The effects of autogenic exercises and the ability of college students to think abstractly as measured by electromyographic biofeedback

by Dennis Lorry Weems

A dissertation submitted in partial fulfillment of the requirements for the degree of DOCTOR OF EDUCATION
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Abstract:
This study concerns itself with the effect of skeletal -muscle tension and the ability of college students to think abstractly. It used an Autogen 1700 Electromyograph (EMG) to measure muscle potentials produced during a mathematics test designed to elicit abstract thinking in college students. Two specific muscle groups were measured during the abstract thinking ability test. They were frontalis and trapezius muscle groups.

The Pretest-Posttest Control Group experimental design was used to collect the data. Statistical analysis was performed on two dependent variables: mathematics test raw scores and test item indices obtained on the EMG during the mathematical test administration. A Student's "t" was used to analyse the difference between group means of the experimental and control groups. This method was chosen to determine whether or not the "treatment" (autogenic relaxation exercises and biofeedback) was at all related to observed differences in the group means. Further statistical treatment was performed on each dependent variable in conjunction with five biographical variables. These biographical variables are: gender, age, marital status, GPA, and handedness. Multiple-regression analysis was performed to find out if either abstract thinking or skeletal muscle tension could be predicted by the five independent variables operating jointly and/or individually.

The study found that the treatment was capable of significantly increasing abstract thinking ability in the experimental group. It was found that differences between experimental and control groups' posttest measures of abstract thinking ability were also significant.

It was discovered that the control group increased their abstract thinking scores significantly. However, an analysis of gain scores between the experimental and control groups shows that the experimental group increased their scores by a group average of 3.16 scores while the control group increased their scores by a group average of 1.32 scores. The study found that only the independent variable "gender" was statistically significant when used to predict abstract thinking ability or skeletal muscle tension. A review of the control group raw data shows that men tended to gain .987 on the item tension indices scale while women tended to gain .282 on the same scale.

THE EFFECTS OF AUTOGENIC EXERCISES AND THE ABILITY OF COLLEGE STUDENTS TO THINK ABSTRACTLY AS MEASURED BY ELECTROMYOGRAPHIC BIOFEEDBACK

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ABSTRACT

This study concerns itself with the effect of skeletal-muscle tension and the ability of college students to think abstractly. It used an Autogen 1700 Electromyograph (EMG) to measure muscle potentials produced during a mathematics test designed to elicit abstract thinking in college students. Two specific muscle groups were measured during the abstract thinking ability test. They were frontalis and trapezius muscle groups.

The Pretest-Posttest Control Group experimental design was used to collect the data. Statistical analysis was performed on two dependent variables: mathematics test raw scores and test item indices obtained on the EMG during the mathematical test administration. A Student's "t" was used to analyse the difference between group means of the experimental and control groups. This method was chosen to determine whether or not the "treatment" (autogenic relaxation exercises and biofeedback) was at all related to observed differences in the group means. Further statistical treatment was performed on each dependent variable in conjunction with five biographical variables. These biographical variables are: gender, age, marital status, GPA, and handedness. Multiple-regression analysis was performed to find out if either abstract thinking or skeletal muscle tension could be predicted by the five independent variables operating jointly and/or individually.

The study found that the treatment was capable of significantly increasing abstract thinking ability in the experimental group. It was found that differences between experimental and control groups' posttest measures of abstract thinking ability were also significant. It was discovered that the control group increased their abstract thinking scores significantly. However, an analysis of gain scores between the experimental and control groups shows that the experimental group increased their scores by a group average of 3.16 scores while the control group increased their scores by a group average of 1.32 scores. The study found that only the independent variable "gender" was statistically significant when used to predict abstract thinking ability or skeletal muscle tension. A review of the control group raw data shows that men tended to gain .987 on the item tension indices scale while women tended to gain .282 on the same scale.

Chapter 1

INTRODUCTION

In September, 1968, two researcher/educators published their "polemical tract" entitled the Teaching-Learning Paradox: A Comparative Analysis of College Teaching Methods. Robert Dubin and Thomas Taveggia under a contract with the Division of Educational Laboratories of the Office of Education and under the auspices of The Center for the Advanced Study of Educational Administration, University of Oregon at Eugene, produced this state-of-the-art review of some four decades of studies done on the comparative college teaching methods in the United States. These studies began with the period just following World War I and continued through to the 1960's. The authors proceeded not to merely present a collection of "findings" and "conclusions" of past studies but rather to restudy all the available "data" and draw their own conclusions.

> It has only been in the current decade that recognition has grown apace that we really do not know what the linkage is between teaching and learning. . . This monograph will have made significant contribution if it does nothing more than fortify the conclusion that we have not yet established adequate theories of the linkages between teaching and learning. (Dubin and Taveggia, 1968).

The findings of this study do not hold many surprises for most educational practitioners. "We are able to state decisively that no particular method of college instruction is measureable to be preferred over another, when evaluated by student examination performances" (Dubin and Taveggia, 1968, p. 10).

The fundamental conclusion of this study implies that educators cannot afford to ignore the teaching-learning link. The authors go on to extend their conclusion by stating:

> We do, however, believe that anyone working or doing research at the college level of instruction can most readily make useful contribution when this linkage between teaching and learning becomes the center of their attention. (Dubin and Taveggia, 1968, p. 8).

It is the abundance of evidence that is presented in the Dubin/Taveggia study as well as the author's own experience and observations regarding adult college level teaching that prompts the writer to take the exhortation of the Dubin/Taveggia study and "make useful contributions" by taking a small step in the direction of removing some of the myths and persistent traditionalisms which have prevented the empirical determination of the learning-teaching process.

If one conceptualizes the teaching-learning process from a systems analysis viewpoint there are two basic models which become most evident. The first is the familiar "black box."

Figure 1.
First Variant: Learning Process Model

Input ⟶ Teaching-Learning "Black Box" ⟶ Output

The "inputs" are whatever particular teaching methodologies have been employed by the instructor. The "outputs" represent measurable changes in the student as determined by examination performance. The assumption that is made is that "learning" has taken place within the domain of the "black box."

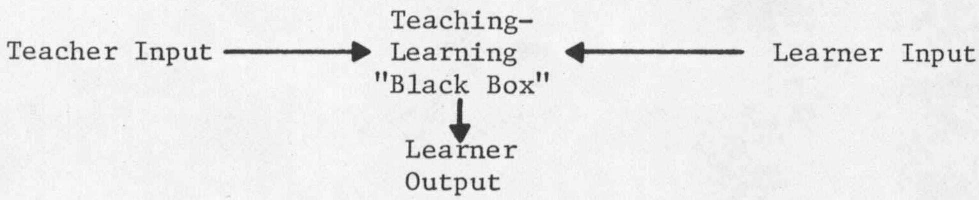
Figure 2.
Second Variant: Learning Process Model

Inputs		Outputs
Method A →	Teaching-Learning "Black Box" →	Exam A
Method B →		Exam B

In Figure 2, the "inputs" are designated as two teaching methods covering the same subject matter and content area. The "outputs" are student measures of "learning." Without attempting to explain what happens inside the "black box," one can conclude that when "outputs" A and B are compared, they will either produce the same result or differing results. Should the results, as measured by the examination, differ by a statistically significant amount, two assumptions can be made. Either there is a concomitance between teaching methods A and B and the "outputs" and/or that the examination used to measure the student performances was unreliable enough to produce such random differences (Dubin and Taveggia, 1968, p. 4). Regardless of the interpretation of the "outputs", the process within the "black box" remains a mystery to the investigator.

The second basic learning model is a variant of Figure 1. This model somewhat elaborates the first since the instructor is not the only source of system input.

Figure 3.
Third Variant: Learning Process Model



If one applies the same scrutiny to the interpretation of the system output in Figure 3, differences between methods may be, in part, attributed to student knowledge of the subject area. This second model is more applicable to college level teaching since it is very clear that college students are adults or near adults who bring with them an experience base and a body of knowledge which far exceeds that of learners younger than they (Knowles, 1968, pp. 62-68). Dubin and Taveggia see three factors characterizing the teaching-learning experience at the college level. The first is voluntarism on the part of the student in choosing not only to engage in a learning activity but also the particular subject matter of the learning activity. Secondly, adults possess a knowledge base from which judgments of content and assessments of the quality of instruction received can be made. This ability to make judgments often is influential in the voluntary choices made by the adult learner. Thirdly, the adult has a much more complex system of "culturally derived expectations and behaviors" (Dubin and Taveggia, 1968, p. 7). It is for these reasons that a more accurate characterization of the adult learning model should look like the model represented in Figure 3.

