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AN INVESTIGATION OF THE RESPONDENT
CONDITIONABILITY OF THE
MIDDLE EAR REFLEX

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
Susan H. Brainerd
1971

THESIS

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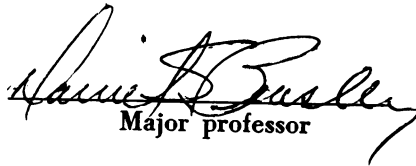
AN INVESTIGATION OF THE RESPONDENT CONDITIONABILITY
OF THE MIDDLE EAR REFLEX

presented by

Susan H. Brainerd

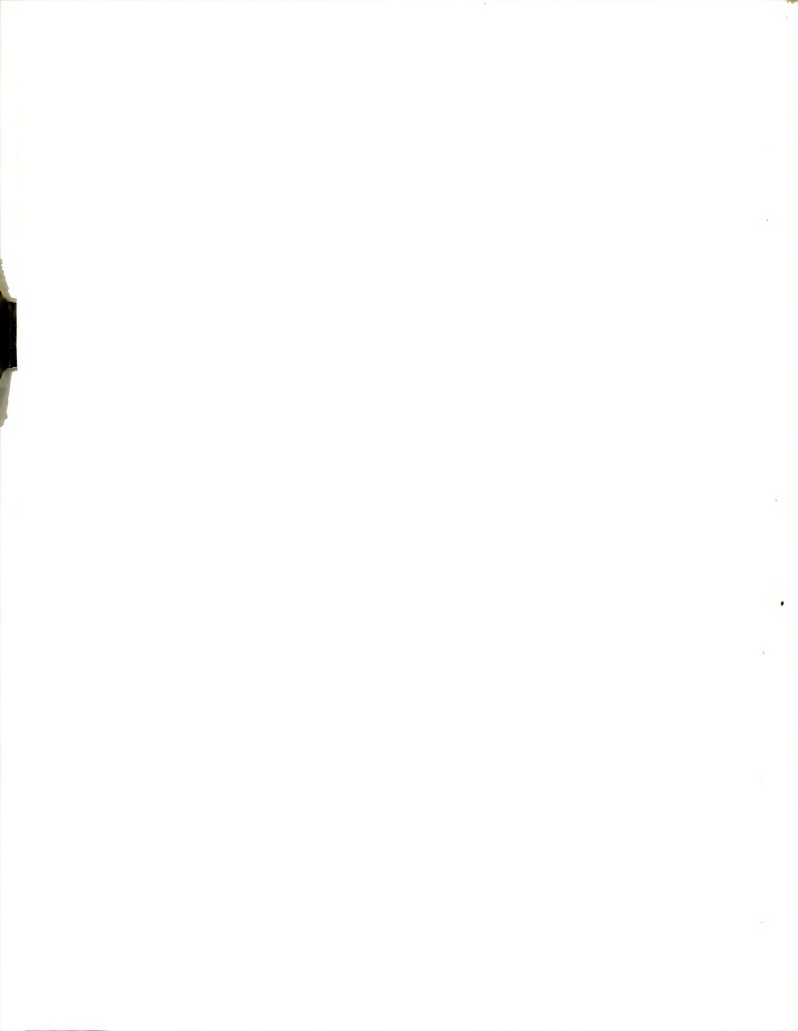
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ABSTRACT

AN INVESTIGATION OF THE RESPONDENT CONDITIONABILITY
OF THE MIDDLE EAR REFLEX

By

Susan H. Brainerd

Three experiments are reported which investigate the behavior of the middle ear reflex. For the most part, the investigations are concerned with determining the susceptibility of the middle ear reflex to classical conditioning. Specifically, attempts to condition the middle ear reflex both to a temporal interval and to a visual stimulus are reported.

The focus of the first experiment was on temporal conditioning. Five normal hearing college age females were employed as subjects. Each subject received a total of 100 conditioning trials and four test trials. The unconditioned stimulus was a 1000 Hz tone presented 10 dB above the subject's middle ear reflex threshold level for a duration of 45 seconds. All reflex responses were measured with an electro-acoustic impedance bridge and the correlated voltage changes were permanently recorded. The data were independently scored by two judges in terms of the number of conditioned reflexes which occurred during the test trials. The results indicated that no conditioned responses were elicited from any subject during any test trial. Therefore, temporal conditioning of the middle ear reflex was not demonstrated.

The purpose of the second experiment was to investigate the ability of a visual stimulus to elicit the middle ear reflex. The chosen stimulus was a light with an effective illumination of 0.2 fc.

Again, five normal hearing college age females served as subjects. Each subject received a total of 50 experimental trials consisting of 25 presentations of the light and 25 empty intervals, randomly ordered. The duration of each experimental trial was one second and the time interval between successive trials was 45 seconds. All reflex responses were measured with an electro-acoustic impedance bridge and the correlated voltage changes were permanently recorded. Two judges independently scored the data in terms of the number of reflexes which were elicited during any of the experimental trials. The results indicated that no reflexes were elicited from any of the subjects during any of the 50 trials. Therefore, since there was no difference in the number of spontaneous reflexes elicited during the empty intervals and the number of reflexes elicited by the light, it was concluded that the experimental light did not normally elicit the middle ear reflex.

In the third experiment an attempt was made to condition the middle ear reflex to a neutral stimulus. Twenty normal hearing college age females served as subjects. As in the first experiment, each subject received a total of 100 conditioning trials and four test trials. The unconditioned stimulus was a 1000 Hz tone presented 10 dB above the subject's middle ear reflex threshold level for a duration of one second. The conditioned stimulus was a light with an effective illumination of 0.2 fc. During each conditioning trial the onset of the conditioned stimulus preceded the onset of the unconditioned stimulus. Moreover, four interstimulus intervals were employed. Specifically, these were 0, 0.5, 1.5, and 2.5 seconds. Each of these interstimulus intervals was randomly assigned to five different subjects. The termination of

the stimuli presentations was simultaneous. The time intervals between successive presentations of the unconditioned stimulus were varied randomly at 30, 45, and 60 seconds. All reflex responses were measured with an electro-acoustic impedance bridge and the correlated voltage changes were permanently recorded. Two judges independently scored the data in terms of the number of conditioned responses that occurred during the test trials. The results indicated that no reflexes were elicited from any subject during any of the test trials. Therefore, neither simultaneous nor delayed conditioning were demonstrated. Moreover, it was not demonstrated that the conditionability of the middle ear reflex varies with the interstimulus interval that is employed.

Approved



Date

5/14/71

AN INVESTIGATION OF THE RESPONDENT CONDITIONABILITY
OF THE MIDDLE EAR REFLEX

By

Susan H. Brainerd

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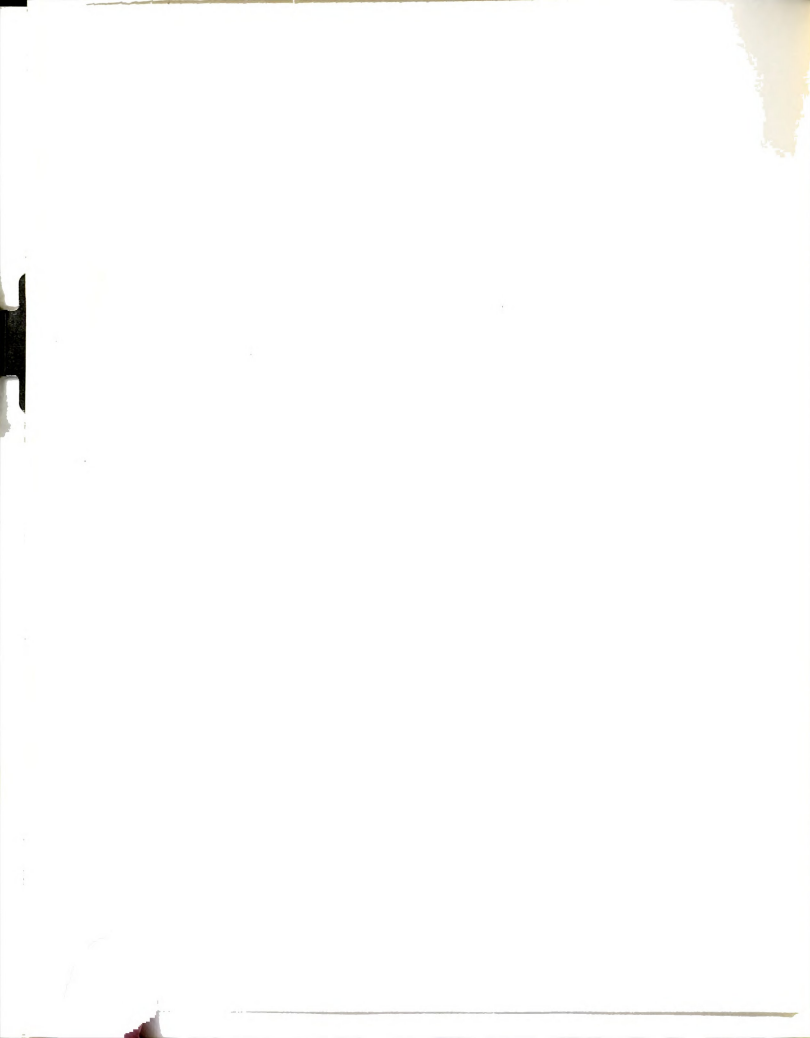
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INTRODUCTION

Investigations of the middle ear reflex began in the late 1880's and, since then, numerous clinical and experimental studies concerned with the reflex have been carried out (Jepson, 1963). While some of these investigations have been concerned with the properties of the reflex itself, the majority of studies have employed the reflex as a method for investigating the function of the auditory system (Dallos, 1964). Moreover, these applied investigations have focused on a wide variety of acoustic variables.

A number of investigators have demonstrated the importance of the middle ear reflex as a clinical tool in the differential diagnosis of auditory impairments. For example, Metz (1952) reported that the intensity level of the reflex threshold could supplement the results of loudness balancing for the determination of cochlear impairments. Similarly, Klockhoff (1961), Feldman (1964) and Djupesland (1969) all have reported success in using the reflex as an aid in the topical diagnosis of facial nerve lesions. Finally, Zwislocki and Feldman (1970) demonstrated that the reflex could be used to identify the location of disarticulation in cases of ossicular separation.

Other investigators have identified relationships between the middle ear reflex and a variety of auditory phenomena. For example, Ward (1961) and Gjaevenes and Vigran (1967) suggest that middle ear reflex activity is an important variable in remote masking. Likewise, Melnick (1965) and Ross (1968) contend that reflex activity is an important variable in loudness judgments. In addition, several

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investigators have demonstrated that middle ear reflex activity is related to variability in speech discrimination scores (Liden, Nordlund and Hawkins, 1963; Clubb, 1965; and Jauhianen, Hakkinen, Lindroos and Raij, 1967). Finally, Sedlacek (1965) and Lawrence (1965) argue that middle ear reflex activity has important implications for theories on binaural hearing.

Even a cursory review of the studies, such as those noted above, reveals that the middle ear reflex is becoming a prominent topic in studies of the auditory system. However, although the reflex is being used widely, a vast number of questions remain concerning its behavior. In fact, Dallos (1964) commented that more questions concerning the behavior of the middle ear reflex were unresolved than answered.

The most basic question concerning the behavior of the middle ear reflex which has not yet been resolved is the question of its susceptibility to conditioning procedures. The evaluation of such susceptibility clearly is needed if we are to understand fully middle ear reflex activity. In addition, such an evaluation would provide a means for comparing the middle ear reflex with reflexes associated with other sensory modalities. Finally, a well controlled investigation of the conditionability of the middle ear reflex would provide a means of assessing the validity of the empirical results of previous studies in which the investigators did not control for possible conditioned reflexes to incidental stimuli. In response to this need for determining the conditionability of the middle ear reflex, the experiments presented below were designed to investigate the susceptibility of the middle ear reflex to a variety of classical conditioning paradigms.

