the frequency was raised to 2048, 4096, and 8192 cycles in that order and the procedure repeated. The conditioning trials were continued until the subject conditioned, within a time limit of one hour. If it became apparent that the subject was not conditioning after a 40 minute period, the test was discontinued.

A conditioned response was defined as an eyelid movement occurring between the limits of 150 to 450 msec. as measured from the onset of the tone. It was necessary for the eyelid movements to be strong enough to actuate the recording apparatus; however, a slight movement was sufficient. Eyeblinks were often recorded which were not visible a few feet away.

Test Trials. When three consecutive conditioned responses were recorded during the conditioning trials, the conditioning period ended and the test trials were begun without interruption. The frequency dial was set at 512 cycles and the intensity dial at 70 db. Four test trials were presented at this setting. If two conditioned responses occurred, out of the four presentations, the intensity was reduced 10 db. and four additional trials given. The intensity of the tone was reduced in 10 db. steps until two conditioned responses did not occur. At this point the intensity was increased 5 db. If two conditioned responses occurred, the intensity was lowered in 5 db. steps. The lowest intensity at which two conditioned responses were obtained was assumed to be the threshold for that frequency and was recorded on the audiogram blank. The process was repeated at 1024, 2048, 4096, and 8192 cycles in that order. The subject's random blinks were controlled by beginning the test trial immediately following a spontaneous eyeblink.

During the test trials a procedure of 50% random reinforcement was used to maintain the conditioned response. Cole (5) noted that the conditioned response became unpredictable when the subject no longer expected the unconditioned stimulus. Reinforcement serves to maintain the subject's expectancy. The random order of reinforcement used in this study was slightly modified so that three consecutive presentations of the light or its absence did not occur.

The test trials and the pattern of reinforcement were, in part, adapted to the person being tested. The use of a flexible rather than a fixed procedure made it possible to allow for individual differences in the ease of conditioning, the frequency and intensity of the conditioned response, and the rapidity of extinction. Actually, only slight modifications of the basic procedure were needed. In the following circumstances alterations were made: (1) if the subject frequently recorded conditioned responses but did not record three consecutive responses, the test trials were begun, (2) if, in the conditioning trials, conditioned responses occurred at low intensities, the test trials were begun at low intensity, (3) if the subject recorded consistent conditioned responses during the test trials, the percentage of reinforcement was reduced, (4) similarly, if few conditioned responses were recorded, the percentage of reinforcement was increased, (5) if the subject frequently recorded only one conditioned response out of the four trials and did not record conditioned responses at lower intensities, the threshold was recorded in view of the single response.

Subjects

Thirty-three subjects were tested in this study. Eighteen of the subjects were men and fifteen were women. Twenty-eight of this group were enrolled in speech and education courses at the University of Arizona during the summer session of 1957. Three others had been enrolled the previous year. All of the subjects volunteered for the experiment. The age range of the subjects was from 15 to 51 years. The average age of the women was 29.5 and the average age of the men was 24.8. The experimenter was not aware of the subject's hearing acuity prior to the experiment.

Administration of the Test

The tests were given in a quiet air-conditioned room. The equipment was placed on a desk and arranged so the subject could not see the controls. The experimenter was seated in front of the desk and the subject seated in a straight back chair at the side of the desk facing the spot lamp. The only persons present during the test were the experimenter and the subject.

When the subject arrived for his appointment, he was asked to be seated and his name and age were recorded on the audiogram blank. The instructions were then read and the paper eyelash, oto-scopic headband, and earphones fixed in place. The subject was asked if the apparatus was comfortable and necessary adjustments were made. The spot lamp was adjusted to the subject's eye level and the conditioning trials were begun as previously described. The test trials followed without interruption and the thresholds were recorded on the audiogram blank. The time required to give the test was recorded to the nearest five minute interval. Upon completion of the experimental test, the apparatus was removed and the subject told that the standard hearing test would begin. He was instructed to answer "yes" each time a tone was heard. The tones were presented through the apparatus and the threshold at each frequency was crossed several times.

