AUGMENTATION OF THE AVERAGED ELECTROENCEPHALIC AUDITORY RESPONSE IN PASSIVE ADULTS

by

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ABSTRACT

The purpose of this investigation was to determine if the amplitude of the AER to auditory stimulation at 10 dB SL could be increased in adults who were passive during testing. Three groups, each consisting of nine adults with normal hearing, were tested using conventional AEA procedures. An AER wherein a tone was presented alone at 10 dB SL served as the control condition. Different experimental conditions were administered to each group. The auditory stimulus was at 10 dB SL for all conditions. One group received an auditory signal and a visual stimulus simultaneously 40% of the time. The AER was obtained for those trials where the auditory stimulus occurred alone. Another group was stimulated with a colored light. During the time that this light was on the auditory signal was presented. The third group received a shock following 40% of the auditory signals. Comparisons in response amplitude for N1-P2 were made between the control and experimental conditions for each group. Latency measurements were made for N1, P2, and N2.

When the averaged amplitude of the response was compared for each group between the control condition and their respective experimental conditions significant differences were not observed. Comparisons between groups concerning the average response amplitudes obtained for the control condition did not yield a significant finding. However, a significant difference was noted when amplitude comparisons

were made between groups for the experimental conditions. Subjects who were administered a shock following the auditory signal yielded an average response having significantly larger amplitude than that seen for the group who received their auditory stimulus within the presentation of a colored light.

Significant differences in latency were not observed between any of the response components between conditions or between groups.

The lack of significant differences in amplitude between the control and experimental conditions suggest that attempts to augment response amplitude in passive subjects using conditions like those reported herein which attempted to modify attention externally will be unsuccessful.

CHAPTER I

Introduction

According to Brazier (1961), Caton was the first investigator to substantiate the presence of the fluctuating electrical activity of the cortex in 1875 using an optical magnifying technique. His recordings were taken directly from electrodes placed on the cortex of rabbits and monkeys. The activity picked up by the electrodes was directed to a reflecting galvanometer. Using a series of lens the EEG activity was progressively magnified and projected on a wall where it could be viewed. Over fifty years passed before Hans Berger demonstrated the existence of EEG activity in man (Brazier, 1961). His recordings were made using electrodes situated on the scalp. In addition Berger was successful in demonstrating changes which occurred in the ongoing cortical electrical rhythm with the presentation of different types of strong sensory stimuli.

In 1939, P. A. Davis described a diphasic waveform which occurred in the ongoing electroencephalic activity following auditory stimulation. A negative wave was seen as early as 30 to 40 msec after stimulus presentation. This was followed by a positive going component. In most instances the response was completed by 300 msec after the stimulus onset. She also observed that similar waveforms were evident to both the initiation and the cessation of the stimulus although the amplitude of the "off" response was markedly smaller and observed less frequently than that of the "on" response.

Additional investigation (Davis, Davis, Loomis, Harvey, & Hobart, 1939) revealed that the amplitude of the auditory potential measured at the temporal area was much smaller than that observed at the vertex suggesting that the late sensory evoked cortical potentials, i.e. those beginning approximately 40 msec after stimulation, were nonspecific in origin. If the late cortical potential was specific to the modality stimulated (auditory in this instance) the amplitude of the response should have been largest at the location on the skull corresponding to the primary cortical receptor (temporal area for audition), and not at the vertex. The fact that the reciprocal was true indicated that this response was not specific to a given receptor area within the cortex. Later investigations (French, Verzeano, & Magoun, 1953; Winters, Mori, Spooner, & Bauer, 1967) suggested that the late response was initiated at the reticular formation and from there radiated over the cortex.

The late electroencephalic response to intense auditory stimulation can easily be visualized from the perusal of raw EEG data. However, as intensity is decreased the amplitude of the response decreases making it difficult to distinguish from the ongoing EEG activity even for a person highly skilled in this technique. In order to determine if this response could be used to accurately estimate auditory threshold Perl, Galambos, & Glorig (1953) and Derbyshire, Fraser, McDermott, & Bridge(1956) systematically lowered the intensity of the auditory stimulus and observed the changes that occurred in the EEG activity with the introduction of each signal. The lowest intensity level at which responses could be visualized was termed threshold. They noted that behavioral thresholds were 10 dB (Perl et al., 1953) to 18 dB (Derbyshire et al., 1956) lower than the thresholds established by reading individual EEG responses. Since the latter - technique tended to underestimate auditory sensitivity additional enhancement of response amplitude was needed so that the response could be seen at threshold in a greater number of subjects.

Earlier, Dawson (1951) had developed a method of augmenting response amplitude by superimposing several individual responses photographically. Since the phase of the response was timelocked to stimulus onset he reasoned that the visual inspection of overlayed responses obtained at the same intensity would enable one to determine if the waveforms were enhanced. A similar procedure which utilized an integrator and a graphic writeout has been reported by Barlow (1957).

Although superimposition techniques did enhance response amplitude and were therefore an improvement to reading waveforms from raw EEG activity the visualization of responses at the behavioral threshold of an adult was still difficult. Thus, in order for EEG audiometry to have accuracy equivalent to that of behavioral test procedures in assessing threshold sensitivity additional enhancement of the response was needed.

Investigation into the ability of computers to more effectively separate a response having small amplitude from the background EEG activity was initiated by Rosenblith (1957) and his associates (Giesler, Freshkopf, & Rosenblith, 1958). Results soon indicated that thresholds established using responses averaged by a computer agreed closely to the behavioral thresholds of adults (McCandless & Best, 1964). Suzuki and Taguchi (1965) made direct comparisons between thresholds established using computer averaging and those found using Dawson's superimposition technique. Although responses were clearly seen at 50 dB SL using either procedure response detectibillty was 25% greater at 10 dB SL and 18% greater at 0 dB SL using data averaged by a computer than when the photographic superimposition technique was used. Despite the advantages that computerized averaging offered in enhancing EEC responses to auditory stimuli the averaged electroencephalic response (AER) was still quite small at low sensation levels. Even when behavioral and stimulus parameters were appropriate an AER at threshold was not always seen.

In most older children and adults the amplitude of the AER at 10 dB or 15 dB SL was large enough so that it was identifiable by the examiner (McCandless, 1967; McCandless & Lentz, 1968b). In contrast, infants frequently yielded their lowest averaged response at 40 dB HL (Lentz & McCandless, 1970; Rapin & Graziani, 1967) although there was no reason to believe that their peripheral auditory sensitivity was poorer than that of adults. These observations suggested that if the response amplitude could be increased slightly it would be most helpful.

Reading during the recording of the auditory AER has been shown to depress the amplitude of the response by some (Gross, Begleiter, Tobin, & Kissin, 1965; Williams, Morlock, Morlock, & Lubin, 1964). Keating (1969), in contrast observed an Increase in the auditory AER during reading.

A number of investigators have observed that response amplitude can be increased by having the subject selectively attend to one of alternatively administered stimuli (Davis, 1964; Donchin & Cohen, 1967; Mast & Watson, 1968; Satterfield, 1965; Spong, Haider, & Lindsley, 1965). In all cases the stimulus to which attention was being given yielded a larger AER than the one to which attention was not being directed.

In a series of investigations Button and his associates (Sutton, Braren, & Zubin, 1965; Sutton, Braren, Zubin, & John, 1967) found that the size of the AER could be enhanced by increasing stimulus uncertainty. A preliminary visual or auditory cuing stimulus was provided and followed at intervals varying from two to five seconds by (1) a click, or (2) either a click or a light. Subjects were instructed to predict the modality in which the latter mentioned stimulus would occur. When the cuing signal was always followed by a click the response amplitude was less than when the second occurring stimuli were randomized and averaged separately. Still others report that the AER amplitude can be increased by simply having the subject count each click as it is presented (Gross et al., 1965; Williams et al., 1964).

The aforementioned methods all have one point in common. They involve the subject actively in a task which serves to focus his attention on or during the presentation of a specific stimulus. Procedures which require the active participation of the subject are of little assistance when the person being tested cannot understand essential instructions or will not cooperate. Unfortunately, when the subject is passive during testing his vigilance and the amplitude of

There is, however, limited evidence (Rose, 1967) which suggests that the amplitude of the AER can be enhanced even in some passive adults.

Interestingly, individuals who purposefully feign a hearing loss for such reasons as to avoid military service or to gain monetary compensation typically yield AER's which are much larger than the non-malingering subject (see Figure 1). Explained using Sokolov's model (Lynn, 1966), it would appear that the cortical sensitivity of a malingerer for tonal stimuli is especially enhanced when he is presented with and hears auditory stimuli which are below his admitted threshold of hearing. It should be noted that whereas the malingerer is passive overtly the attention that he gives to auditory stimuli which are below his volitional threshold is probably high which may account for the heightened AER amplitude. Thus, the malingerer might be considered a special type of active subject.

Traditionally, the most effective classical conditioning procedure is when the conditioned stimulus (CS) is followed at an interval of one second or less by an unconditioned stimulus (UCS) according to Smith and Moore (1966). These writers also point out that the simultaneous presentation of the CS and the UCS is generally considered to be a poor conditioning program. Rose (1967) observed, however, that the simultaneous presentation of stimuli was useful in enhancing response amplitude in some rare individuals with normal hearing who failed to yield an AER even to intense auditory stimulation. By randomly pairing a visual and an auditory stimulus and averaging only those trials in which the tone occurred alone auditory AER's were easily observable at a sensation level of 10 dB.

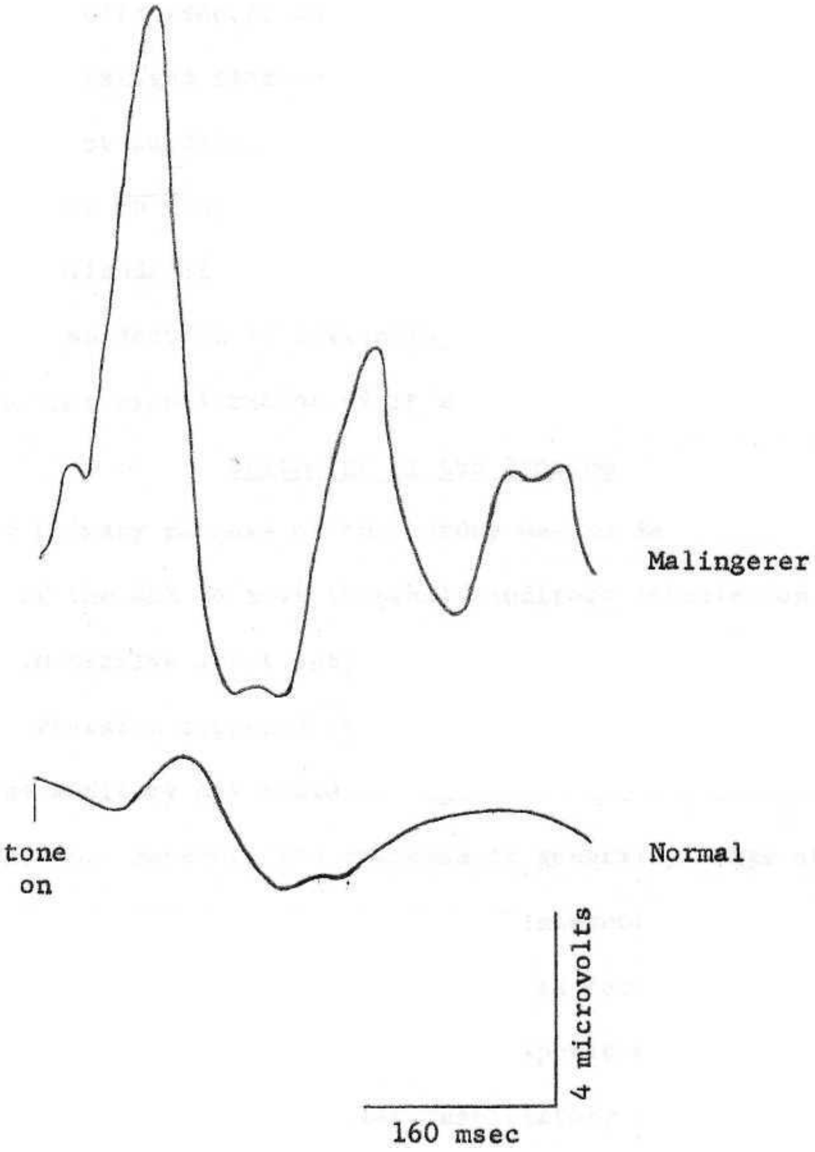


Figure 1. Comparison of AER, from a malingerer and a normal subject for 2000 Hz at 20 dB HL. Negative is up.

In summary, research indicates that the amplitude of the auditory AER can be enhanced by having the subject perform a conscious task which is coincidental with stimulus onset. However, most of those tested using averaged electroencephalic audiometry (AEA) are passive, i.e. they do not perform a task which would cause them to increase their attention to tone onset and thereby enhance their response. Since the amplitude of the AER at low sensation levels is small in the nonattending subject it is desirable to determine if it can be increased so that visualization of it would be easier.

Statement of the Problem

The primary purpose of this study was to determine if the amplitude of the AER to near threshold auditory stimulation could be increased in passive adult subjects. Preliminary investigation by the writer and research reported by Rose (1967) suggested that the amplitude of the auditory AER could be augmented when stimulation was at 60 dB to 80 dB SL. However, the response is generally large at high sensation levels and does not require enhancement for easier visualization. The present study was interested in determining whether the conditions which were used to increase response amplitude at high sensation levels would have a similar fascillatory effect at lower sensation levels where the response is small and enhancement is needed most for threshold determination.