Both Figures 1 and 3 present plausible models for the learning process. Both, however, ignore the inner-functioning or processing that occurs within the teaching-learning "black box." To attempt to modify "input" implies that methodology and its manipulation/variation can be a factor effecting "output." The Dubin/Taveggia study presents evidence and asserts that such a "cause and effect" relationship between methodology and measurable outcome cannot be supported with data collected over the past forty years.

To attempt to refine the process of evaluation is seemingly the only other alternative when dealing with the "black box" paradigm. Refining the ability to secure "true measurements" of student performance will most always be limited by the ability to instrument measures of hypothetical constructs such as mathematical ability, intelligence and the like. Because of the nature of these constructs it is difficult to determine all of the factors which collectively become the construct being tested. Therefore, it becomes highly likely that conditions which may not be relevant to the purpose of the test will represent error variance (Anastasi, 1976, p. 103). It is our imperfect way of knowing what specific nature and constructs these hypothetical entities are which cause our attempts to refine measurements of them to fall short of the end goal: true measures.

Although such strivings in which skills are sought to further refine the ability to obtain "true measures" are necessary and plausible, they speak only to the periphery of the main effect. The main effect is to determine what can be done educationally which has a confirmable, observable effect upon student performance as determined by measurable outcomes.

The approach that will be pursued in this study is the notion that electromyographic biofeedback can be used as a technique for providing relevant information regarding the adult "teaching-learning" process and that knowledge of the relationship between myoneural phenomena and the output (measurable product) of the educational environment can provide the educator with tangible and applicable means by which the ability to learn may be strengthened or enhanced.

STATEMENT OF THE PROBLEM

A research investigation may be said to concern itself with a general problem. A general problem is one which is encountered in many situations and at various times. The purpose of solving the problem is not to achieve the goal indicated in any particular situation, but to discover or identify methods which are "effective in that regard and which will be effective in similar problem situations" (Crawford, et al, 1968, p. 6). Therefore, the problem of this study was to determine if there are significant differences between control and experimental groups randomly assigned from college student volunteers at Montana State University given that the experimental group received electromyographic feedback training utilizing the frontalis and trapezius muscle groups and that the control groups received no electromyographic feedback training, when their ability to think abstractly is measured by the number of correct responses to mentally solved mathematical problems of varying degrees of difficulty.

NEED FOR THE STUDY

Curriculum planning and student evaluation procedures often constitute the majority of teaching preparation time. The choice and prescription of teaching methodologies comprise the major portion of curriculum planning undertaken by the teacher. Curriculum planning or program planning, as it is often referred to, may be said to be constituted of numerous discrete entities. Among those discrete entities are (a) an attempt to relate the program plan to current social aims, forces and problems, (b) the utilization of knowledge of human developmental theories and learning processes, (c) and knowledge of the nature of knowledge (Hass, Bondi, Wiles, 1974, p. 15). These three statements may be distilled into simpler statements. Curriculum planning is comprised of (a) curriculum environment, (b) the teaching-learning link, and (c) the structure and taxonomy of knowledge. This study concerns itself primarily with the aspect of investigating the teaching-learning link and how knowledge of the myoneural process and its proprioceptive control can be utilized to enhance the ability to think abstractly. It cannot, however, be left unsaid that there is an interdependence among all three of the aspects and that acknowledgment and consideration of this fact must be taken into account in an investigation of the teaching-learning link. Since there is a sizable investment of teacher energy and time in curriculum planning processes, it follows that research which is directed toward the pursuit of answers to questions which attempt to explain the teaching-learning phenomena will be relevant, necessary, and profitable for the educator.

With many decades of prior research as a data base from which to begin an investigation of the teaching-learning link, the summative study of Dubin and Taveggia provides the educational community with evidence that no methodology can be shown to be preferable when the learning outcomes are measured by an examination. If, in fact, the method of instruction is an essentially moot consideration when pursued along the traditional rubics of educational research, it becomes clear that an investigation of methodologies and their comparative values as teaching tools is an exercise in redundancy.

In their summarization of Edwin Guthries' personality theory as it relates to learning, Hilgard and Bowers make the point that "A student does not learn what was in a lecture or a book. He learns only what the lecture or book caused him to do" (Hilgard and Bowers, 1966, pp. 86-87). The point made by Guthrie and reinterpreted by Hilgard and Bowers is that from the Behaviorists' view of the learning process the behavior (learning outcome) which one wishes to encourage or discourage is as much a function of the educational environment as well as or rather in spite of the methodology used to present the material or elicit the behavior. In Jean Piaget's monumental work on the developmental stages of the child he concludes that learning is more a result of genetically inherited scheduling which ranges over developmental periods controlled largely by the physiological maturation of the organism rather than by a series of Freudian psychological impresses (Miller, 1962, p. 299). Psychologist Donald Hebb who forcibly called attention to the necessity of relating behaviors (learning outcomes) to neural mechanisms, concludes that if psychology is to be a "basic science" of man and useful as a tool for explaining innate processes (i.e. the learning process), it is inescapable that this science should correlate functions (behaviors, learning outcomes) with structure. Nevertheless, Hebb asserts that:

> Psychology cannot become a branch of physiology. We cannot escape the need of large-scale unity of analysis, nor the need of the special methods of behaviorial study on which such analysis is based. To discuss what goes on inside a rat's head as he runs a maze, for example, we use such terms as 'hunger-drive,' 'expectancy of food,' 'stimulus time,' and 'the stimuli of the choice point.' Such constructs have little direct reference to neural function. (Hebb, 1958, pp. 262-264).

What Piaget and Hebb seem to be saying is that if the study of how the human being learns is to make impact upon educational entities which govern the research and development of learning theory and especially those agencies which engage in the professional training of educators, the educator as well as the psychologist at the applied level of the research spectrum must use organic structures for models in attempting to explain how the human organism negotiates environment, takes in data, makes decisions about the data, and transforms decisions into socially relevant behavior. Hebb summarizes his view of learning as "reduction of resistance of a synapse" and of inhibition, inattention, or absent mindedness as "neural drainage." In physiopsychological terminology these two definitions constitute the antithetical positions of learning and non-learning. Learning occurs when resistance is low enough for a synapse to occur and non-learning occurs when neural interference occurs and inhibits synapse. Hebb's theoretical structures are based upon hypothetical constructs called "cell assemblies" (groups of neurons) and "phase sequences" (groups of cell assemblies). In presenting his view concerning the relation of psychology of learning to the biological sciences, Hebb concludes his thoughts by saying:

> . . .the basic science of psychology-physiological psychology - differs from physiology in that it operates on a molar level: that it must nevertheless 'devise physiological hypotheses about the nature of some of psychologies intervening variables', that the barrier between psychology and physiology is one of communication, and that this barrier can be removed by a sort of 'adult education' whereby the psychologist and biologist do homework on each others subject. (Esper, 1964, p. 284).

Unlike the theorists such as Thorndike, Hull, Tolman and Gagne who believe that learning can occur by means of arranging conditions that are external to the learner (environment), the physiological psychologist believes that any learning theory must begin with the human physiology as the paradigm for explaining behavior and that learning theories which deal with only external conditions treat the "symptom" of the disease and not the "cause." This analogy transformed into educational terms states that instead of manipulation of external condition (curriculum environment) and the manipulation of the delivery system (methodology), the most efficient and accurate way to effect changes in behavior or learning is to find out the physiological conditions for the behavior. Then prescriptions for methodologies can and will enhance the teaching-learning link. To restate the position of Dubin and Taveggia, any research dealing with college level instruction can make the most useful contribution if the teaching-learning link is investigated. The physiological psychologist underscores and generalizes this conclusion to include all of the learning processes.

As Donald Hebb exhorts the psychologist and biologist to do homework on each other's area, so may this be extended to the educator wishing to do research in learning theory.