When the test was completed, the subject was given a card indicating his threshold of hearing at the various frequencies and the audiogram was discussed. The purpose of the experimental test was briefly explained and this concluded the testing session.

Instructions. It was found in the review of the literature that conditioning was aided when the subjects were asked to develop an attentive attitude toward the experiment. It is probable that such an attitude could not be developed in patients with whom it would be necessary to use an objective measure of hearing. Since the present investigation dealt with the clinical use of the conditioned eyeblink test, facilitory instructions were not given.

The instructions read to the subjects were essentially passive and are as follows:

> You will be given two hearing tests. The first is an experimental test and the second is the usual test of hearing. During the experimental test the movement of your eyelid will be recorded by this phonograph cartridge when a paper eyelash rubs against the plastic tip. You will hear different musical tones from the earphones and this spot lamp will sometimes flash on. During the experiment don't blink your eye on purpose, but if you want to blink don't try to keep from blinking. You will need to look in the direction of the lamp, but other than that all you have to do is just sit and relax. I'll tell you more about the test later.

Treatment of the Data

The major comparisons made in this study were of the thresholds obtained with the conditioned eyeblink test to those found using the standard test of hearing.

1. The extent and direction of the deviation of each conditioned eyeblink measurement from the standard threshold measurement was presented in table form.

2. The average number of decibels, for the five frequencies tested, that each person differed from the standard test was indicated in table form and graphed.

3. The average number of decibels that all of the subjects differed at each frequency was indicated in table form and graphed.

4. A composite audiogram was drawn based on the average conditioned eyeblink measurements and the average standard threshold measurements.

5. A graph was drawn which indicated the percentage of conditioned eyeblink measurements identical with the standard measurements and different from the standard measurements in 5db. steps. Similar graphs were made for each frequency.

Information concerning the number of subjects who were conditioned and the length of time required to give the test was also presented.

CHAPTER IV

RESULTS

In the process of adapting the conditioned eyeblink hearing test to the clinical situation, the use of a shortened conditioning procedure and simplified apparatus were investigated. The practical value of these modifications was observed by noting the number of persons who were conditioned, the length of time required to give the test, and by comparing the thresholds so obtained with those found using the standard test of hearing.

Conditioning Results

The time required for the subjects to condition ranged from less than one minute to 45 minutes. Most of the subjects conditioned in approximately 20 minutes. These results compare favorably with those found by Doerfler and McClure (7) who noted a range of five to 26 minutes in galvanic skin response testing.

Of the 33 subjects used in this study, 24 completed the test. These 24 subjects were equally divided as to sex. Nine of the subjects, six men and three women, did not condition. Two of those who failed to condition did not remain awake during the test, and the response of another was too inconsistent to measure accurately with either the eyeblink or standard tests. The remaining six subjects recorded few conditioned responses during the conditioning period. The failure of these subjects to condition and the variations in the time required for conditioning to occur were probably due to personality factors. Taylor (47) and Franks (8) found that anxious groups condition more readily than non-anxious groups.

Approximately 80% of the subjects tested in this study conditioned in one sitting. Most of these subjects conditioned in approximately 20 minutes. These figures suggest the feasibility of using the test in a clinical situation.

The Length of the Test

The time required for the completion of the test was dependent on the rate of conditioning and the consistency of the conditioned response. The average time needed to administer the conditioned eyeblink test was 33.1 minutes. The average time for the men was 32.5 minutes and the average time for the women was 33.7 minutes. The subjects aged 25 or over averaged 32.0 minutes and the subjects under 25 averaged 33.9 minutes. The slight differences between the age and sex groupings and the total were not considered to be significant. Table 1 indicates the number of subjects who completed the test at various five minute intervals.

TABLE 1

THE TIME REQUIRED TO COMPLETE THE EYEBLINK TEST

No. of Subjects	Minutes
3	20
5	25
6	30
3	35
4	40
1	45
2	60

A Comparison of the Thresholds Obtained

The thresholds obtained with the conditioned eyeblink hearing test are presented in Table 2 in relation to the thresholds found using the standard test. The number of decibels above or below the standard measurement are given for each subject at each frequency tested. The average deviation for each subject at all frequencies and for all subjects at each frequency is given in decibels in the right hand column and lower row respectively. These deviations are graphically presented in Figures 3 and 4.