Three experimental conditions were designed to implement these procedures and to determine if the amplitude of the auditory AER at 10 dB SL could be enhanced using independent groups of passive subjects. The experimental conditions used were:

1. For one condition onset of a light preceded tone presentation by one second. The light was turned off one half second after tone offset.
2. Another experimental condition consisted of random pairings of a visual and an auditory stimulus.
3. A third condition presented a noxious electrical shock after tone onset according to a partial reinforcement schedule.

The control condition for each group consisted of obtaining an averaged auditory response at 10 dB SL. For this AER auditory stimuli were presented alone.

The experimental design permitted the following questions to be answered regarding the amplitude of the auditory AER.

1. Are significant differences in the amplitude of the AER observed between the control condition and the experimental condition for Group I, II, or III?
2. Will a stimulus program wherein a tone and a light are presented simultaneously be legs effective in augmenting the amplitude of the auditory AER than a classical conditioning paradigm, such as when the auditory signal is presented after light onset or when the tone is followed by a shock?

It was also recognized that changes in the latency of the AER components might occur as a result of these experimental conditions. Although latency measurements were made the primary purpose of this investigation was in determining if response amplitude could be augmented since this parameter was most directly related to the difficulty encountered in reading small AER's.

CHAPTER II

Review of Literature

The late AER with which the present investigation was concerned is continuous with a response which occurs earlier in time. The precise point at which the early AER ends and the late response begins is arbitrary. So that the reader will be somewhat familiar with both aspects of this response a brief summary of studies related to the early AER is presented. The major portion of this review is devoted to those factors which influence the amplitude and latency of the late AER. Finally, studies which present evidence showing the relationship between attention, which plays an important role in determining the amplitude of the AER, and yet another aspect of the brain's electrical activity, the Contingent Negative Variation (CNV) are reviewed.

The Early AER

Giesler et al. (1958) were the first to report the presence of an electroencephalic potential which was evident approximately 12 msec after tone onset. Investigations at the Mayo Clinic (Bickford, Jacobson, & Cody, 1964; Cody & Bickford, 1965; Cody, Jacobson, Walker, & Bickford, 1964) summarily dispatched this early waveform complex as being myogenic rather than neurogenic in origin on the basis of their studies using high intensity auditory stimulation (90 to 120 dB HI) and an inion to earlobe electrode placement. Mast (1965) pointed out that this electrode placement tended to emphasize myogenic influence while minimizing the electroencephalic response to sensory stimulation.

In contrast, he indicated that the electrode placement at the vertex and mastoid, as used by Giesler (1960), minimized muscle artifact and was more favorable for the recording of the early cortical response.

In order to verify the origin of the early auditory response Ruhm, Walker, and Flanigin (1967) recorded the responses of adult patients to clicks delivered at sensation levels of 40 and 110 dB. The response was evident when measurements were taken directly from the cortical surface, thus it was concluded that the early AER was primarily of cochlear, not muscular origin.

The Late AER

An example of the late AER to auditory stimulation for an adult at 80 dB and at 10 dB SL is presented in Figure 2. Although as many as nine separate components have been identified in this waveform (Keating, 1969) only three of the components have been reported to occur with regularity (Davis, Mast, Yoshi, & Zerlin, 1966; McCandless & Best, 1966; McCandless & Lentz, 1968b; Price, Rosenblut, Goldstein, & Shepherd, 1966; Rapin, Shimmel, Tourk, Krasnegor, & Pollack, 1966; Rose & Ruhm, 1966; Suzuki & Taguchi, 1965; Teas, 1965). These are N1, P2, and N2 which have latencies of 100, 170, and 285 msec, respectively at 80 dB SL in Figure 2.

Response Criteria

The need for guidelines which can be used to assist in reading responses arises from the observation that not all waveforms represent the response of the system to auditory stimulation. The process of signal averaging does not entirely eliminate the muscular and electrical artifact picked up by the electrodes. The problem then is in

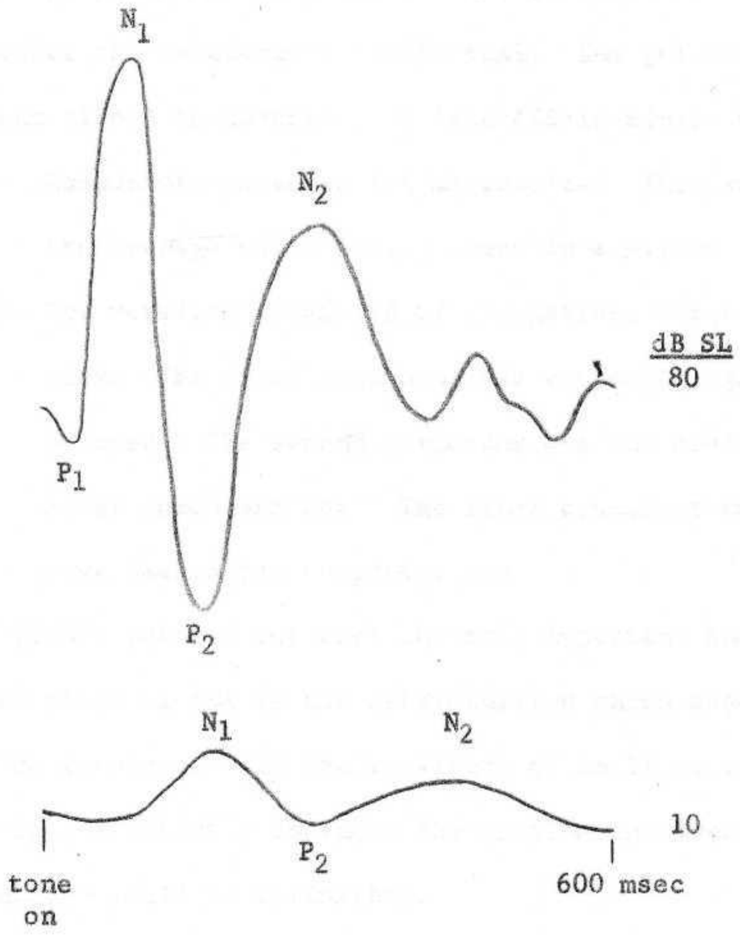


Figure 2. AER for normal hearing adult at 10 dB and 80 dB SL for 2000 Hz. Negative is up.

deciding whether the waveform seen has characteristics which are similar to those observed for the BEG response to auditory stimulation or whether the waveform is artifactual. The guidelines used by Rose and Ruhm (1966) to identify the late AER in adults were:

1. Components exceeded 1,6 microvolts. This value represented the average noise levels found in a silent run.
2. The waveform consisted of a negative, positive, negative complex. The first component was the most negative point after 40 msec. The second component was the most positive point after component one. The final component was the most negative peak after component two.

Price (1969) pointed out that the most important and yet the moat subjective phase of AEA is the determination which separates a "response" from "no response." If the amplitude of small or equivocal AER's could be sufficiently enhanced the problem involved in making this distinction would be diminished.

Factors Which Affect the Amplitude and Latency of the AER

Since the present study was interested in augmenting the amplitude of the late AER a discussion of those factors which have been found to affect this parameter is found in the following portion of the review of literature. Sutton (1968) has indicated that research relating to cortical potentials always involves three basic classes of variables which occur simultaneously. These are physical, physiological, and psychological events. Although these factors are closely interrelated they will be divided into two categories, physical events, i.e. intensity, and psychophysiological events, i.e. hypnosis, for this presentation.

Physical Events

Physical events concern those factors which are related to the modification of stimulus parameters and the transmission of data.

Intensity. The amplitude of the AER is generally large enough at high intensities that it does not need to be enhanced for easier visualization. However, as sensation level is lowered the amplitude of the response diminishes. Because of this difficulty may be encountered in determining whether a pattern is actually a response due to its small amplitude at near threshold intensities.

Measurement of the peak to peak amplitude of components N1 to P2 by several investigators (Davis et al., 1966; Davis & Zerlin, 1964, 1966; McCandless & Lentz, 1968b; Suzuki & Taguchi, 1965) indicated that the amplitude of the AER increased in a roughly linear manner as intensity was increased. Davis and Zerlin (1966) for instance, found that an increase of approximately 25 dB was required to double AER voltage. Additional evidence has suggested that the amplitude of the AER to pure tone stimuli does not increase at hearing levels above 75 dB (Roeser & Rose, 1967). Rapin and others (1966) reported that the amplitude of the response grew somewhat more irregularly when clicks were the stimulus as opposed to the more linear growth observed with pure tones.

There is disagreement concerning the interaction of intensity with the latency of the response components. Davis et al. (1966) found essentially no difference in the peak latencies measured at 20 dB and 75 dB HL although they did suggest that a slight prolongation may have occurred at threshold. McCandless and Lentz (1968b), however, observed an average decrease in latency of 20 msec for P1, 52 msec for N1, and 65 msec for P2 when stimulus intensity was changed from 60 dB to 15 dB HL in adults. The variability in latency at 60 dB SL was considerably less than that noted at lower levels. It was suggested that this finding may have been partly related to the problem of assigning a precise latency to responses at near threshold intensities due to the plateauing of the component peaks. Rapin et al. (1966) found that the latencies of the AER components failed to increase as sensation level was decreased when clicks were used in contrast to a definite prolongation when pure tones were the stimulus.

Intarstimulus interval. From a clinical standpoint it is desirable to obtain a maximum amount of data in a minimum length of time. Walter (1964) has observed, however, that when two stimuli in the same modality are systematically presented closer together in time the amplitude of the second response gradually decreases. He found that the second response could not be seen when the interval between stimuli was 100 to 200 msec suggesting that the system mediating the response was in a refractory state.

Using clicks McCandless and Best (1964) were unable to observe an increase in the amplitude of the AER components with intervals of two seconds or longer between stimuli. A marked reduction in amplitude was noted with intervals of less than two seconds, Davis et al, (1966) studied this relationship at 85 dB HL using tone pips. They found that maximum amplitude was achieved with intervals of 10 seconds or longer. The average amplitude of N1 to P2 with an interstimulus interval of one second was eight microvolts which was approximately 75% smaller than that measured with a 10 second interval. It was concluded that when a short temporal separation existed between tones an interaction between the first and the second response occurred which was detrimental to the amplitude of the first response. Nelson and Lassman (1968) also observed an increase in the amplitude of N1 to P2 as interstimulus interval was increased from 0.5 to 10 seconds at 60 dB SL. The amplitude of their responses were consistently smaller and exhibited a more gradually rising function with an increase in intensity than was reported by Davis et al. (1966). These differences were attributed to the use of different intensities.

Nelson and Lassman (1968) also noted that the latency of P. and N1 was not affected by intervals between stimuli ranging from 0.25 to 10 seconds. In contrast, an increase in the latency of P2 and N2 was observed as interstimulus interval was increased.

Tone duration and rise time. Before the experience of hearing can occur an acoustic stimulus must be on for a critical period of time. This on time is related to both the rise time and the duration of the stimulus. As the following data show, the amplitude of the AER is also influenced by the duration and rise time of the acoustic signal.

Onishi and Davis (1968) used durations ranging from 0 to 300 msec and rise times of 3 and 30 msec at 1000 Hz. At 45, 65, and 85 dB HL maximum amplitude of the N1 to P2 complex was attained when a rise time of three msec and a duration of 30 msec was used. Rise times of 30 msec having only a duration which encompassed the rise and fall cycle were as effective in eliciting an AER as those signals with measureable durations. Rise times in excess of 50 msec resulted in a demunition of the response amplitude. At 45 dB HL the latency of N1 revealed a gradual prolongation as rise time was changed from 3 to 50 msec. With still longer rime times the latency of N1 increased markedly.

McCandless and Best (1966) observed that the average latency of N1, P2, and N2 for click stimuli was shorter than that for pure tones. For example, latencies at 50 dB SL were longer by 30 msec for N1, 50 msec for P2, and 75 msec for N2 when a pure tone was used than when the stimulus was a click. Similar findings are reported by Rapin et al. (1966).

Order of stimulus presentation. Rapin (1964) observed that thresholds were lower in children when stimuli were presented in a descending intensity order than when an ascending intensity protocol was used. She did not quantify this observation, however. Although others have failed to confirm her finding (Henry & Teas, 1968; McCandless & Best, 1964; McCandleas & Lentz, 1968b) Price (1968) stated that response amplitude was optimal when stimulus parameters were altered often during testing. He suggested that changes in frequency and intensity be made for each successive average and that the ear being tested be alternated regularly.

These results suggest that although attempts have been made to augment the amplitude of the AER by changing one or several stimulus parameters frequently during testing the effect is generally minimal.

Direct vs telemetered recordings. As a general rule EEG activity collected at the scalp electrodes has been passed by wires to an amplifier. Recently, however, interest has been shown in determining the efficacy of EM telemetry in transmitting these data thus eliminating the direct coupling of the patient to the amplifier (Jerger & Golden, 1968; Lentz & McCandless, 1970; Moore & Reneau, 1968; Reneau & Mast, 1968). Since a response having maximum amplitude at threshold is desired it is important that the influence these procedures have on this characteristic are known.

After obtaining thresholds on twelve subjects using telemetry and direct recording procedures Moore and Reneau (1968) reported that they were unable to distinguish any differences in the amplitude of the responses. Similar results were reported by Lentz and McCandless (1970) for infants.

Psychophysiological Events

This category encompasses those factors which influence the behavioral status of the subject and/or his physiological processes, i.e. the effect of hypnosis on the amplitude of the AER.

Electrode placement. The location of the electrodes on the scalp has a direct relationship to the amplitude of the AER. Most investigations have reported that the AER to auditory stimulation was largest when measured at or near the vertex (Davis et al., 1939; Lamb & Graham, 1967; McGandless & Best, 1964; Teas, 1965; Walter, 1964; Williams et al., 1964).