RESEARCH QUESTIONS

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises:

1. can a group of adult learners' ability to think abstractly be improved so that empirical validation can occur utilizing scores from a posttest designed to measure abstract thinking ability?
2. what will be the effect of the presence or absence of autogenic exercises on the abstract thinking ability scores when the group means of both the control and experimental group are analyzed so as to reveal differences between pre and posttest administration?
3. can the average muscle tension in the frontalis and trapezius muscle groups be made to decrease so that empirical validation can occur when average posttest tension readings from a biofeedback instrument (EMG) are used as indices of muscle tension?
4. what will be the effect of the autogenic exercises' presence or absence on the average level of muscle tension in the frontalis and trapezius muscle groups when group means of both the control and ex-

perimental group are analyzed so as to reveal differences between pre and posttest readings?

5. can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the abstract thinking ability of adult learners when the raw scores from their pretest measures are used as the dependent variable?

6. can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the abstract thinking ability of adult learners when the raw scores from their posttest measures are used as the dependent variable?

7. can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from their pretest EMG measures are used as the dependent variable?

8. can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from the posttest EMG measures are used as the dependent variable?

GENERAL PROCEDURE

Subjects were solicited from the Montana State University campus to participate in the biofeedback experiment. This recruitment was done under the guidance and auspices of Dr. William Jankel of the Psychology Department. A minimum of fifty (50) student subjects were chosen to participate in the experiment. The entire group was scheduled to be pretested. When the pretesting was complete, the subjects were matched and divided into two groups; a control group and an experimental group. The randomly assigned experimental group was contacted individually and appointments made by the experimentor to receive autogenic training in deep muscle relaxation using the Autogen 1700 electromyograph. On completion of the treatment phase of the experiment both the control and experimental groups were post-tested. This completed the scheduled activities involving the subjects.

During the pretesting of the individual subjects, the following data were collected: (1) whether the solution was correct or incorrect, and (2) the magnitude of the muscle potentials (frontalis and trapezius). The number of correct responses to the pretest and the magnitude of muscle potentials as they correspond to each test item was used to determine the comparability of both control and experimental groups and served as a means of validating the level of difficulty of the test problems respectively.

The Sigma-7 computer was used to generate a series of mathematical problems. Twenty problems were chosen from those generated and typed onto 3 X 5 cards. The assigned degrees of difficulty were initially ascertained by the level of difficulty of the algorithm used to generate the problems. An administration of the test to a Montana State University College class was also used to "de-bug" the test, verify that the verbal instructions were clear, and allow validation of item difficulty utilizing the number of correct responses to each item.

Each subject was interfaced with the electromyograph (Autogen 1700) by a series of six electrodes. Three were attached to the frontalis muscle and three were attached to the trapezius muscle. Each subject was seated in a reclining chair within a shielded booth. The electrodes were inserted into the electrode input connectors and the EMG activity scale was equaled out. The subject was presented the problems, on the 3 X 5 index cards, one at a time and asked to solve the problem mentally. Each subject viewed the series of twenty problems in a pre-determined random order so as to minimize whatever effects might follow the presentation of a consistent order. The subject was told to begin solving the problem and to answer verbally when he/she had computed an answer. If the subject could not solve the problem he/she was instructed to allow the time limit to elapse. A small rest period was observed between each problem. A twenty (20) second maximum was observed for the time given each participant to solve each problem.

During the posttest, the experimentor recorded the magnitude of muscle potentials and whether the subjects' response was correct, incorrect, or whether no response was given. The posttest for the experimental group did not differ from the control group posttest. Both the experimental group and the control group received audio feedback from the Autogen 1700 while solving the mathematical problems.

The data were recorded by the experimentor in terms of the number of correct responses for each problem, and the magnitude of muscle potentials as expressed units of microvolts of electricity (mv). These data were subsequently analyzed and interpreted according to the hypotheses in Chapter Three, general questions within Chapter One and are reported in Chapter Four.

LIMITATIONS OF THE STUDY

The "pretest-posttest control group design" was used to collect the data from the experiment. This design was chosen for its ability to control for all of the major sources of internal invalidity, and because the use of a pretest activity allows for the control group equivalency (Campbell and Stanley, 1963, p. 3).

Sources of external validity which affect this design such as interaction of testing and "X" (treatment), interaction of selection and "X", and reactive arrangements were controlled. Interaction of testing and "X" was not potentially a hazardous factor since testing sensitization (test wisdom) was avoided as the subjects did not receive the answers to the test problems. This, it was hoped, did not increase the educational effect of "X" and consequently obscure any gains that could be attributed to "X". Should the participants have chosen to work out any problem after the pretest, this opportunity was equally probable for all participants. Thus, the effect can be judged to be equal across both the control and experimental groups. The effect of the pretest upon "X" as it restricts external validity is a function of the extent to which repeated measurements and characteristic of the universe one wishes to generalize to. Testing was not unique to the subjects in the experiment as they were students; therefore, generalization to the educational setting should be possible (Campbell and Stanley, 1963, p. 18). Advertising for subjects campus-wide should have elicited responses from a close representative sample of college students. This abrogates the possibility of selection of subgroups such as classes within the student population (Campbell and Stanley, 1963, p. 19). Reactive arrangements are also a source of external invalidity. However, "the more obvious the connection between the experimental treatment and the posttest content, the more likely this effect becomes" (Campbell and Stanley, 1963, p. 21). The treatment consisting of autogenic exercises designed to teach the experimental subjects to control proprioceptive tension did not confirm an obvious connection, in this experimentor's mind, between the treatment and the content of the posttest which is performance on a set of mathematical problems. The treatment and posttest were enough dissimilar as to discourage connection between it and the posttest content.

While use of the randomized pretest-posttest control group design keeps to a minimum the effect of jeopardizing internal validity - "the basic minimum without which any experiment is uninterpretable" - (Campbell and Stanley, 1963, p. 5) there is some danger of threat to external validity which asks the question of generalizability: specifically "to what populations, settings, treatment variables, and measurement variables can this effect (treatment) be generalized?" (Campbell and Stanley, 1963, p. 5). The author also believes that the limitations of the method of recruitment of subjects will constitute a sample, although not random, which may not be as representative as it might be of the population from which they are drawn because of their choice to participate in the experimentation. It is possible, however, to delimit the scope of the population and thereby modify subsequent inferences by the knowledge that errors implicit within the sampling process may not allow an extensive scope of generalizability. However, these limitations in random sampling procedures should not curtail the experiment.

DEFINITION OF TERMS

acetylcholinesterase: an enzyme which breaks acetylcholine down into acetate and choline thereby inactivating the transmitting process of the presynaptic cell and initiating the activation of the postsynaptic cell.

acetylcholine: a chemical transmitter molecule found in the terminal ends of neuron axonal fiber.

axon: an extended single fiber emanating from the cell body which is interrupted at regular intervals by nodes called "nodes of Ranvier." The axonal fiber consists of two coverings: a thin membrane on the outside called "neurilemma" and between it and the axonal fiber a fatty sheath called the "myelin sheath." Axons deliver electrical potentials from receptor to receptor and from receptor to effector cells.

biofeedback: the technique whereby one seeks to consciously regulate a bodily function thought to be involuntary, by using a device to monitor the function and to signal changes in the function.

dendrites: branch-like fibers which extend from the cell body and connect their parent neuron to other neurons or body receptor cells. Dendrites "receive" impulses from other neurons or receptor cells.

electrical potential: the electrical discharge given off by neurons during the depolarization process.

electromyograph (EMG): an electronic device used to amplify neuron electrical discharge by use of a series of metal electrodes.

frontalis muscle: the frontalis muscle or forehead muscle is frequently used in EMG monitoring because it acts as a general "barometer" of muscular tension throughout the head, neck and shoulders and is also useful for studying attention and anxiety due to its extreme response to physiological arousal mechanisms.

micro volt: an expression of units of electricity into millionths of a volt.

motor unit: a single motor nerve cell (motorneuron) with its microscopic body located in the spinal cord, its enlongated nerve fiber (axons) running among the multitude of others and the variable number of muscle fibers that the axon supplies.

myoneural junction: the point of contact between neurons and muscle tissue. myo = muscle / neural = nerve

neuron: a nucleated cell body consisting of a cell body (soma), one or more dendrites, and an axon.

proprioception: the stimulation of muscles, tendons, glands, organs and joints which arrives from within the organism and consequently is not recognized at a cognitive level by the organism.