The average deviation for all subjects at all frequencies is 5.83 db. from the standard test measurements. This 5.83 db. average error, when separated into average error above and below the standard measure, becomes 3.87 db. above and 1.96 db. below. It is interesting to note in Table 2 that the conditioned eyeblink thresholds measured at 8192 cycles contain the five largest errors as well as the greatest number of accurate measurements. If these five errors are not included in the overall average, the average error becomes 4.17 db.

TABLE 2

THE DEVIATION OF THE CONDITIONED RESPONSE THRESHOLDS IN DECIBELS ABOVE OR BELOW THE STANDARD THRESHOLD

Subject	Frequency					Mean
	512	1024	2048	4096	8192	
1	5	5	0	0	0	2
2	5	5	0	0	0	2
3	5	10	10	10	30	13
4	10	5	0	5	0	4
5	-15	0	0	0	0	3
6	10	20	0	20	0	10
7	-5	0	-5	0	-15	5
8	-5	-5	-10	0	0	4
9	0	0	0	-5	0	1
10	-5	-15	-5	-5	0	6
11	-5	0	0	5	5	3
12	5	-5	-5	-5	0	4
13	-5	-5	0	10	60	16
14	0	0	5	-20	5	6
15	0	0	0	0	0	0
16	0	5	5	0	-5	3
17	0	-10	-5	0	0	3
18	0	0	5	10	0	3
19	0	-5	20	-10	50	17
20	-5	0	-5	0	0	2
21	-10	0	0	20	50	16
22	-5	-5	5	0	-10	5
23	5	5	5	0	0	3
24	-5	-5	0	-5	30	9
Mean	4.58	4.58	3.75	5.42	10.83	

The conditioned eyeblink thresholds obtained by Galloway and Butler (10) averaged 4.95 db. above the standard test measurements. Those found in the present study averaged 1.91 db. above the standard measurements. This apparently indicates a large reduction in error; however,