Physiological Basis of the Middle Ear Reflex

Kobrak (1959), Polyak (1946), Wever and Lawrence (1954), and Zemlin (1968) have provided pertinent discussions on the anatomy and physiology of the middle ear. Moreover, a review of the discussions presented by each of the above authors reveals a great consistency in their descriptions of the middle ear and its associated structures. Therefore, the discussion presented below has been compiled from the general consensus of the above authors.

The middle ear is a minute air-filled space in the part of the temporal bone that forms the base of the skull. The cavity is located about one-third of the distance between the surface of the skull at the entrance of the external meatus and the mid-sagittal plane. The diameter of the middle ear varies from about 2 mm to 8 or 9 mm. Its vertical direction measures up to 13 or 14 mm. The structures enclosed in the middle ear include: (a) the ossicles and their ligaments, (b) the muscles and their tendons, (c) the chorda tympani nerve, and (d) the tympanic plexus of nerves.

Two muscles are housed in the middle ear: the stapedius and the tensor tympani. These muscles are the smallest striated muscles in the body. Moreover, since they are of the pennate type they have a great capacity for exerting tension with little linear displacement.

The tensor tympani is the larger of the tympanic muscles. It is a slender, spindle-shaped muscle, about 25 mm in length and 5.85 mm^2 in cross sectional area. The tensor tympani is located in the upper compartment of the musculo-tubal canal of the Eustachian passage on the anterior wall of the middle ear. It is separated from the Eustachian

tube by a bony partition. The muscle fibers of the tensor tympani originate in the cartilaginous portion of the framework of the musculo-tubal canal. The muscle then passes out of the canal over the cochleariform process which serves as a pulley for the muscle tendon. As the tendon passes over the cochleariform process it makes nearly a right angle turn laterally and crosses the tympanic cavity. The tendon inserts into the manubrium just below the neck of the malleus. Upon contraction, the tensor tympani draws the malleus medially, inferiorly and anteriorly. The force is almost at a right angle to the course of the ossicular chain.

The stapedius muscle averages 6.3 mm in length. It has a cross sectional area of about 5 mm^2 . It takes origin from a canal which runs almost parallel to the facial nerve canal and is located on the posterior wall of the tympanic cavity. The muscle fibers take their origin from the walls of the bony canal. The tendon of the muscle emerges from an aperture at the apex of the pyramidal eminence. From this point the tendon proceeds anteriorly to insert into the posterior surface of the neck of the stapes. Contraction of the stapedius exerts a force on the head of the stapes, drawing it posteriorly at a right angle to the direction of movement of the ossicular chain.

An involuntary contraction of the two middle ear muscles to effective stimulation constitutes the middle ear reflex. Moreover, as in other body reflexes, a specific neural pathway is followed in the production of the response. Lorente de No (1935) and Rasmussen (1946) have outlined the reflex arc for the middle ear muscles. These authors maintain that the cochlear nerve constitutes the afferent (sensory) part of the reflex arc. The "reflex center" is believed to

be in the pons, specifically in the superior olivary complex. The efferent (motor) part of the reflex arc consists of various cranial nerves. The facial nerve is known to be the sole innervator of the stapedius muscle. However, multiple neural connections have been identified for the tensor tympani muscle. Specifically, the tensor tympani is believed to be connected to the tympanic plexus of nerves besides being innervated by the mandibular branch of the trigeminal nerve (Lawrence, 1962).

Acoustic Responses of the Middle Ear Muscles

Luscher pioneered the investigation of the middle ear reflex in humans (Jepson, 1963). During the 1920's and 1930's Luscher determined that the response of the middle ear muscles to acoustic stimulation is a consistent phenomenon in man. In addition, he demonstrated that unilateral acoustic stimulation elicits a bilateral reflex contraction, that the reflex depends upon the intensity of the stimulation, and that the reflex threshold varies across stimulus frequencies with the mid-frequencies providing the most sensitive reflex thresholds. This later finding has been more recently confirmed by Jepson (1963) and Peterson, Lamb and Hansen (1965) who demonstrated that the midfrequencies produce the most sensitive and reliable reflex thresholds both within and across subjects.

Other investigators have studied the recovery time and the relaxation time of the middle ear muscles. Metz (1951) demonstrated that the middle ear muscles do not require any recovery time between successive contractions to independent stimuli. However, both Metz (1951) and Dallos (1964) have demonstrated that the middle ear muscles do require some time following the cessation of an auditory stimulus in order to

attain a relaxed state. Metz found that measureable activity could endure in the muscles for more than one second following the cessation of an auditory stimulus and Dallos demonstrated that in some instances the muscles were not relaxed completely in less than two seconds following cessation of an auditory stimulus. Neither Metz nor Dallos were able to identify any consistency in the amount of relaxation time required across subjects.

Several investigators have been concerned with identifying the relative importance of each of the middle ear muscles in the middle ear reflex. Studies employing infrahuman subjects have suggested that both the stapedius muscle and the tensor tympani play active roles in the acoustic reflex (Pollak, 1887; Kato, 1913; and Wersal, 1958). On the other hand, investigators employing human subjects unanimously contend that only the stapedius muscle is involved in the middle ear reflex (Metz, 1946; Jepson, 1955; Klockhoff, 1961; Salomon and Starr, 1963; and Feldman, 1967).

Nonacoustic Responses of the Middle Ear Muscles

Several investigators have demonstrated that the middle ear muscles will contract in response to both cutaneous stimulation of the external auditory meatus and to forceful contraction of the orbital muscles (Klockhoff, 1961; Salomon and Starr, 1963; and Djupestrand, 1965). In addition, Salomon and Starr (1963) and Djupestrand (1965) have recorded muscle activity accompanying such voluntary motor activities as swallowing, coughing, yawning, and head turning. Moreover, it has been demonstrated also that middle ear muscle activity precedes vocalization (Salomon and Starr, 1963; Shearer and Simmons, 1965; and Djupestrand, 1965). Finally, it has been determined that middle ear muscle contractions are one of

the motor components of a general startle response (Klockhoff and Anderson, 1959; Klockhoff, 1961; Salomon and Starr, 1963; and Djupestrand, 1965).

Conditioning the Middle Ear Reflex

There have been relatively few attempts made to determine the conditionability of the middle ear reflex. Moreover, the results of such attempts have not demonstrated conclusively whether or not the middle ear reflex is susceptible to classical conditioning procedures.

Successful Attempts

Human Studies. Luscher reportedly was successful in conditioning the middle ear reflex during the 1920's (Jepson, 1963). In addition, Kobrak (1948) reports that "the patient may be 'conditioned' by repetition and may show contractions due to expectation." However, since both Luscher and Kobrak only visually observed the reflexes in question, their conclusions need to be accepted cautiously. Without either permanent records or reports of interjudge reliability the results of both investigators are potentially open to significant experimenter bias. In particular, the results may reflect expected rather than actual observations.

Loeb and Fletcher (1963) reported success in conditioning the middle ear reflex to a temporal interval. In their investigation, the authors compared the amounts of temporary threshold shift (TTS) acquired by subjects who were exposed to five experimental presentations of either continuous or intermittent noise. The continuous noise was presented at 110 dB SPL for a total of 50 minutes while the intermittent noise was presented at 120 dB for an equivalent time period. The on- and off-times of the intermittent noise were each one second. The results indicated

that subjects in the continuous group acquired a constant amount of TTS at each of the five sessions. However, subjects in the intermittent group tended to acquire less TTS at each successive session. The authors concluded that the results demonstrated temporal conditioning of the middle ear muscles. However, based on the work of Metz (1951) and Dallos (1964) which has been cited above, it appears likely that Loeb and Fletcher did not allow sufficient time between stimulus presentations for the middle ear muscles to relax completely. Therefore, Loeb and Fletcher's results may be confounded by the fact that during the experimental sessions the middle ear muscles of the subjects in the intermittent noise group were in a state of continuous activity.

Mendelson, Fletcher and Loeb (1965) reported observing tonic contractions of the middle ear muscles in a group of subjects who were exposed to a series of noise impulses with on-times of 300 msec and off-times of 660 msec. The experimenters contended that the tonic contractions were due to conditioning since the subjects were all in the military and had "chronic exposure to impulsive noise." Alternatively, the argument could be made that the observed reflex activity was not a form of conditioned response but merely the normal muscle activity which follows the cessation of an auditory stimulus (Metz, 1951 and Dallos, 1964). Moreover, since Mendelson et al. did not report having pre-exposure records on their subjects and they did not run a control group, any conclusion of conditioning would be tenuous.

Mendelson et al. (1963) also reported observing modified reflex activity in one subject who was a "sonabuooy listener" and, therefore, was required to make difficult auditory discriminations. Investigations

on the subject revealed that his reflex activity was increased during some difficult listening situations. Therefore, the authors concluded that this activity was a conditioned response which had developed through the subject's experience as a "sonabuoy listener." However, again Mendelson et al. failed to obtain pre-exposure data or to run control subjects. It is feasible that the subject may have had the ability to vary the contractibility of his middle ear muscles prior to the experience of being a "sonabuoy listener." Such ability has been demonstrated by Reger (1960) in college students.

Brasher, Coles, Elwood and Ferres (1969) reported success in eliciting middle ear muscle contractions in anticipation of gunfire initiated by the subject himself. Brasher et al.'s subjects fired pistol shots at regular intervals of about every 5 seconds. The peak noise of each shot was between 145 and 155 dB. Middle ear muscle activity was measured with the Madsen Bridge Model Z061. Of Brasher et al.'s 16 subjects, nine showed impedance changes both before the shots were fired and with misfire clicks, while two more subjects showed impedance changes with misfire clicks only. Brasher et al. did not report how many conditioning trials were employed. However, they did provide an example which illustrated a slight anticipatory effect by the third shot and a marked effect by the tenth shot.

Although the results by Brasher et al. appear to suggest conditioning of the middle ear muscles, the results obtained in a similar study by Djupesland (1965) suggest that Brasher et al. were merely recording one component of a general muscle contraction rather than an isolated conditioned response of the middle ear muscles. In his

investigation, Djupesland presented a toy pistol to his subjects and told them that the gun would produce a loud and unpleasant sound. Of his 30 subjects, 24 reacted to sight of the pistol with a general muscular contraction. Moreover, in each case, the general muscle contraction was accompanied by contractions of the middle ear muscles. All of Djupesland's results were based on electro-myographic recordings.

Infrahuman Studies. Simmons, Galambos, and Rupert (1959) have presented the only report of successful conditioning of the middle ear muscles in infrahumans. Specifically, Simmons et al. reported success in conditioning the middle ear reflex in awake cats to a neutral stimulus under three different conditioning procedures. In all of their studies, moreover, a truck horn was employed as the unconditioned stimulus (UCS) and a light served as the conditioned stimulus (CS). (Unfortunately, however, Simmons et al. did not provide quantitative levels for any of their stimuli.) In each of the three experiments the subjects were placed in a dark, sound treated room during both the conditioning and the test trials. All reflex responses were recorded as changes in cochlear microphonics measured by electrodes which were permanently implanted in the round window of each subject.

In their first experiment, Simmons et al. employed a photographic flash unit for the CS. During the conditioning trials the flash was followed immediately by a "blast" from the UCS (the truck horn). Six cats served as subjects and Simmons et al. reported that five of the six cats were "well conditioned" in less than 30 trials. (A quantitative definition of "well conditioned" was not provided.)

Simmons et al. reported, however, that there might have been a confounding variable in their first experiment. Specifically, they

noted that due to intense levels of stimulation a form of pseudo-conditioning might have occurred. Kimble (1961) reports that whenever a noxious stimulus is employed nonassociative pseudoconditioning to the general situation may occur rather than true conditioning to the specific stimulus.