Walter (1964) compared the amplitude of auditory, visual, and somatosensory responses obtained from electrodes positioned at the vertex and left mastoid to the AER obtained with electrodes placed at the left occiput and left mastoid. The averaged responses were 20% to 75% larger when an electrode was at the vertex than when it was at the occiput. Similarly, Lamb and Graham (1967) reported that the AER measured when electrodes were at the temporal area was smaller than when electrodes were placed at the vertex and mastoid. Observations made earlier by Davis et al. (1939) in regard to the individual unaveraged responses are in agreement with these data.

Wake vs sleep. Many infants and young children go to sleep spontaneously during AEA. The effect that sleep and wake states have on the amplitude of the AER has not been clearly substantiated as the studies reported in this area indicate.

Ornitz, Rltvo, Carr, La Franchi, and Walter (1967), for example, found that the amplitude of component N2 was largest during a five minute period immediately preceding and following sleep onset in adults and children. Within the first five minutes after sleep began the amplitude of N2 decreased. These writers concluded that the stage of sleep had less effect on the amplitude of N2 than going from wakefulness to sleep. Contradictory results are presented by Williams et al. (1964). They observed an increase in the amplitude of P1 and N2 with the onset of sleep. The amplitude of P2 and N1 decreased, however.

Results of investigations by Williams et al. (1964) suggest that rapid eye movement sleep produces highly variable amplitudes and latencies whereas other states of sleep are characterized by greater stability in these parameters. Others have noted that active low voltage sleep yields fewer responses than quiet high voltage sleep, the latter being preferential for performing AEA (Davis & Onishi, 1968; Rapin & Graziani, 1967)

Hypnosis. Attempts have also been made to enhance the amplitude of the AER through hypnotic suggestion. Walter (1964) reported that some hypnotized subjects yielded an unusually large response to a tone when they were told that it would be especially powerful.

Clynes, Kohn, and Lifshitz (1964) observed a reduction in the amplitude of the visual AER in an adult placed in a deep hypnotic trance. The subject was told to focus his attention on an object other than the light flash. These findings could not be replicated using another subject who was placed in a medium hypnotic state.

Shagass and Schwartz (1964) failed to observe a change in the somatosensory AER using hypnotic suggestion. Similar findings were reported by Beck, Dustman, and Beier (1966) using visually elicited potentials.

The use of drums. Shepherd, Wever, and McCarren (1968) demonstrated that movement of the electrode wires during conventional recording caused a high voltage noise to be generated which obliterated the smaller electroencephalic potential. In children where movement is often a serious problem the electrical and myogenic artifact resulting could hinder the interpretation of the results. Thus, it is sometimes necessary to place the subject into a drug induced sleep for testing. The investigations reported below suggest that the drug used to place the subject into a sleep state should be selected with caution since many depress or obliterate the late AER.

Allison, Goff, Abrahamian, and Rosner (1963) observed the somatosensory response of subjects who were scheduled for nonneurologic surgery. Preoperative administration of 100 to 150 mg of Seconal and 0.5 to 0.6 mg of Atropine had "variable" effects on the late AER after 110 msec. When Pentothal was administered for anesthesia the late components of the AER were abolished. Investigation by Davis and Onishi (1968) and Rapin and Graziani (1967) reported that the late auditory AER could not be observed when Pentobarbital was administered.

Domino (1967) studied the effect that four drugs which are used as general anesthetics have on the early and late visual AER. Monkeys having implanted electrodes at several locations in the cortex and subcortex were used. He found that the late response was abolished when the animals were placed in a state of deep general anesthesia using Diethyl Ether, Cyclopropane, Methoxyflurane, or Thiamylal Sodium. Winters et al. (1967) present data showing that when cats were placed in a state of general anesthesia the amplitude of the auditory evoked potential recorded at the reticular system and the late AER (after 30 msec) recorded from the ectosylvian gyrus were reduced or abolished with all but one of the drugs used. When Pentobarbital, Halothane, or Ether was used the responses at these locations disappeared. Nitrous Oxide resulted in a reduction in the amplitude of these responses. In contrast, administration of Gamma-Hydroxybutyrate augmented the ampli--tude of the response evoked by auditory stimulation. These findings show that the amplitude of the late AER measured at the ectosylvian gyrus is dependent on the integrity of the reticular formation. In this respect their data are in agreement with those presented by French et al. (1953). These investigators also observed that a reduction in EEC amplitude at the reticular system was accompanied by a decrease in the amplitude of this activity at the cortex (French et al., 1953).

Chloral Hydrate and Chlorpromazine also act on the central nervous system (Pfeiffer & Murphree, 1965). However, research by Price and Goldstein (1966) and Rapin, Graziani, and Lyttle (1969) have suggested that these drugs do not depress the amplitude of the late auditory AER.

These, investigations indicate that when the subject being tested by AEA must be placed in a drug induced sleep that Chloral Hydrate or Chlorpromazine are the drugs of choice to avoid depressing or obscuring the late auditory AER. Additional research regarding the possible enhancitory effects that Gamma-Hydroxybutyrate has on the late AER should be initiated.

Relationship of Thresholds by AEA to Behavioral Audiometry

Many have attempted to determine the accuracy with which AEA can estimate the sensitivity of the peripheral auditory mechanism. The results of this research are reported as they relate to adults, children, and infants.

Testing the Auditory Sensitivity of Adults

Suzuki and Taguchi (1965) reported that 70% of the adults they tested using AEA yielded responses within 10 dB of their behavioral threshold. At 20 dB SL all subjects produced a recognizable AER. McCandless and Lentz (1968a) found correlations ranging from 0.82 to 0.99 between the behavioral and AEA thresholds obtained for normal hearing adults and those having slight auditory impairments. Subjects who were feigning a hearing loss yielded consistently lower responses using AEA than when voluntary procedures were employed, the average difference being 48.3 dB. It was concluded that the close agreement between the lowest AER's and the behaviorally established thresholds on adults indicated that the former procedure could be used with confidence to estimate the auditory sensitivity of malingerers. Similar findings have been reported by Goldstein and Price (1966).

These data suggest that the enhancement of AER amplitude would be needed in only a small percentage of adults since current AEA procedures yield responses which have adequate amplitude at near threshold levels in most adults. However, the amplitude of the response at threshold is very small and difficult to distinguish even for the experienced examiner. Thus, a slight increase in this amplitude would facilitate visualization of the threshold AER in adults. From a practical point of view AEA is seldom necessary with adults since in most instances adequate information can be obtained using far simpler and less time-consuming procedures.

Testing the Auditory Sensitivity of Children

In 1949 Marcus, Gibbs, and Gibbs predicted that with adequate refinement EEG audiometry would be useful in evaluating the peripheral hearing sensitivity of children. The majority of investigations since that time have found that threshold obtained by AEA and behavioral audiometry agree within 10 dB in over 50% of the children tested (Beagley & Knight, 1966; Davis, 1966; Davis, Hirsh, Shelnutt, & Bowers, 1967; Davis & Niemoeller, 1968; Davis & Onishi, 1968; Goldstein, Kendall, & Arick, 1963; McCandless, 1967; Price & Goldstein, 1966;

Rapin, 1964). The closest agreement between thresholds obtained using AEA and behavioral audiometry has been reported with the deaf.

Davis et al. (1967), for instance, found that of 162 deaf and hard-of-hearing children tested at age four to ten years 119 or 73% yielded responses by AEA which were within 2.5 dB of their behavioral thresholds. Only 7% of those tested obtained behavioral thresholds which were more than 10 dB lower than their AEA thresholds. Earlier evidence presented by Davis (1965, 1966) had suggested that AEA was a highly satisfactory means of assessing auditory sensitivity in the deaf. It should be pointed out that since these children were old enough to permit behavioral testing the need for using AEA was minimal.

Mc Candless (1967) tested twelve children ages three to seven years. All but one of those tested had significant hearing impairments. He reported that 72% of the responses obtained by AEA were within 10 dB of the behaviorally established thresholds.

Others have reported more conservative results (Suzuki & Taguchi, 1965, 1968). None of the normal one to six year olds tested by these investigators yielded an AER at 5 dB HL and only 13% responded at 15 dB HL. Responses were seen at 25 dB HL in 67% of those tested (Suzuki & Taguchi, 1968). No attempt was made to obtain behavioral results, thus these percentages cannot be compared directly with those studies who obtained both AEA and behavioral thresholds. In testing a slightly older group of normal children ages six to ten years comparisons were made between AEA and behavioral thresholds. Although only 8%. yielded AER's at 10 dB SL, 58% produced responses at 20 dB SL and 91% yielded a response at 40 dB SL.

These results indicate that a greater need for augmentation of the AER amplitude exists in young children then in older subjects.

Testing the Auditory Sensitivity of Infanta

Behavioral techniques which require the cooperation and the participation of the subject are not applicable to infants. Yet an accurate estimate of their peripheral auditory sensitivity is desirable especially when a hearing impairment is suspected. The degree to which AEA provides this type of information is somewhat controversial.

Rapin and her associates (Rapin & Bergman, 1969; Rapin & Graziani, 1967; Rapin et al., 1969) have contended that ABA is a powerful tool for assessing the acuity of the peripheral hearing mechanism and higher auditory pathways in infanta. The majority of their data indicate that the lowest responses by AEA were at 40 dB to 45 dB HL for normal infants. Confirmation of these findings was reported by Lentz and McCandless (1970) who tested premature and normal infants ages one, three, six, and twelve months. At one month of age the lowest response by AEA averaged 43 dB HL for infants with normal birth weights (>2500 grams) as compared to 59 dB HL for a premature group (<2500 grams). At three months infants weighing less than 1500 grams at birth yielded their lowest AER at 60 dB HL in contrast to 40 dB HL for those having higher birth weights. Results at six months revealed only slight differences yet the lowest response for all groups averaged 40 dB HL. Behavioral difficulties encountered with the subjects tested at twelve months resulted in slightly higher average responses than were observed at six months. Since it was improbable that more than five per cent of those tested had hearing losses it would appear that AEA tended to underestimate the peripheral auditory sensitivity in a high percentage of the infants tested.

Lowell, Goodhill, and Lowell (1968) looking back over a decade of research in AEA commented that its value was probably overestimated originally in regard to the accuracy with which thresholds could be estimated in young children and infants using this procedure.

These investigations indicate that the enhancement of response amplitude would be helpful in essentially all tests involving infants in order that the lowest response obtained by AEA would more closely reflect the potential of their peripheral hearing mechanism.

Attention, Learning, and the CNV

To this point the discussion has been in regard to the influence that different factors have had on the amplitude of the late auditory AER. Some of the topics presented in this section, i.e. sleep and hypnosis, have a common effect; they modify the subject's ability to willfully attend to the stimulus used to obtain the AER. As pointed out in Chapter I and in this chapter the attention that the subject gives to the stimulus can modify the amplitude of the AER. Some feel that additional insight into the relationship between attention, learning, and the electrical activity of the brain can be gained from investigations which have observed an averaged potential termed the contingent negative variation by Walter (1964).

The CNV is described as a slowly rising, negative dc potential occurring between the presentation of two stimuli. Since this potential develops rather slowly the duration between the first and the second stimulus has generally been one second or longer. This waveform was originally reported by Walter (1964) and is, he feels, related to the excitability cycle of the brain. The origin of the CNV has been attributed to the depolarization of the cortical dendritic structure (Low, Borda, Frost, & Kellaway, 1966; Mnukhina, 1969; Walter, 1964; Walter, 1968) beginning after the presentation of the initial stimulus and ending after the presentation of the second stimulus.

When two stimuli are initially associated the CNV can be observed during the first few pairings. However, unless the subject is required to respond in some manner to the second stimulus the CNV will disappear (Cohen & Walter, 1966; Low et al., 1966; Walter, 1968). The amplitude of the CNV has also been found to diminish markedly when the subject becomes bored or tired (Cohen & Walter, 1966). However, when the second stimulus acquired special significance, i.e. the subject responded to its onset, the amplitude of the CNV was restored to maximum (Cohen & Walter, 1966; Low et al., 1966; Hillyard & Galambos, 1967; Walter, 1968).

The importance of mental set or readiness to respond is also illustrated by the following example. When the subject was told in advance that the second stimulus would not occur the GNV failed to develop whether or not it was presented. Reciprocally, when the subject was informed that the UCS would be presented when in fact it would not occur the CNV was observed (Low et al., 1966; Walter, 1968).

According to Low et al. (1966) and Walter (1968) the amplitude of tha CNV could be maintained at maximum when the probability of association between the CS and the UGS was no lower than 70% to 75%.

In contrast, Hillyard and Galambos (1967) found that the CNV amplitude was unaffected when the second stimulus occurred as infrequently as 50% of the time.

Walter (1968) suggested that the CNV reflected a state of readiness by the cortex to execute a motor response. This assumption was based on the observation that reaction time was shorter when the CNV was forming. Waszak and Obrist (1969) suggested that the use of a constant interval between the CS and the UCS could account for the decrease in reaction time due to anticipation. In an attempt to minimize the influence of this factor two tones having different pitches were used for the UCS. Half of the subjects were instructed to respond to the high pitched tone and the other subjects were told to respond only when the low pitched tone was heard. Since presentation of these tones was randomized the subject had no way of knowing when a response would be required. Using this procedure it was observed that the fastest reaction times were associated with the largest CNV's.

It would seem unlikely that this experimental design entirely eliminated the factor of anticipation. Although the subject would not know whether a response would be necessary it was probable that upon presentation of the CS a high state of readiness existed. This readiness, or set has been shown to decrease reaction time (Weiss, 1959; Walter, 1964).

Only one investigation has sought to determine the applicability of the CNV to the measurement of auditory threshold. Pollack (1967) presented a tone and light, in that order. This sequence was repeated and the intensity of the tone systematically lowered until the CNV was no longer present. The hearing level of the tone at which the CNV disappeared corresponded to within 10 dB of behavioral threshold in the majority of adult subjects tested.