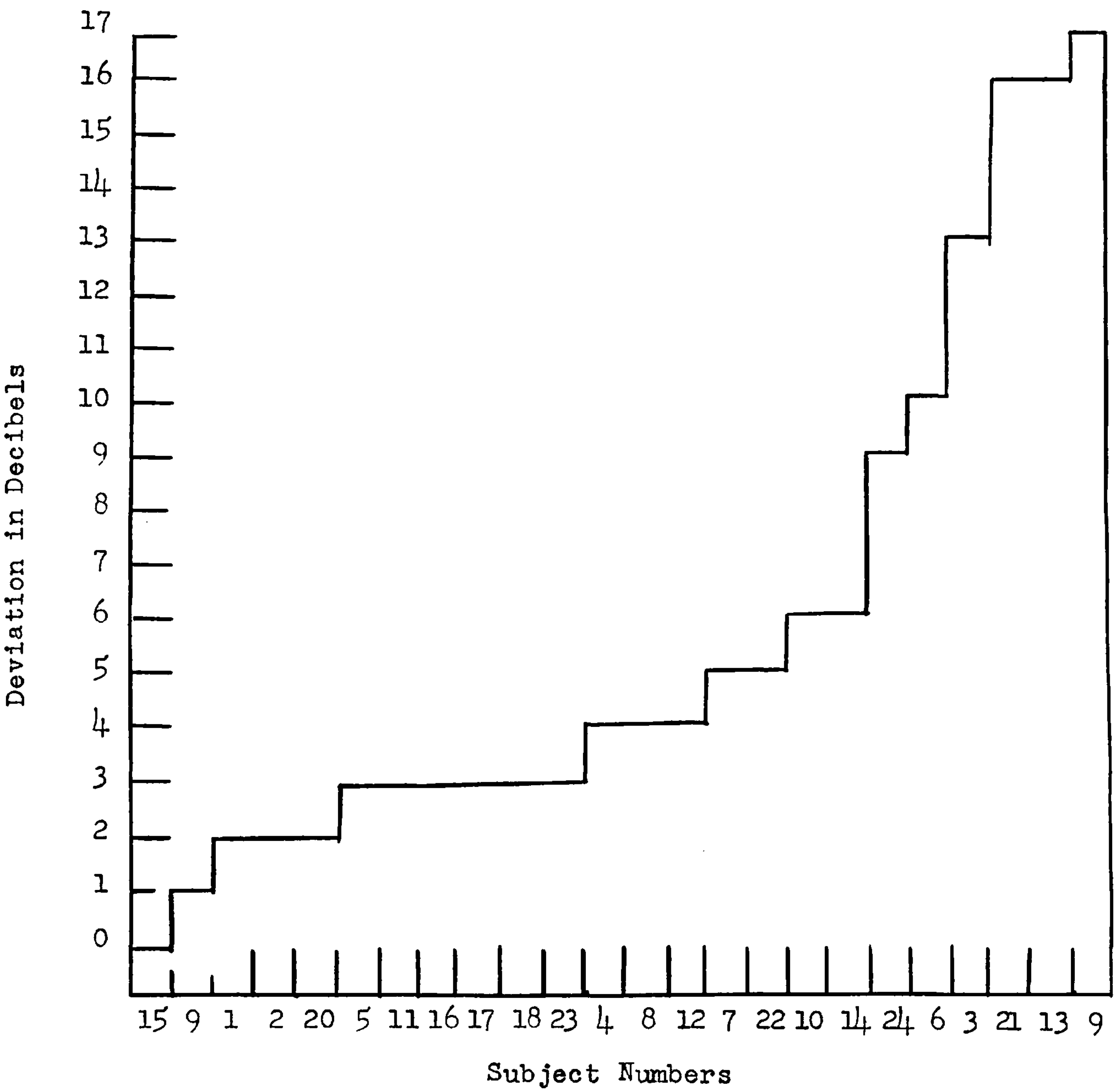

Fig. 3. The average deviation of the conditioned eyeblink thresholds from the standard threshold for each subject at all frequencies.

