

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

1970

Effect of alerting stimuli on learning and responding under induced muscle tension (IMT)

Jim Fillmore Farnes
The University of Montana

Follow this and additional works at: <https://scholarworks.umt.edu/etd>

Let us know how access to this document benefits you.

Recommended Citation

Farnes, Jim Fillmore, "Effect of alerting stimuli on learning and responding under induced muscle tension (IMT)" (1970). *Graduate Student Theses, Dissertations, & Professional Papers*. 4916.
<https://scholarworks.umt.edu/etd/4916>

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.

THE EFFECT OF ALERTING STIMULI ON LEARNING AND
RESPONDING UNDER INDUCED MUSCLE
TENSION (IMT)

By

Jim F. Farnes

B.A., University of Montana, 1968

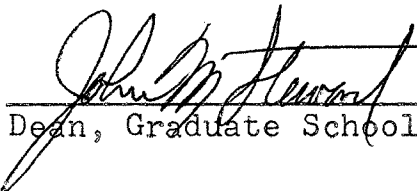
Presented in partial fulfillment of the requirements
for the degree of
Master of Arts

UNIVERSITY OF MONTANA

1970

Approved by:


Chairman, Board of Examiners


Dean, Graduate School

6/1/70
Date

1
153.15
F235e

UMI Number: EP40380

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI EP40380

Published by ProQuest LLC (2014). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

8-3-70

ACKNOWLEDGEMENTS

Satisfactory completion of this experiment was due in part to the generous assistance of several people. My thanks to: Dr. John R. Means, committee chairman, for his useful suggestions; to Dr. Laurence H. Berger for his knowledge of electrophysiology; to Dr. Charles M. Allen for his advice on verbal learning; and to Dr. Charles D. Parker for his suggestions and the generous loan of testing facilities and EMG equipment. Additional thanks to Darrell J. Micken for his technical assistance, and to Mike Nash and Durrell Kinghorn for construction and testing of the feedback circuitry.

TABLE OF CONTENTS

	Page
LIST OF FIGURES	iv
Chapter	
I. INTRODUCTION	1
Purpose	3
Alerting Stimuli	4
Supportive Evidence	6
Hypotheses	9
II. METHOD	13
Subjects	13
Apparatus	14
Task	18
III. RESULTS	21
IV. DISCUSSION	26
V. SUMMARY	35
REFERENCES	37
APPENDIX A	40
APPENDIX B	41
APPENDIX C	44
APPENDIX D	49
APPENDIX E	50
APPENDIX F	51

LIST OF FIGURES

Figure	Page
1. Graphic Comparison of Experimental Groups . . .	22

Chapter 1

INTRODUCTION

There have been numerous reports in the past that experimentally induced muscle tension (IMT) facilitates learning (Courts, 1942a; Bills, 1927; Stauffacher, 1937; Freeman, 1938a). There have been relatively few reports that relaxation enhances learning or recall (Pascal, 1949; White, 1940).

Meyer (1953) has more recently hypothesized that IMT facilitates responding rather than learning. That is, a response occurring simultaneously with a condition of IMT (which is in itself a response) may be strengthened, but the ability to learn (habit strength) cannot be affected. Meyer's hypothesis was confirmed by Bourne (1955) with a paired associate learning task in which time intervals of various lengths were introduced between the learning and recall trials to allow dissipation of IMT. The condition with a 0 sec. interval duplicated the design used by the majority of previous experimenters who reported an increase in ability to recall the learned material under IMT. Bourne's condition of 240 sec. intervals between the learning and recall trials tested Meyer's hypothesis that learning under

¹This study was supported by NIMH Research Fellowship 1-FO1-MH-46022-01 (MTLH) awarded to Jim F. Farnes.

tension should result in no better recall than learning under no tension, given enough time for that tension to dissipate. Muscle tension induced by the traditional method of requiring the S to squeeze a hand dynamometer dissipates in about 240 sec., according to R. C. Davis (Bourne, 1955).

Two major theoretical positions provide contrasting interpretations of the possible effects of IMT. Meyer, as noted above, assumes that any facilitative effect results only from the interaction of simultaneously occurring responses. That is, proprioceptive stimulation arising from the joints, tendons, and muscles during contraction may facilitate any other response, such as responding to verbal stimuli in a paired-associate task. The locus of interaction, according to Meyer, is in the motor nuclei. Thus, a response may be enhanced when muscle tension is induced, but habit strength--learning--cannot be affected. This view attempts to explain previously reported facilitative effects of IMT as being due to undissipated tension from the learning trial carrying over into the recall trial which followed immediately.

In contrast, Malmo (1959) provides a rationale, supported by Pinneo (1961) which assumes that an explanation of facilitation based on interaction effects in the motor system alone is too limited. He suggests that IMT affects the activation level of the organism by its influence on the ascending reticular activating system (ARAS). In contrast

to Meyer, Malmo indicates that activation level is determined by a summation of internal stimulation, such as proprioceptive stimulation arising from the induced muscle tension, which affects the "tonic balance" of the ARAS, in addition to stimulation from external sources, such as from visual and cutaneous sources.

Purpose

The major methodological contribution of this study has been an attempt to separate the effects of IMT from the possible effects of alerting stimulation inherent in the mechanical procedure previously used to induce that tension.

In most muscle tension studies, Ss in the non-tension condition are typically seated before a memory drum with no additional apparatus or instruction to alter their muscle state. When in the tension condition, however, they are usually instructed to squeeze a hand dynamometer during the learning trial, as described by Courts (1942a). Conclusions have usually been based on the independent variable of IMT without considering the possible alerting and activating influence of several sources of stimulation which are an integral part of the induction procedure in the tension condition but which have not been present in the non-tension condition. Such external stimulation may contribute significantly to the effect formerly attributed only to the proprioceptive stimulation arising from IMT. Support for

such a hypothesis is provided by Malmo's (1959) theoretical statement that a facilitative activation level can be a function of summated internal and external stimulation. Such a possibility is not recognized by Meyer's (1953) statement that facilitation can be a function only of simultaneously occurring responses.

Alerting Stimuli

The primary visual alerting stimulus in studies of IMT and learning is usually a signal light. The 6 v. bulb is positioned about 2 inches above the center of the memory drum aperture, and is activated when the required degree of dynamometer compression is attained. Such a feedback signal usually is not present in the non-tension condition. Further, no significance has been given the variable of the number of times the light bulb might blink off during the learning trials, and require instant reinstatement by the S even as he is attending to the verbal material being presented at a 2 sec. rate. Two of the few studies reporting the range of IMT variability allowed before the bulb blinked off were those of Courts (1939) and Lovaas (1960). A change of approximately plus or minus 3 lbs. was permitted before the signal light turned off. The author found in a pilot study that 83 per cent of the 30 Ss sampled evidenced an involuntary decrease of up to 7 lbs. of compression while attending to a simple reading task for 30 sec. One would

therefore expect at least several "bulbs off" during a given 30 sec. trial.

Another primary alerting stimulus of previous studies, again necessarily present only in the tension condition when a dynamometer is used, is the extensive discomfort in the fingers from gripping the handles for 30 sec. Courts (1942) notes that this is an important but uncontrolled variable. Since it has been completely absent from the non-tension conditions of previous studies, the extensive stimulation may contribute to the effect formerly attributed to muscle tension alone.

There may be an additional effect due to the actual presence of the dynamometer, which is typically mounted in the peripheral vision of the S. The pointer which indicates the degree of compression, and which completes an electrical circuit when in the proper position, can be a source of movement within the S's field of vision. Even though the dynamometer is present in the non-tension condition, there may be something very significant about the fact that the S is directing effort and attention toward it in only one condition. Further, the effect of an S being aware that the movement of this apparatus is registering his responses and conveying information to the E is unknown.

Summary. The total configuration of alerting stimuli which are not equated across the conditions of

tension and non-tension may provide a significant effect on learning or recall which has not previously been isolated, or which has been attributed to the effect of IMT alone.

Supportive Evidence

Several diverse approaches lend support to the hypothesis that certain alerting stimuli may have an effect which may summate with the effect of IMT and thereby influence various performances.

Many researchers have ascribed the alerting and general activation of higher cortical processes to the stream of proprioceptive stimulation which arises primarily from muscle tension (Malmo, 1959; Jones, 1949; Freeman, 1938; Bills, 1927; Jacobson, 1912).