Schwann cell: the bulbous swelling terminal branch of an axon in which acetylcholine is housed and where the neuron and muscle cells are conjoined in a series of synaptic clefts, junctional folds, and active zones.

synapse: the point of near contact between neurons and effector cells and other neurons.

synaptic cleft: the intervening space which separates the axon from the linked cell.

trapezius muscle: the trapezius or shoulder muscle which runs from the base of the occiput to the middle of the back. It is sensitive to head, neck and shoulder tension.

SUMMARY

In this chapter the author has presented the setting for the study as an experiment designed to give evidence of physiological processes and their subsequent proprioceptive control as possible applied techniques for the enhancement of college students' ability to think abstractly when measured by their correct responses to a set of mentally solved mathematical problems. General questions have been raised, a general procedure outlined, limitations of the study discussed, and a set of terms defined. The next chapter will present a brief historical and conceptual discussion on psychological theories as they relate to the experiment and a necessary discussion of the state-of-the-art of physiological psychology and its relationship to electromyography. The second section will present a detailed summary of related research.

Chapter 2

REVIEW OF RELATED RESEARCH

The purpose of this chapter is to present to the reader an historical and conceptual discussion of psychological theories. The discussion deals with how the theories relate to the experiment along with a brief presentation of a state-of-the-art discussion of the relationship of physiological psychology and electromyographic feedback as well as an explanation of the use of electromyographics within the context of physiological psychology. The second section of Chapter 2 will contain a detailed summarization of related research.

HISTORICAL AND PHILOSOPHICAL BACKGROUND

Historical Background

The psychological under-pinning of educational practice has for too long been a "one-tool" variant. The universe within which the educational practitioner operates has long been recognized as being multivariant not only by the educational practitioner but also by the psychologist (Ornstein, 1968, p. 11). However, certain useful and productive products have resulted from the "one-tool" viewpoint. Behaviorism as a psychological theory and as an educational paradigm produced a mechanistic model of human behavior and learning principles which, beyond the vagaries of "Associationism" (Woodworth, 1931, p. 45) provided the psychologist and educational practitioner with quantifiable and experimentally controllable variables. John Watson's attempt to make that which he perceived as "intangibles" and "unapproachables" subject to quantification, as in the natural sciences, became known as Behaviorism. Behaviorism began as an intellectual objection to the Associationist's view of psychology as a "science of consciousness and to introspection as a method for use in the study of man (Woodworth, 1931, p. 43). The Associationists, on the other hand, attempted to distill all mental processes into a single process of association and proceeded to apply their views directly to morals, economics, and the social sciences in general. This doctrine highly influenced early nineteenth century psychologists and by the mid-nineteenth century had clearly dominated the established order (Woodworth, 1931, p. 47).

The conflict that existed between the Associationists and the Behaviorists in the mid 1800's predated the persistent struggle between a later division within the psychological community. That division can be defined as those psychologists who subscribed to the "mechanistic model" of psychological and learning theory and those who propounded the antithetical "organismic model." In his text, The Adult Learner: A Neglected Species, Malcolm Knowles defines the "mechanistic model," to which Behaviorism and Associationism belong, as representing:

> . . . the universe as a machine composed of discrete pieces operating in a spatio-temporal field. These pieces - elementary particles in motion - and their relations form the basic reality to which all other more complex phenomena are ultimately reducible. (Knowles, 1973, p. 17).

Within this definition is the inference that the organism (human) is passive and at rest and that the active forces which cause changes to the homeostatic state of the organism are solely the result of external forces (environment). It then follows that all such activities as thinking, willing, perceiving are nothing more than simple phenomena by efficient causes (Knowles, 1973, pp. 17-18). Change, or learning, as it were is the product of behaviorial change and not change in the structure of the organism.

> The appearance of qualitative changes is considered either as epiphenomenal (caused by another phenomenon) or as reducible to quantitative change, since the organism, like the elementary particles of classical physics, does not exhibit basic qualitative changes. (Reese and Overton, 1970, pp. 131-132).

"The 'organismic model' represents the universe as a unitary, interactive developing organism (Knowles, 1973, p. 18)." Unlike the "mechanistic model," the organism is a functioning, purposive, active member within the processes of change or learning. It sees man as an active organism who is a source of acts as opposed to a collection of acts precipitated by environmental forces. Simply stated, the whole is greater than the sum of its parts. Reese and Overton summarize the views of the "organismic model" and compare the major points of contention with the "mechanistic model" when they state:

> The individual who accepts this model (organismic) will tend to emphasize the significance of processes over products and qualitative change over quantitative change. . .In addition, he will tend to emphasize the significance of the role of experience in facilitating or inhibiting the course of development. (Reese and Overton, 1970, p. 134)

Theories which represent the organismic orientation are; Functionalism (Dewey, Woodworth, Carr, McGeogh, Melton, Robinson, and Underwood), Purposive Behaviorism (Tolman), Gestalt (Wertheimer, Wheeler, Koffka, Kohler, and Lewin), Developmentalism (Piaget, Sheldon, and Bruner) (Knowles, 1973, pp. 23-28).

Conceptual Background

Physiological psychology incorporates aspects of both the mechanistic and organismic models. While sharing a common denominator, the human organism, human psychology and physiology share many other similarities. In their respective developmental phases, both grew in size that, though still "young" sciences, they had grown sufficiently to leave their respective parental roofs. Physiology grew from alchemy to biology to physiology: a differentiated field marked by a body of knowledge, professorships, and a department established within a university. So psychology grew from mental chemistry to associationism to psychology. It too had an expanding body of knowledge, professorships, and departments within universities (Woodworth, 1931, p. 7). Both psychology and physiology find their roots in the laboratory setting. Experimental psychology had taken its direction from such scientists as W. Wundt who in 1879 founded the first active psychological laboratory in Leipzig. It is no surprize to see that physiological psychology is the receiver of that tradition and direction begun almost 100 years ago (Esper, 1964, p. 46).

Currently, physiological psychology is defined as the "study of the physiological basis of human and animal behavior." Within the context of its beginnings it is primarily a "fundamental or pure science, concerned with understanding the physiological events that underlie behavior" (Morgan, 1965, p. 7). The major divisions, like physiology, concern themselves with the senses, the peripheral and central nervous systems, neuronal physiology, the organs and the glands. Behavior is interpreted as a simple response mechanism to afferent stimuli or a series of complex multiple electro-chemical chains. What this branch of psychology can bring to the larger body of knowledge that is called psychology and what it can bring to learning theory in the way of clear cut, empirical, and biologically consistent answers can be beneficial to the field of Education as well.

There are, however, others who have taken their academic preparation in the physiological sciences into another dimension. As Abraham Maslow warns us, "If the only tool you have is a hammer, you tend to treat everything as if it were a nail" (Ornstein, 1968, p. 3). Clearly, an approach based entirely upon empirics may stifle other productive answers to complex questions about human behavior. William James in his classic The Principles of Psychology, defines psychology as the science of "mental life" (Ornstein, 1968, p. 4). That is to say, regarding consciousness, certain amounts of vagueness are appropriate to the state of knowledge.

In their joint paper, Psychology and Scientific Research, Cantril, Ames, Hastorf, and Ittelson echo the concepts of James' when they insist that we must not:

> . . . foreclose the possibilities, must always attempt to maintain a broad and open view of the field and to build science toward the limits, not inward from the "sure and hard facts." (Ornstein, 1968, p. 4).

Cantril, et al, stress that quantification is but one function of science, one that has currently over dominated psychological inquiry to the detriment of a full scope and an open view of the possibilities. The physicist Robert Oppenheimer underscored this feeling when he commented on the scientific and mystical ways of knowing:

> These two ways of thinking, the way of time and history, and the way of eternity and timelessness, are both part of man's effort to comprehend the world in which he lives. Neither is comprehended in the other nor reducible to it . . . each supplementing the other, neither telling the whole story. (Ornstein, 1968, p. 5).