Overview

In Chapter II studies have been cited which indicate that AER amplitude can be altered by modification of either physical and/or psychophysiological events. However, the proper selection of stimulus parameters coupled with a favorable behavioral state still yields a response at or near threshold which is not easily visualized in most subjects. To expect a large response to threshold stimulation in older subjects who have completely developed central nervous systems is contrary to physiologic principles. Similarly, it is not surprising that those with central nervous systems still undergoing major development (infants and children) yield their smallest AER at higher sensation levels.

The evidence presented in Chapter I indicates that augmentation of response amplitude is possible in active subjects. However, most of those who are tested using AEA are passive, i.e. young children and infants. If response amplitude could be increased as much as 30% in these subjects the visualization of the response at near threshold levels would be much easier. This would enable a more accurate appraisal of threshold sensitivity to be made than is now possible in infants and young children using AEA. The current study was designed to determine if the AER could be augmented using adults. This investigation served as a procedural model from which the techniques used might be extended to other groups where response enhancement is needed most.

CHAPTER III

Subjects and Procedures

Subjects

Twenty-seven adults having normal hearing at 1000 Hz (no poorer than 15 dB HL) were randomly assigned to one of three groups. Each group contained nine persons. These individuals were selected from among the faculty and students at the University of Utah and ranged in age from 18 to 46 years.

Procedure

A single Beckman silver/silver chloride electrode was situated at the vertex on an interaural plane and attached with Grass electrode creme. A reference electrode was placed at the right mastoid with a ground electrode at the forehead. These electrodes were coated with Beckman gel and were held in place by an adhesive collar. The scalp locations were washed with alcohol prior to seating of the electrodes. Interelectrode resistance was maintained below 10k ohms.

Subjects were tested in a single walled sound treated room located in a quiet area of the University of Utah College of Medicine. The noise levels averaged 27.5 dB as measured using the "A" scale of the Bruel and Kjoer Sound Level Meter (Model 2203). The subjects were told to refrain from movement and to keep their eyes open during testing. A five minute break was taken between each of the three conditions administered to each subject. Since some of the test conditions employed light flashes the test room was not lighted directly, but gained its illumination from a single window partially covered by a thin sheet of translucent white paper. This also prevented the subject from observing events occurring within the control area.

Stimulus Program

The auditory stimulus consisted of a 1000 Hz tone generated by a Hewlett-Packard Audio-Oscillator (Model 200 ABR). Rise time of the signal was 10 msec as controlled by a Grason-Stadler Electronic Switch (Model 829C). Duration of the auditory stimulus was 250 msec. This parameter was controlled by a Grass Stimulator (Model S-4). Signals were delivered to the left ear by means of a TDH-39 earphone. Using this equipment voluntary threshold was determined for each subject. Threshold was designated as the lowest hearing level at which two of three tones were heard.

Visual stimulation was provided by one of three conventional 40 watt bulbs colored red, orange, or blue. These lights were mounted on a gray wall approximately 28 inches in front of the subject and separated laterally by 12 inches.

The shock stimulus was generated by a Grass Stimulator and had a duration of 500 msec. The shock electrodes were taped to the index and ring finger of the left hand after they were prepared with a saline solution.

The interval between each sequence of stimuli was three seconds for all conditions (see Figure 3). Measurement of this interval was from the offset of the final stimulus in a given sequence to the start of the first stimulus of the following sequence, i.e. for the control averages only a tone was presented and the interval between tones was

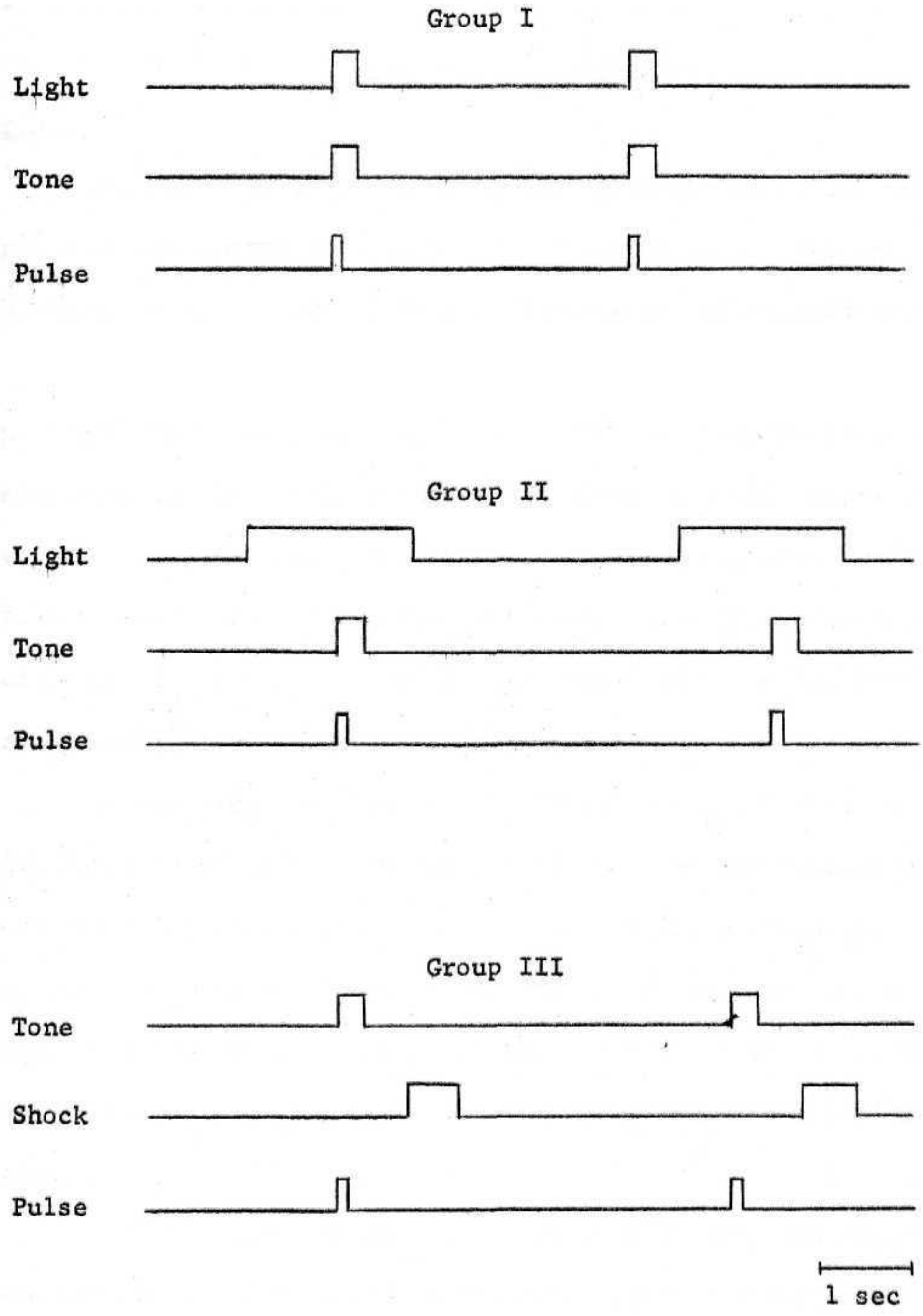


Figure 3. Temporal sequence of stimuli for the experimental condition administered each group. The pulse triggered the computer to begin averaging data for one second.

three seconds. The temporal presentation of stimuli was controlled by two Grass Stimulators working synchronously.

Experimental Conditions

Group I

Auditory and visual stimuli having durations of 250 msec were presented simultaneously for the first five trials. The intensity of the auditory signal was 10 dB SL. Subsequent pairings of these stimuli occurred according to a 40% random reinforcement schedule. Color of the light flash was blue. A total of 80 trials was administered. Thirty-two of these trials contained paired stimuli. Averaging was performed only for the remaining 48 trials in which the auditory signal occurred alone. As mentioned earlier, Rose (1967) used this procedure to elicit AER's to auditory stimuli which had theretofore proven ineffective in producing a response.

It was previously pointed out that conditioning was generally minimal or nonexistent when the CS and the UCS were presented simultaneously. It was proposed that the uncertainty created by randomizing the presentation of the paired and single stimulus conditions would, however, prolong attention and thereby result in larger AER's for the auditory signal than when this program was not employed.

Group II

A light flash having a duration of 1750 msec was presented in association with each auditory stimulus. The auditory signal was presented at 10 dB SL. Onset of the tone occurred one second after initiation of the light. Color of the light flash was randomized among red, blue, and orange. Forty-eight trials were administered.

In contrast to the preceding condition the alignment of stimuli in this treatment were more favorable to the formation of a conditioning bond. In classical conditioning the CS and the UCS presentation generally does not overlap temporally. However, it was hoped that the presentation of the tone within the duration of the light would tend to prolong the orientation of the subject's attention. The combinetion of color and spatial change was an attempt to counteract adaptation to the visual stimulus. Preliminary investigation suggested that the peak to peak amplitude of N1 to P2 could be increased from 20% to 95% in some passive adults using a similar stimulus program. These initial observations were made at 80 dB HL in order that the single unaveraged responses could easily be visualized from the ongoing EEC activity.

Group III

For this experimental condition auditory stimulation was followed by administration of a noxious shock stimulus at an interval of 600 msec according to a 40% random reinforcement schedule. The tone was presented at 10 dB SL. Forty-eight trials were administered.

Intensity of the shock was increased until the subject indicated that it was quite annoying, but not painful. Shock intensity remained at this voltage for four presentations. On the fifth shock the voltage was increased by 10 volts. Voltage was systematically increased by this amount following each series of four shocks in an attempt to counteract the influence of adaptation to this stimulus.

The tone was presented first in order that it might become a strongly conditioned alerting cue for the shock. It was proposed that this sequence would give the auditory stimulus greater significance and thereby result in larger AER's than those which would be observed for the control condition. Utilization of a random and a partial reinforcement schedule was expected to prolong any enhancitory effect that this condition might have on response amplitude. Investigation initially had suggested that the amplitude of the auditory response could be increased by at least 25% in those tested when a shock was presented following auditory stimulation. Rose (1967) reported similar facilitory effects using a shock stimulus.

Control Condition

Averaged auditory electroencephalic responses for each subject were obtained at sensation levels of 20 and 10 dB. The averaged response at 10 dB SL was used as the basis for judging amplitude differences with the auditory AER for the experimental condition. The response at 20 dB SL was used to assist in designating the components of the average at 10 dB SL. The order in which the experimental and the control averages were obtained was counterbalanced across subjects for each group.

Recording and Storage of Data

EEG activity picked up at the electrodes was fed into a Grass Preamplifier (Model 7plA) where it was amplified and monitored. The signal was then directed to an Ampex Magnetic Tape Recorder (Model SP-300) for storage. A trigger pulse was stored on a separate channel at the time of tone onset so that the data could be retrieved for averaging later.

Averaging of Data

Due to the presence of 60 Hz electrical artifact in some of the records the data stored on magnetic tape was directed through a 60 Hz filter. EEG activity was subsequently fed into a Fabri-tex 1062 Signal Averager for the averaging of waveforms. The averaged responses were plotted on graphic paper by a Hewlett Packard X-Y Recorder (Model 7035B) for the final amplitude and latency measurements. A block diagram of this instrumentation is shown in Figure 4.

Amplitude and Latency Measurements

Amplitude measurements were made from the peak of component N1 to the peak of component P2. N1 was defined as the most negative component occurring after 50 msec. P2 was defined as the most positive component after N1.

Latency measurements were made for these components and when possible also for component N2. Measurement of N2 was often difficult due to the fact that one stimulus in a sequence either created an off response, i.e. light for Group II, or an on response, i.e. shock for Group III, at or slightly after N2 occurred. For this reason N2 was defined as the most negative component after P2 occurring prior to 500 msec and thus before offset of the light or onset of the shock.

Calibration of Instrumentation

The intensity of the 1000 Hz tone was calibrated according to the reference levels established by the International Standards Organization (Davis & Kranz, 1964) using a Bruel and Kjoer Sound Level Meter and artificial ear assembly.