Therefore, in their second experiment, Simmons et al. employed a 6 volt light in place of the photoflash in an attempt to eliminate any pseudoconditioning. The light bulb was placed "a few inches" from the subject's head and as in the first experiment, a "blast" from the horn immediately followed each presentation of the light. Four cats were employed as subjects in the second experiment and only one of the four cats was successfully conditioned. Simmons et al. concluded that this proved conditionability of the middle ear reflex. However, statistically this result would be of only questionable value based on the small number of subjects that were conditioned. In addition, it could still be argued that a form of pseudoconditioning occurred. For even though Simmons et al. did not report the effective level of their light, the present author measured the illumination produced by a 6 volt tungston lamp and found it to be 16 fc at approximately 3 inches from the bulb.¹ Such a level is sufficiently intense to produce an avoidance response.

In their third experiment, Simmons et al. reportedly demonstrated differential conditioning. In this experiment both the light flash and the light bulb were presented to each subject. However, only the presentation of the light bulb was reinforced with the horn. A 500 msec

¹Throughout this manuscript, 1 fc is taken to be approximately equal to 10.7 lumens/m².

delay was allowed between the cessation of the light and the horn "blast." Three cats served as subjects and two of the three were successfully conditioned. However, both of these animals required about 200 trials before differentiation was complete.

In general, the results of the above three experiments need to be viewed with caution since Simmons et al. did not employ any control groups. The only form of control that they employed was one recording made from a single cat which showed no reaction to the photoflash being presented by itself. The recording was reportedly made after the cat had been "successfully conditioned" to the photoflash and the conditioned response subsequently extinguished. However, since the authors did not present a record of the cat's response to the photoflash prior to conditioning, it could be argued that the subject originally produced a startle response to the photoflash but that after sufficient presentations of the stimulus, the startle response was finally adapted. In this case, Simmons et al. were measuring a form of adaptation rather than a form of conditioning.

Unsuccessful Attempts

Human Studies. Ward and Flear (1961) reported an unsuccessful attempt to condition the middle ear reflex temporally in an experiment similar in design to that employed by Loeb and Fletcher (1963). In their experiment, Ward and Flear measured the amount of TTS produced by exposure to high intensity acoustic clicks (peak value of 155 dB SPL) with either periodic (2.4 seconds) or aperiodic (1-5 seconds) interclick intervals. Their results reflected no difference in the amount of TTS acquired by the subjects in the two experimental groups. Therefore, based on the assumption that a temporally conditioned reflex would have reduced the

amount of acquired TTS in the intermittent noise group, Ward and Fleeer concluded that the middle ear reflex is not susceptible to temporal conditioning. There is a possibility, however, that Ward and Fleeer suppressed conditioning by using such intense levels of stimulation. Kimble (1961) reports that the use of noxious stimulation may reduce or eliminate conditioned activity.

Infrahuman Studies. Simmons (1964) reported an unsuccessful attempt to condition the middle ear reflex in cats to a neutral stimulus. Simmons recorded muscular activity with cochlear microphonics. A tone of variable frequency and intensity (range of 105-120 dB) served as the UCS. A second tone, also of variable frequency and intensity (range of 40-70 dB) served as the CS. The UCS was presented for a duration of 200 msec, while the duration of the CS varied from 200-300 msec. A trace conditioning paradigm was employed, with the presentation of the CS stopping before the UCS presentation was initiated. It should be noted, however, that although Simmons reported that he could not consistently elicit reflex contractions without continually varying the stimuli, it is very likely that such stimulus variations served to eliminate conditioned responses.

Summary

A review of the investigations presented above reveals that studies which have attempted to condition the middle ear reflex suffer from serious methodological deficits. For example, none of the investigators provided a quantitative definition for a conditioned reflex. Likewise, they neither employed a control group nor attempted to control for incidental reflexes which would be elicited by voluntary motor activities. Other additional methodological flaws included failure to control for

relevant background variables (i.e. Mendenson et al., 1963; Brasher et al., 1969; and Simmons et al., 1959), failure to control for the possible elicitation of a general startle response (i.e. Simmons et al., 1959; Ward and Fleer, 1961; and Brasher et al., 1969), and failure to allow sufficient relaxation time for the middle ear muscles (Loeb and Fletcher, 1963 and Mendelson et al., 1963).

Therefore, based upon a review of past investigations, there is a clear need for a well controlled investigation of the conditionability of the middle ear reflex. Such an investigation, moreover, is presented below in the form of two experiments which attempt to condition the middle ear reflex both to a temporal interval and to a visual stimulus. In addition, a third experiment determines the neutrality of the visual stimulus. Specifically, the following questions are investigated:

1. Can the middle ear reflex be conditioned to a temporal interval?
2. Does light serve as an unconditioned stimulus for the middle ear reflex?
3. Can the middle ear reflex be conditioned to a neutral visual stimulus?
4. Is the middle ear reflex differentially sensitive to conditioning as a function of the interstimulus interval employed?

EXPERIMENT I: TEMPORAL CONDITIONING

In the first experiment an initial attempt was made to classically condition the middle ear reflex. The purpose of the experiment was to determine whether or not time could serve as an effective CS.

Method

Subjects

Five normal hearing female volunteers who were students at Michigan State University served as subjects. The subjects ranged in age between 20.8 years and 24.8 years with a mean of 22.4 years. All subjects had normal pure tone thresholds, i.e. their air conduction thresholds were bilaterally less than 25 dB ISO at all octaves from 250 Hz through 8000 Hz and their bone conduction thresholds were within ± 5 dB of their air conduction thresholds. In addition, all subjects had normal acoustic impedance scores,¹ ranging from 320 to 510 acoustic ohms, with a mean of 390 acoustic ohms. Finally, all subjects had a middle ear reflex which could be measured with the Madsen Electro-Acoustic Impedance Bridge (Model Z070). The reflex thresholds at 1000 Hz ranged from 90 to 100 dB with a mean of 93 dB.² All testing was done in an experimental room which had an

¹Acoustic impedance is defined as pressure/volume-velocity and it refers to the amount of "resistance" offered by the middle ear to the propagation of sound waves (Møller, 1964). Zwislocki and Feldman (1970) reported that the impedance of the normal ear lies within a conservative range of 280 to 630 acoustic ohms at 250 Hz.

²The rise and decay times of the 1000 Hz tone were 25 msec and 35 msec respectively.

ambient noise level of 50 dB as measured on the C scale of a Bruel and Kjaer sound level meter (Model 2204). (Octave band levels of the ambient noise are presented in Appendix II.)

Design and Conditioning Procedure

As indicated above, a temporal conditioning paradigm was employed in the first experiment. Therefore, the experiment was designed to present the UCS by itself with constant time intervals between successive presentations. The UCS was a 1000 Hz tone presented 10 dB above the subject's reflex threshold for a duration of 1 second (± 6 msec) and the CS was a time interval of 45 seconds (± 160 msec).¹

During the experiment, each subject received the same number of conditioning trials and test trials. (See Table 1.) Specifically, each subject received a total of 100 conditioning trials and four test trials within a 24 hour period.² The conditioning trials were presented in four groups of 25 trials with each block of conditioning trials being followed by a test trial. In addition, three unreinforced trials were presented immediately prior to each set of conditioning trials in order

¹Stimulus values were not picked totally at random. The choice of 1000 Hz as the UCS frequency was based on the reports of Luscher and Jepson (cited above) which indicate that the midfrequencies produce the most sensitive and reliable measurements. In addition, the intensity of the UCS was chosen as a compromise between obtaining consistent reflex responses yet eliminating general startle responses. Finally, choice of the CS interval was based on the reports of Metz and Dallos (cited above) concerning relaxation time of the muscles and also on Morgan's (1965) finding that humans are best able to discriminate time intervals between 30 and 60 seconds in length.

²One subject received a total of 123 trials. The extra block of conditioning trials was presented because an instrumentation difficulty disrupted the timed presentations of conditioning trials numbered 99 and 100.

to establish a baseline of responding. Each subject was seen twice within the 24 hour period. At each of these experimental settings, the subject received two blocks of conditioning trials (a total of 50 trials). In addition, the subject was given a 15 minute rest period after the first 25 conditioning trials at each session.

Table 1

Stimulus Presentations in Temporal Conditioning

<u>Trial</u>	<u>Sequence</u>
Conditioning or Reinforced Trial	45 Second Time Interval 1000 Hz Tone Presented for 1 Second 45 Second Time Interval
Test or Unreinforced Trial	45 Second Time Interval Tone Withheld for 1 Second 45 Second Time Interval

Instrumentation¹

Stimulus Presentation. As indicated above, the UCS was presented for a duration of one second every 45 seconds during the conditioning trials. A Beltone portable audiometer (Model 10C) generated the UCS and controlled its frequency and intensity. Two Hunter timers (Model 100C, Series D and Model 111C, Series D) controlled and automated repetition of

¹A complete listing of the equipment employed may be found in Appendix III.

the UCS - time interval - UCS sequence. (A schematic wiring diagram may be found in Appendix IV.) The first timer (T1) controlled the UCS presentations and the second timer (T2) controlled the time interval between successive presentations. T1 and T2 were wired together so that when either timer finished its timed interval it activated the other timer. In addition, T1 was wired to the audiometer so that when T1 was activated (by the shut off of T2) the UCS was simultaneously turned off. The automated sequence started when the experimenter manually turned on T2 and stopped when the experimenter manually turned off the same timer. The stimulus presentation switch on the audiometer was used to delete the UCS during the test trials.

Response Measurement. Responses to the stimuli were measured with the Madsen Electro-Acoustic Impedance Bridge (Model Z070). (A complete description of the Madsen Bridge may be found in Appendix V.) The responses which took the form of impedance changes in the subject's ear were correlated with voltage changes in the Madsen Bridge and appeared as deflections on the balance meter of the bridge (Terkildsen and Nielson, 1960).

Recording. Recordings were made of both the stimulus and response signals utilizing a Brush graphic recorder. (Sample recordings may be found in Appendix VI.) The recorded stimulus signal was correlated with the CS and UCS presentations. The signal originated at T1 and was amplified by the Brush DC amplifier before being recorded on the graphic recorder. Two six volt batteries were employed to drive the needle of the graphic recorder.

The recorded response signal was correlated with impedance changes in the subject's ear canal as measured by the Madsen Bridge. The signal

from the Madsen Bridge was then amplified respectively by a Tektronix amplifier (Type 2A63) and the Brush amplifier before it was recorded by the Brush graphic recorder.

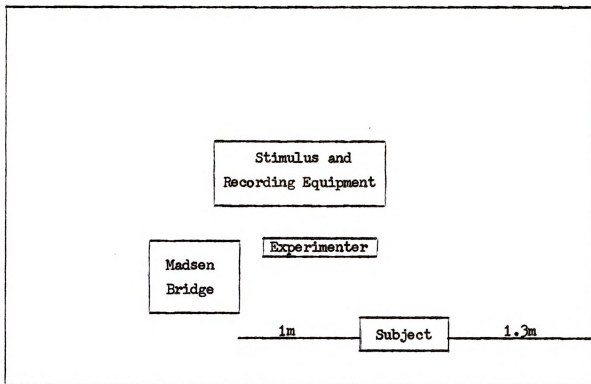


Figure 1. Block diagram of experimental situation for temporal conditioning.