This crossing of both scientific and cultural forces may catapult the study of learning theory to a position where both the intellectual and the intuitive modes can be recognized as performing complementary functions. The blending of scientific and cultural forces can be extrapolated to the blending of both the eastern and western philosophies as well as the blending of the two ways of knowing.

In his book <u>The Nature of Human Consciousness</u>, Robert Ornstein uses an example of how science and direct experience can be used in a complementary manner. It involves a Sufi character named Nasrudin.

> Nasrudin was made a judge and listened to his first case. When the prosecution rested its argument, he stood up and said: 'I believe you are right!' When the defense had finished its summation, Nasrudin again stood up and said: 'I believe you are right!' The clerk of the court came in front of the judge: 'Your honor, they cannot both be right!' 'I believe you are right!', said Nasrudin.

While it is easy to understand this juxtaposition of forces intellectually, it is not nearly so easy to put it into operation when pursuing actual scientific inquiry. John Dewey once remarked,

> It tends to go against the grain of the psychologist's working procedures to regard any formulation merely as a certain 'connection of condition' . . . The interactional treatment, as everyone is aware, entered psychological inquiry just about the time it was being removed from basic position by the physical sciences from which it was copied. (Murphy, 1949, p. 213).

Dewey defines "transactional psychology" as a process which, from birth to death, every human being is a party.

> So that neither he (humankind) nor anything done or suffered can possibly be understood when it separated from the fact of participation in an extensive body of transactions, to which a given human being may contribute and which he modifies, but only in virtue of being a partaker in them. (Ornstein, 1968, p. 17).

Biofeedback, in all its variant forms, is an attempt to involve the organism in that "extensive body of transactions" which allows an individual trained in using biofeedback and autogenic exercise to "contribute" and "modify" the "body of transactions." Biofeedback can provide the opportunity to pursue actual scientific inquiry within the area of the study of human consciousness and still maintain a balance between the empirical and intuitive ways of knowing.

Definition of Biofeedback

Feedback is the return to input of some of the output of a system. An indefinite modification of input and output results from this process even when the feedback is damped. The system acts on information gathered by itself. Biofeedback occurs when the system acts on information gathered by itself, on itself.

> Biofeedback is simply the feedback of biological information to the person whose biology it is. Feedback is a shorthand term for something being 'fed back' to the same something. The expression developed in the field of engineering to define control systems which operate by their ability to detect changes in the environment of their operation, then to make internal adjustment so that their functions remain both optimal and continuously appropriate to the demands of the environment. (Brown, 1974, p. 4).

Definition of Electromyography

Electromyography interest centers on the tension of skeletal muscles. It can be defined as the recording of electrical responses from muscles (Greenfield and Sternback, 1972, p. 329). The electrical responses are direct indices of muscle tension present within the area being measured. Muscle tension, as Jacobson refers to it, is "a vaguely defined state of nervous hypertension or hyperexcitability" (Jacobson, 1938, p. 4). Some of the later writers term this state as "tonus" while others such as Freeman, clearly distinguish between the two by defining "tonus as sustained contraction caused by continuous barrage of nerve impulses" and differentiates the word "tension" for certain events coming under cerebral control" (Freeman, 1931-b, p. 480). Where complete relaxation occurs, there is no muscular contraction, and consequently, no tension (Greenfield and Sternback, 1972, p. 329). Therefore, stimulation of the muscle or muscle group leads to its contraction and to the simultaneous electrical, chemical, structural, and thermal changes that result in the muscle action potential. The record of these electrical events within a specific muscle group makes up the output of an electromyograph (EMG).

Muscle Action Potentials

The typical muscle is an elongated mass of tissue consisting of millions of separate muscle fibers bound together by a sheet of connective tissue. Each time an action potential passes along a muscle fiber, a small portion of electrical activity spreads from the muscle to the skin. The number of muscle fibers involved in the contraction is proportional to the amount of electrical activity which is given off. During the resting state each fiber within the muscle maintains a negative intracellular potential of between 50 to 100 mv. This negative potential is the basis for the phenomenon of the muscle action potential. "Within each cell there is a selectively permeable membrane and a system for active transport of ions" (Greenfield ans Sternbach, 1972, p. 331). In the resting state, negative chloride ions and positive potassium ions move freely in and out of the muscle cell keeping the cell in a homeostatic state. Sodium ions are less capable of diffusion in and out of the cell although they, in the resting state, pass both in and out of the cell. Because of the low reentry rate of sodium ions into the cell, there is a consequent build up of positively charged ions on the outside of the cell and of negatively charged ions inside the cell. A muscle action potential is a brief reversal of the polarization of the ions within the cell or depolarization which caused the cell to become active (Venable and Martin, 1967, p. 249). When the muscle cell becomes active, the permeability of the cell membrane changes to allow the sodium ions to reenter the cell at such a rate that the resultant concentration of the sodium inside the cell returns the muscle cell to a state of rest. This whole procedure occurs within milliseconds of initial activation (Venables and Martin, 1967, p. 251). When the membrane senses that the potential is at zero within the cell or becomes internally positive, permeability to potassium increases and the permeability to sodium decreases. The combined increase in permeability to potassium and the decrease in permeability to sodium causes a rapid fall of the potential to the original resting level. This sudden excitation of the cell results in a traveling, self-propagated area of excitation on the cell membrane.

> This is accompanied by a wave of contraction that spreads over the fiber with constant velocity and diminished amplitude. The contraction of the fibers exerts a force on the tendons. If the force is sufficient, shortening of the fibers occurs. (Greenfield and Sternback, 1972, p. 331).

Motor Units

Since muscle fibers do not contract individually but rather in groups. It is necessary to understand the function of the motor unit. Muscle groups are "innervated" by single nerve fibers called neurons. Innervation is the conjoining of the axonal endings of the neuron to the muscle fiber (Venables and Martin, 1967, p. 249). Just before reaching the muscle fibers, axons of the nerve fiber (neuron) divide into a number of small branches, or axon fibrils. This state resembles the finer gradation of a tree trunk to the smallest twig. Each axon fibril ends on a muscle fiber so that there is usually a one-on-one relationship between muscle fiber and axon fibril. A complete motor unit consists of the nerve cell body, its axon, the axon fibrils, and all of the muscle fibers innervated by these fibrils.

There is an "innervation ratio" which exists between the muscle fibers to nerve axons. The size of the motor unit is directly related to the precision of movement of the particular muscle group involved. For example, the slowly moving postural muscle groups may have as many as 3000 individual muscle fibers to one neuron, while muscles that react rapidly and have a more precise control, such as those which control the eye, have very low innervation ratios, and some as low as ten muscle fibers to one neuron (Basmajian, 1967, p. 34).

Neuronal Anatomy and Functions

Thus far the discussion has been centered around the anatomy of the muscle fiber and the process by which it contracts or relaxes. All cells exhibiting action potentials can be classified into three groups: receptors, adjustor neurons and effectors. Receptors sense afferent environmental stimuli such as heat, light and pressure receptors. Effectors are the cells by which an organism responds to the environment or is a part of the efferent system such as muscle tissue. The adjustor neurons, which are found in a greater number than the receptor and effector cells, connect the effector and receptor cells. The adjustor neuron has three parts: the cell body (soma), the axon, and the dendrites. In most discussions, the axon and dendrites are called "fibers" and are not differentiated unless their characteristic functions are mentioned (Morgan, 1965, pp. 16-23). Dendrites are found in positions around the cell body so that they can be stimulated by environmental stimuli. The dendrites are the receiving end of the adjustor neuron. The axon is connected to effector cells and other neurons and delivers the stimuli or passes it on to the next adjustor neuron. Where the axonal fiber innervates effector cells which are muscles, the juncture is called the myoneural junction (Morgan, 1965, p. 19).