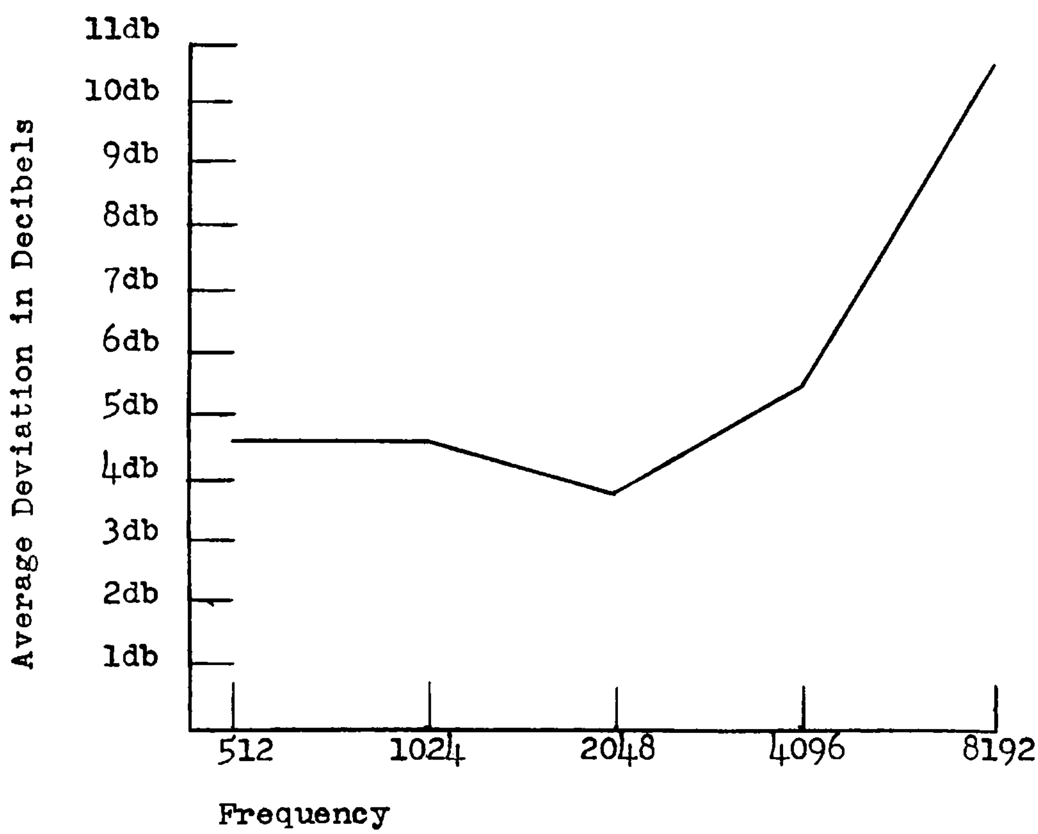

Fig. 4. The average deviation at each frequency tested of the conditioned eyeblink thresholds from the standard thresholds as measured in decibels.

these figures may be misleading. If all of the errors made by Galloway and Butler were above threshold, then the 3.87 db. average error in the present study is more apt for comparison.

A slightly different presentation may clarify the previous discussion. Of the 120 threshold measures made in this study, 33 were below the standard threshold, 52 were correct, and 35 were above threshold. The 33 measures which were below the standard threshold averaged 7.12 db. below. The 35 measures which were above threshold averaged 13.28 db. above. If the five large errors made at 8192 cycles are not included, the average error above threshold is changed to 8.16 db.

In Figure 5 a composite audiogram was plotted in decibel steps at each frequency tested. One audiogram is based on the average measurements made with the conditioned eyeblink test and the other is based on the average measurements made with the standard test of hearing. The proximity of the two audiograms indicates the validity of the conditioned eyeblink test with the exception of the measurements made at 8192 cycles. Since the composite audiogram is based on averages, the agreement of the two tests should not be considered an indication of the predictive value of the conditioned eyeblink test with a single subject.

The percentage of conditioned eyeblink measurements identical with the standard test measurements, and the