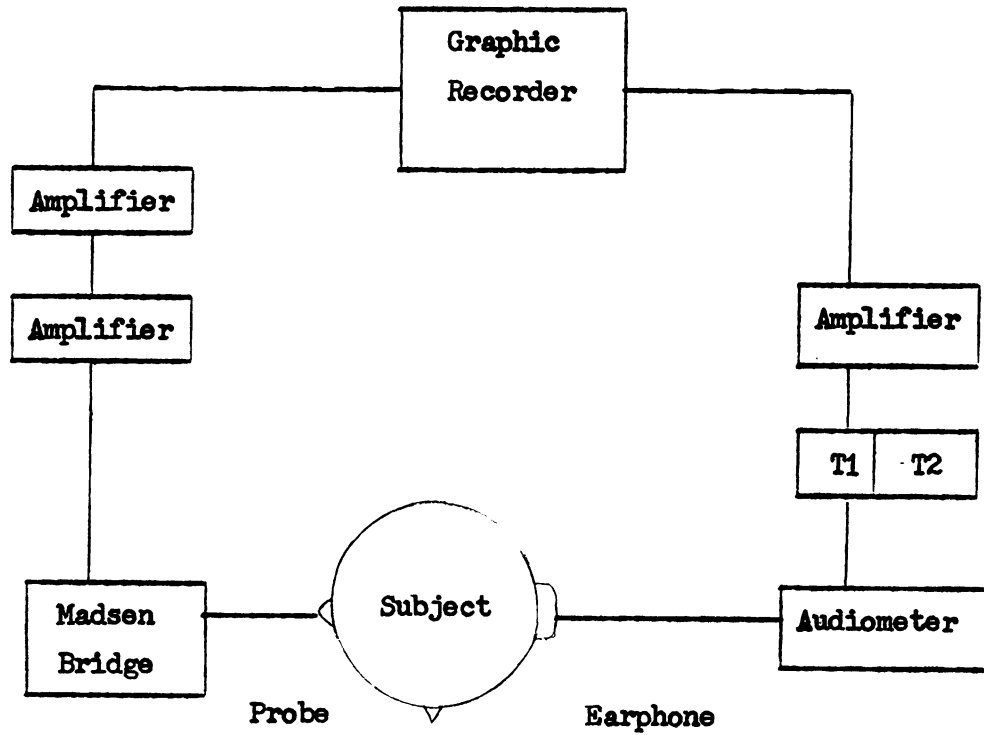


Figure 2. Schematic illustration of instrumentation for temporal conditioning.

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (1)$$

where x is a real number.

The function $f(x)$ is called the arctangent function.

It is easy to see that

$$f(0) = 0.$$

Moreover, we have

$$f'(x) = \frac{1}{1+x^2}.$$

Therefore, the function $f(x)$ is increasing on the whole real line.

Let us now consider the function

$$g(x) = \frac{1}{1+x^2}.$$

It is easy to see that

$$g(0) = 1.$$

Moreover, we have

$$g'(x) = -\frac{2x}{1+x^2}.$$

Therefore, the function $g(x)$ is decreasing on the interval $(0, \infty)$ and increasing on the interval $(-\infty, 0)$.

$$\lim_{x \rightarrow \infty} g(x) = 0.$$

$$\lim_{x \rightarrow -\infty} g(x) = 0.$$

Let us now consider the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (2)$$

Procedures

The experimenter calibrated the Madsen Bridge and the Beltone audiometer each day that a conditioning attempt was made. (A listing of the equipment employed in the calibration may be found in Appendix III.) The calibration of the Madsen Bridge consisted of insuring that the indicator needle on the pressure gauge was at a 0 reading when no pressure was being applied. Calibration of the audiometer consisted of determining the SPL outputs at each octave frequency from 250 Hz through 8000 Hz for air conduction and from 250 Hz through 4000 Hz for bone conduction. The SPL outputs were then compared with the air conduction standards as published by the International Standards Organization (1964) and the interim bone conduction standards as published by the Hearing Aid Industry Conference (Lybarger, 1966). Compensations for intensity norm deviations were made during testing.

At each subject's first experimental session, her name and age were recorded on a standardized form. (A copy of this form may be found in Appendix VII.) Following this formality, the criteria tests for hearing were administered. The pure tone test was always administered first followed by the impedance measurements. Pure tone thresholds were determined by the Hughson-Westlake technique as described by Carhart and Jerger (1959). This same technique was employed in determining the middle ear reflex threshold level.¹ Acoustic impedance values were determined through use of the following expression which was provided in the manual for the Madsen Bridge: $Z_x = (Z_1 \times Z_2) / (Z_1 - Z_2)$. The

¹Lamb, Peterson and Hansen (1968) recommend employing the Carhart and Jerger ascending technique for determining middle ear reflex thresholds.

required values were determined through the following steps. First the pressure in the ear canal was increased to +200 mm water pressure and the compliance control was adjusted as necessary to obtain a zero reading on the balance meter when the meter was set for a sensitivity of ± 1 cc. The correlated impedance reading represented the point of least compliance of the middle ear system and this value was employed as Z_1 in the above expression. The value of Z_2 was obtained by reducing the pressure in the ear canal until the balance meter needle had reached its maximum swing to the left and the compliance control was subsequently adjusted to again produce a zero reading on the balance meter. The correlated impedance reading here represented the maximum compliance of the middle ear system. Finally, the two impedance values were combined in the expression provided above to determine the acoustic impedance in the plane of the eardrum (Z_x). All impedance measurements were made with the probe from the Madsen Bridge fitted to the subject's right ear.

Prior to the experimental session, all of the equipment was warmed up for a period of 10 minutes. During the hearing tests, however, the Tektronix amplifier and its power supply and the Brush graphic recorder were turned off. These instruments had been found to increase the ambient noise in the room from 50 dB to 55 dB as measured on the C scale of a Bruel and Kjaer sound level meter (Model 2204).

Following the administration of the criteria tests for hearing, all of the equipment was again turned on. At this time, the instructions were read to the subject. (A copy of these instructions may be found in Appendix VIII.) A carbon copy of the instructions was given to the subject so that she could follow along with the verbalization. After the instructions were read, the experimenter answered any questions posed by

the subject. After all questions had been answered, the subject was given a 3 minute period to adjust to the experimental situation, i.e. an habituation period. Following this, the experimental trials were administered as outlined above.

Results and Discussion

The data were independently analyzed by two judges employing the following criteria.¹ A middle ear reflex response was operationally defined as a needle deflection on the graphic recorder of approximately 90° from the baseline with a minimum deflection magnitude corresponding to a 20 mv change. During the conditioning trials, only responses which occurred during the one second interval when the UCS was presented were counted. During the baseline trials and the test trials, however, a response meeting the operational definition was accepted if it occurred anytime after the first four-fifths of the intertrial interval (ITI).² The results of both judges' analyses were in perfect agreement and they are summarized below in Figures 3 and 4.

All subjects responded with an acceptable reflex on each of the UCS conditioning presentations.³ However, inspection of Figure 3 reveals that no spontaneous reflexes were elicited during the baseline trials which preceded each block of conditioning trials. In addition,

¹The experimenter served as one judge. The other judge was a graduate student in English.

²Morgan (1965) reported that the normal error allowance in studies of temporal discrimination is one-fifth of the time interval.

³One subject failed to respond with an accepted reflex to one UCS presentation during her first block of conditioning trials. The given response did not meet the magnitude criteria.

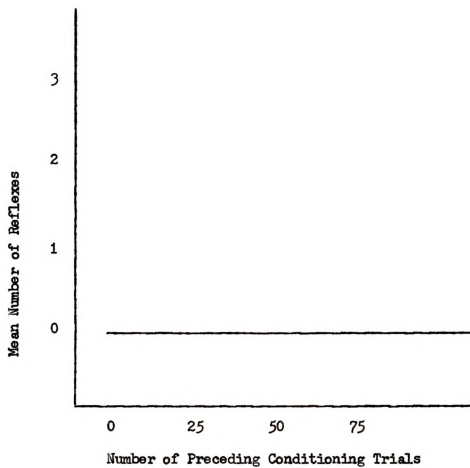


Figure 3. Spontaneous reflexes elicited during temporal conditioning.

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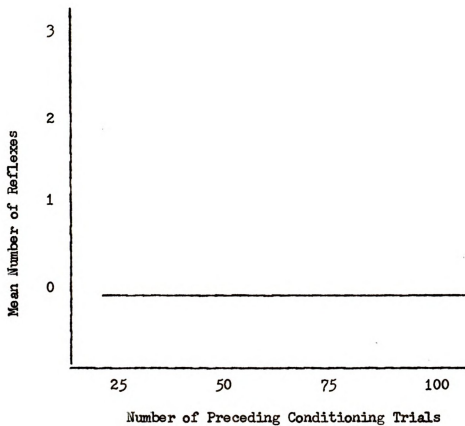


Figure 4. Conditioned reflexes elicited during temporal conditioning.

1. The first part of the report is a general
 introduction to the subject of the study.
 2. The second part is a detailed description
 of the methods used in the study.
 3. The third part is a discussion of the
 results of the study.
 4. The fourth part is a conclusion of the
 study.
 5. The fifth part is a list of references.
 6. The sixth part is an appendix.
 7. The seventh part is a list of figures.
 8. The eighth part is a list of tables.
 9. The ninth part is a list of abbreviations.
 10. The tenth part is a list of symbols.

The following table shows the results of the study.

inspection of Figure 4 reveals that there were no conditioned reflexes (CRs) elicited during any of the test trials. Therefore, since there was no difference in the baseline response and in the number of CRs, temporal conditioning of the middle ear reflex was not demonstrated.

This absence of temporally conditioned responses is consistent with the results obtained by Ward and Fleer (1961). However, such a result is incompatible with the conclusion drawn by Loeb and Fletcher (1963) and Mendelson et al. (1963). As indicated above, these later experimenters reported success in conditioning the middle ear reflex to a time interval.

A cursory review of the literature, therefore, might suggest that the conditionability of the middle ear reflex to time is an equivocal question since two studies have reportedly demonstrated such conditioning and two studies have failed to demonstrate such conditioning. A careful review of the employed methodologies, however, reveals that in both of the successful investigations ITIs were equal to or less than one second. Moreover, according to the data presented above by Metz (1951) and Dallos (1964) such ITIs may be too short to allow complete relaxation of the middle ear muscles. Thus, the results obtained by Loeb and Fletcher (1963) and Mendelson et al. (1963) possibly are confounded and, therefore, cannot be interpreted. This suggests that based on present research, the only conclusion that can be drawn at this time is that the middle ear reflex has not been shown to be susceptible to temporal conditioning.

EXPERIMENT II: LIGHT AS AN UNCONDITIONED STIMULUS

In the second experiment an attempt was made to elicit the middle ear reflex with visual stimulation. The purpose of the experiment was to determine whether or not the chosen visual stimulus consistently evoked the reflex response.¹

Method

Subjects

Five normal hearing female volunteers served as subjects. Four of the subjects were students at Michigan State University and one subject was an alumnus of the same institution. Subjects ranged in age between 20.9 years and 24.7 years with a mean age of 22.8 years. All subjects had normal pure tone thresholds of hearing under the criteria outlined in the first experiment. In addition, all subjects showed normal acoustic impedance values, ranging from 350 to 540 acoustic ohms with a mean value of 420 acoustic ohms. Finally, all subjects had middle ear reflexes which could be measured with the Madsen Electro-Acoustic Impedance Bridge (Model 2070). The reflex thresholds ranged from 80 to 95 dB with a mean of 88 dB. All of the hearing criteria tests were administered in the experimental room employed in the first experiment.

¹The chosen visual stimulus was a 6 volt tungston lamp with an effective illumination of 0.2 fc measured at the subject's eye. The light provided an illumination of 16 fc measured approximately 3 inches from the bulb. The illumination at the subject's eye provided by the room lights was 4 fc. All illumination measurements were made with a Spectra Exposure Meter manufactured by the Photo Research Corporation.

Design and Experimental Procedure

The second experiment was designed to determine if the light evoked the middle ear reflex at a greater than chance frequency. This determination was made by comparing the number of reflexes that occurred during 25 one second time intervals when the light was presented with the number of reflexes that occurred during 25 one second time intervals when the light was withheld.

Testing was completed in one session with the subject receiving a 15 minute rest period halfway through the testing. The instrumentation was automated to present the light for a duration of 1 second (± 6 msec) every 45 seconds (± 160 msec). During the session a total of 50 stimulus presentations were originated. However, by means of a switch, the experimenter deleted a random 50% of these presentations so that the subject observed the light only 25 times. The same random pattern of presentations was used for all subjects. (This random sequence is presented in Appendix IX).