Gain of the amplifying system was calibrated using square wave

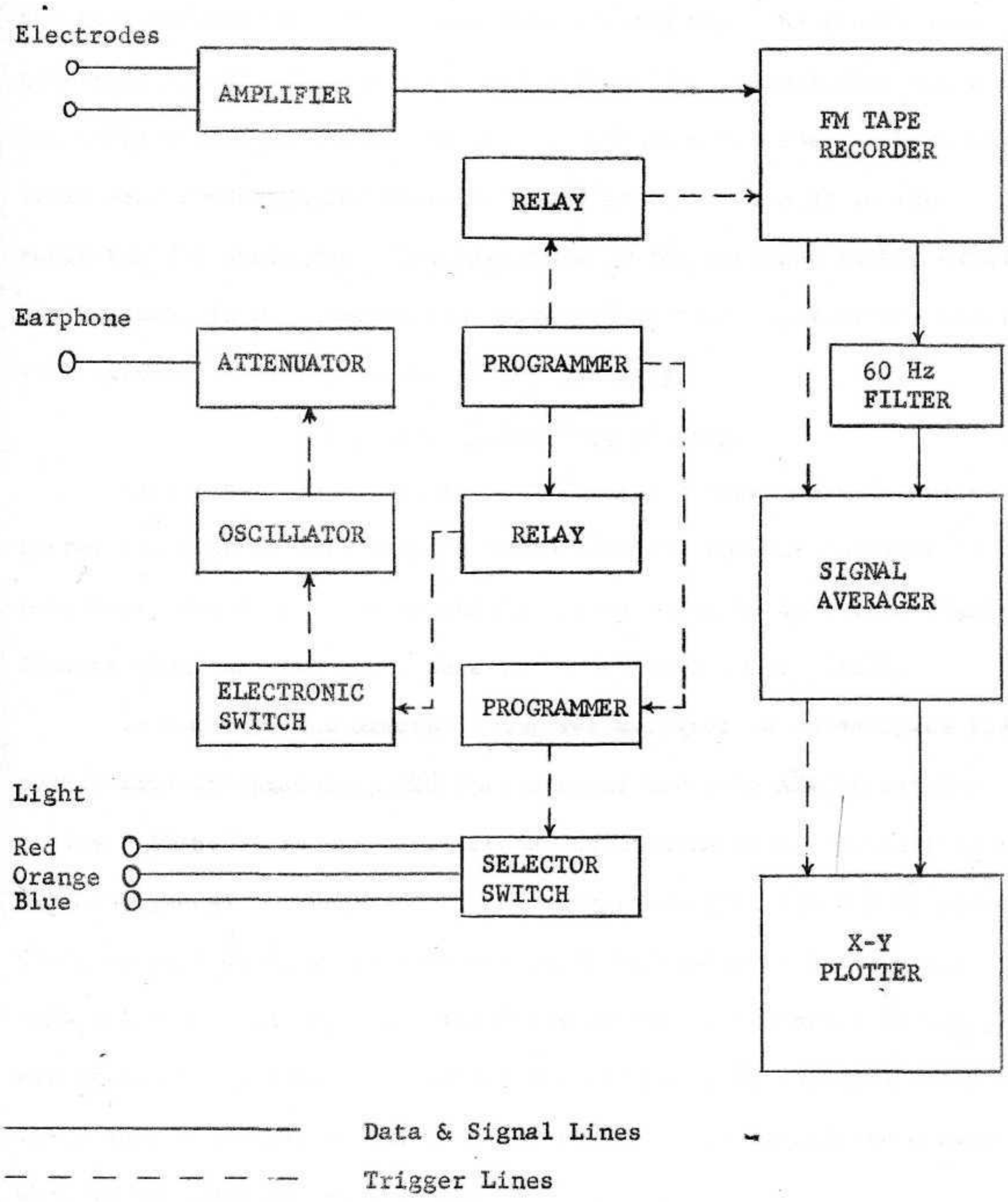


Figure 4. Block diagram of instrumentation.

pulses generated by a Grass Square Wave Calibrator (Model IB). A. trigger pulse from a small programmer was directed to one channel of the tape recorder and the square wave calibrator. The square wave generated by the calibrator was fed through the preamplifier and subsequently stored on another channel of the tape recorder. These waveforms were then directed through the 60 Hz filter and on to the Fabri-tex for averaging. The amplitude of the averaged square waves was measured in millimeters and converted to their appropriate millivolt values. Calibration was performed daily.

Statistical Analysis of Data

Comparisons involving the differences between three means were tested for significance using a fixed effects, one way analysis of variance. The t test for matched pairs was used to determine significance when only two means were to be compared (Hays, 1963).

In summary, the present study was designed to investigate the possibility of augmenting the amplitude of the late AER in passive adults. Three different experimental conditions were administered to separate groups of subjects. It was suggested that the visual and the , shock stimuli which were presented in relationship to the auditory stimulus would tend to: (1) focus the subject's attention during presentation of the tone, (2) prolong his attention by changing color of the visual stimulus, or (3) give the tone special significance such as when it was followed by a shock.

In the following chapter the results of this study and a discussion of their relevance are presented.

CHAPTER IV

Results and Discussion

The primary purpose of this investigation was to determine whether the amplitude of the AER to auditory stimulation at 10 dB SL could be enhanced in passive adults. Three groups of subjects were each administered a different experimental condition. These were:

1. For Group I a visual and an auditory stimulus was presented simultaneously for 32 of 80 trials. Only the auditory stimuli which occurred alone for 48 of the trials were summed. The order of the combined and the single stimulus presentations were randomized and only the unpaired auditory trials were averaged.
2. For Group II a light was presented one second prior to tone on#et and was turned off one half second after tone offset, Color of the visual stimulus was randomized. Averaging was initiated at the onset of the auditory stimulus for each of the 48 trials.
3. For Group III an auditory stimulus was followed by a noxious shock for 40% of the 48 trials. The order in which the shock reinforcement was applied was randomized. Averaging was for the auditory stimulus only.

To minimize confusion which might arise from associating the wrong group and treatment the experimental condition for each group warn identified in the following manner. Since a tone and a light were sometimes presented simultaneously for Group I their experimental condition was identified by the letters "STL" (simultaneous tone and light). Group II was identified by the abbreviation "T in L" since the tone was presented during a visual stimulus which preceded and exceeded the temporal presentation for the tone. The letters "TS" were used to identify the experimental condition for Group III since these subjects received a shock after presentation of the tone.

The results are presented and discussed in two sections: (1) those pertaining to the amplitude of the AER and (2) those relating to the latency of the AER components.

Amplitude Comparisons

In Chapter III it was pointed out that the control AER at 20 dB SL was obtained only to serve as a reference for designating the components of the response at 10 dB SL should the need arise. Previous research has shown that response amplitude grows in a roughly linear manner as intensity is increased (Davis et al., 1966; Davis & Zerlin, 1964). In view of this amplitude comparisons between the AER's at 20 dB SL and those obtained at 10 dB SL were not made in this study. The primary interest was in determining whether the experimental condition for a given group produced a significantly larger N1-P2 amplitude at 10 dB SL than was obtained for the control condition at 10 dB SL. That is, whether the experimental conditions served to make the response more obvious by heightening its amplitude.

Amplitude Comparison Between the Control and the Experimental Conditions for Each Group

In order to determine whether the experimental condition administered to Group I (STL), II (T in L), or III (TS) resulted in an increase in response amplitude the following comparisons were made. The mean amplitude of the auditory AER for the experimental condition was compared to the mean amplitude for the control condition. These comparisons were made for each group separately, as shown in Figure 5.

The average amplitude of the AER for Group I (STL) was 7.3 microvolts for the experimental condition. This was only 0.7 microvolts larger than the mean response amplitude observed for the control condition. Although this difference did not appear to be significant a t test was performed for verification. The results of this analysis are presented in Table 1 and indicate that indeed these differences were not significant. Stated differently, the random pairing of a light and tone failed to enhance the amplitude of the AER over that which was observed when the auditory stimulus was presented alone.

The experimental conditions used with Groups II (T in L) and III (TS) appeared to have had a slightly deleterious effect resulting in a smaller average response than was observed for the control condition. For example, the mean AER amplitude for Group II was 5.6 microvolts for the experimental condition and 7.6 microvolts for the control condition. It will be recalled that the experimental condition for this group entailed the presentation of the auditory stimulus during a period of ongoing visual stimulation. The t ratio for the difference in amplitude between the control and the experimenal condition administered Group II failed to reach significance at the .05 level of confidence.

Group III (TS) yielded a mean response amplitude of 9.3

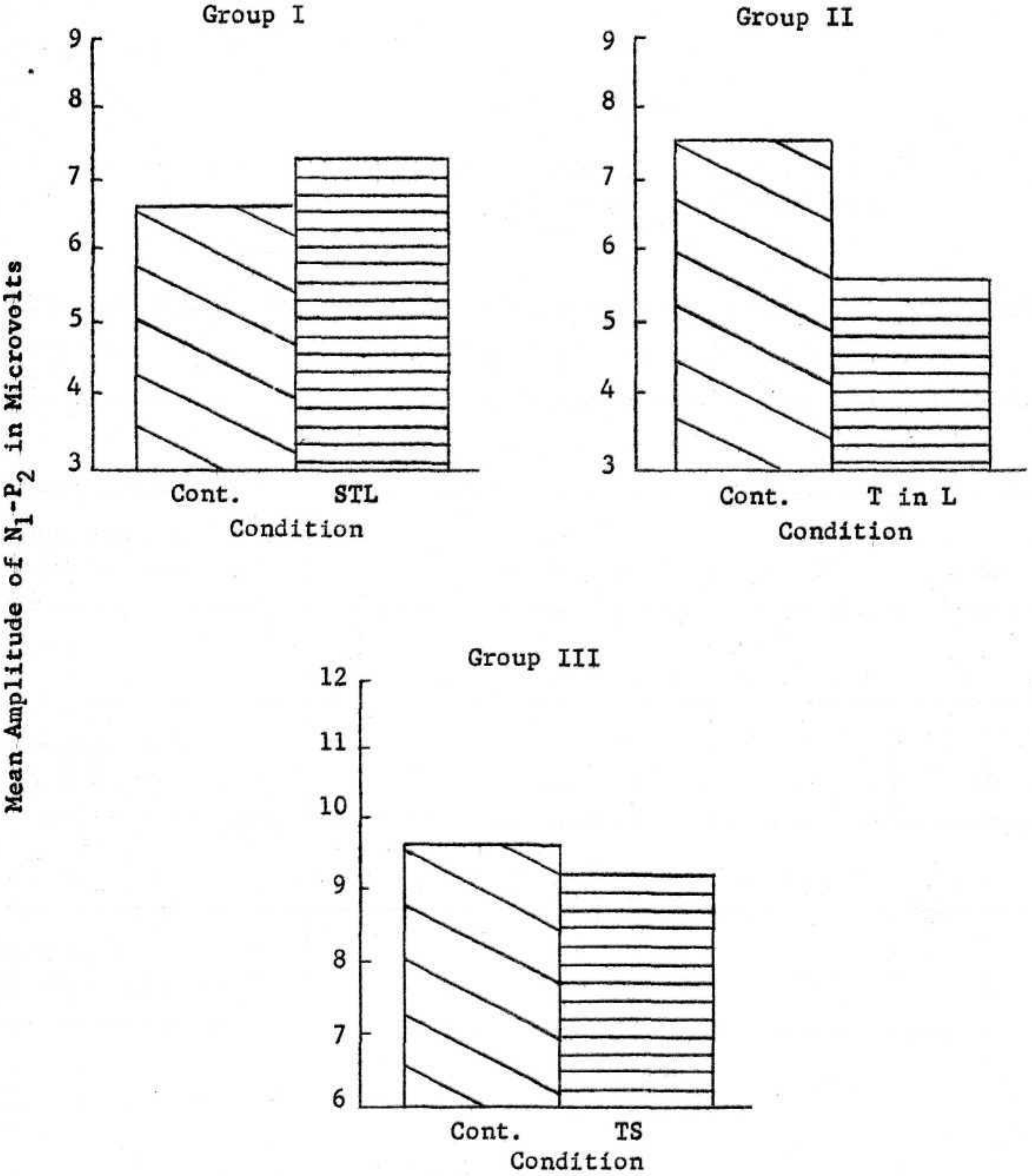


Figure 5. Mean amplitude of N1-P2 for the control and the experimental condition for each group at 10 dB SL. Simultaneous tone and light - STL; Tone in light - T in L; Tone followed by shock - TS. Note differences in ordinate values.

TABLE 1

Summary of the t Tests Between the Mean Amplitude of Nl-P2 for the Control and Experimental Condition at 10 dB SL for Group I, II, and III

Condition & Mean	Mean Diff.	t	df	Sig.
Group I				
Control, 6.6 Experimental, 7.3	0.7	0.42	8	NS
Group II				
Control, 7.6 Experimental, 5.6	2	1.49	8	NS
Group III				
Control, 9.7 Experimental, 9.3	0.4	0.35	8	NS

microvolts for the experimental condition in contrast to 9.7 microvolts for the control condition. The fact that this difference was insignificant was not surprising since the mean AER amplitude for the experimental condition was only 0.4 microvolts smaller than that observed for the control condition. It would appear that although the shock reinforcement following auditory stimulation may have increased anxiety it did not serve to increase response amplitude.

The aforementioned results indicate rather forcefully that in the passive adults tested, none of the experimental conditions administered achieved the result desired, an increase in the amplitude of the AER to near threshold auditory stimulation.

Amplitude Comparisons Between Groups for the Control Condition

The mean amplitude of N1-P2 obtained by Group I for the control condition was 6.6 microvolts. Group II obtained an average response amplitude of 7.6 microvolts and the average amplitude for Group III was 9.7 microvolts for this condition (see Figure 6). The results of the analysis of variance which are presented in Table 2 indicate that the mean response amplitude did not differ significantly between groups for the control condition. A significant difference in mean amplitude was not anticipated since subjects had been randomly assigned to each group in an attempt to apportion their response amplitudes equally.

Amplitude Comparisons Between Groups for the Experimental Condition

The average AER amplitudes obtained by these groups for the experimental condition were also compared. As shown in Figure 6 the mean response amplitude for Group I (STL) was 7.3 microvolts. Group

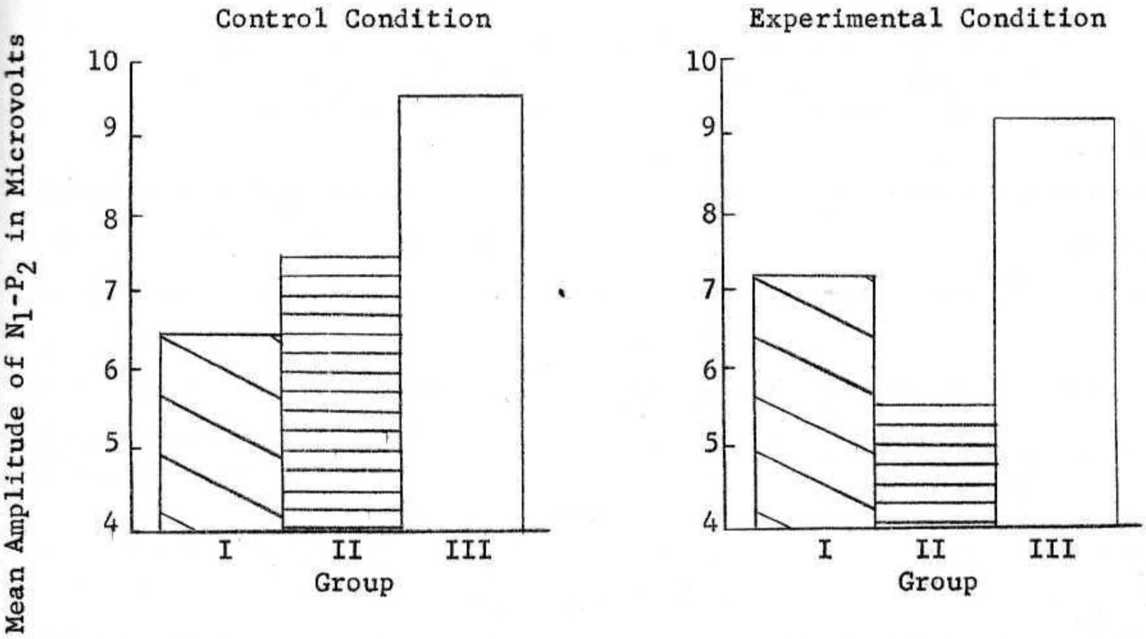


Figure 6. Mean amplitude of N1-P2 for each group for the control condition and for the experimental condition at 10 dB SL.