Further, Malmo (1959), Chappell (1931), Pike (1922), and others make the assumption that higher cortical processes involved in greater receptivity and responsiveness to stimuli from the environment are a function of exteroceptive stimulation as well as of proprioceptive stimulation. Such summation is held to alter the thresholds of cortical processes by a spread of excitation, leading to a generalized facilitative effect (Darrow, et. al., 1957; Courts, 1942b; and Malmo, 1959). According to these researchers, increased activation of the cortex enhances complex mental operations, and in general the relationship between the degree of IMT and any facilitation of learning is an

inverted U-shaped function.

The tone feedback introduced in this study, for example, would be assumed to operate through the afferent pathways and the ascending reticular activating system to increase alertness of the S to the learning stimuli being presented to him (Lindsley, 1957). The visual feedback, used in most previous studies as well as in the present study, could operate similarly to elicit a generalized form of the orienting response described by Sokolov (1963). A number of studies, typified by that of Solley and Thetford (1967), note that an orienting response can be elicited by an unexpected tone, and that such a stimulus produces a finer discrimination of cues and a reduced misperception of tachistoscopically presented information. The probable blinking of the signal light and the concurrent variations in the feedback tone of the present study are neither unexpected by the S nor of a great intensity. However, these stimuli could be considered to intrude suddenly on the concentrated attention of the S to the paired adjectives being presented at a 2 sec. rate. One might presume such stimuli to have differential effects when present in the tension condition but not present in the non-tension condition. The primary aim of this study is to isolate such a factor.

The fact that alerting stimuli arising from the maintenance of IMT may affect activation is supported by Solley

and Thetford (1967), who indicate that heightened activation may be detected by the diphasic skin potential. They report that indications of activation can easily be elicited by such diverse stimuli as a 1,000 Hz. 72 db tone, by simply saying the S's name, or by the E entering the room where the S is resting.

Another possible component of the effects formerly attributed to IMT alone is a distraction factor pointed out by Morgan (1916). He reported that Ss expend more effort in attending to a primary task in order to overcome the effects of a distracting stimulus. Todd (1912) demonstrated that reaction time to two sensory stimuli was shorter than to either one alone. Bills (1927) reported that a distracting stimulus caused the Ss to increase their effort in attending to a tone, which resulted in the tone being judged as louder.

These diverse pieces of evidence bear directly on the thesis of this study that various obvious and subtle stimuli involved in inducing and in maintaining muscle tension by the hand dynamometer method may summate with the effects of muscle tension and may contribute significantly to performance in a paired adjective task.

Although central facilitation assumptions have traditionally been employed to interpret the results of muscle tension studies, such results may also be considered in terms of generalization decrement. Forgetting may

be increased by the removal or insertion of the three major contextual cues of muscle and cutaneous stimulation, feedback light, and feedback tone (Abernethy, 1940; Pan, 1926).

Hypotheses

Briefly, the three conditions of tension and of alerting stimuli, described more fully in the Apparatus section, will be given the following codes:

N. Normal, resting state, with no tone or light feedback. Electrodes were attached to the forearm in this condition, and a record of ongoing EMG taken.

Nf. Normal, resting state with the tone and light feedback. (Although in the orientation period each S was shown that the unresisted movement of one finger as little as $\frac{1}{4}$ inch gave feedback that tension was rising, 5 "bulbs off" were manually given during each Nf trial in order to equate groups for amount of alerting stimulation).

Tf. Tension state ($\frac{1}{4}$ of max.) with tone and signal light feedback.

Combinations of these three conditions formed 7 groups: N-N, N-Tf, Tf-N, Nf-Tf, Tf-Nf, Tf-Tf, Nf-Nf. The first notation of each group indicates the condition of muscle tension or alerting stimuli under which the S will learn the list of paired adjectives. The second notation

indicates the condition of muscle tension or alerting stimuli under which the S will recall the material.

Hypotheses 1 through 4 predict that the recall of paired adjectives will be facilitated by the alerting stimulation of the feedback tone and light as used in this study, as well as by the induced muscle tension.

$H_1: \underline{Nf-Nf} > \underline{N-N}$. When alerting stimulation of the feedback tone and light are present during both the learning and recall trials, the mean number of adjectives recalled should be greater than when no such stimulation is present. The result would be predicted by Malmo's assumption that exteroceptive stimulation may increase activation of higher cortical processes and thereby facilitate learning and recall. The result would not be predicted by Meyer's assumption that recall can be facilitated only by the effect of a response, such as muscle tension, occurring simultaneously with the response of recalling.

$H_2: \underline{Tf-Tf} > \underline{N-N}$. When the exteroceptive stimulation from the feedback tone and light summates with the proprioceptive stimulation of induced muscle tension, the mean number of adjectives recalled should exceed that of the control group receiving neither feedback stimulation nor induced muscle tension.

$H_3: \underline{Tf-Tf} > \underline{Nf-Nf}$. When two groups are equated for the alerting stimulation of the feedback tone and light, the

addition of induced muscle tension in the learning and recall trial of one group should facilitate the recall of paired adjectives.

$H_4: (\underline{Nf-Tf+Tf-Nf}) > (\underline{N-Tf+Tf-N})$. If alerting stimulation of the feedback modes and induced muscle tension has a facilitative effect when present in the learning or recall trials, the combined mean adjectives recalled by the two groups having 4 conditions of feedback stimulation and 2 conditions of muscle tension should exceed the combined mean adjectives recalled by the two groups having feedback stimulation in only 2 conditions and muscle tension in 2 conditions.

Hypotheses 5 and 6 test Meyer's assumption that facilitation of verbal performance results only if the response of maintaining muscle tension occurs simultaneously with the response of recalling the paired adjectives. Hypotheses 5 and 6 are predicted by Malmo's assumption that external stimulation, as from the feedback tone and light in this study, may have a facilitative effect whether present in the learning or recall (responding) trial.

$H_5: \underline{Nf-Tf} > \underline{N-Tf}$. The group receiving feedback stimulation during the learning trial should recall the experimental adjectives better than the group receiving no feedback stimulation during the learning trial, all other conditions being similar.

H₆: Tf-Nf > Tf-N. The group receiving feedback stimulation during the recall trial should recall the adjectives better than a similar group which receives no feedback stimulation in the recall trial.

All hypotheses are based on the assumption that the recall of paired adjectives may be facilitated by the alerting effects of the feedback tone and light used in this study, in addition to the formerly demonstrated facilitative effects of the induced muscle tension. The electrophysiological approach taken in this study allows manipulation of the alerting stimulus variables which were formerly an integral and inseparable aspect of the mechanical procedure used to induce muscle tension.

Chapter 2

METHOD

Subjects

The undergraduate Ss were volunteers between the ages of 18 and 24 from a general psychology class. They were screened for the ability to see typed words, for color vision, hearing, and naivete in verbal learning. An equal number of male and female Ss were randomly assigned to one of 7 groups of 16 Ss each, in which they served individually and only once. The population was comparable to that used in similar studies.

Every S was given verbatim instructions and a standard treatment. Each participated in a sound-protected audiology lab and was monitored by the E from a control room by means of a one-way mirror and an intercom.

Upon entering the testing room, each S was given brief instructions (see Appendix B) and then learned to the criterion of one correct trial a list of 10 highly similar paired adjectives from Bourne's 1955 study (Bourne, 1969). The list provided practice for all Ss, and a measure of group equivalence. A female assistant, without knowledge of hypotheses or the group to which each S was later assigned, taped electrodes to the preferred arm, determined the maximum tension level, and assisted in obtaining

instrument settings. Standard, verbatim instructions were then used to familiarize each S with his ability to respond to the feedback tone and light in both the tension and non-tension conditions. Hearing was then tested over an 800-2200 Hertz range, which included the possible frequency range of the feedback tone. After brief, general instructions were given for the experimental trial, each S was assigned to group I through group VI by the throw of a die, and assigned to group VII if the S's number in the consecutive order of entering the testing room was a multiple of 7. If the group to which a particular subject was assigned already contained 2 more Ss than any other group, the S was reassigned by another throw of the die. Specific instructions for the experimental trial (Appendix B), with directions appropriate to the seven possible combinations of tension and non-tension (Appendix C) were given. An attempt was made to equate the seven sets of instructions for common phrases and motivational words.

Apparatus

A Stowe memory drum, Model 459B, was used to present the adjective lists. A Stoelting Company hand dynamometer was used to determine maximum tension for each S, and in calibration of the feedback instruments for each S.