Generically the point of contact between adjustor neuron and effector neuron is called a "synapse" (Lester, 1977, p. 107). Lester explains that,

> At the nerve-muscle synapse the motor-nerve fiber lacks its fatty myelin sheath and branches into fine terminals. Each terminal lies in a shallow gutter-like depression on the surface of the muscle cell. As an impulse arrives at the presynaptic nerve terminal it causes an influx of calcium ions across its membrane. This induces several hundred synaptic vesicles to fuse with the presynaptic membrane at specialized regions called active zones, liberating the vesicles' content of acetylcholine molecules into the synaptic cleft. The transmitter diffuses rapidly across the cleft to the muscle-cell membrane, where it combines with the receptor molecules.
>
> Within .3 milliseconds after each package or vesicle load of acetylcholine is released it causes some 2,000 channels in the muscle-cell membrane to open . . . The flow of these ions (sodium into the cell, potassium out) gives rise to a net electric current that short-circuits the normal potential of -90 micro-volts across the resting cell membrane; this brief depolarization is known as end-plate potential or the excitory postsynaptic potential. Under normal circumstances the end-plate potential exceeds the threshold value for initiating an impulse that spreads through the entire muscle-cell membrane and causes the muscle-cell to contract (Lester, 1977, p. 109).

An enzyme called acetylcholinesterase breaks down the acetylcholine into molecules of acetate and choline. The speed with which acetycholine is passed from the axon to the muscle cell and inactivated makes it possible for the entire process of neuromuscular transmission to be repeated up to several hundred times a second (Lester, 1977, p. 109).

It was this phenomenon of motor units which brought about a new direction in the field of psychology which directed experimentors to the inner bodily systems and their place and function within the framework of human behavior and learning.

SUMMARY OF RELATED RESEARCH

For many years it was a commonly held belief that intense mental work was accompanied by set facial expressions, furrowed brow, and tense posture. The literature tends to justify the opinion that a high level of bodily tension accompanies concentrated mental activity (Grinsted, 1947, p. 379).

Early experimentors, who worked with the knee jerk as an index of muscular tension level, invariably obtained an increase in tension when work begun (Forrest, 1960, p. 325). More recent research has in general confirmed this finding (Jacobson, 1930, 1931, 1932) (Davis, 1938). It was Jacobson who was the first to use electronics and to come to the conclusion that no mental activity occurred without concommitant measurable tension and Davis who further elaborated these findings by demonstrating that particular patterns of muscular activities are associated with certain mental tasks (Davis, 1938, p. 158). There was general agreement in the 1930's among the many investigators that a steep initial rise occurred in muscular tension during a work period but there was little agreement as to the later course of tension as the work period progressed (Forrest, 1960, p. 325). Tension has been found to increase, decrease, and remain constant while work proceeds. Davis in two separate experiments, found that tension increased (Davis, 1938, p. 158). Other experiments by Golla and Antonovich (1926), Freeman (1930), and Geldreich (1953) found tension to decrease and Bills and Brown (1929) found that tension remained constant while work proceeded (Forrest, 1960, p. 326). The Bills and Brown experiment, it is generally thought, lacked a sensitive enough method for recording muscle tension since the work was done before the use of electronic equipment could enhance the reception and amplification of action potentials. The major differences between the group which found tension to decrease and Davis who found that tension increases was twofold: (a) the length of the prescribed task, and (b) the muscle groups that were measured. The tasks given by Davis were no more than five minutes in length (Davis, 1938, p. 139). While the task length for the group who found a decrease in tension lasted between ten to thirty to 55 minutes per task. The protracted lengths of time assigned for the completion of each task may alone account for the decrease in muscle tension due to diminution of concentration needed to complete the tasks (Forrest, 1960, p. 327). Frederick Courts in his article entitled "Relations Between Muscular Tension and Performance," summarized the research from 1930 up to and including 1942 in the area of changes in muscular states of tension accompanying performance by confirming that:

(1) In general, continuous mental work is accompanied by an increase in muscle tension as measured in various ways over the level maintained during rest (Davis, 1938; Freeman, 1931).

(2) Only rarely are individuals found who show no change or decrement from their resting tension when work is introduced (Davis, 1938).

(3) At the onset of work there is an initial increase in tension which rapidly drops to a level somewhat above that of the rest condition (Davis, 1938).

(4) There is an initial spurt of tension after which tension gradually increases as work increases (Davis, 1938).

A number of attempts have been made to show that there is a demonstratable correlation between level of performance and muscular tension. Courts (1942) reports that Davis (1938) and Hadley (1941) both have reported an increase in muscle potentials from the forearm and neck respectively, with increase in difficulty of arithmetical tasks. These findings were later confirmed by Shaw and Kline who concluded:

(1) When children attempted the solution of a series of arithmetic problems, muscle action potentials in their lower right arms increased as the problems increased in difficulty.

(2) When the problems were arranged to take account of the time, and of the number and kind of errors made in the solution of the problems, the tendency for muscle action potentials to increase was more

marked (Shaw and Kline, 1947, pp. 157-158). Davis also found that muscle potentials accompanying successes and failure reported and actual were not significantly different. The level of muscular activity for failure on a given problem was not significantly higher than that for success (Davis, 1938, p. 157). He also made an important discovery when he reported that muscular tensions are not evenly distributed over the organism during a period of labor. This finding is also reported by Shaw (1938). Davis found that the neck and arms to be most yielding of action potentials. In a later study reported by Greenfield and Sternback (1972) of a study which was done by R. Voas dealing with generalization and consistency of muscle tension levels, it was confirmed that when mental work was the task, the areas which yielded the highest incidence of muscle potentials, based upon a test-retest situation, were the forearm extensors (.93), frontalis (.90), masseter (.87), and the trapezius (.69). Voas believed that these were the best choice for representative muscle potentials during mental work (Greenfield and Sternback, 1972, p. 332).

The research which has been summarized has mainly dealt with the influence of effect of tension as measured by muscle action potentials on problem solving, mental activity. Prior to the 1930's and continuing somewhat after Jacobson's work, research done on skeletal muscle tension was limited to observation of tension and quantification through such devices as a "dynomometer" designed to measure optimal levels of skeletal muscle tension induced by squeezing the dynomometer handles. Freeman and Staffacher both suggested that extreme degrees of tension interfere with certain performances and that mental activity was difficult, if not impossible, under extreme relaxation. It was also demonstrated that there were optimal levels of tension which could be identified using the dynomometer.

Concommitant with this particular "strand" of researchers was another important group of researchers whose emphasis lay in pursuing the concept of "single motor units" and their effect on the skeletal muscles as a whole. Some researchers pursued the physiological effects of "single motor units" beginning with O. C. Smith (1934) when he dealt with the concept of the relation between voluntary muscle contraction and muscle action potentials.

It was not, however, thoroughly understood what muscle action potentials were much less how to record them with any degree of accuracy until Jacobson utilized the electromyograph (EMG) to record the "spike waves" with paper and ink. It was not until the works of Harrison, Mortensen, and Basmajian and the advent of the oscilliscope that accurate "pictures" of the "spike" phenomenon was understood and measured with any degree of accuracy. Harrison and Mortensen found that single spike potentials (1) could be interpreted as muscular activity of single motor unit potentials, (2) that the activity of individual motor units could be identified and isolated to a variable degree by voluntary effort, (3) and that either auditory or visual feedback was essential to selection and controlled contraction of single motor units (Harrison and Mortensen, 1962, pp. 115-116). Basmajian further discovered that (1) single motor units not only can be recruited in isolation but also that in doing so, its neighboring units are inhibited, (2) subjects at first depend on aural and visual "feedbacks" from muscles, however, "the controls are learned so quickly, are so exquisite and are so well retained after artificial feedbacks are eliminated that one cannot help believe that fundamental processes are involved," (3) proprioceptors exist within the motor units which are sensory receptors that respond to stimuli from "within" the organism (Basmajian, 1963; Basmajian, 1967, p. 485). Basmajian's discovery that not only do recruited neurons (motor units) inhibit their neighbors but also that one can "learn" to control without biofeedback (artificial) systems leads one to the inescapable conclusion that much more control is possible over the bodily functioning than was previously anticipated. The concept of "proprioception" drives the creative possibilities of application of biofeedback training to even more complex conclusions. Basmajian demonstrated that not only can one learn to selectively control motor unit firings but also that these units respond to not just "external" stimuli but some "internal stimuli." The literal "thinking" of an act can and does trigger the motor unit "prior to conscious or kinetic awareness." This is called "proprioception." The work of Wagman, Pierce, and Burger further elaborates the function and role of the proprioceptive system and its essential sensory information for coordination of motor performance. Three basic observations are herein reported: (1) there is a demonstrated importance of peripheral input (actual muscle movement) in establishing control over individual motor units, (2) during any single training period, less and less effort from other muscles was necessary to activate specific units which were originally dependent in part on contraction, and (3) as the ability of a subject to control motor units became progressively refined and accurate, the subject was able to activate certain higher-threshold units by using less tension than had originally been required to activate the lowest threshold units (Wagman, Pierce, Burger, 1965, pp. 957-958).