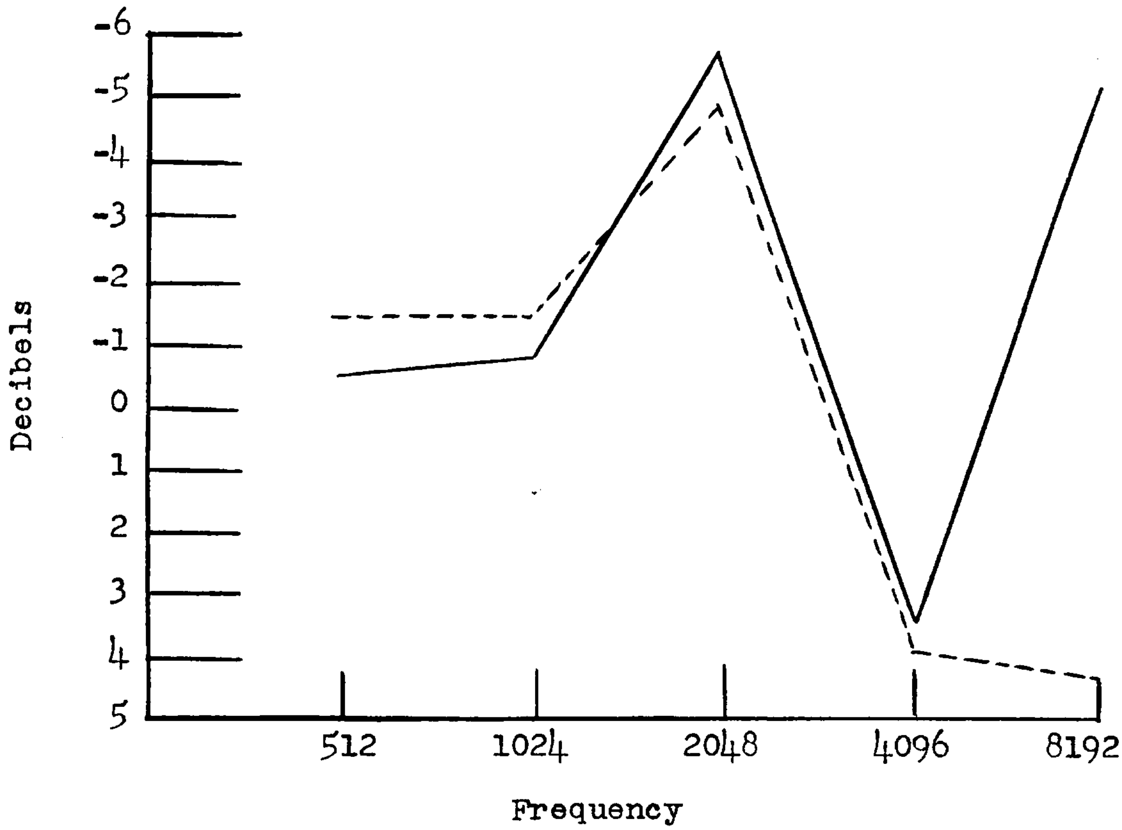

Fig. 5. A composite audiogram indicating the average thresholds for both the conditioned eyeblink and standard hearing tests. The solid line indicates the standard test and the broken line indicates the conditioning test.

percentage which differed at various db. steps, are graphed in Figure 6. Similar graphs for each frequency are shown in Figures 7, 8, 9, 10, and 11.

It should be noted in Figure 6 that a sharp reduction in the percentage of measurements occurs as the error exceeds 5db. Actually, 80% of the conditioned eyeblink thresholds differed 5 db. or less from the standard threshold test. This measure seems to warrant an investigation of the modified test in the clinical situation.

Fig. 6. The reduction in the percentage of conditioned eyeblink threshold measurements, at increasing decibel distances from the standard threshold measurements.

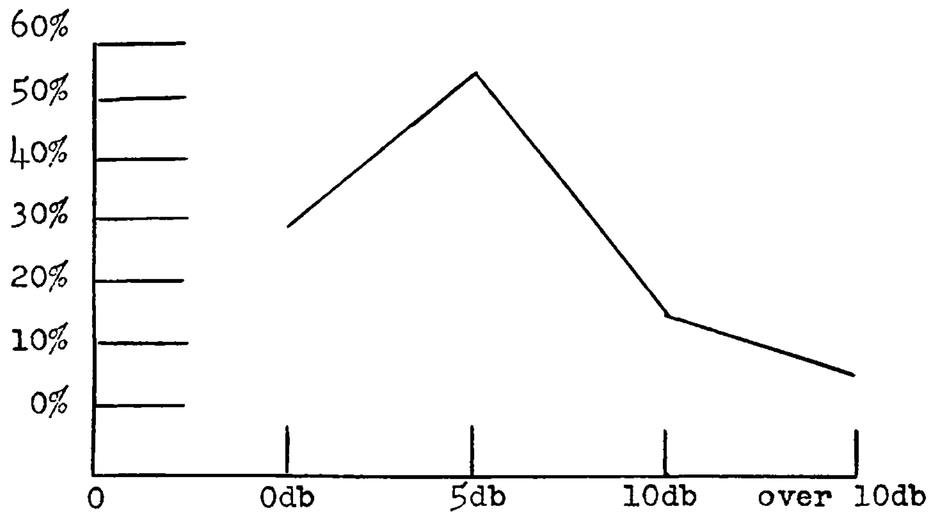

Fig. 7. The reduction in the percentage of conditioned eyeblink threshold measurements, for the frequency of 512 cycles, at increasing decibel distances from the standard threshold measurements.