TABLE 2

Summary of the Analysis of Variance Between the Mean Amplitude of N1-P2 for Groups I, II, and III for the Control and Experimental Condition at 10 dB SL

Source	SS	df	MS	F	Sig.
Control Condition					
Between Groups	45.8	2	22.9	1.83	NS
Within Groups	300.1	24	12.5		
Total	345.9	26			
Experimental Condition					
Between Groups	62.5	2	31.3	3.16	.05
Within Groups	237.0	24	9.9		
Total	299.5	26			

II (I in L) yielded a mean amplitude of 5.6 microvolts which was the smallest value for the three groups. The largest average amplitude for this condition was 9.3 microvolts for Group III (TS). As previously, these means were also tested for significance using the analysis of variance (see Table 2). The F ratio obtained was significant at the .05 level of confidence. In order to determine where the source of this significance was, i.e. between Group I and II, II and III, or I and III, a series of t tests were performed. According to these results which are presented in Table 3 the only significant difference in mean amplitude existed between Group II (T in L) and Group III (TS). These findings suggest that the AER's for subjects receiving partial shock reinforcement after tone presentation were consistently larger than the responses for subjects who received their auditory stimulus during a long period of visual stimulation. Although the experimental condition for Group II (T in L) did not produce an AER which differed significantly from the AER amplitude noted for the control condition it was slightly smaller (see Figure 5). The reduced size of this response coupled with the tendency of the subjects in Group III (TS) to yield larger responses for all conditions probably explains this significant finding.

Latency Comparisons

In addition to observing the effect that the experimental conditions administered had on the amplitude of the AER it was also recognized that they might produce systematic shifts in the latency of components which would differ from those obtained for the control condition. For this reason the mean latency observed for components N1,

TABLE 3

Summary of the t Tests Between the Mean Amplitudes for the Experimental Conditions

Group & Mean	Mean Diff.	t	df	Sig.
I (7.3), II (5.6)	1.7	1.11	8	NS
II (5.6), III (9.3)	3.7	2.72	8	.05
III (9.3), I (7.3)	2.0	1.41	8	NS

P2, and N2 for the control condition and the experimental condition was compared separately for each group. All results presented herein pertain to the averages at 10 dB SL.

Latency Comparisons Between the Control and Experimental Condition for Group I

As shown in Figure 7 the mean latencies for N1, P2, and N2 were highly similar for both the control and the experimental conditions for Group I (STL). For example, the mean latency of N1, was 195.4 msec for the control condition and 194.6 msec for the experimental condition. A mean difference in latency of only 5.8 msec was observed between the control condition (310.6 msec) and the experimental condition (316.4 msec) for component P2. Component N2 was also characterized by similar average latencies for the control and the experimental conditions (443.8 msec and 445.4 msec, respectively). The results of the t tests which are summarized for each component in Table 4 confirm the observation that no significant difference in latency occurred for N1, P2, or N2 between the control condition and the experimental condition for Group I.

Latency Comparisons Between the Control and the Experimental Condition for Group II

For Group II (T in L) the average latency of N for the control condition (176.1 msec) and the experimental condition (176.6 msec) differed by only 0.5 msec as can be seen in Figure 8. In contrast, an average difference in latency of 25.8 msec was observed between these conditions for component P2. The mean latency for P2 was 293.5 msec for the control condition and 319.3 msec for the experimental condition.

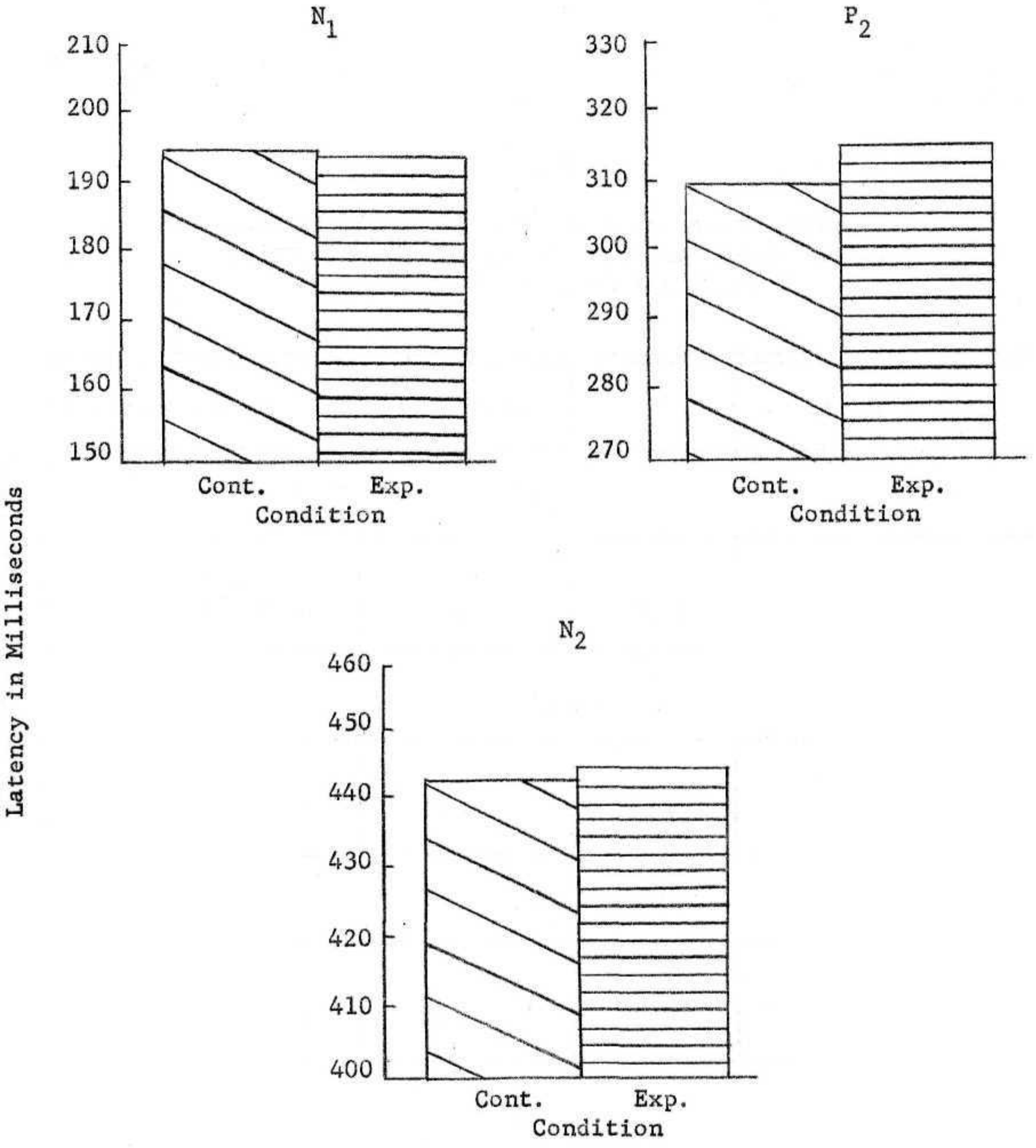


Figure 7. Mean latency of components N,, P2, and N2 for the control and experimental (simultaneous tone and light) condition at 10 dB SL for Group I. .Note the differences in ordinate values.

TABLE 4

Summary of the t Tests Between the Mean Latency of N1, P2, and N2 for the Control and Experimental Condition at 10 dB SL for Group I

Condition & Mean	Mean Diff.	t	df	Sig.
N1				
Control, 195.4 Experimental, 194.6	0.8	0.02	7	NS
$^{P}2$				
Control, 310.6 Experimental, 316.4	5.8	0.37	7	NS
N_2				
Control, 443.8 Experimental, 445.4	1.6	0.09	7	NS

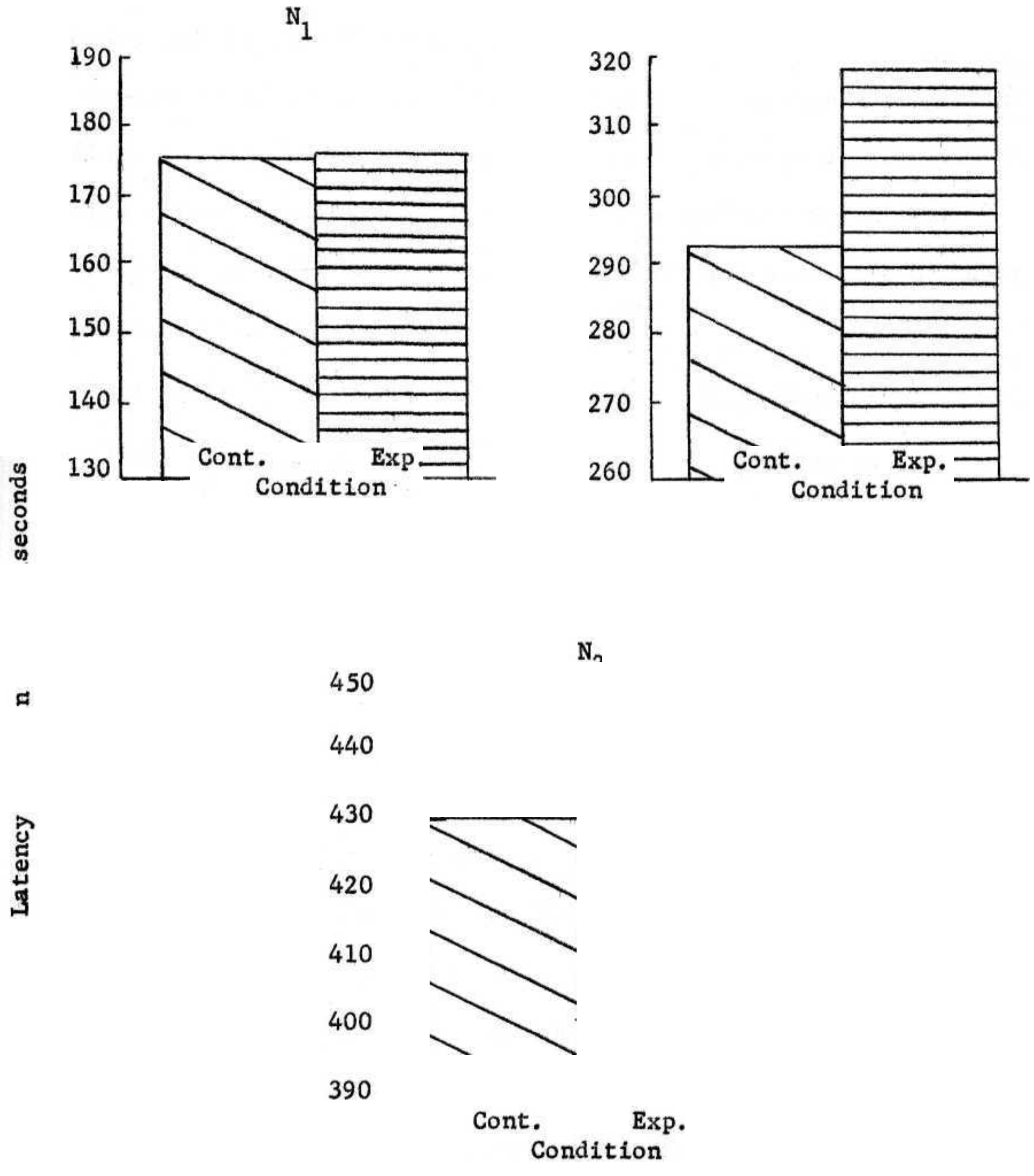


Figure 8. Mean latency of components N1, P2, and N2 for the control and experimental (tone in light) condition at 10 dB SL for Group II. Note the differences in ordinate values.

Less mean difference in latency was observed for component N2. An average latency of 430.4 msec was obtained for the control condition as opposed to 436.1 msec for the experimental condition for N2. In Table 5 the results of the t tests for each component are shown. This analysis indicated that as with Group I the differences in mean latency observed for Group II between the control and the experimental conditions were not significant.

Latency Comparisons Between the Control and the Experimental Condition for Group III

Similar results were obtained for Group III (TS) as for the other groups. The largest difference in mean latency for Group III between conditions occurred for component N1. Figure 9 shows that the average latency of this component for the control condition was 184.3 msec in contrast to 202.4 msec for the experimental condition. A mean difference of only 1.8 msec existed between the latency of ?2 for the control condition (296.6 msec) and the experimental condition (298.4 msec). The latency for component N2 averaged 463.7 msec for the control condition and 456.9 msec for the experimental condition. This represented a mean difference of only 6.8 msec. The results of the t tests presented in Table 6 indicate that no significant differences in latency were observed for any component between conditions for Group III.

These findings indicate that the latency of the three components measured were relatively unaffected by any of the experimental conditions administered.