Instrumentation

Stimulus Presentation. A General Electric tungston lamp (Model 51) attached to an Electronic DC power supply (Model 1020) generated the stimulus. The stimulus-time interval-stimulus sequence was automated and controlled by two Hunter timers (Model 100C, Series D and Model 111C, Series D). (A schematic wiring diagram may be found in Appendix IV.) The wiring of the timers was the same as in experiment I except that in the second experiment T1 was wired to the power supply for the light rather than to the audiometer. In addition, the experimenter employed a switch which was wired to the power supply of the light to delete presentations of the light during appropriate time intervals.

Response Measurement. As in the first experiment, the subject's response to the stimulus was measured by the Madsen Electro-Acoustic Impedance Bridge (Model Z070).

Recording. The recording procedure for the second experiment was the same as in the first experiment. The only difference was that the recorded stimulus event in the second experiment was the interval correlated with a light presentation or deletion rather than an interval correlated with a tone presentation.

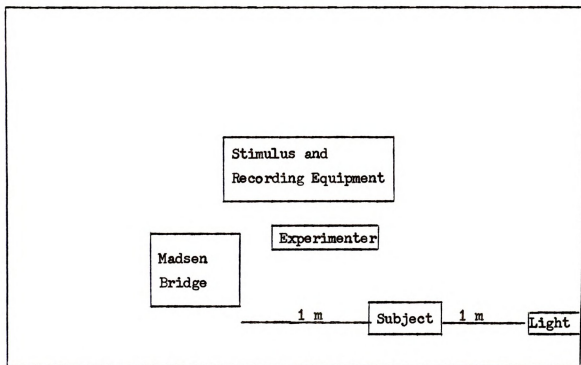


Figure 5. Block diagram of experimental situation for determining the neutrality of a visual stimulus.

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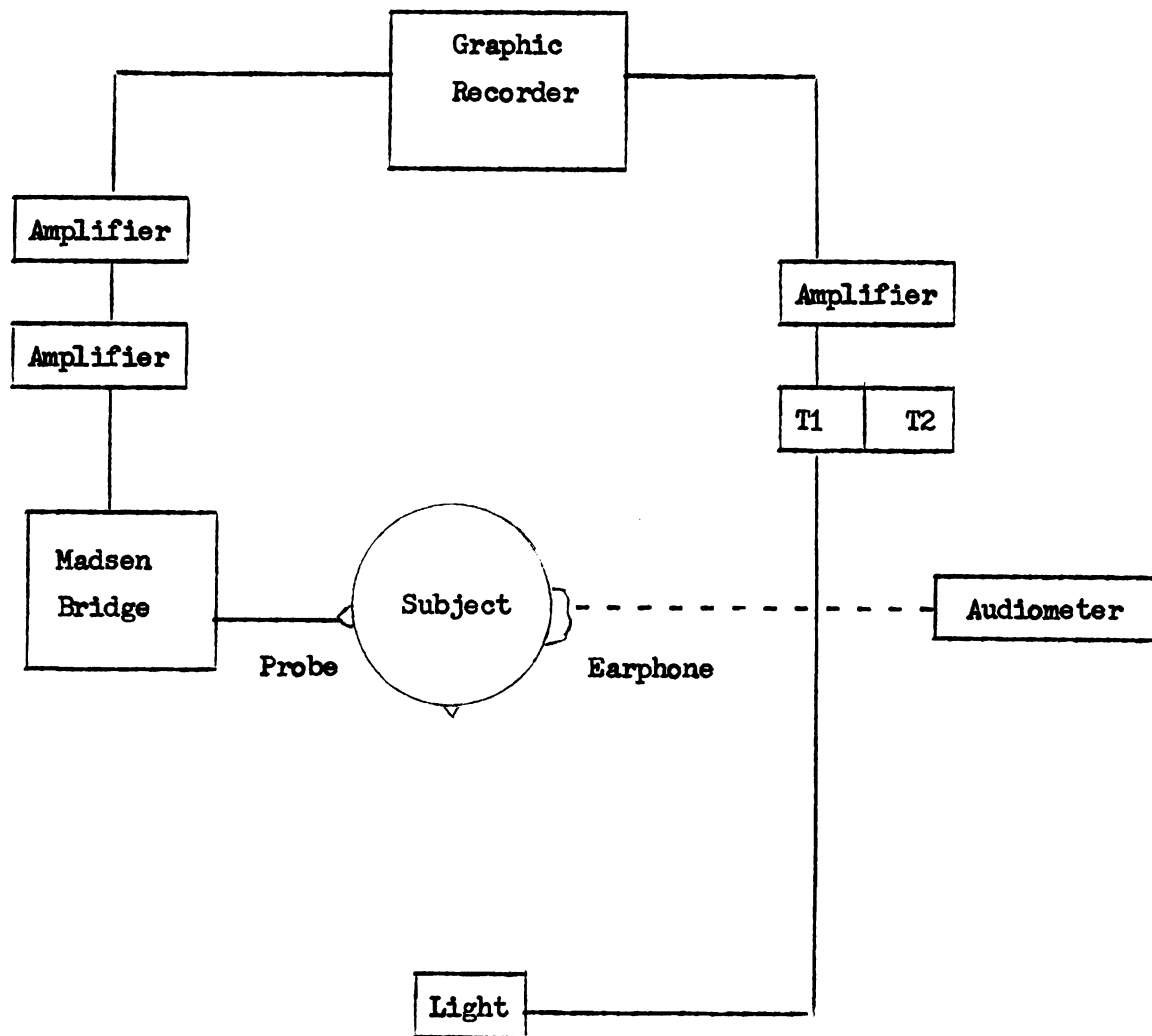


Figure 6. Schematic illustration of instrumentation for determining the neutrality of a visual stimulus.

Amplifier		Amplifier
Amplifier		Amplifier
Amplifier		Amplifier

Subject	Amplifier
Amplifier	Amplifier

Amplifier is a device that is used to increase the amplitude of a signal. It is a common component in many electronic circuits, and is used to drive a load that requires a higher power than the source can provide. The amplifier is a device that is used to increase the amplitude of a signal. It is a common component in many electronic circuits, and is used to drive a load that requires a higher power than the source can provide.

Procedures

All of the procedures employed as precedents to administering the experimental trials in experiment II were the same procedures as employed in the first experiment. However, as indicated above, all of the testing in the second experiment was completed in one session. In addition, following the 50th trial in the second experiment, a reflex response was elicited from each subject with a 100 dB stimulus at 1000 Hz as confirmation that the probe from the Madsen Bridge had remained in place during the entire session.

Results and Discussion

The data were independently analyzed by the two judges employed in the first experiment. Likewise, the data were objectively scored by applying the operational definition of a reflex response which was presented in the first experiment. In the second experiment, however, only those reflexes were considered which occurred either during the light presentations or during the empty intervals during which the light was deleted. Again, the judges were in perfect agreement in their analyses and the results are summarized below in Figures 7 and 8.

Inspection of Figure 7 reveals that no spontaneous reflexes were elicited from any subject during any of the 25 empty intervals. Likewise, inspection of Figure 8 reveals that no reflexes were elicited in response to any of the 25 light presentations. Therefore, since there was no difference in the number of spontaneous reflexes and the number of unconditioned responses, it was concluded that the experimental light is not an unconditioned stimulus for the middle ear reflex.

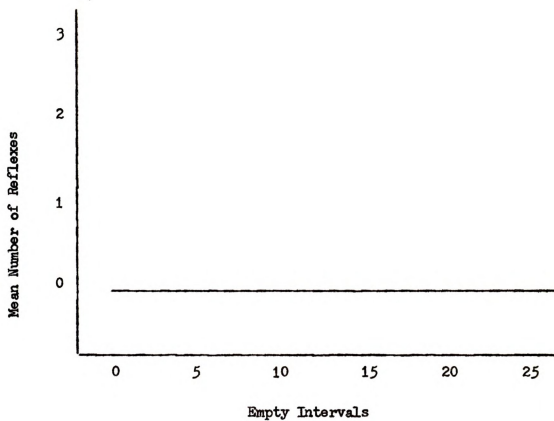


Figure 7. Spontaneous reflexes elicited during the determination of the neutrality of the visual stimulus.

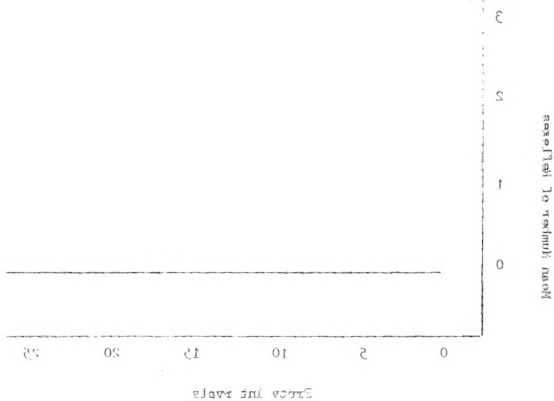


Figure 7. Spontaneous reflexes elicited during the determination of the neutrality of the visual stimulus.

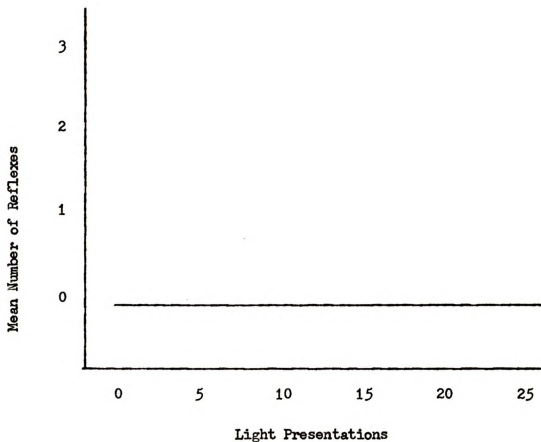
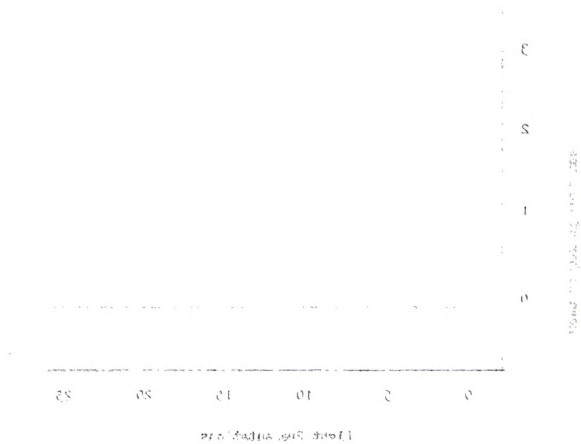


Figure 8. Unconditioned reflexes elicited during the determination of the neutrality of the visual stimulus.



The flow rate is constant at approximately 22 ml/min throughout the 30-minute period.

EXPERIMENT III: SIMULTANEOUS AND DELAYED CONDITIONING

The third experiment provided a final attempt to classically condition the middle ear reflex. Specifically, the main purpose of the experiment was to determine whether or not the middle ear reflex could be conditioned to a neutral visual stimulus. The chosen stimulus was the light which had been employed in experiment II. Moreover, since prior conditioning studies on other modalities have demonstrated that conditioning frequently depends upon an appropriate delay time between the onset of the CS and the onset of the UCS (Kimble, 1947; Gerall and Woodward, 1958; and Jones, 1962 among others), the present experiment was also designed to determine if the conditionability of the middle ear reflex varied with different interstimulus intervals (ISIs).