Both the Nf and Tf conditions required the S to regulate his muscle state on the basis of the variable

frequency tone and feedback light. The tone varied in frequency as a direct function of the ongoing muscle action potential (MAP) rate¹ being monitored by the silver chloride surface electrodes of an Evoked Response Audiometer. The audiometer, Model 140, was manufactured by the Princeton Applied Research Corporation. The tone was obtained by feeding the amplified EMG signal through a voltage controlled oscillator (Appendix E). Forearm flexors of the preferred arm were monitored since they were the muscles primarily involved in squeezing the hand dynamometer as it was used in previous studies.

In order to equate the tension and non-tension conditions for alerting stimuli, which are associated primarily with the feedback modes, the tone and signal light were based on the electrical activity of the muscles rather than on the mechanical compression of a dynamometer. Although it is not perfect, a high correlation does exist between the electrical event of motor discharge and the mechanical event of tension level as indicated by compression of the dynamometer (Sidowski, 1966). Care was taken to calibrate the feedback information while the S was squeezing the dynamometer to $\frac{1}{4}$ of his maximum, and to retest in case minor adjustments were necessary. Electronically registered

¹The concept was developed by Thomas H. Budzynski, University of Colorado Medical School.

levels then became the criteria in the experiment proper as the S, in both the tension and non-tension conditions, held his fingers around a soft foam pad with a firm core of the same dimensions as the dynamometer handle.

This electrophysiological approach reduced the alerting stimulation associated with the presence of a dynamometer in the experimental groups but not in the control group. Unlike many previous studies, the tension and non-tension conditions in this study were assumed to differ significantly only on the dimension of muscle state.

In the Nf condition, for example, the S maintained a normally resting flexor group on the basis of a 1300 Hz, 54 dB tone and a lighted signal lamp. In changing from the Nf to the Tf condition (with 4 minutes intervening between the two in this study) the S was required to increase and maintain his flexor tension at $\frac{1}{4}$ of his maximum level on the basis of the tone which steadied in the possible range of 1600-1900 Hz, 54 dB, and the signal light which stayed on. The alerting stimuli associated with both the tension and non-tension conditions, therefore, are more nearly equal. Any important differences in group results can thus be differentiated more clearly.

The present study employed an all-or-nothing feedback light, which was the only form of feedback in most previous studies. The tone provided additional and continuous

feedback on the direction of variations in tension. A rising pitch, for example, immediately informed the S--who was attending to the adjectives passing at a 2 sec. rate-- that the light bulb blinked off because he was squeezing too hard. Confusion and distraction may have resulted in previous studies when an S was uncertain as to whether the bulb blinked off because he was squeezing too hard or not hard enough.

Visual feedback was provided by a 6.3 v., .15 amp. clear pilot lamp mounted 2 inches above the memory drum aperture, as in previous studies. A voltage controlled relay was adjusted to allow a range of amplified EMG signal equivalent to that of plus or minus 2.5 lbs. variation in actual dynamometer compression, as determined during the orientation period for each S.

Dynamometer setting. Courts (1942a) concluded that 1/3 of maximum tension on a dynamometer optimally facilitated verbal learning, with maximum level defined as the reading after 30 sec. of maximum effort. Stauffacher (1937) reported that 1/4 of maximum optimally facilitated memorization. The present study employed a 1/4 of maximum criterion, with maximum being the reading after 15 sec. Many researchers have described the relationship between activation and behavioral efficiency as an inverted U-shaped function (Lorente de No, 1939; Malmo, 1959; Duffy, 1957). The

relationship apparently holds for the specific case of the relationship between verbal learning and the degree of experimentally-induced muscle tension (Courts, 1939, 1942a, 1942b; Freeman, 1931, 1938; Stauffacher, 1937). Overactivation was presumed to be less likely in this study because of the criterion of $1/4$ of maximum tension as well as because of the relatively easy learning task, the practice each had on the same practice list, and the complete familiarization with the feedback information.

The tone and light feedback, then, informed the S on whether he was maintaining the prescribed degree of tension while attending to the learning task. The E was able to hear variations in the tone level over the intercom, and could monitor the number of times the bulb blinked off through the one-way mirror.

Few previous studies controlled for muscle tension occurring spontaneously in those Ss who were in the normally relaxed condition. The sensitive EMG approach of this study permitted such control. Since a record of the ongoing EMG level was obtained for each S in the present study, data from those showing tension greater than 2 per cent of their maximum during more than one-half of the learning and/or recall trial were discarded.

Task

Upon entering the lab and being given a short

paragraph of instruction (Appendix B), each S learned to the criterion of one correct trial a list of 10 paired, highly similar adjectives (Appendix A) from Bourne (1969).

Each pair of adjectives was presented for a 2 sec. rate by the alternate study-test method. The S read each pair aloud during the study trials. As in the 1955 Bourne study, the first task served as practice for all Ss, as well as to provide a measure of group equivalence. Since all Ss, regardless of the group to which they were later assigned, received the same practice list, most effects of learning the list were presumed to be constant for all Ss. Differential practice due to variations in the trials to criterion was not controlled.

The experimental list (Appendix A), also from Bourne and of approximately the same difficulty as the practice list, was presented at the same 2 sec. rate. One study trial was given in which the pairs were again read aloud. A test trial followed immediately, then a 3 1/2 minute color viewing task, and then a second test trial. The conditions of tension or non-tension, with feedback information or without, occurred only during the learning (study) trial and the final recall (test) trial. The first test trial was to obtain a measure of acquisition so that any decrement over the 3 1/2 minute interval could be attributed to treatment during the second test trial without contamination by differential learning or forgetting. The S was told that

after the session he would be asked to answer a question about the order of the 5 basic colored squares which appeared in random order frequencies at the usual 2 sec. rate (Appendix F). The question was to ensure attention to the colors in order to prevent rehearsal of the adjectives. Such a silent color-viewing task is considered by Bourne (1955) to be less interfering than the naming of colors aloud since the latter variation requires an overt verbal response much like that required by the actual verbal learning activity. The purpose of the color-viewing task is, as noted above, to prevent rehearsal over a span of time sufficient for any tension induced in the learning trial to dissipate before the recall trial.

Chapter 3

RESULTS

The results of this study are shown in Figure 1.

Data from 21 Ss was discarded during the course of the experiment (Appendix D).

Although Ss in the 7 groups were not equated for ability to learn paired-associates, the trials to criterion score of the practice list provided a useful measure of group equivalence. Random assignment to groups did not ensure acceptable equivalence since the criterion score range was 2.1 trials. An analysis of covariance, employing the practice scores as covariates, was used to adjust the dependent variable data (recall scores) for this differential ability to learn paired adjectives. The analysis of covariance was not significant ($F(6,104)=0.41, p < .25$).

An analysis of variance of the dependent variable (recall) scores, which were not adjusted for rate of learning, approached significance with $F(6,105)=2.05, p > .10$. Such a result suggests that the results of those previous studies which did not adjust the dependent variable data for the ability to learn may have failed to control for a potential source of error.

The 6 hypotheses of this study were derived from Malmo's assumption that activation--the heightened ability