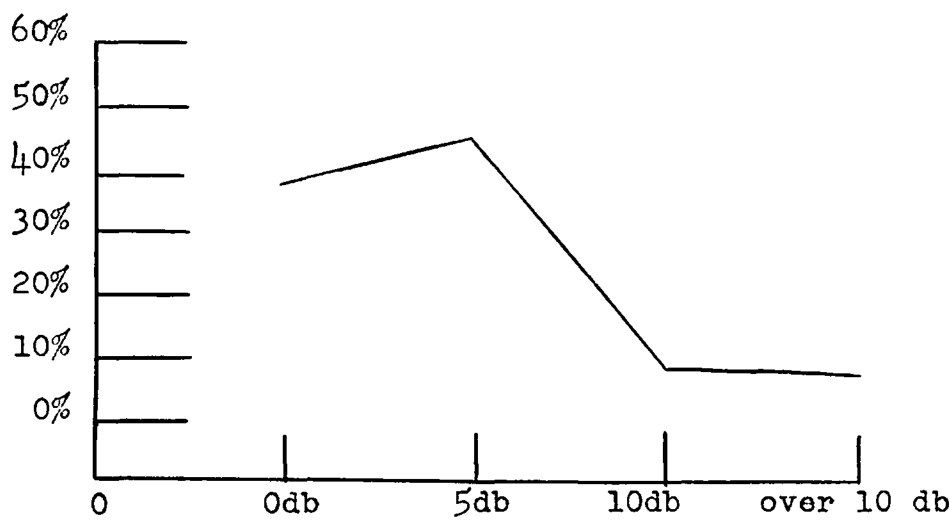

Fig. 8. The reduction in the percentage of conditioned eyeblink threshold measurements, for the frequency of 1024 cycles, at increasing decibel distances from the standard threshold measurements.

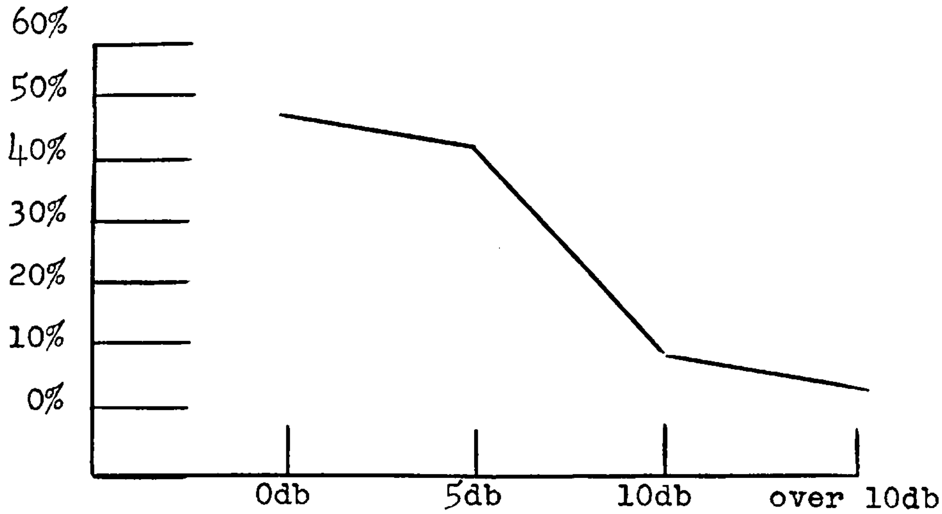

Fig. 9. The reduction in the percentage of conditioned eyeblink threshold measurements, for the frequency of 2084 cycles, at increasing decibel distances from the standard threshold measurements.