Method

Subjects

Twenty normal hearing female volunteers served as subjects. Fifteen of the subjects were students at Michigan State University and five of the subjects were alumni of the institution. Subjects ranged in age between 20.0 and 24.6 years with a mean of 22.0 years. All subjects had normal pure tone thresholds of hearing under the criteria outlined in the first experiment. In addition, all subjects showed normal acoustic impedance values, ranging from 290 to 560 acoustic ohms with a mean value of 400 acoustic ohms. Finally, all subjects had middle ear reflexes which could be measured with the Madsen Electro-Acoustic Impedance Bridge (Model Z070).

THE HISTORY OF THE UNITED STATES

The history of the United States is a story of growth and development. It begins with the first settlers who came to the continent in search of a new home. These early pioneers faced many hardships, but they persevered and built a nation that would become one of the most powerful in the world. The story of the United States is a story of the struggle for freedom and the pursuit of the American dream. It is a story of the many men and women who have sacrificed for the sake of their country and the values it represents. The history of the United States is a story that continues to unfold, and it is one that we all have a part in writing.

Conclusion

The history of the United States is a story of growth and development. It begins with the first settlers who came to the continent in search of a new home. These early pioneers faced many hardships, but they persevered and built a nation that would become one of the most powerful in the world. The story of the United States is a story of the struggle for freedom and the pursuit of the American dream. It is a story of the many men and women who have sacrificed for the sake of their country and the values it represents. The history of the United States is a story that continues to unfold, and it is one that we all have a part in writing.

The reflex thresholds ranged from 80 to 100 dB with a mean of 92 dB. All screening was done in the experimental room employed in the first two experiments.

Design and Conditioning Procedure

As indicated above, the purpose of the third experiment was to determine if the middle ear reflex could be conditioned to a neutral visual stimulus. The UCS was a 1000 Hz tone presented 10 dB above the subject's middle ear reflex threshold for a duration of one second (+/- six msec) and the CS was a tungston lamp with an effective illumination of 0.2 fc. In order to avoid any possibility of temporal conditioning, the time intervals between successive UCS presentations were randomly varied at 30, 45 or 60 seconds. The same random order was used for all subjects. (This random order may be found in Appendix X.)

The conditioning trials were presented in the same manner as they were in the first experiment. That is, a total of 100 reinforced trials were presented in two sessions within a 24 hour period. A test trial followed each block of 25 conditioning trials and the subject was given a 15 minute rest period after the first test trial at each session.

Four experimental groups were employed in the third experiment. The dependent variable of concern was the effect on conditioning of various delay times between the onset of the CS and the UCS presentations. Four delay times, varying from 0 delay to a 2.5 second delay were employed. The stimulus presentation sequences for each experimental group are presented in Table 2.

The experimental situation in the present experiment was the same as in experiment II. A block diagram of this situation may be found in Figure 5.

Table 2

Stimulus Presentations for Simultaneous and Delayed Conditioning*

<u>Group 1</u>	-	<u>Simultaneous Conditioning Group</u>
		Reinforced Trial - CS and UCS presented concurrently for a duration of one second. Intervals between UCS onsets are randomly varied at 30, 45 or 60 seconds.
		Test Trial - CS and UCS off for an interval varying randomly from 30 to 60 seconds. CS on for one second, UCS remains off.
<u>Group 2</u>	-	<u>Delayed Conditioning: ISI of 0.5 Seconds</u>
		Reinforced Trial - CS onset precedes UCS onset by 0.5 seconds. After UCS onset, both CS and UCS remain on for one second. Intervals between UCS onsets are randomly varied at 30, 45 or 60 seconds.
		Test Trial - CS and UCS off for an interval varying randomly from 29.5 to 59.5 seconds. CS on for 1.5 seconds, UCS remains off.
<u>Group 3</u>	-	<u>Delayed Conditioning: ISI of 1.5 Seconds</u>
		Reinforced Trial - CS onset precedes UCS onset by 1.5 seconds. After UCS onset, both CS and UCS remain on for one second. Intervals between UCS onsets are randomly varied at 30, 45 or 60 seconds.
		Test Trial - CS and UCS off for an interval varying randomly from 28.5 to 58.5 seconds. CS on for 2.5 seconds, UCS remains off.
<u>Group 4</u>	-	<u>Delayed Conditioning: ISI of 2.5 Seconds</u>
		Reinforced Trial - CS onset precedes UCS onset by 2.5 seconds. After UCS onset, both CS and UCS remain on for one second. Intervals between UCS onsets are randomly varied at 30, 45 or 60 seconds.
		Test Trial - CS and UCS off for an interval varying randomly from 27.5 to 57.5 seconds. CS on for 3.5 seconds, UCS remains off.

*Ranges and averages of the delay times in msec for each experimental group are presented in Appendix XI.

Instrumentation

Stimulus Presentation. A Beltone portable audiometer (Model 10C) generated the UCS and controlled its frequency and intensity. The CS was generated by a General Electric tungston lamp (Model 51) and an Electronic DC power supply (Model 1020). Three Hunter timers (Model 100C series D and 2 Model 111C series D) controlled the UCS and CS presentations for each conditioning trial. The first timer (T1) initiated the onset of the CS. The second timer (T2) initiated the UCS onset. Finally, the third timer (T3) set the delay interval between the onset of the CS and the onset of the UCS. The random time intervals were measured individually with a Dimco-Gray universal timer.

A manually operated mercury relay was used as a switch to originate each conditioning sequence. Whenever the relay was tilted out of the vertical direction, it closed a switch on T3 thereby starting that timer. Moreover, T3 was wired to T1 in such a way that when T3 was activated it simultaneously turned on T1. In addition, T3 was wired to T2 in such a manner that when T3 finished its timed interval it activated T2. T3 remained in its finished position until T2 completed its timed cycle. When T2 finished its timed interval it acted to reset timers T3 and T1 thus also resetting itself.

Response Measurement. As in the first experiments, the response of the middle ear to the stimulus was measured with the Madsen Electro-Acoustic Impedance Bridge (Model Z070).

Recording. Stimulus and response recordings for the third experiment were the same as outlined in experiment II.

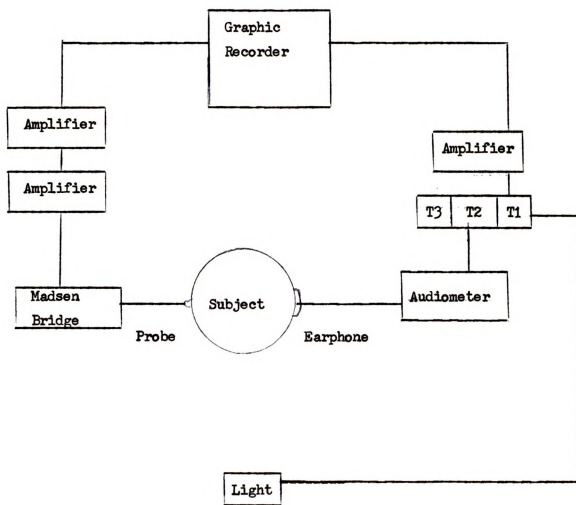


Figure 9. Schematic illustration of instrumentation for simultaneous and delayed conditioning.

Procedures

All of the procedures employed as precedents to administering the conditioning trials in experiment III were the same procedures as employed in the first two experiments.

Results and Discussion

The data were independently analyzed by the two judges employed in the first two experiments. Likewise, the data were objectively scored by applying the operational definition of a reflex response which was presented in the first experiment. In the third experiment, however, only those reflexes were considered which occurred while the CS was being presented. Again the judges were in perfect agreement in their analyses and the results are summarized in Figures 10 and 11.

Criterion reflexes were elicited from all subjects in response to each UCS presentation during the conditioning trials. However, inspection of Figure 10 reveals that no CRs were elicited from any subject in response to the CS during the test trials. Likewise, inspection of Figure 11 reveals that there is no difference in the mean number of CRs obtained from subjects across experimental groups. Therefore, the results suggest that the middle ear reflex cannot be conditioned to a neutral stimulus through either a simultaneous conditioning paradigm or a delayed conditioning paradigm in which various ISIs are employed.

The results of the present experiment were in agreement with the results obtained by Simmons (1964). However, the results contradict those obtained by Simmons et al. (1959), Mendelson et al. (1963) and Brasher et al. (1969). Yet, as indicated above, a careful inspection of the methodologies employed in each of these "successful" studies



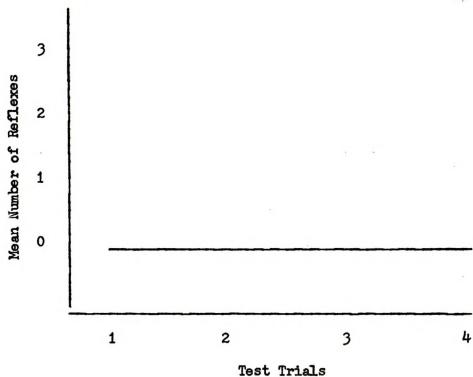


Figure 10. Conditioned reflexes elicited from all subjects during simultaneous and delayed conditioning.



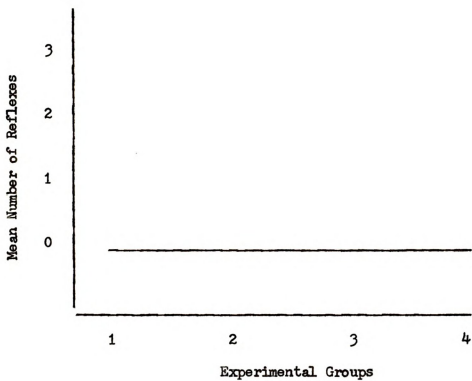


Figure 11. Comparison of conditioned reflexes elicited in each experimental group during simultaneous and delayed conditioning.

1950 10/10/50 10/10/50

1950 10/10/50 10/10/50

reveals that all of the investigations contain significant methodological flaws. Specifically, all of the investigators failed to quantitatively define a conditioned reflex, failed to employ control groups, and failed to control for voluntary motor activities which might elicit incidental reflexes. In addition, Simmons et al. (1959) and Brasher et al. (1969) may have elicited startle responses from their subjects and thus confounded their results. (Alternatively, the present investigator quantitatively defined the reflex response, made a determination of the neutrality of the conditioned stimulus as a control procedure, reduced voluntary motor activities through instructions to the subject and reduced the possibility of startle responses by employing a stimulus only 10 dB above the subject's reflex threshold.)

Thus, a careful review of the literature indicates that conditioning of the middle ear reflex to a neutral stimulus has not yet been demonstrated. Moreover, since Simmons (1964) employed constantly varying stimuli in his "unsuccessful" investigation of conditioning, the present investigation of the conditionability of the middle ear reflex is left as the most methodologically sound study of this phenomenon.

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GENERAL DISCUSSION

In this section the nature of a CR remains to be considered lest the present experiments be criticized at a later date for employing excessively stringent criteria in defining a reflex contraction. The implication of such a criticism could be that true CRs were overlooked through the use of the chosen quantitative definition. Such a criticism would be based on the assumption that CRs are never exactly the same as their associated UCRs (Kimble, 1961). In point of fact, although the form of the responses are generally similar, the magnitude of the CR is decidedly reduced from that of the UCR. Indeed, inspection of the "CRs" obtained by both Simmons et al. (1959) and Brasher et al. (1969) reflects this similarity of form but reduction in magnitude of the conditioned middle ear reflex.

In the present investigation the operational criteria were developed under full awareness of the nature of the typical CR. In fact, the criterion level magnitude proved to be less than one-fourth of the typical UCR magnitude obtained from any subject in any of the experimental groups. Nevertheless, an added precautionary measure was taken to guard against the employment of excessively stringent criteria. Specifically, a month after all of the criterion analyses were made, the same judges again reviewed the data. During this final review no criteria were employed and the judges were instructed merely to identify any impedance changes that they even suspected could be related to the presentation of the CS. Even under these instructions, however, no CRs

were identified. Therefore, it can be assumed that the criteria employed in the present investigations to define a reflex contraction were not excessively stringent.