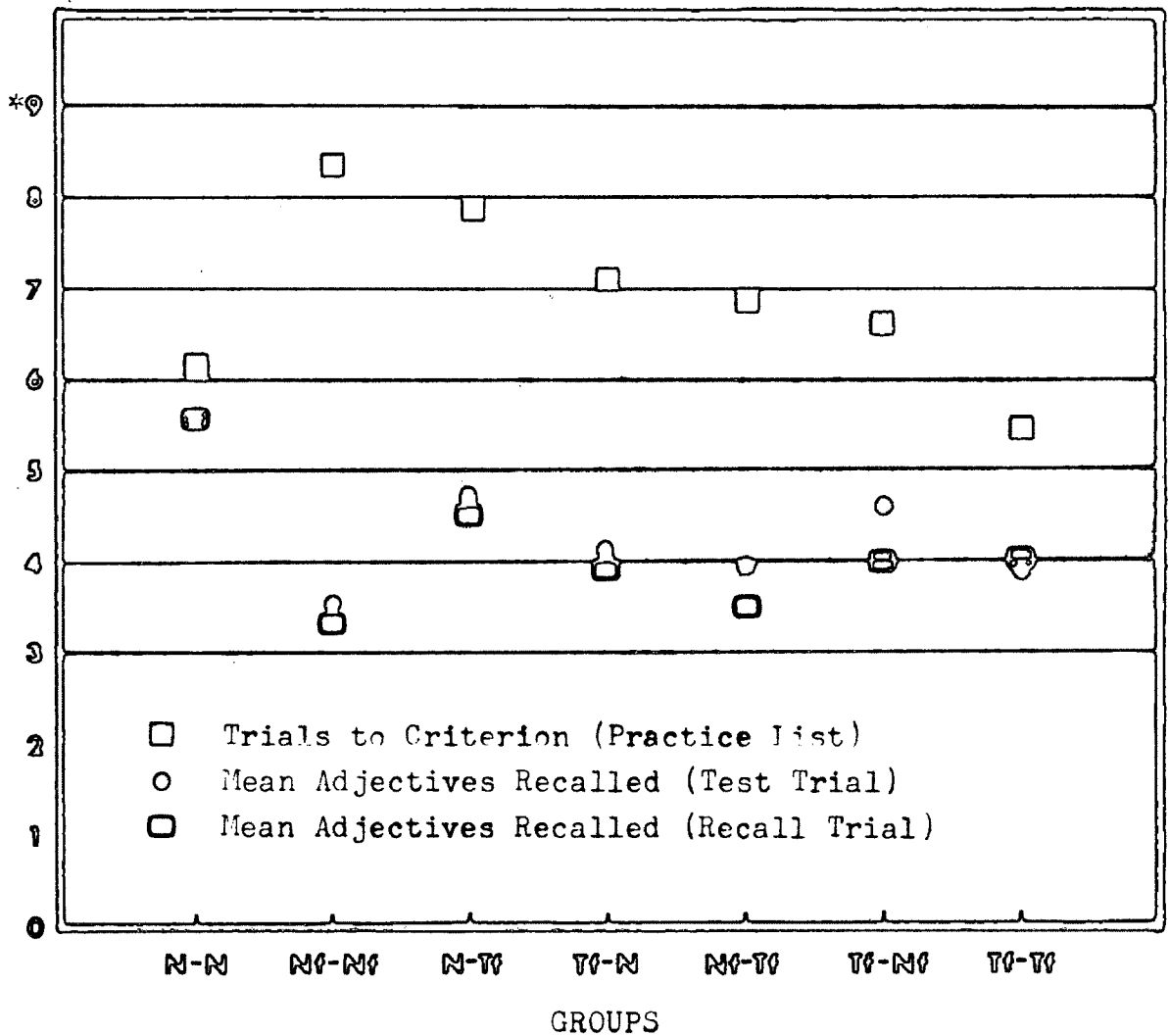


Figure 1. N=16 per group. Trials to criterion and mean adjectives recalled are plotted across groups. The time interval between learning and the first test trial was 0 sec., and for the recall trial, 240 sec.

*The ordinate scale indicates both trials to criterion (over a 5.5-8.4 range) and mean adjectives recalled (over a 3.4-5.6 range) to show the relationship of adjectives recalled to rate of learning. See the Key for the specific variable plotted.

of higher cortical centers to process information--may be increased by the stimulation from external sources (such as the feedback tone and light used in this study) as well as by stimulation from internal sources (the proprioceptive impulses arising from induced muscle tension). T-tests of 2 hypotheses were significant, but in the direction opposite of that predicted, and tests of the remaining 4 hypotheses were non-significant. The tests were between mean recall scores only. That is, the practice scores were not used to adjust the recall scores for rate of learning. The .05 level was considered to be an acceptable level of significance.

H_1 : Nf-Nf > N-N isolated the primary variable: that feedback stimulation introduced during the learning and recall trials might facilitate performance on a paired adjective task. With $t(30)=4.04$, $p < .001$, the effect was significant but in the direction opposite of that predicted. The mean recall scores had not been adjusted for differential rate of learning, which would have decreased the significance.

H_2 : Tf-Tf > N-N tested the summated effect of feedback stimulation and induced muscle tension and resulted in $t(30)=2.86$, $p < .01$. Significance was in the direction opposite of that predicted. The combined muscle tension and feedback stimulation apparently had an inhibitory effect when compared with the control group.

H_3 : $\underline{Tf-Tf > Nf-Nf}$ isolated the effect of the induced muscle tension which was introduced in the learning and recall trials of the first of two groups already equated for amount of feedback stimulation. $t(30)=1.48$, $.10 > p > .05$ (one-tailed). Although the result approached significance, an adjustment of the recall scores for differential rate of learning would have modified this tendency.

H_4 : $(\underline{Nf-Tf+Tf-Nf}) > (\underline{N-Tf+Tf-N})$ tested the assumption that a summated effect of such feedback stimulation as employed in this study may be facilitative, regardless of whether it was introduced during the learning or recall trial. With acceptable homogeneity of variance of the pooled data, $t(62)=0.58$, $p > .8$, in the direction opposite of that predicted, giving no support to the assumption.

H_5 : $\underline{Nf-Tf > N-Tf}$ tested the hypothesis, based on Malmo's assumption, that the introduction of feedback stimulation during the learning trial would facilitate performance. Meyer's assumption, in contrast, was that facilitation can result only from the introduction of a second response during the responding (recall) trial. The $t(30)=1.41$, $p > 0.2$ indicates a non-significant difference, with a trend in the direction opposite of that predicted. The finding is not consistent with Meyer's prediction.

H_6 : $\underline{Tf-Nf > Tf-N}$ tested the effect of introducing feedback stimulation in the recall trial. The $t(30)=1.50$, $p > 0.2$ indicates a non-significant difference with a trend

in the direction opposite of that predicted.

Data from the 2 males and 2 females were discarded¹ from the control group N-N since more than 2 per cent of their maximum tension was present during more than one-half of the learning and/or recall trial. When recall scores of the 4 discarded Ss were tested against the scores of the N-N group from which they were discarded, the result was $t(18)=0.3$, $p>0.8$. There is no evidence from this small sample that self-induced muscle tension, which was a variable generally uncontrolled in previous studies, may have a facilitative effect on paired adjective performance. One would not expect any possible facilitative effect to be very great, however, since 2-8 per cent of maximum tension is low on the inverted U-shaped function which describes a range of 25-33 per cent of maximum as being optimally facilitative (Stauffacher, 1937; Courts, 1942a).

¹See Appendix D for the list of subjects discarded.

Chapter 4

DISCUSSION

The results give no support to the assumption that the two feedback modes employed in this study--the on-off signal light which informed the S that he was maintaining the proper level of tension, and the 1300-1900 Hz, 54 dB variable frequency tone which also reflected ongoing changes in tension level--had any facilitative effect on the learning or recall of paired adjectives. When compared with the recall mean of the control group, the recall means of the 6 treatment groups receiving combinations of feedback stimulation and induced muscle tension were actually depressed. Such results are therefore not consistent with Malmo's assumption that stimulation from external sources may have an activating influence on higher cortical processes and thereby facilitate the learning or recall of a paired adjective list, for example, which was the dependent variable of this study.

In neurological terms, the consistently lower recall scores of all treatment groups as compared with the scores of the control group should not be the result of overactivation; that is, the result of more than optimal degrees of induced muscle tension and feedback stimulation. The 25 per cent of maximum tension used was well within the

25-33 per cent range considered optimally facilitative by Stauffacher (1937) and Courts (1942a). Further, Group Tf-Tf, which received muscle tension and feedback stimulation in both the learning and recall trials was not significantly lower in recall than the other 5 groups receiving lesser degrees of tension and stimulation. Finally, there was no evidence of overactivation in the results of Group Nf-Nf which received no tension but nevertheless obtained the lowest of all group means.

The design of this study should have minimized any detrimental interaction of treatments which might have accounted for the depressed scores of the treatment groups. For example, the learning task was relatively easy, and each S had previous practice on a similar list. Also, each S was given a standard and thorough practice with the feedback tone and light so that he could monitor his tension level with a minimum of distraction from the adjectives which were presented at a 2 sec. rate. Further research employing only the on-off feedback light--the only form of feedback in all previous studies--but based on the electromyographic level which was the unique contribution of this study, might clarify any possible detrimental interaction of the two feedback modes as used in this study. Such distraction should have been minimal since the variable frequency tone complimented the on-off signal light and should actually have reduced confusion by instantly informing

the S on the direction of his error in squeezing. For example, when the light blinked off, a rising frequency of the tone informed the S that his muscle tension was exceeding the desired level.