TABLE 5

Summary of the t Tests Between the Mean Latency of N1, P2, and N2 for the Control and Experimental Condition at 10 dB SL for Group II

Condition & Mean	Mean Diff.	t	df	Sig.
Control, 176.1 Experimental, 176.6	0.5	0.08	7	NS
P2				
Control, 293.5 Experimental, 319.3	25.8	1.22	7	NS
N2				
Control, 430.4 Experimental, 436.1	5.7	0.11	6	NS

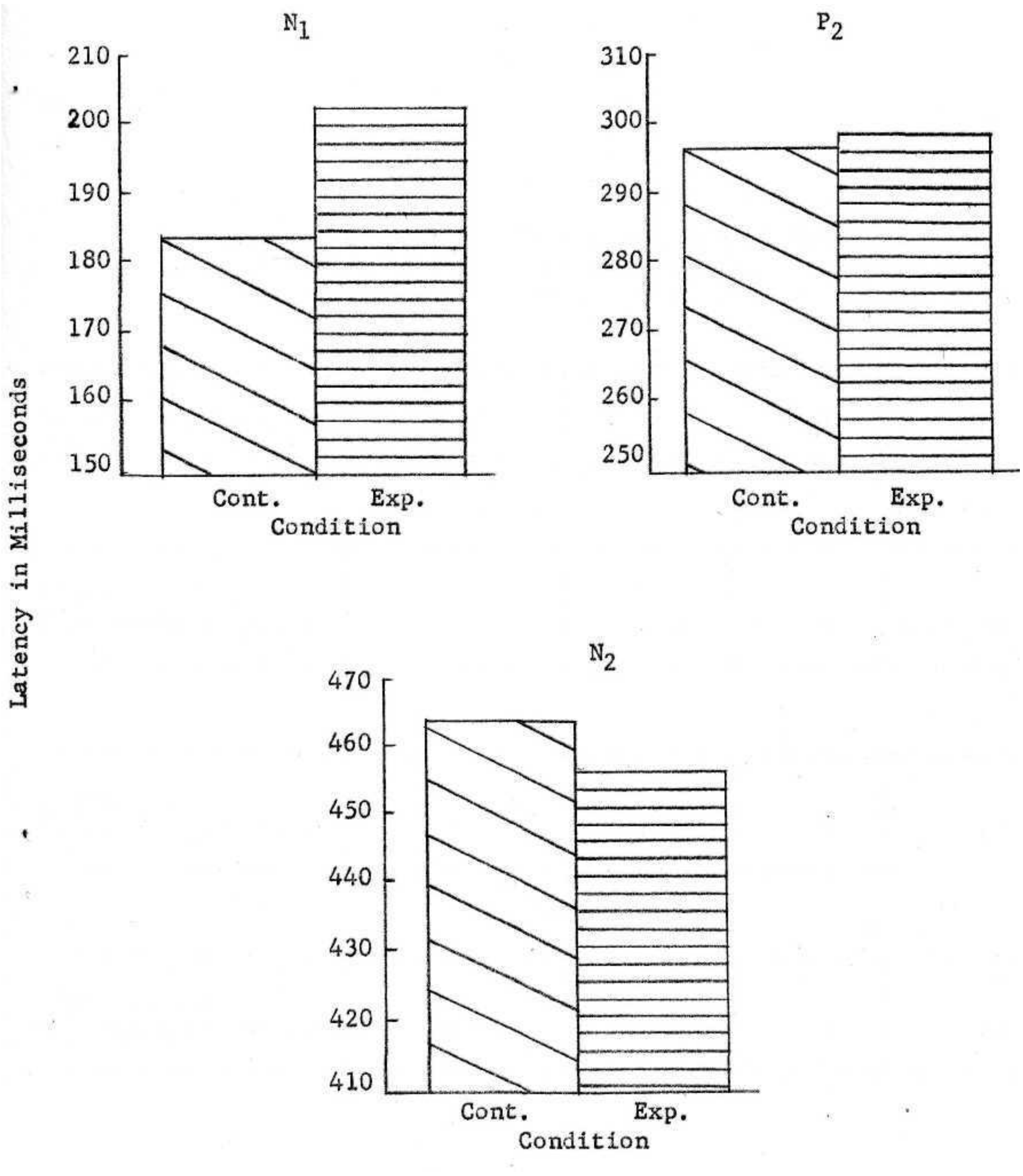


Figure 9. Mean latency of components N1, P2, and N2 for the control and experimental (tone followed by shock) condition at 10 dB SL for Group III. Note the differences in ordinate values.

TABLE 6

Summary of the t Tests Between the Mean Latency of N1, P2, and N2 for the Control and Experimental Condition at 10 dB SL for Group III

Condition & Mean	Mean Diff.	t	df	Sig.
N_1				
Control, 184.3 Experimental, 202.4	18.1	2.21	8	NS
P_2				
Control, 296.6 Experimental, 298.4	1.8	0.19	8	NS
N_2				
Control, 463.7 Experimental, 456.9	6.8	0.21	6	NS

Latency Comparisons Between Groups for the Control Condition

The average latency of each component for the control condition was compared for all three groups of subjects.

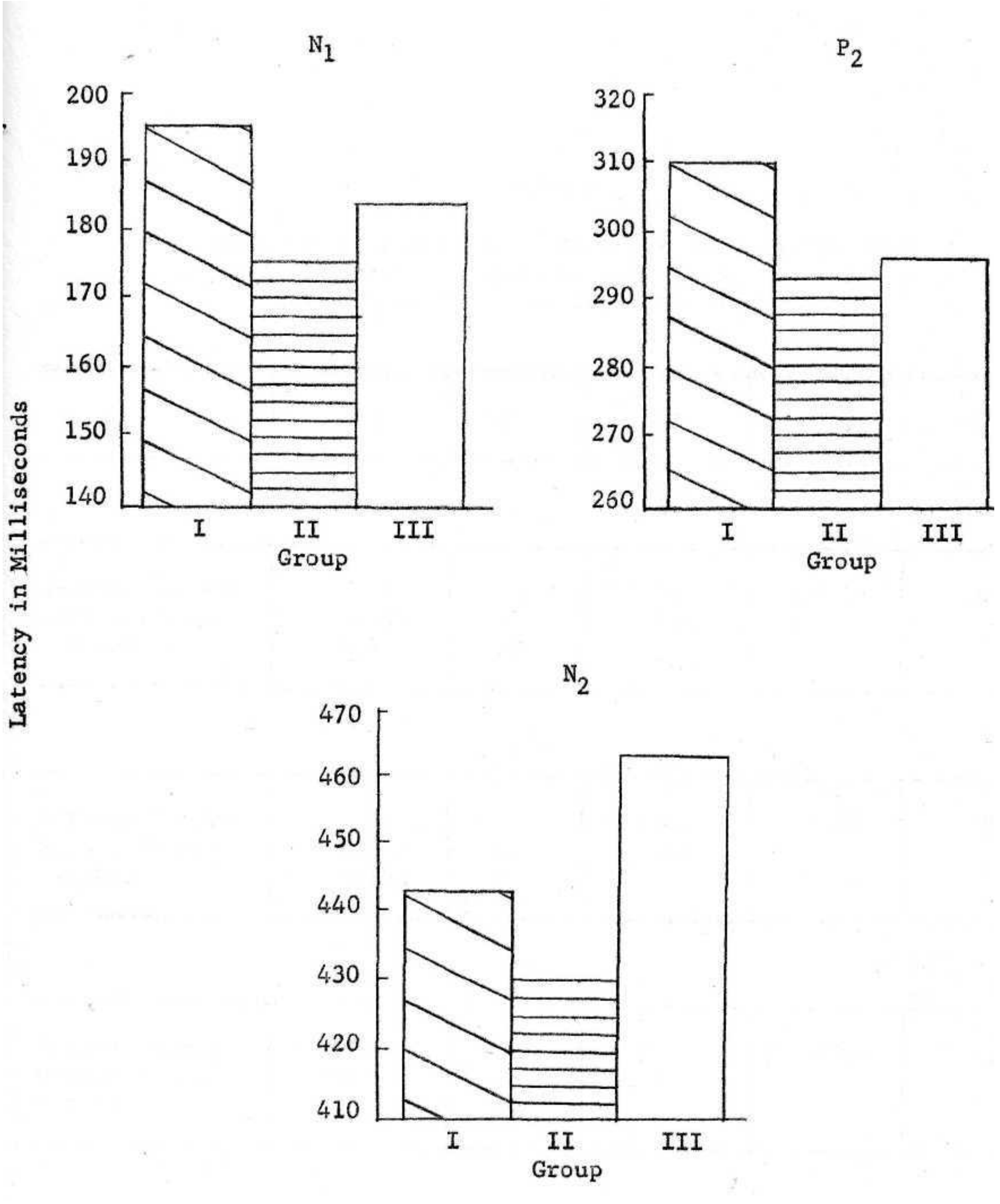
The mean latency obtained by the three groups for each component are illustrated in Figure 10 for the control condition. Group I yielded the longest average latency for N1 at 195.4 msec. The shortest latency averaged 176.1 msec for Group II. The mean latency for Group III for N1 was 184.3 msec. The results of the analysis of variance for this component are presented in Table 7 and indicate that the average latencies observed for N1 did not differ significantly between groups.

Group I also yielded a longer mean latency for component P2 (310.6 msec) than either of the other groups. The latency of Group II was, as noted for N1, shorter than the average latency observed for Group III. The respective latencies for Groups II and III for P2 were 293.3 msec and 296.6 msec. These latencies were tested for significance using the analysis of variance. An F ratio of 0.18 was obtained indicating that the mean latency of Groups I, II, and III did not differ from one another to a significant degree for component P2.

The greatest range in mean latency was observed for component N2. The average latency of Group I for this component was 443.8 msec. This compared to 430.4 msec for Group II and 463.7 msec for Group III. These differences were not significant.

Latency Comparisons Between Groups for the Experimental Condition

The average latency obtained by the three groups for each AER component was also compared for the experimental condition as shown in



N_1

P_2

N_2

Figure 10. Mean latency of N1, P2, and N2 for Group I, II, and III for the control condition at 10 dB SL. Note the differences in ordinate values.

TABLE 7

Summary of the Analysis of Variance Between the Mean Latency of Groups I, II, and III for N1, P2, and N2 for the Control Condition at 10 dB SL

Source	SS	df	MS	F	Sig.
		N1			
Between Groups	1494	2	747.0	1.13	NS
Within Groups	14505	22	659.3		
Total	15999	24			
Between Groups	1347	2	673.5	0.18	NS
Within Groups	82236	22	3738.0		
Total	83583	24			
		N2			
Between Groups	3933	2	1966.5	0.35	NS
Within Groups	105298	19	5542.0		
Total	109231	21			

Figure 11.

For N1 the mean latency ranged from 176.6 msec for Group II (T in L) to 202.4 msec for Group III (TS). Group I (STL) yielded an average latency of 194.6 msec for this component. These latencies were compared using an analysis of variance procedure (see Table 8). An F ratio of 1.84 was obtained indicating that the differences in latency observed were not significant at the .05 level of confidence.

Whereas the mean latency of Group II was shortest for N1 this group produced the longest average latency for component P2 at 319.3 msec. The average latency of Group I for P2 was 316.4 msec. The shortest latency for P2 was 298.4 msec for Group III. As with component N1 the F ratio for P2 indicated that the differences in mean latency were insignificant between groups.

These comparisons were repeated for component N2 and in accordance with the previous results no significant differences were observed between the mean latencies of Groups I, II, and III. Group II yielded the shortest mean latency for N2 at 436.1 msec. The mean latency for Group I was 445.4 msec. The longest average latency for component N2 was obtained by Group III at 456.9 msec.

These findings indicate that the latency of the components were not influenced differently as a result of the experimental condition used with each group.

Summarization of Findings

The results of this investigation are summarized briefly as they were reported in this chapter.