Conclusions and Implications

Within the limits imposed by the instrumentation employed in the present experiments and the subjects who participated, the following conclusions seem warranted.

1. The middle ear reflex cannot be conditioned to a temporal interval.
2. Light does not serve as an unconditioned stimulus for the middle ear reflex.
3. The middle ear reflex cannot be conditioned to a neutral stimulus through either a simultaneous or a delayed conditioning paradigm.
4. The conditionability of the middle ear reflex is not differentially affected by the interstimulus interval employed in a delayed conditioning paradigm.

Based on these conclusions, therefore, it appears that incidentally conditioned reflexes do not serve as experimental sources of error. Moreover, this implies a greater degree of validity may be assigned to the results of past experiments which have investigated the role of the middle ear reflex in auditory functioning. That is, based on the present results, it does not appear likely that CRs confounded the reported results.

Nevertheless, before conditioning is ignored as an experimental variable, the results of the present experiments should be cross

we have found that the most common type of error is the omission of the subject. This is usually due to the fact that the subject is not clearly stated in the question.

Another common error is the omission of the verb.

When a subject is omitted, the sentence is usually incomplete. When a verb is omitted, the sentence is usually incomplete. When both are omitted, the sentence is usually incomplete.

It is important to note that the subject and verb are the two most important parts of a sentence.

Therefore, it is important to make sure that the subject and verb are clearly stated in the question.

When a subject is omitted, the sentence is usually incomplete. When a verb is omitted, the sentence is usually incomplete.

When both are omitted, the sentence is usually incomplete. When both are present, the sentence is usually complete.

Therefore, it is important to make sure that the subject and verb are clearly stated in the question.

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validated by other experiments. In particular, the following variables, which have been proven to have significant effects on conditioning, should be considered: age of subject, type of stimulation, and type of instructions. Braun and Geislarth (1959), for example, demonstrated that conditionability of the eyelid reflex decreases with age. Moreover, Brackbill, Fitzgerald, and Lintz (1967) demonstrated differential conditionability both as a function of the type of CS employed and as a function of the age of the subject. Specifically, Brackbill, et al. demonstrated that the pupillary reflex may be temporally conditioned in infants but not in adults; yet the same reflex may be conditioned to an auditory stimulus in adults but not in infants. Finally, Miller (1939) illustrated the effects of various types of instructions on the rate of acquisition and extinction of the conditioned eyelid response. He suggests that the type of instruction may serve to either restrain or facilitate CRs.

The results of the present experiments also suggest that the middle ear reflex may be grouped with reflexes such as the patellar reflex, the abdominal reflex, the plantar reflex and the pupillary reflex, since all of these reflexes are considered to be difficult to condition. Kimble (1961) suggests, moreover, that any reflex which is resistant to conditioning probably is only slightly involved in the processes of motivation and reward. That is, these difficult to condition reflexes do not appear to contain the same amount of drive reduction value as do easily conditioned reflexes such as the eyelid reflex or salivation.

Finally, it could be argued that the middle ear reflex is not easily conditioned because the middle ear muscle contractions are integral parts of a general auditory processing system rather than isolated responses to sufficiently intense auditory stimuli. Such an argument, moreover, would be

upheld by the results of several investigations which have been reviewed above. In particular, the results reported by Sedlacek (1965) and Lawrence (1965) suggest that the middle ear muscles are actively involved in binaural hearing. Likewise, the results obtained by Liden et al. (1963), Clubb (1965), and Jauhianen et al. (1967) suggest that middle ear muscle activity is related to variations in speech discrimination. Finally, the findings of Salomon and Starr (1963), Shearer and Simmons (1965) and Djupesland (1965) all suggest that the middle ear muscles are activated by motor control centers which initiate vocalization. Therefore, if the middle ear muscles are assumed to be part of an auditory processing system rather than isolated respondents, possibly the total system would need to be involved before any conditioning could be demonstrated.

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APPENDICES



APPENDIX I
SUBJECT VARIABLES

Subject Number	Age in Years	Impedance in KOhms	Reflex Threshold in dB	Sensation Level of Threshold	Hours Between Experimental Sessions
<u>Temporal Conditioning Group</u>					
1	22.6	.32	95	90	21
2	20.8	.35	100	95	14
3	22.5	.43	90	85	21
4	24.8	.51	90	90	15
5	21.4	.34	90	90	14/20
<u>Neutrality Determining Group</u>					
6	23.9	.42	90	85	
7	22.2	.54	85	80	
8	20.9	.38	90	90	
9	24.7	.35	95	90	
10	22.0	.43	80	75	
<u>Simultaneous and Delayed Conditioning Groups</u>					
11	23.9	.44	95	90	24
12	24.3	.29	85	85	24
13	23.0	.33	100	90	21
14	24.6	.50	95	90	23
15	20.8	.45	95	85	18
16	20.5	.30	100	90	24
17	20.2	.56	85	85	20
18	20.8	.47	95	90	20
19	20.7	.35	90	90	23
20	24.1	.31	100	95	19
21	22.9	.42	85	80	21
22	21.0	.48	95	90	23

Subject Variables, continued

Subject Number	Age in Years	Impedance in KOhms	Reflex Threshold in dB	Sensation Level of Threshold	Hours Between Experimental Sessions
23	21.8	.35	90	90	21
24	22.5	.40	95	90	24
25	21.1	.51	85	85	14
26	20.0	.29	90	90	15
27	23.1	.35	90	90	27
28	21.1	.37	85	85	24
29	22.7	.47	80	80	18
30	22.4	.47	100	95	20

Subject Variable

[illegible]

APPENDIX II

NOISE LEVELS IN OCTAVE BANDS

Center Frequencies in Hz	dB Levels, Equipment On	dB Levels, Equipment Off
31.5	51	50
63	40	38
125	45	40
250	51	33
500	48	20
1000	43	10
2000	42	Less than 10
4000	41	Less than 10
8000	36	Less than 10
16000	22	Less than 10

1. Introduction

The purpose of this study is to investigate the effects of various factors on the performance of a system.

Factor	Performance	Significance
Factor 1	High	Significant
Factor 2	Medium	Significant
Factor 3	Low	Significant
Factor 4	High	Significant
Factor 5	Medium	Significant
Factor 6	Low	Significant
Factor 7	High	Significant
Factor 8	Medium	Significant
Factor 9	Low	Significant
Factor 10	High	Significant
Factor 11	Medium	Significant
Factor 12	Low	Significant
Factor 13	High	Significant
Factor 14	Medium	Significant
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Factor 91	High	Significant
Factor 92	Medium	Significant
Factor 93	Low	Significant
Factor 94	High	Significant
Factor 95	Medium	Significant
Factor 96	Low	Significant
Factor 97	High	Significant
Factor 98	Medium	Significant
Factor 99	Low	Significant
Factor 100	High	Significant

APPENDIX III

EQUIPMENT

Temporal Conditioning Group

Screening

Portable Audiometer	Beltone Model 10C (Calibrated to ISO)
Earphones	Telephonics Model TDH 39 102
Earphone Cushions	Telephonics Model MX 41/AR
Bone Oscillator	Radioear B70A
Electro-Acoustic Impedance Bridge	Madsen Model Z070

Calibration

Sound Level Meter	Bruel & Kjaer Type 2304
Octave Band Filters	Bruel & Kjaer Type 1613
Microphones	Bruel & Kjaer Type 4144
Pistonphone	Bruel & Kjaer Type 4220
Artificial Ear	Bruel & Kjaer Type 4152
Volt Meter	Bruel & Kjaer Type 2409
Artificial Mastoid	Beltone Model M5A
Amplifier	Beltone Model M5A
Electronic Counter and Timer	Beckman Model 7370

Stimulus Presentation

Decade Timers (2)	Hunter Model 100C Series D
	Hunter Model 111C Series D
Portable Audiometer	Beltone Model 10C (Calibrated to ISO)
Earphone	Telephonics Model TDH 39 102
Earphone Cushion	Telephonics Model MX 41/AR

Response Measurement

Electro-Acoustic Impedance Bridge	Madsen Model Z070
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Recording

Differential Amplifier	Tektronix Type 2A63
DC Power Supply	Tektronix Type 129
6 Volt Batteries (2)	
Graphic Recorder	Brush
DC Amplifier	Brush

Equipment, continued

Neutrality Determining Group

Screening	Same as in experiment I
Calibration	Same as in experiment I
Stimulus Presentation	
Decade Timers (2)	Hunter Model 100C Series D Hunter Model 111C Series D
Tungston Lamp	General Electric Model 51
DC Power Supply	Electronic Model 1020
Response Measurement	Same as in experiment I
Recording	Same as in experiment I

Simultaneous and Delayed Conditioning Groups

Screening	Same as in experiment I
Calibration	Same as in experiment I
Stimulus Presentation	
Decade Timers (3)	Hunter Model 100C Series D (1) Hunter Model 111C Series D (2)
Portable Audiometer	Belton Model 10C (Calibrated to ISO)
Earphones	Telephonics Model TDH 39 102
Earphone Cushions	Telephonics Model MX 41/AR
Tungston Lamp	General Electric Model 51
DC Power Supply	Electronic Model 1020
Universal Timer	Dimco-Gray
Response Measurement	Same as in experiment I
Recording	Same as in experiment I

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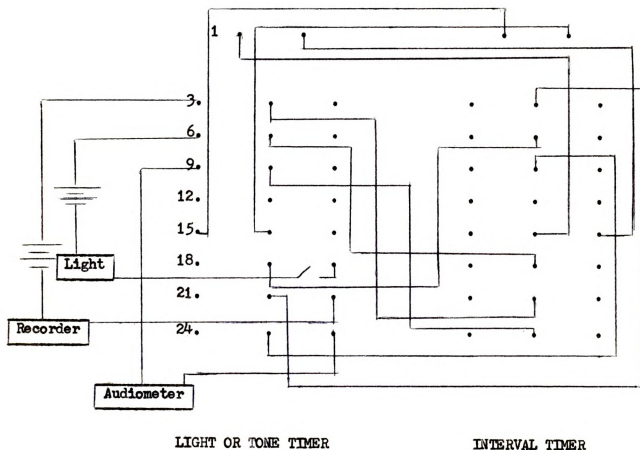
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APPENDIX IV
SCHEMATIC WIRING DIAGRAM OF TIMERS

Temporal Conditioning Group and Neutrality Determining Group



General Notations:

Left Column - Open Relays
Center Column - Common Relays
Right Column - Closed Relays

Relays 3-14 Start Relays
Relays 15-26 Stop Relays

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY

PLANT INDUSTRY REPORT NO. 1000

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715	716	717	718	719	720
721	722	723	724	725	726
727	728	729	730	731	732
733	734	735	736	737	738
739	740	741	742	743	744
745	746	747	748	749	750
751	752	753	754	755	756
757	758	759	760	761	762
763	764	765	766	767	768
769	770	771	772	773	774
775	776	777	778	779	780
781	782	783	784	785	786
787	788	789	790	791	792
793	794	795	796	797	798
799	800	801	802	803	804
805	806	807	808	809	810
811	812	813	814	815	816
817	818	819	820	821	822
823	824	825	826	827	828
829	830	831	832	833	834
835	836	837	838	839	840
841	842	843	844	845	846
847	848	849	850	851	852
853	854	855	856	857	858
859	860	861	862	863	864
865	866	867	868	869	870
871	872	873	874	875	876
877	878	879	880	881	882
883	884	885	886	887	888
889	890	891	892	893	894
895	896	897	898	899	900
901	902	903	904	905	906
907	908	909	910	911	912
913	914	915	916	917	918
919	920	921	922	923	924
925	926	927	928	929	930
931	932	933	934	935	936
937	938	939	940	941	942
943	944	945	946	947	948
949	950	951	952	953	954
955	956	957	958	959	960
961	962	963	964	965	966
967	968	969	970	971	972
973	974	975	976	977	978
979	980	981	982	983	984
985	986	987	988	989	990
991	992	993	994	995	996
997	998	999	1000	1001	1002

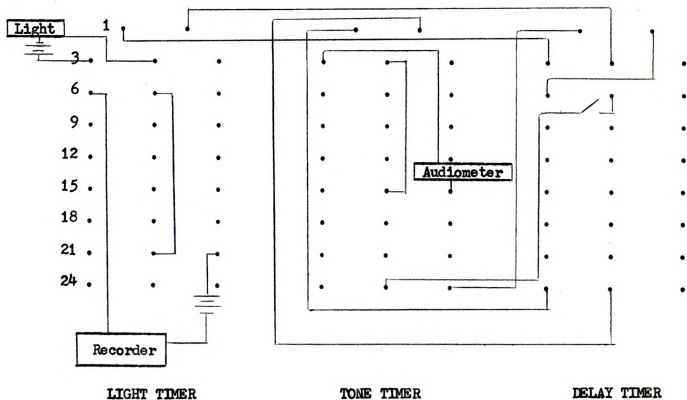
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Wiring, continued

Simultaneous and Delayed Conditioning Groups



And so, dear friends, I have the honor to be, very respectfully,
Yours truly,
J. W. B. B.