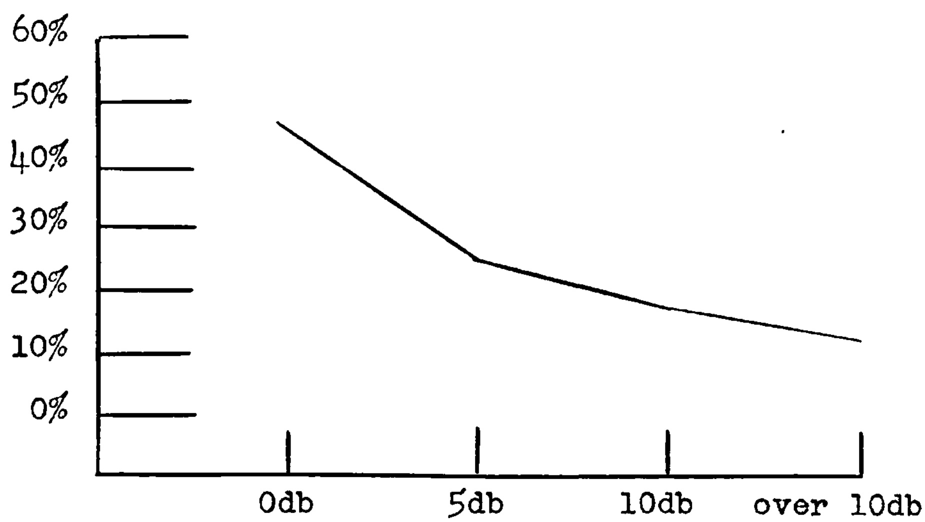

Fig. 10. The reduction in the percentage of conditioned eyeblink threshold measurements, for the frequency of 4096 cycles, at increasing decibel distances from the standard threshold measurements.

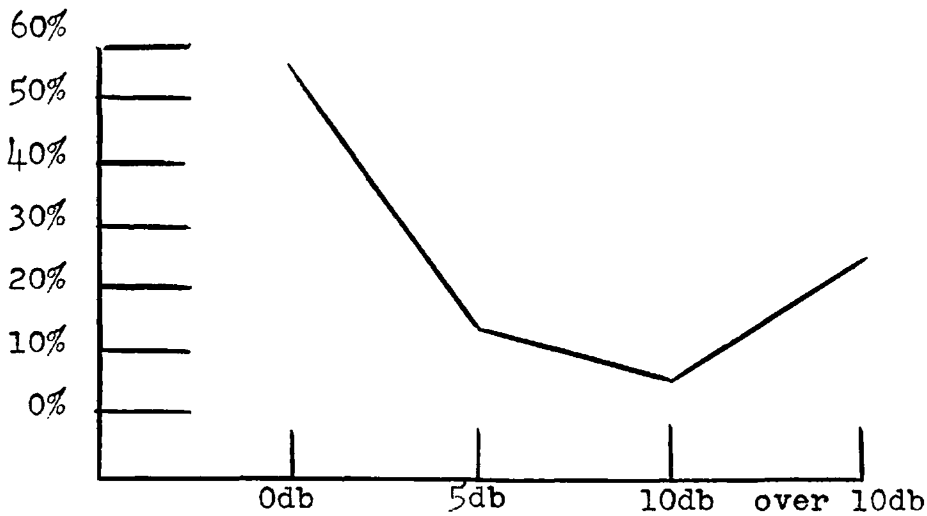

Fig. 11. The reduction in the percentage of conditioned eyeblink threshold measurements, for the frequency of 8192 cycles, at increasing decibel distances from the standard threshold measurements.

SUMMARY AND CONCLUSIONS

An effort was made to design a conditioned eyeblink hearing test for clinical use. It was deemed desirable to use simple apparatus and a conditioning procedure which would allow rapid administration.

A review of the literature on eyelid conditioning provided much of the information needed to set up an efficient conditioning procedure and suggested possible types of equipment.

The proper time intervals, time limits, and order of the stimulus presentations were incorporated into a simple switching device which utilized the constant speed of a synchronous motor and slider contacts to present and time the stimuli. The eyeblink was detected by a phonograph cartridge, and the amplified signals, via the switching device, operated a relay used to switch on a conditioned response indicator. A pure tone audiometer provided the conditioned stimulus and a flash of light was used as the unconditioned stimulus.

The test was given to 33 subjects in an average time of 33.1 minutes. The threshold measures obtained were compared to the subjects' pure tone thresholds. Forty-three percent of these measures were the same and 90% were within 10 db.

It can be concluded that these results warrant a further examination of the modified test in the clinical situation.

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