Rather than attempting to account for the generally lower scores of the treatment groups by postulating inhibitive effects of the three treatment variables, one might consider possible facilitative effects present only in the control group. Whereas Ss in previous studies simply squeezed a hand dynamometer which was mounted in front of them, the Ss of this study had two electrodes and a ground wire taped to their forearms. Although each S was told that there would be no shocks or discomfort, those in the control group may have experienced a generalized anxiety which was not discharged by the act of squeezing the foam pad or responding to the light and tone when they indicated an adjustment of tension was required. Spence, Farber and McFann (1956) and Spence, Taylor and Ketchel (1956) demonstrated that high anxiety (drive), as measured by the Taylor Anxiety Scale, facilitated the recall of highly similar paired adjectives. Synonymous adjectives were used in this study. Interestingly, Lovaas (1960) found that induced muscle tension had the same facilitative effect on the recall of highly similar adjectives as did anxiety. Thus, a generalized anxiety may have been experienced by the control group Ss, and may have been an artifact of

the electromyographic approach of this study which facilitated the recall of that group.

The depressed performance of all experimental groups in comparison with the control group cannot be accounted for by the concept of proactive inhibition. Since all groups received the identical practice list and the identical experimental list, any inhibitory effects on recall of the second list because of the learning of the first list should have been equal for all groups.

No substantial evidence was found for the frequently stated conclusion that proprioceptive stimulation arising from induced tension facilitates paired-associate learning. The third hypothesis ($T_f - T_f > N_f - N_f$: that the introduction of tension during the learning and recall trials would facilitate performance) only approached significance ($.10 > p > .05$). Finally, the self-induced tension of the 4 Ss discarded from control group N-N had no significant effect on recall performance.

There was no clear evidence for Meyer's assumption that IMT can affect responding if introduced during the recall trial but cannot affect learning (habit strength) if introduced during the learning trial. The data shows certain non-significant differences not predicted by Meyer. For example, although the N-Tf group, which received tension in the recall trial, did recall slightly better than the Tf-N group, which received IMT during the learning trial,

the Nf-Tf group which also had tension in the recall trial recalled less well than the Tf-Nf group which had tension during the learning trial. Further, the N-N control group which did not have tension in either the learning or recall trial recalled considerably better than any of the three groups having tension in the recall trial (N-Tf, Nf-Tf, Tf-Tf).

No support was found for the hypothesis, tested by Bourne (1955), that previous findings of IMT facilitating learning were due to the presence of residual tension in the recall trial which had not yet dissipated after being introduced during the learning trial. As shown in Figure 1, the first test trial scores (with 0 sec. interval between learning and recall trials) differed very little from the second test trial (recall) scores (with 240 sec. interval between learning and recall trials). The 0 sec. test trial of this study was included to obtain a measure of acquisition in order that the amount of forgetting over the 3 1/2 minute color-viewing task could be clarified. Any subsequent decrement could then be attributed to treatment effects. Whereas the average decrement over the 4 minute interval in Bourne's study was about 1.1 adjectives, the average decrement over the 3 1/2 minute interval in this study (with a list of adjectives from the Bourne study) was only 0.3 adjectives. Evidently the 0 sec. test trial of this study had the effect of an immediate rehearsal

which retarded forgetting. The effect of this test trial may therefore have been related to that demonstrated by Greenberg (1950) and others, that rate of learning is directly related to stage of practice. Treatment effects may have been masked by the rehearsal, which prevented a greater decrement and differential spread of scores.

Davis' contention that tension induced by a hand dynamometer dissipates over a 240 sec. interval (Bourne, 1955) was given marginal support by the EMG records of 8 of the 48 Ss in groups receiving IMT during the learning trial (Tf-N, Tf-Nf, Tf-Tf) which evidenced decreasing forearm flexor tension for approximately the first 2 minutes of the color-viewing task which followed the learning trial. That such undissipated tension should have an activating influence, and therefore a facilitating effect on recall performance, was not supported in this study.

The results of this study cannot be predicted by the contextual cue approach to verbal learning (Abernethy, 1940; Pan, 1926). If during the learning process a response becomes associated not only with the stimulus presented but with the total configuration of contextual cues present during the learning trial, those groups receiving identical cues of tension, cutaneous stimulation, feedback tone, and light stimulation during the recall as well as the learning trial (Tf-Tf, Nf-Nf) should have obtained the highest recall scores. They did not.

Those previous studies which based their analysis on the dependent variable (recall) scores only may not have controlled for an important source of error in view of the failure of random assignment to groups in this study to ensure acceptable group equivalence. When a change in learning or recall is used as the dependent variable in an experiment, the rate of learning of the Ss should be controlled by methods in addition to random sampling. Control can be achieved experimentally by the use of a counter-balanced or repeated measures design, as used in some studies, or statistically by an analysis of covariance design, as used in this study. As noted in the Results section, an analysis of covariance with the practice (trials to criterion) score as a covariate resulted in an $F=0.41$, while an analysis of variance of dependent variable scores not adjusted for rate of learning resulted in an $F=2.05$, with $F=2.52$ required for significance. A significant F with data not adjusted for individual rates of learning would seem possible, and would therefore give unjustifiable confidence in the results and subsequent conclusions.

Further research on the effects of induced muscle tension on verbal learning should include tests over an extended range of tension. Hopefully, with adjustment for rate of learning, and an extended range of tension, the results may then bear more relation to previous studies showing evidence of an inverted U-shaped function in which

lower-order increases in tension result in increased performance up to some optimum, after which further increases in tension have a detrimental effect on performance. Due to the fact that the major focus of this study was to isolate and study possible effects of the feedback stimulation in an electrophysiological approach which was not possible with the mechanical induction procedures of all previous studies, additional studies should also include a group which receives feedback on their tension level from an on-off signal light only, as in all previous studies. More direct comparisons could then be made with the results of those previous studies. The 0 sec. test trial should be eliminated so that the rehearsal it provides does not mask the effects of treatment. Further, the alerting or distracting effect of the 5 manually-presented "bulbs off" in the Nf (no tension, with feedback) condition should be studied more completely. The signal light feedback was given 5 times by the E in a standard way during the 30 sec. Nf condition to ensure a similar amount of such stimulation for all Ss in this condition. The actual number of "bulbs off" in all other Tf (tension, with feedback) conditions averaged 5.8 per trial. Inclusion of an Nf-N group (no tension, with feedback in the learning trial) and an N-Nf group (no tension, with feedback in the recall trial) would aid study of the effects of manually presented feedback stimulation. Finally, a post-test interview should be

employed in any additional studies to obtain subjective reports of individual reactions to the bulb flickering off while attention is being directed toward the verbal items being presented at a 2 second rate. A post-test interview may also clarify the possible presence of an anxiety in the N-N group due to electrode attachment, which is different in character from that experienced by the treatment groups.

Chapter 5

SUMMARY

The recall of highly similar paired adjectives was studied as a function of possible activating effects of a variable frequency tone and an on-off signal light which provided each S with continuous feedback on his level of muscle tension, as well as possible activating effects of proprioceptive stimulation arising from induced muscle tension. An electrophysiological basis of the feedback information permitted the separation of possible activating factors which in previous studies were an integral and inseparable component of the mechanical procedure used to induce muscle tension by the hand dynamometer method.

Seven groups of 16 Ss each received combinations of the three treatment conditions of induced muscle tension, non-tension, and feedback stimulation from the tone and light during the learning and test trials. Time intervals between the learning and test trials were 0 sec. and 240 sec.

With an analysis of covariance design used to adjust scores for rate of learning, no substantial evidence was found for a significantly facilitative effect upon recall of either the exteroceptive feedback stimulation, as predicted by Malmo's assumptions, or the proprioceptive stimulation from the 25 per cent of maximum induced muscle tension.

Meyer's assumption that induced muscle tension can facilitate responding but not learning was neither supported nor refuted.

REFERENCES

- Abernethy, E. M. The effect of changed environmental conditions upon the results of college examinations. J. Psychol., 1940, 10, 293-301.
- Bills, A. G. The influence of muscular tension on the efficiency of mental work. Amer. J. Psychol., 1927, 38, 227-251.
- Bourne, L. E. Jr. An evaluation of the effect of induced tension on performance. J. exp. Psychol., 1955, 49, 418-422.
- Bourne, L. E. Jr. Personal correspondence, 1969.
- Chappell, M. N. Inhibition, facilitation, learning; summation of stimuli. Psychol. Rev., 1931, 38, 317-331.
- Courts, F. A. Relations between experimentally induced muscular tension and memorization. J. exp. Psychol., 1939, 25, 235-256.
- Courts, F. A. The influence of practice on the dynamo-genetic effect of muscular tension. J. exp. Psychol., 1942, 30, 504-511.
- Courts, F. A. Relations between muscular tension and performance. Psychol. Bull., 1942, 39, 347-367.
- Darrow, C. W., Wilcott, R. C., Siegal, N., Wilson, J., Walanobe, K., Viette, R. The mechanism of diphasic skin potential response. EEG clin. Neurophysiol., 1957, 9, 169.
- Duffy, E. The psychological significance of the concept of "arousal" or "activation." Psychol. Rev., 1957, 64, 265-275.
- Freeman, G. L. Mental activity and muscular processes. Psych. Rev., 1931, 38, 428-449.
- Freeman, G. L. The optimal muscular tension for various performances. Amer. J. Psychol., 1938, 51, 146-150.
- Freeman, G. L. The energetics of human behavior. New York: Cornell University Press, 1948.
- Greenberg, Rand, Underwood, B. J. Retention as a function of stage of practice. J. exp. Psychol., 1950, 40, 452-457.