1. When comparisons in amplitude were made for each group

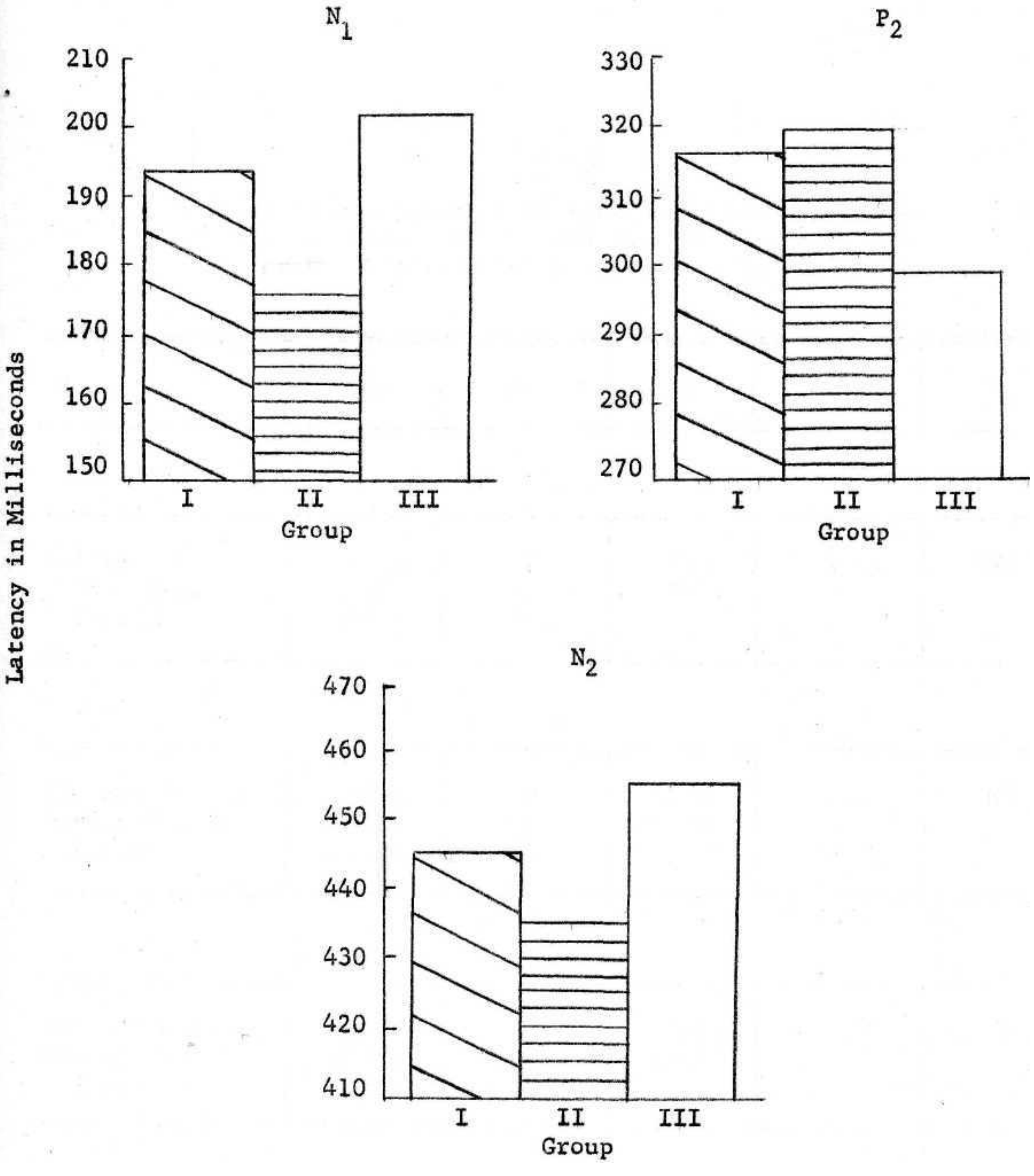


Figure 11. Mean latency of N1, P2, and N2 for the experimental condition for Group I (simultaneous tone and light), Group II (tone in light), and Group III (tone followed by shock) at 10 dB SL. Note the differences in ordinate values.

TABLES 8

Summary of the Analysis of Variance Between the Mean Latency of Groups I, II, and III for N1, P2, and N2 for the Experimental Condition at 10 dB SL

Source	SS	df	MS	F	Sig.
Between Groups	2931	2	1465	1.84	NS
Within Groups	17429	22	792		
Total	20360	24			
		P2			
Between Groups	2193	2	1096	0.17	NS
Within Groups	134996	22	6136		
Total	137189	24			
		N2			
Between Groups	1508	2	754	0.37	NS
Within Groups	39064	19	2056		
Total	40572	21			

separately between the control condition and their experimental condition significant differences were not observed.

2. When comparisons in the average amplitude of N1-P2 were made between all three groups for only the control condition significant differences did not emerge.
3. Comparisons in the average amplitude between all groups for the experimental condition did reveal significant differences. Subjects receiving an electrical shock after tone presentation yielded auditory AER's which were of significantly greater amplitude than those auditory responses obtained in subjects tested when the tone was presented during a long duration light stimulus. The response amplitude observed for the experimental condition where in the visual and the auditory stimulus were randomly paired failed to differ significantly from these conditions.
4. When comparisons in latency were made for each group separately between the control condition and their experimental condition significant differences were not found for any of the components.
5. When comparisons in the average latency of a given component, i.e. N1, were made between all three groups for only the control condition significant differences were not observed.
6. Significant differences in mean latency were similarly not noted when the latency of a given component was compared between all groups for the experimental conditions.

CHAPTER V

Summary and Conclusions

The major purpose of this research was to determine if the amplitude of the AER to near threshold auditory stimulation could be increased in adults who were not assigned an active task. Passive subjects were used since most of those tested with AEA are passive, i.e. they are infants and young children who do not actively attend to tone presentation. The present investigation served as a procedural model from which subsequent investigation in young children and infants might be initiated, The need to increase AER amplitude is greatest in these groups since their thresholds by AEA often underestimates the potential hearing sensitivity pf their peripheral auditory mechanisms.

Three groups, each consisting pf nine adults with normal hearing, were tested using conventional AEA procedures. An AER was obtained at 20 dB and at 10 dB SL for a 1000 Hz stimulus. The AER at 20 dB SL was used only to assist in designating the response characteristics at 10 dB SL when necessary. In addition to these responses, an averaged auditory response was obtained during an experimental condition which was used in an attempt to augment the amplitude of the auditory response at 10 dB $L. The experimental condition administered differed for each group.

1. Group I received the auditory signal and a visual stimulus simultaneously 40% of the time. An AER was obtained for those

trialS where the auditory stimulus occurred alone. This experimental condition was identified by the abbreviation "STL" (simultaneous tone and light).

2. Group II was stimulated with a colored light. During the time that this light was on the auditory signal was presented. The abbreviation "T in L" (tone in light) identified this experimental condition.
3. Group III received a shock following 40% of the auditory presentations. This experimental condition was identified by the letters "TS" (tone followed by shock).

After the auditory responses were averaged, amplitude and latency comparisons for the control condition at 10 dB SL and the experimental condition at 10 dB SL were made.

The experimental conditions administered failed to significantly increase the amplitude of the auditory AER for any of the three groups of subjects. For Group II (T in L) and II (IS) the average amplitude of the auditory responses obtained during the experimental condition were smaller than those averaged during the control condition. Only the experimental condition administered to Group I (STL) resulted in a slight but insignificant increase in the mean AER amplitude.

The amplitude of the average AER for the control condition was smallest for Group I, somewhat larger for Group II and largest for Group III, The differences in response amplitude noted were not significant, however.

The smallest average amplitude observed for the experimental condition was for those subjects who received their auditory stimulus within the presentation of a colored light (Group II). Subjects who were administered an auditory signal which was randomly paired with a visual stimulus (Group I) yielded an average response having slightly larger amplitude than that seen for Group II. The largest amplitude for the average AER was obtained during the experimental condition administered to Group III. For this group the presentation of the auditory stimulus was randomly reinforced by a shock. The difference in mean amplitude observed between Groups II (T in L) and III (TS) was significant.

The average latency of the AER components observed for the control condition did not differ significantly from the latency noted during the experimental condition for Group I (STL). The differences in the average latency between these conditions were also insignificant for Group II (T in L) and Group III (TS).

The average latency obtained for component N1 did not differ significantly between Groups I, II, and III for the control condition. The latency differences for component P2 also failed to reach significance between groups as did those noted for N2. Similarly, the differences in mean latency noted between Group I (STL), II (T in L), and III (TS) for these components during the experimental condition were not significant.

The findings of this study which indicate that the experimental conditions did not enhance the AER over that found for the control condition should be interpreted with caution since they are in direct contrast with the majority of data which suggest that the late AER can be augmented (Davis, 1964; Donchin & Cohen, 1967; Gross et al., 1965;

Keating, 1969; Mast & Watson, 1968; Rose, 1967; Satterfield, 1965; Spong et al., 1965; Sutton et al., 1965; Button et al., 1967; Williams et al., 1964). There are three factors which should be given consideration regarding the inability to observe enhancement of the response between the experimental conditions and the control condition in the present study.

First, it will be recalled that preliminary investigation by the writer indicated that the amplitude of the auditory response could be enhanced in some adults at 80 dB SL using the experimental conditions reported herein. These observations were based on measurements of the individual responses occurring in ongoing, unaveraged EEG data. Since the primary purpose of this study was to determine if the response could be enhanced at 10 dB SL averaging was necessary in view of the fact that the auditory response at this level is generally too small to visualize from raw EEG activity. Since the enhancement noted at 80 dB SL in the raw EEG occurred for only the first six to eight waveforms the averaging of 48 responses could easily have obscured this effect. Whereas slight variations in the latency of the component peaks would have no effect on amplitude measurements of the individual unaveraged response these differences would result in a diminished amplitude when the responses were averaged by the computer. Thus, the inability to observe enhancement of the AER during the experimental conditions over the amplitude noted for the control condition may be related to the limitations imposed by the averaging procedure.

Second, consideration must be given to the possibility that the number of trials used were insufficient to bring about adequate conditioning for Groups II and III, Since conditioning should have occurred most rapidly for the tone and shock treatment (Group III), it is doubtful that the lack of response augmentation can be explained simply as a result of poor conditioning. Failure of the experimental conditions to effect an increase in AER amplitude may be related to the fact that the intensity of the secondary stimulus (light or shock) was subjectively greater than that of the primary stimulus (auditory). Asratyan (1968) has suggested that the number of neural units brought into activity with a mild CS or UCS tends to weaken the effect of conditioning. Many of those tested indicated that the brightness of the light or the strength of the shock caused them to focus their attention on these stimuli and not on the tone.

Last, previous research has shown that the stimulus to which the subject attended yielded a larger AER than those which were igpored (Davis, 1964; Donchin & Cohen, 1967; Gross et al., 1966; Mast & Watson, 1968; Satterfield, 1965; Spong et al., 1965; Williams et al., 1964), In all instances attention was internally generated, the subject consciously attended to or disregarded a given stimulus. Thus, an increase in the amplitude of the auditory AER may not have been seen simply because the subjects were passive, i.e. they did not actively respond or attend to the auditory stimulus. If active participation is essential then attempts to significantly augment response amplitude in passive subjects using stimulus conditions like those reported herein which attempted to modify attention externally will be unsuccessful.

The only significant difference found in this study was between the average response amplitude of Group II (T in L) and Group III (TS) for the experimental condition. A combination of factors would appear to explain this finding. The first concerns the fact that subjects in Group III tended to yield larger AER's than those in either of the other groups for the control condition as well as for the experimental condition (see Figure 5). Although the mean response amplitude observed for Group III during the experimental condition decreased it was only slightly smaller than that observed for the control condition. In contrast the mean AER amplitude for Group II observed during the experimental condition was much smaller, although not significantly so, than that obtained during the control condition. The decreased amplitude of the AER observed during the experimental condition administered to Group II (T in L) coupled with mean responses of relatively high amplitude for the conditions administered to Group III (TS) probably explains this significant result and not the superiority of one experimental condition over the other. Another factor should also be considered. It will be recalled that all subjects were informed of the experimental condition they would be given before testing began. They were also told in which of the three averages the experimental condition would occur. It is possible that merely the knowledge that they would eventually receive a shock during the test increased the attention that subjects in Group III gave to the auditory stimulus and thus enhanced their response amplitude during both the control and the experimental conditions. In retrospect it might have been more appropriate to refrain from providing information as to the nature of the experimental condition.

Other methods might have proven more useful in observing the effects that the experimental conditions used had on the amplitude of the late AER. In the event that enhancement is of short duration lasting only for six to eight responses averaging a smaller "N" might have been more appropriate. In addition amplitude measurements could be extended to Include the total energy under the waveform. This would permit the detection of the overall effects that these conditions had on the amplitude of the AER and would not limit the observations made to two components of the response as reported herein.

The findings reported in this investigation do not necessarily indicate that these procedures would also fail to assist in the test ing of younger subjects. Since movement artifact is a problem especially with young children the presentation of colored lights as used with Group II might reduce movement momentarily during which time the tone could be presented. In this case the condition employed would be to reduce the influence of movement artifact in the averaged waveform.

In conclusion, the findings reported in this study should not be interpreted as meaning that the amplitude of the late auditory AER at 10 dB SL cannot be augmented in all passive adults. Additional investigation using other techniques of conditioning augmentation is needed to make this determination.

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APPENDIX

TABLE 9

Amplitude of N1-P2 in Millivolts for the Control and Experimental Condition at 10 dB SL for Group I, II, and III

Subjects	Control Condition	Experimental Condition
Group I		
SS	5.8	4.5
MN	6.2	8.9
KN	0.0	11.9
TN	7.7	8.3
DN	7.5	7.1
VS	3.4	4.5
JE	6.3	5.4
BT	14.8	8.9
TT	7.9	6.3
Group II		
	9.6	10.4
	1.5	1.7
MT	10.6	0.0
RJ	10.4	8.3
MM	8.4	6.6
KK	12.5	7.9
KS	3.3	3.1
SS	6.5	4.8
NG000	5.8	7.5
Group III		
DR	5.0	6.3
GM	7.9	7.3
MJ	3.3	8.5
DM	16.5	13.9
GH	7.7	7.9
KW	12.7	15.8
VR	12.1	5.8
MK	14.6	10.6
MN	7.9	7.7

TABLE 10

Latency of N1, P2, and N2 in Milliseconds for the Control and Experimental Condition at 10 dB SL for Group I, II, and III

Subjects	Control Gondition			Experimental Condition		
	Nl	P2		Nl	P2	N2
			Group I			
TT	205	290	369	184	287	390
BT	174	317	492	194	325	492
JE	164	328	481	203	277	431
VS	205	330	415	170	287	481*
DN	170	308	410	170	328	452
TN	240	330	500	185	338	471
MN	235	306	425	164	320	398
KN	...	...	...	153*	328*	500*
SS	170	276	415*	287	369	448
			Group II			
MG	172	265	307	186	358	500
SS	150	286	...	164	297	399
KS	212	308	448	194	287	392
KK	144	267	453	164	275	420
MM	196	317		174	456	...
RJ	185	292	409	174	307	425
MT	...	312*	432	...	...	...
KW	185	346	406	204	305	500
LS	165	267	358	153	269	417
			Group III			
MN	215	328	500	200	336	500
MK	164	297	438	215	307	500
VR	148	290	431	174	230	358
KW	205	308	500	197	317	443
GH	154	317	500	174	299	—
DM	170*	267	390	189	276	481
MJ	205	307*	...	200*	307	500
GM	194	287	499	227	297*	420
DR	194	268	498*	246	317	

* Data not used in analysis so the N for the comparison would be the same.

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