In the selection of the problems and hypotheses, the research from both "strands" was considered. Both control of single motor units and the relation between skeletal muscle tension and abstract performance are important. The summarized research leads this author to these conclusions:

1. mental work is related to muscle tension,
2. the relationship of mental work and muscle tension is positively correlated; as work increases, tension increases,
3. mental work of varying degrees is related to muscle tension,
4. the relationship between mental work of varying degrees and

muscle tension is positively related. As mental work becomes more difficult, muscle tension increases,

5. performance time is related to muscle tension,
6. the relationship of performance time to muscle tension is positively correlated. As more time is taken for performance, muscle tension increases,
7. if muscle tension "interferes" with mental performance, mental performance can be improved by lowering muscle tensions.

With these conclusions in mind, the author has pursued answers to the research questions stated in Chapter One (pp. 12 and 13) and subsequently tested the hypotheses listed in Chapter Three (pages 57 and 58).

SUMMARY

This chapter has presented an historical and philosophical background of psychological theories and attempted to relate them to a state-of-the-art discussion of the relationship of physiological psychology and electromyographic feedback. The second section has presented a summarization of the related research as it directly regards the experiment.

Chapter Three will outline the procedures used to organize, collect, and analyze and interpret the data generated by the experiment.

Chapter 3

PROCEDURES

This study was designed to collect data to determine if significant differences existed between a control and experimental group of randomly assigned Montana State University volunteer students, given that the experimental group received electromyographic feedback from the frontalis and trapezius muscle groups and the control group received no feedback when their ability to think abstractly was measured by the number of correct responses to mentally solved mathematical problems of varying degrees of difficulty. Also, the study was designed to collect data relevant to determining the prediction of abstract thinking ability and muscle tension by utilizing selected biographical data. Chapter Three contains a description of the population and sampling procedure, defines and describes the treatment, describes the method for collecting the data, its subsequent organization and display, the statistical hypotheses, and the specific statistical tools used to analyze the data. Precautions for accuracy are also outlined.

POPULATION DESCRIPTION AND SAMPLING PROCEDURE

The sample used in this study was taken from the population of summer students at Montana State University. Summer students are defined as those who were enrolled in the 1977 Summer session at the University. The population contained both undergraduate and graduates.

No attempt was made to stratify the sample to reflect the percentage of undergraduates to graduates.

The author began the week of July 18th to advertise for subjects who, in order to be used in the experiment, were required to meet the population parameters described above (see Appendix A). Fifty applicants were selected; those being the first fifty volunteers who met the population parameters. Fifty-three volunteers responded to the advertisement. Two did not meet the population parameters and lacking another volunteer to match, the remaining volunteer was not used. After the pretest had been given to all applicants, the sample was matched using the number of correct responses on the pretest and the average tension reading taken at rest prior to the pretest. In cases where there were more than two subjects with the same score on the pretest, the average tension reading was used to match the subjects (see Appendix B). Matching was done so as to insure a greater degree of equivalency between the control and experimental group. Using matching as a device to control for extraneous variance is based upon the notion that:

> Matching is not limited to the matching of subjects. If we think of matching in variance terms, we can readily apprehend this point. When certain subsets of the total set of sampled units are more alike than other subsets the variance due to the differences between the subsets is probably present. (Kerlinger, 1964, p. 335).

Matching precipitates several design problems which must be addressed. Unless it can be shown that a "fairly substantial" relationship exists between the dependent variable and the variables chosen for matching, this process becomes a wasted effort as well as being misleading. Secondly, matching places severe limitations on the design. The more variables which are chosen for matching the less chance there will be of finding subjects who possess like attributes or measures (Kerlinger, 1964, p. 311). Thirdly, in the pretest-posttest control group design, the technique of matching should be adjunct to randomization and not used as a substitute for randomization (Campbell and Stanley, 1963, p. 49; Kerlinger, 1964, p. 311).

The author believes that the design sufficiently answers all these major questions raised about the advisability of using the technique of matching. There is a substantial relationship between the dependent variable (abstract thinking ability) and the two variables chosen for matching which are (1) the individual's ability to think abstractly as measured by the number of correct responses on the pretest, and (2) the amount of muscular tension exhibited by two muscle groups who are associated with mental work; those being the trapezius and the frontalis (Greenfield and Sternback, 1972, p. 339). Each subject had both measures used for the matching variables as they were taken in the pretest prior to any attempts to match the subjects. Randomization through a volunteer process as well as matching was used to insure an equivalency between the control and experimental groups through control for extraneous variance.

After the matching was completed, the pairs were then randomly assigned to the control or experimental group. Group means were subsequently computed using the total scores on the pretest and the pretest item tension average of the subjects to further validate the similarity of the control and experimental groups. A Student's "t" for independent samples was used (Nie, et al, 1970, pp. 270-271) to determine whether the group means of both the raw scores and pretest item tension averages were significantly different. This test was performed with the following results:

TABLE 1.

t - Test Independent Samples
Pretest Raw Scores

	Experimental Group	Control Group
No. of Cases	25	25
Mean	9.60	9.40
Standard Deviation	3.77	4.14
"t" Value	.178	
df	48	
2-Tailed Probability	.859	

The differences found between the group means of the control and experimental groups subsequently obtained to matching and random assignment shows that they are significant at the .85 alpha level. The probability of such differences in group means, for that degree of freedom, occurring by chance is 85 out of 100 times. This may be interpreted to indicate that the matching and random assignment to groups produced two closely equivalent groups in regards to their ability to think abstractly as measured by the raw scores on the pretest.

The following table shows the result of the Student "t" performed on the pretest item tension averages.

TABLE 2.

t - Test Independent Samples
Pretest Item Tension Averages

	Experimental Group	Control Group
No. of Cases	25	25
Mean	3.32	2.63
Standard Deviation	.365	.796
"t" Value	1.71	
df	48	
2-Tailed Probability	.092	

The differences found between the group means of the control and experimental groups subsequently obtained to matching and random assignment shows that they are significant at the .09 @ level. The probability of such differences in group means, for that degree of freedom, occurring by chance is 9 out of 100 times. This may be interpreted to indicate that the matching and random assignment to groups, done primarily on the basis of the pretest raw score data, produced two closely equivalent groups when the pretest item tension averages were used to match subjects when more than two possessed the same raw score.

DEFINITION OF TREATMENT

The treatment occurred when the experimental group of 25 subjects were identified, contacted by the experimentor, and scheduled for the treatment session. At the same time, the control group was scheduled for the posttest. This scheduling was done to insure that the time span was as close to being the same for the control group and experimental group with regard to the taking of the pre and posttest.

The treatment was administered in the Cortical Function Laboratory on the campus of Montana State University. The treatment consisted of autogenic exercises as outlined by Dr. Wolfgang Luthe, M. D. in his Volume I of the series "Autogenic Therapy," (Luthe, 1969b) entitled Autogenic Techniques. The autogenic treatment consisted of an introduction of the method of relaxation, a portion of which was broken down into the following segments:

(1) reduction of afferent stimuli.

(2) training pattern and passive concentration.

(3) a standard exercise involving tension-relaxation of the frontalis and trapezius muscle groups.