- Jacobson, E. Further experiments on the inhibition of senses. Amer. J. Psychol., 1912, 23, 345-369.
- Jones, P.N. Some psychological implications of cortical suppressor areas. Psychol. Rev., 1949, 56, 95-97.
- Lindsley, D. D. Psychophysiology and motivation. Nebr. Symp. on Motivation, M. R. Jones (Ed.), Lincoln: University of Nebraska Press, 1957, 44-105.
- Lovaas, O. I. Supplementary report: the relationship of induced muscular tension to manifest anxiety in learning. J. of exp. Psych., 1960, 59, 243-244.
- Meyer, D. R. On the interaction of simultaneous responses. Psychol. Bull., 1953, 50, 204-220.
- Malmo, R. B. Activation: a neuropsychological dimension. Psychol. Rev., 1959, 66, 367-386.
- Morgan, J. J. B. Overcoming of distraction and other influences. Arch. Psychol., 1916, 35, 1-84.
- Nó, R. L. Transmission of impulses through cranial motor nuclei. J. Neurophysiol., 1939, 2, 402-464.
- Pan, S. Influence of context upon learning and recall. Amer. J. Psychol., 1949, 62, 32-47.
- Pascal, G. R. The effect of relaxation upon recall. Amer. J. Psychol., 1949, 62, 32-47.
- Pike, F. H. Organization of the nervous system of respiration. Science, 1922, 56, 691-693.
- Pinneo, L. R. The effects of induced muscular tension during tracking on the level of activation and performance. J. exp. Psychol., 1961, 62, 523-531.
- Sidowski, J. B. (ed). Experimental methods and instrumentation in psychology. New York: McGraw-Hill, 1966.
- Sokolov, E. N. Perception and the conditioned reflex. New York: Macmillan, 1963.
- Solley, C. M. and Thetford, P. E. Skin potential responses and the span of attention. Psychophysiology, 1967, 3, 397-403.

- Spence, K. W., Farber, I. E., and McFann, H. A. The relation of anxiety (drive) level to performance in competition and non-competition paired-associates learning. J. exp. Psychol., 1956, 52, 296-305.
- Spence, K. W., Taylor, J., and Ketchel, R. Anxiety (drive) level and degrees of competition in paired-associates learning. J. exp. Psych., 1956, 52, 306-310.
- Stauffer, J. C. The effect of induced muscle tension upon various phases of the learning process. J. exp. Psychol., 1937, 21, 26-46.
- Todd, J. W. Reaction to multiple stimuli. Arch. of Psychol. 1912, 25.
- Travis, R. C., and J. L. Kennedy. Prediction and automatic control of alertness. J. Comp. Physio. Psychol., 1957, 40, 457-461.
- White, R. W. Hypnotic hypermnesia for recently learned material. J. Abnorm. Psychol., 1940, 35, 88-103.

Appendix A

ADJECTIVE LISTS AND SUBJECT DATA SHEET

Practice List

lowly-servile	faulty-unsound
required-urgent	inert-lazy
inane-absurd	merry-jovial
daring-brazen	gracious-pleasant
wary-cautious	shabby-ragged

Dynamometer max. kg. _____, 25% of max. _____

Relaxed condition instrument settings: DCS _____
acquiescence _____ (voltage) interval width _____
UCK 2.3, _ _ _
LCK _____, _ _ _

Tension condition (25% of max.): meter _____ v.,
interval _____
UCK _____ v., _ _ _
LCK _____ v., _ _ _

Screening tests:
color vision _____, naive _____, able to see _____,
hearing _____

Group: N-N, N-Tf, Tf-N, Nf-Tf, Tf-Nf, Tf-Tf, Nf-Nf.

Experimental List

clever-adept	crabbed-grouchy
thorough-complete	twisted-winding
immense-mammoth	composed-tranquil
giddy-fickle	hurried-speedy
awful-horrid	
burning-ardent	

No. "Bulbs off": Learning trial _____, Recall trial _____

Comments:

Appendix B

INSTRUCTIONS FOR PRACTICE LIST AND ORIENTATION

Sequence of instructions for every subject: "What is your name . . . age?"

Practice List Instructions

"I'd like you to be seated in front of the table with the black shield. I can talk to you through the intercom, and I can hear what you say as well. By the way, can you read the words on the card in front of you with no difficulty? Fine, we'll begin with the instructions . . .

"This is a learning experiment in which you will learn to associate one word with another word. The list will consist of 10 pairs of words like the pair on the card in front of you. When we begin, each pair of words will appear in the lighted window, one pair after another. You are to say all words aloud as they appear, and try to remember which word goes with which. After a blank space, you will see the first word of each pair again, and you are to say that word aloud and try to say the word that goes with each. Another blank space means we are starting a new trial in which all ten pairs will again be presented. You are to follow the same instructions. That is, say each pair aloud and try to associate the two words. Then after a blank space, when you see the first word of each pair, say it aloud and try to say the word that goes with it. You will continue to go through these alternating trials until you correctly name the ten words. Do you have any questions? Fine, we'll begin, then."

Orientation Period

"Now we are going to mark your arm for some sensors which will pick up the activity of the muscles of your arm. Are you right-handed? There won't be any shocking or discomfort, so don't worry about that. After the sensors have been taped on, we'll practice with--and get accustomed to--the feedback information you will be getting from them. (Assistant is attaching electrodes to forearm flexors). In a moment you will hear a tone. You will also see the light bulb there in front of you come on when I have it set

properly. These are the two forms of feedback information that will help you later in the experiment to maintain a certain degree of tension or relaxation.

"I'd like you to squeeze the dynamometer as hard as you can for 15 seconds. (Pause.) Now I'd like you to squeeze the dynamometer until the pointer is on _____ (25 per cent of max.) and hold it there very steady. (Obtain instrument settings.)

"Now you probably noticed that the harder you squeezed, the higher in pitch the tone became. And after I had it set, the bulb came on when you were maintaining the proper degree of tension. Notice that when you squeeze too hard, the bulb flickers off and the tone frequency goes up--this tells you that your tension level is raising above that amount that we are interested in. And when your tension started to decrease, the bulb blinked off and the tone frequency was decreasing. You know then that your muscle tension is decreasing below that point that we are interested in.

"Now I'd like you to lay your hand in your lap and let it relax completely. Notice that now I have set the light bulb so that it comes on only when you are very relaxed. The fact that the tone is low pitched and steady also tells you that your hand is relatively relaxed. Wiggle your middle finger just a tiny amount. Notice how sensitive the bulb is to the slightest tension.

"Do you have any questions so far?"

"Now let's test your hearing. Do you have normal color vision? Have you ever been in an experiment like this where you learn words?"

Experimental List Instructions
(General, for all subjects)

"This next verbal task is much like the first one, but now you will see 10 new pairs of words. As before, you are to say each pair aloud and try to associate the two words. After a blank space, you will see the first words of each pair. Say each aloud and try to say the word that goes with each. You will only do this twice this time, so do your best. We will do something else differently. . . . After you say the ten pairs aloud--then try to say the second word of each pair--you will watch a 3 1/2 minute series of colored squares. Later, I will ask you a question

about their pattern, so pay close attention to that pattern. At the end of the colors we will pause just a moment, and then you will again read aloud the first word of each pair and try to say the word that goes with each. Do you have any questions?"

(At this point, the subject was assigned to one of the 7 groups.)