1999

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APPENDIX V

DESCRIPTION OF THE MADSEN BRIDGE

The Madsen Electro-Acoustic Impedance Bridge was developed by Terkildsen and Nielson (1960) for the dual purpose of measuring both middle ear pressure and acoustic impedance. Moreover, construction of the bridge (see Figure 12) reflects its dual purpose in that it contains two separate measurement systems. However, both of these systems are connected to the subject's ear via a single metal probe and rubber ear tip.

The acoustic impedance section of the bridge consists of a loudspeaker, a microphone, and a pure tone generator. The loudspeaker and microphone are contained in a metal case which is attached to a headband worn by the subject. A 220 Hz oscillator generates a "probe tone" which is applied to the loudspeaker and the resulting sound wave travels down a rubber tube to one of three pipettes in the metal probe which is fitted to the subject's ear. The microphone, which is connected by a second rubber tube to another of the probe pipettes, serves to monitor the SPL of the probe tone in the ear canal by delivering the transduced voltage through an amplifier to a bridge circuit and balance meter. The balance meter is nulled by a SPL of exactly 95 dB in the ear canal. Moreover, the SPL in the ear canal can be manually attenuated by compliance variations (a range of 0.2 to 5.0 cc is provided).

The air pressure system of the Madsen Bridge consists of an electro-manometer and a pump which are connected via flexible tubing to the third

Madsen Bridge Description, continued

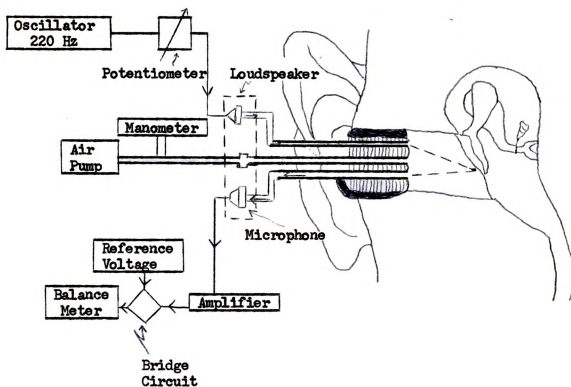


Figure 12. Schematic diagram of principal components of the Madsen electro-acoustic impedance bridge. (Jerger, 1970, p. 313)



Section 101, Chapter 101, Act 101

Section 101, Chapter 101, Act 101

Section 101, Chapter 101, Act 101

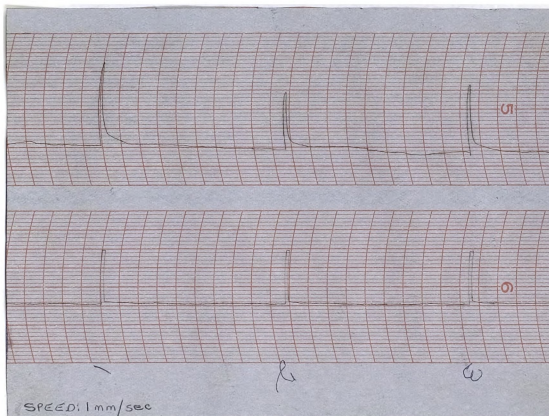
Section 101, Chapter 101, Act 101

Madsen Bridge Description, continued

probe pipe. The pump permits variations in air pressure in the ear canal over a range of 400 mm (water pressure). The air pressure is read on the electro-manometer. When the air pressure is set at +200 mm the associated compliance reading is almost totally determined by the ear canal space. However, when this artificial pressure is reduced, the compliance increases and reaches a maximum when the pressures in the ear canal and middle ear are identical, i.e. when the ear drum is in the midline position. In the present investigation, all measurements of the middle ear reflex were made from the midline position.

APPENDIX VI
STIMULUS AND RESPONSE RECORDINGS

Conditioning Trials (Sample Recording)

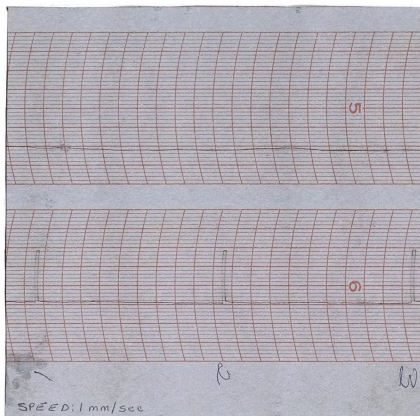


Top Graph: Response Signal

Bottom Graph: Stimulus Signal

Recordings, continued

Test Trials (Sample Recording)



Top Graph: Response Signal

Bottom Graph: Stimulus Signal



APPENDIX VII
INFORMATION SHEET

Name _____ Subject Number _____

Age: Years _____ Months _____

1st Session: Date _____ Time _____

2nd Session: Date _____ Time _____

Impedance Values:

200 mm (Z1) _____ Midline (Z2) _____

Plane (Zx) _____ where $Zx = \frac{Z1 \times Z2}{Z1 - Z2}$

Reflex Threshold _____ Sensation Level _____

SECRET

1. The purpose of this document is to provide information regarding the activities of the [redacted] in the [redacted] area. This information is being provided for your information and is not to be distributed outside of your office.

2. The [redacted] has been identified as a [redacted] and is currently active in the [redacted] area. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area.

3. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area.

4. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area.

5. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area. The [redacted] is currently active in the [redacted] area and is currently active in the [redacted] area.

APPENDIX VIII

INSTRUCTIONS

Temporal Conditioning Group

1. Your job in this experiment is to maintain a relaxed attitude and remain quietly seated. During the experiment you should keep the back of your head against the cushion on the top of the chair and look at the wall in front of you.
2. All head movements need to be kept at a minimum during the experiment. In particular, whenever you hear a tone in your left ear, do not swallow, blink your eyes or make any other movements of your eyes, mouth or throat. Remain perfectly still while the tone is on.
3. The tone will come on for short periods of time throughout the entire experiment. The time intervals between the tone onsets will be constant.
4. Do you have any questions?
5. The experiment has begun.

Neutrality Determining Group

1. Your job in this experiment is to maintain a relaxed attitude and remain quietly seated. During the experiment you should keep the back of your head against the cushion on the top of the chair, and look at the light bulb in front of you.
2. All head movements need to be kept at a minimum during the experiment. In particular, whenever you see the bulb light up do not swallow, blink your eyes or make any other movements of your eyes, mouth or throat. Remain perfectly still while the light is on.
3. The bulb will light up for short periods of time throughout the entire experiment. The time intervals between the light onsets will vary.
4. Do you have any questions?
5. The experiment has begun.

Simultaneous Conditioning Group

1. Your job in this experiment is to maintain a relaxed attitude and remain quietly seated. During the experiment you should keep the back of your head against the cushion on the top of the chair, and look at the light bulb in front of you.
2. All head movements need to be kept at a minimum during the experiment. In particular, whenever you see the bulb light up and you hear a tone in your left ear, do not blink your eyes, swallow or make any other movements of your eyes, mouth or throat. Remain perfectly still while the light and the tone are on.
3. The light and the tone will come on together for short periods of time throughout the entire experiment. The time intervals between the onsets of the light and tone will vary.
4. Do you have any questions?
5. The experiment has begun.

Delayed Conditioning Group

1. Your job in this experiment is to maintain a relaxed attitude and remain quietly seated. During the experiment you should keep the back of your head against the cushion on the top of the chair, and look at the light bulb in front of you.
2. All head movements need to be kept at a minimum during the experiment. In particular, whenever you see the bulb light up, do not blink your eyes, swallow or make any other movements of your eyes, mouth or throat. Remain perfectly still while the light is on. A short time after the light comes on you will hear a tone in your left ear. The tone will go off at the same time as the light.
3. The light, followed by a tone, will come on for short periods of time throughout the entire experiment. The time intervals between the light onsets will vary.
4. Do you have any questions?
5. The experiment has begun.

APPENDIX IX

STIMULUS SEQUENCE PRESENTATIONS IN EXPERIMENT II

Trial	Stimulus	Trial	Stimulus
1	Light	26	Light
2	Light	27	Empty Interval
3	Light	28	Light
4	Light	29	Empty Interval
5	Empty Interval	30	Empty Interval
6	Empty Interval	31	Light
7	Empty Interval	32	Empty Interval
8	Empty Interval	33	Light
9	Empty Interval	34	Light
10	Light	35	Light
11	Empty Interval	36	Light
12	Light	37	Empty Interval
13	Light	38	Empty Interval
14	Empty Interval	39	Empty Interval
15	Light	40	Light
16	Empty Interval	41	Empty Interval
17	Empty Interval	42	Light
18	Empty Interval	43	Light
19	Light	44	Empty Interval
20	Light	45	Light
21	Empty Interval	46	Light
22	Empty Interval	47	Light
23	Empty Interval	48	Empty Interval
24	Empty Interval	49	Empty Interval
25	Light	50	Light

APPENDIX X
INTERTRIAL INTERVALS EMPLOYED IN EXPERIMENT III*

Trial	Interval in Seconds	Trial	Interval in Seconds
1	30	20	45
2	45	21	60
3	45	22	60
4	30	23	60
5	45	24	45
6	60	25	30
7	30	26	30
8	60	27	45
9	60	28	30
10	60	29	30
11	30	30	45
12	45	31	60
13	30	32	45
14	30	33	45
15	45	34	45
16	45	35	30
17	45	36	60
18	30	37	45
19	45	38	45

*The interval values presented depict the intervals between successive UCS presentations. For group 1, this interval also represents the time between successive CS presentations. However, in the other experimental groups the exact interval between successive CS presentations would be reduced by 0.5, 1.5, and 2.5 seconds respectively from the values presented.

Intertrial Intervals, continued

Trial	Interval in Seconds	Trial	Interval in Seconds
39	30	70	60
40	60	71	30
41	30	72	60
42	60	73	60
43	60	74	30
44	30	75	30
45	60	76	30
46	45	77	60
47	30	78	45
48	30	79	60
49	30	80	30
50	45	81	45
51	30	82	45
52	30	83	45
53	45	84	30
54	30	85	30
55	45	86	30
56	60	87	30
57	60	88	30
58	30	89	45
59	60	90	45
60	45	91	60
61	60	92	30
62	30	93	60
63	30	94	30
64	30	95	60
65	45	96	45
66	30	97	45
67	30	98	30
68	60	99	30
69	45	100	60

APPENDIX XI

INTERSTIMULUS INTERVALS EMPLOYED IN EXPERIMENT III

Experimental Group	Average ISI in MSec	Range of ISIs in MSec
1	3	2 - 3
2	516	512 - 520
3	1502	1495 - 1507
4	2481	2475 - 2485

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