Appendix C

INSTRUCTIONS FOR THE EXPERIMENTAL TRIAL

Specific Instructions According to the Group

Group N-N. You will not have the feedback tone or light during this part of the experiment. Let's review the procedure before we begin. You are to leave your fingers around the form pad--but leave them completely relaxed--as you say each of the ten pairs of words aloud and try to associate them. Leave your fingers relaxed through this entire session. After a blank space, when you see the first word of each pair, say it aloud and try very hard to say the word that goes with each. After studying the colors for 3 1/2 minutes, we'll pause for a moment, and then you will say the first word of each pair and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group N-Tf. This time, you will not have feedback tone or light while you say aloud each of the ten pairs of words and try to associate them, nor when you say the first word of each pair and try to say the word that goes with each. From the start you are to leave your fingers over the foam pad, completely relaxed. At the end of the colors, we will pause a moment to turn the tone on and so you can now squeeze hard enough to keep the light on and the tone high-pitched and steady while you again say the first word of each pair and try to say the word that goes with each.

Let's review the procedure before we begin. While leaving your hand relaxed, you are to say each pair of words and try to associate them. Then after a blank space, when you see the first word of each pair, say it aloud and try very hard to say the word that goes with each. After 3 1/2 minutes of colors, we will pause a moment to turn the tone on and for you to squeeze hard enough to keep the light on and the tone high-pitched and steady while you again say the first word of each pair that you just learned, and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group Tf-N. This time, you are to squeeze the foam pad hard enough to keep the light on and the tone high-pitched and steady while you say each of the ten pairs of words aloud and try to associate them. At the blank space, the light and tone will be turned off. You are to leave your fingers around the foam pad, but now completely relaxed, as you say aloud the first word of each pair and try to say the word that goes with each. Then you will study the colors for three and one-half minutes. At the end of the colors we will pause a moment, then you will again say aloud the first word of each pair that you just learned, and try to say the word that goes with each.

Let's review the procedure before we begin. You are to squeeze the foam pad hard enough to keep the light on and the tone high-pitched and steady while you say aloud each of the ten pairs of words and try very hard to associate them. At the blank space, the light and tone will be turned off, and you are to relax your fingers completely as you say aloud the first word of each pair and try very hard to say the word that goes with each. After studying the colors for 3 and 1/2 minutes, we'll pause a moment. Then you will again say aloud the first word of each pair that you just learned, and will try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group Nf-Tf. This time, you are to leave your fingers around the foam pad while you say the ten pairs of words aloud and try to associate them, but leave your fingers completely relaxed in order to keep the light bulb on and the tone low-pitched and steady. You remember from practice how sensitive the bulb is so that if it should flicker off that will tell you to relax even more. At the blank space, the tone and light will be turned off. You are to remain relaxed as you say aloud the first word of each pair and try to say the word that goes with each. After you study the colors for 3 1/2 minutes, we'll pause just a moment to turn the tone on and so you can squeeze hard enough to keep the light on and the tone high-pitched and steady while you again say aloud the first word of each

pair that you just learned, and try to say the word that goes with each.

Let's review the procedure before we begin. You are to leave your fingers around the foam pad, relaxed completely, in order to keep the light on and the tone low-pitched and steady while you say aloud the ten pairs of words and try to associate them. At the blank space, the tone and light will be turned off. You are to stay relaxed as you say the first word of each pair and try very hard to say the word that goes with each. After studying the colors for 3 1/2 minutes, we will pause a moment to turn on the tone and so you can now squeeze hard enough to keep the light bulb on and the tone high-pitched and steady as you again say aloud the first word of each pair that you just learned, and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group Tf-Nf. This time, you are to squeeze the foam pad hard enough to keep the light on and the tone high-pitched and steady while you say each of the ten pairs of words aloud and try to associate them. At the first blank space, the light and tone will be turned off, and you are to leave your fingers over the foam pad, completely relaxed, as you say aloud the first words of each pair and try to say the word that goes with each. After studying the colors for 3 1/2 minutes, we will pause briefly to turn the tone on so you can keep the light on and the tone low-pitched and steady, in a relaxed state, while you again say aloud the first words of each pair and try to say the word that goes with each. You remember from practice how sensitive the light bulb is when you are in this resting condition, so if the bulb should flicker off you will know to relax even more.

Let's review this procedure before we begin. While squeezing the foam pad to keep the light on and the tone high-pitched and steady, you will say the ten pairs aloud and try to associate the two words. After the first blank space the tone and light will be turned off. You are to let your fingers relax completely as you say aloud the first word of each pair and try very hard to say the word that goes with each. After the colors, we will pause a moment for you to stay relaxed in order to keep the light bulb on and the tone low-pitched and steady while you again say the first word of each pair that you just learned, and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group Tf-Tf. This time you are to squeeze the foam pad hard enough to keep the light on and the tone high-pitched and steady while you say the ten pairs of words aloud and try to associate them. At the first blank space, the tone and light will be turned off, and you are to leave your fingers over the foam pad, but now relaxed completely, as you say aloud the first word of each pair and try to say the word that goes with each. After studying the colors for 3 1/2 minutes, we will pause briefly to turn the tone on so you can again squeeze hard enough to keep the light on and the tone high-pitched and steady while you again say aloud the first words of each pair and try to say the word that goes with each.

Let's review this procedure before we begin. While squeezing the foam pad hard enough to keep the light bulb on and the tone high-pitched and steady, you are to say the ten pairs aloud and try to associate them. At the blank space, the light and tone will be turned off. You are to let your fingers relax completely as you say aloud the first words of each pair and try very hard to say the word that goes with each. After studying the colors, we will pause briefly to turn the tone on and so you can again squeeze hard enough to keep the light bulb on and the tone high-pitched and steady while you again say aloud the first word of each pair that you just learned, and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Group Nf-Nf. This time you are to leave your fingers around the foam pad while you say the ten pairs of words aloud and try to associate them. But leave your fingers completely relaxed in order to keep the light bulb on and the tone low-pitched and steady. You remember from practice how sensitive the light bulb is, so that possibly without realizing it, you may tense slightly while going through the task. If the bulb should flicker off and the tone rise slightly in pitch, you will know you should relax even more. At the blank space the tone and light will be turned off, and you are to remain relaxed as you say aloud the first word of each pair and try to say the word that goes with each. After studying the colors for 3 1/2 minutes, we'll

pause a moment to turn the tone on and so you can know you are relaxed by the fact that the light bulb stays on and the tone stays low-pitched and steady while you again say aloud the first word of each pair that you just learned, and try to say the word that goes with each.

Let's review the procedure before we begin. You are to leave your fingers around the foam pad, completely relaxed, in order to keep the light bulb on and the tone low-pitched and steady, while you say aloud each of the ten pairs of words and try to associate them. At the blank space, the tone and light will be turned off. You are to stay relaxed as you say aloud the first word of each pair and try very hard to say the word that goes with each. After studying the colors for 3 1/2 minutes, we will pause a moment to turn the tone on and so you can stay completely relaxed in order to keep the light bulb on and the tone low-pitched and steady while you again say aloud the first word of each pair that you just learned, and try very hard to say the word that goes with each.

Do you have any questions before we begin?

Okay, let's begin.

Appendix D

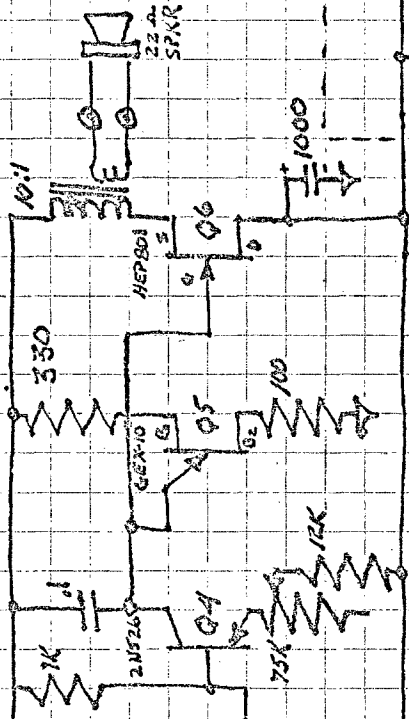
SUBJECTS DISCARDED, AND REASONS

- 6 memory drum failure.
- 4 did not follow instructions.
- 1 couldn't get sleeve up for electrodes.
- 2 could not read typed print without glasses.
- 8 had greater than 2 per cent of maximum tension.

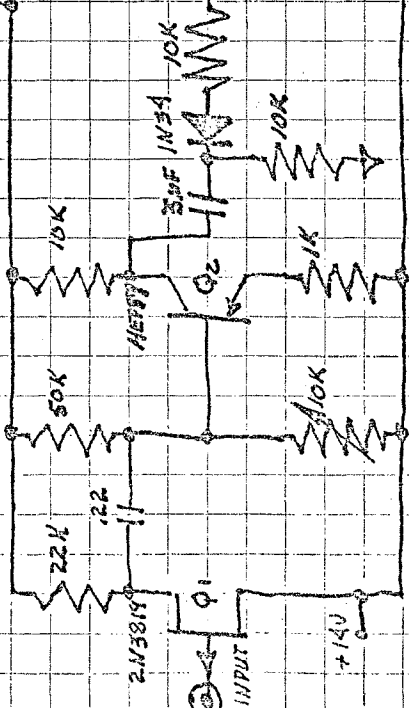
- 4 from Group N-N.
- 1 from Group Nf-Nf.
- 2 from Group Tf-N.
- 1 from Group Nf-Tf.

Total--21 subjects discarded.

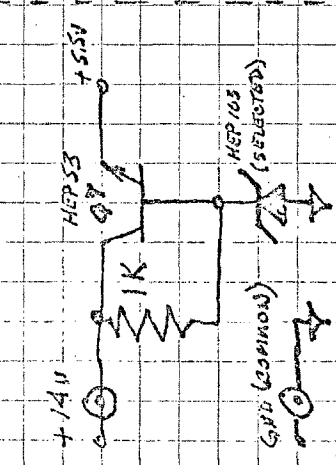
BOARD 3 - VOLTAGE-CONTROLLED OSCILLATOR



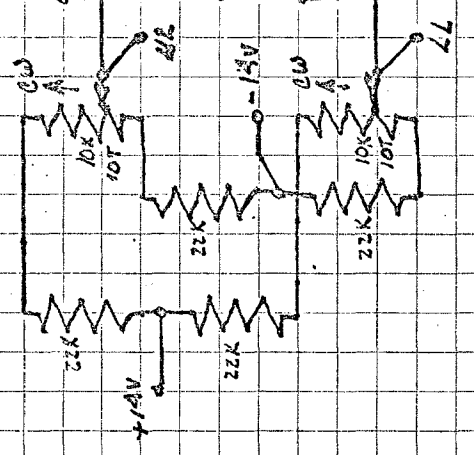
BOARD 2 - INPUT AMPLIFIER / FILTER



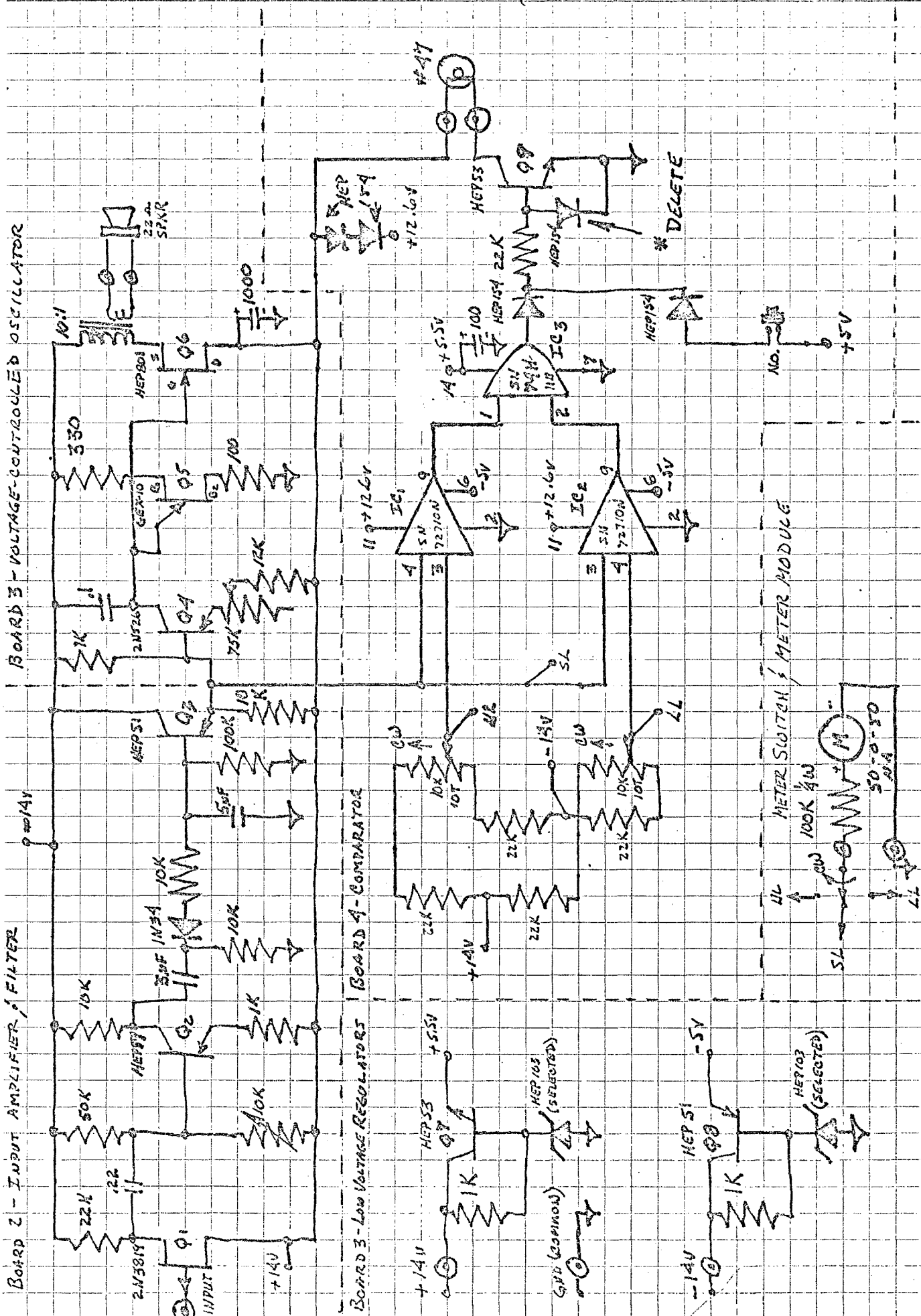
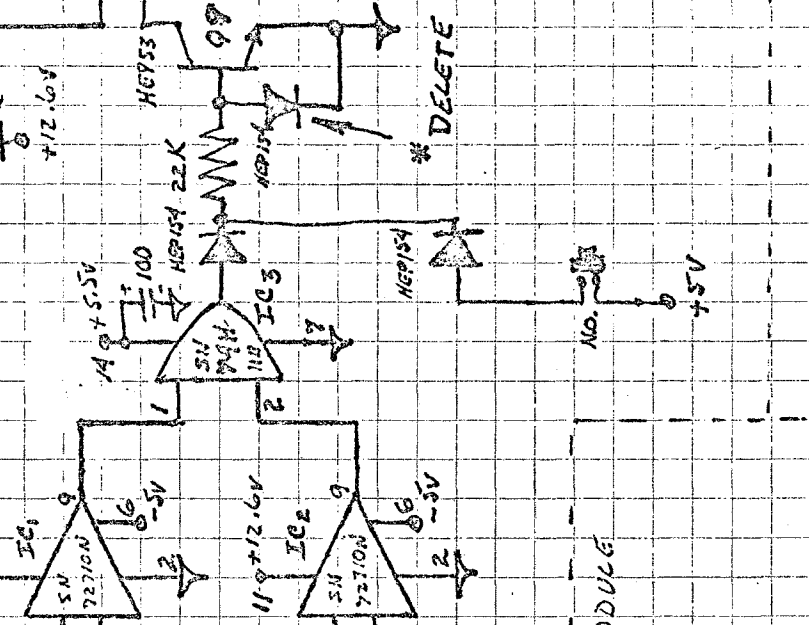
BOARD 3 - Low Voltage REGULATORS



BOARD 4 - COMPARE



BOARD 5 - METER SWITCH & METER MODULE



Appendix F

(Post-test questionnaire on the color-viewing task which was given to each subject immediately after the experimental trial.)

Your name _____

I want to thank you for taking part in this experiment. Your time and cooperation have been appreciated.

In the instructions, I asked you to study the series of colored squares for any apparent pattern. In several sentences, I would like you to carefully describe whatever characteristics you noticed about the pattern, the number, and the type of colors.

Please respect the important obligation that you have of not describing this experiment to your dorm-mates and friends. For consistent results, all subjects who participate after you must be naive to the design of the experiment.

When the study is completed, I will circulate a summary of its purpose and results.

Thanks for your help.

Jim F. Farnes