The first segment (reduction of afferent stimuli) was in part accomplished by the physical environment in which the subjects were tested. The booth used for the experiment was sound-proofed so as to promote the reduction of afferent (in-coming) stimuli. This "closing off" of afferent stimuli from the physical environment is the essential first step in the reduction of tension. Without "turning off" external stimuli, the reticular activation system (RAS) will not allow an internal reduction of stimuli (Ornstein and Naranjo, 1971, p. 143). The booth brings the effect of stabilizing images to a degree that awareness of external stimuli can be reduced. Without the variety of visual stimuli normally available, large eye movements called "sacades" are reduced. These gross eye movements which are fixations at various points in the visual field along with very small involuntary movements called "optical nystagmus" help keep the retina in constant motion. The effect is that awareness of afferent stimuli is maintained at a level sufficient to keep the body and mind at a steady state of readiness (Ornstein and Naranjo, 1971, pp. 165-167). There is a documented contiguity between stabilization of visual images and the production of alpha rhythms. Alpha rhythms are:

> . . . usually thought of as representing a state of decreased visual attention to the environment. It is increased almost always when the eyes are closed or when the eyes are rolled up into the head - when vision is turned down. (Ornstein, 1971, p. 165)

Lehmann, Beeler, and Fender in their investigations into brain states evoked by stabilizing images (Lehmann, et al, 1967) found that the alpha rhythm was likely to appear at the time when the subject reached a state of visual stabilization. Other ways to produce this reduced state of awareness are closing the eyes or concentration on a patternless visual field called a "ganzfeld" (Ornstein and Naranjo, 1971, p. 166).

The second segment of the treatment called for the establishment of a training pattern and passive concentration. This simply means that a pattern be established which can be used by the subjects when they employ the autogenic exercises to reduce muscular tension or anxiety. Passive concentration is the application of the training pattern or regimen so that unconsciousness does not occur. If, as in segment one, the subject reduced all afferent stimuli, sleep or unconsciousness would occur. This, for obvious reasons, is not a desirable state for the experiment when a specific degree of alertness will be required to solve the mathematical problems. The use of the training pattern keeps the subject "alert" enough so as complete (unconsciousness) relaxation does not occur.

The third segment (muscle exercises) is designed to focus on the specific muscle group or groups which are identified for intensive and deep relaxation. This process involves "tension-relaxation" of each muscle group. Each subject was asked to tense and relax the two muscle groups (frontalis and trapezius), first each muscle group separately and then together. These structured exercises are designed to increase the subjects awareness of what tension and relaxation "feels" like relative to each specific muscle group. During the tension-relaxation exercises the subject was "hearing" the analogue feedback from the two muscle groups so that aural as well as kinetic feedback heightened the experience.

Utilizing these three segments, the subjects' feedback was "shaped" by using an audio threshold-selector on the Autogen 1700. This device allows the experimentor to adjust the audio threshold level of the incoming signal (muscle potentials). When activated, the Audio Feedback Threshold Selector determines the minimum or maximum absolute level of EMG activity required for any of the audio feedback signals to be present. Shaping is then performed by either raising or lowering the absolute level of EMG required to produce the audio feedback signal.

As each subject went through his/her exercises under the guidance of the experimentor, an absolute level was found. The subject was then told to maintain the audio signal which meant to retain the level of relaxation necessary to maintain the feedback audio signal. The threshold selector was set so that if the subject became tense in the trapezius or frontalis muscle groups, the audio feedback signal would cease. The experimentor, on the subject's maintenance of the signal subsequent to the setting of an absolute level of EMG feedback, would then leave the booth instructing the subject to maintain the signal. After ten minutes had elapsed, the experimentor would again reenter the booth and, if possible, adjust the threshold selector downwards so that a deeper state of relaxation was necessary in order to continue the audio feedback signal. The entire training session lasted no more than thirty minutes for each subject in the experimental group.

The treatment sessions were carried out in the laboratory to attempt to insure the most similar environmental factors for all subjects. Each session occurred in the Cortical Function Laboratory where each subject was seated in a reclining chair situated in a shielded, sound-proof booth. All treatment sessions, as well as pre and posttest sessions, were carried out by the experimentor in order to reduce the amount of possible intervening variables which could contaminate the treatment session and collection of data.

The Autogen 1700, an electromyograph machine was used to supply the experimental group with audio-feedback and measure the muscle potentials (tension indices) for the experimentor (see Appendix C). The experimentor recorded the data on a pre-printed data sheet (see Appendix D) and performed all treatment regimens utilizing an exact step-by-step presentation (see Appendix E) for each subject attempting to insure a high degree of uniformity for each treatment application.

METHOD OF DATA COLLECTION

As the subjects arrived at the laboratory, they were given an explanation of the general procedures of the pre and posttest sessions. They were not told the specifics of the research design nor were they given the hypothesis or research questions. This procedure was followed so that such knowledge would not bias their response to the experiment. Each subject was then asked to read and fill out the waiver and data sheet supplied by the experimentor. (see Appendix F). The subject was then placed in the booth and seated in an overstuffed reclining chair and given the instructions for the pretest. These were:

(1) mentally solve the mathematical problems given you on each 3 X 5 card. I will hold the cards for you.

(2) you have twenty seconds to solve each problem.

(3) respond with your answer or if you cannot solve the problem, give no response.

(4) I will not verify the answers for you.

(5) the problems are addition, subtraction, multiplication and division of fractions. Each problem will vary in degree of difficulty.

(6) a rest period will be observed between each problem.

(7) do not make unnecessary movements during the solution period.

(8) do you have any questions concerning the directions I have just given you?

An attempt was made to not vary the presentation of directions nor the subsequent test procedures by using an experiment checklist (see Appendix E) designed by the experimentor.

The test procedure then began by interfacing the subject to the Autogen 1700 by attaching the six electrodes. Three were attached to the frontalis and three to the trapezius. The Autogen batteries were checked using the Battery Test Function scale. The microvolt meter was centered to insure a variance for deflection. The Averaging Time Selector was set for twenty (20) seconds. The Audio Feedback Mode Selector was set to AN-1 which is the "variable pulsated analog tone feedback." This audio output consists of "a pulsating tone which varies both in pitch and pulsation rate in logrhythmic proportion to the EMG activity level" (Autogen 1700 Instructional Manual, 1975, p. 24). During the pretest, no audio feedback was given to the subject. It was observed, however, by the experimentor on the microvolt meter on the Autogen. The subject could not see the front of the EMG.

The posttest was conducted in the same manner with the exception that audio feedback was present. During the treatment, the same general checklist was used to interface the experimental group subjects to the Autogen 1700.

The experimentor used the Autogen 1700 to provide accurate measures of muscle potentials in units of microvolts. The responses to the pretest and posttest were recorded on pre-printed, individual subject forms by the experimentor. A stop watch was used by the experimentor on the posttest to measure the time needed by each subject to solve the problem.

The mathematical test involved a twenty item, mentally solved mathematical test involving the addition, subtraction, multiplication, and division of fractions (see Appendix G). These problems were generated by the Sigma-7 computer utilizing an interactive program. The level of difficulty for each item was assessed by item analysis of the pretest results. The level of difficulty was then assigned to each problem by the experimentor. Twenty problems were preordered for each session using a computer program which generated fifty random orderings of the twenty problems (see Appendix H) so that no consistent patterning would affect the test results. Each problem was placed on an individual 3 X 5 card for presentation.

The experimentor had received training on the Autogen 1700 by Dr. William Jankel, head of the Cortical Function Laboratory and continued throughout the experiment to be under the laboratory auspices.

METHOD OF ORGANIZING THE DATA

The data are presented in graphic and tabular form under two main divisions in Chapter Four. The first division concerns all data related to the statistical hypotheses which concern measures of differences and the second concerns the statistical hypotheses which analyze the results of the multiple regression analysis. This division facilitates the presentation in that a differeng statistical treatment of each division will precipitate a particular format for each treatment.

The first division shows different graphs and tables while the second division displays graphs and tables dealing with multiple regression values.

STATISTICAL HYPOTHESES

The problem statement when transformed into statistical hypotheses is:

1. There will be no significant difference between control and experimental group posttest means based upon abstract thinking ability raw scores.

2. There will be no significant difference between the pre-test and posttest group means of the experimental group based upon abstract thinking ability raw scores.

3. There will be no significant difference between the pretest and posttest group means of the control group based upon abstract thinking ability raw scores.

4. There will be no significant difference between control and experimental group means based upon average posttest item tension readings.

5. There will be no significant difference between the pretest and posttest group means of the experimental group based upon average item tension readings.

6. There will be no significant difference between the pretest and posttest group means of the control group based upon average item tension readings.

7. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict abstract thinking ability using pretest mathematics test scores as the dependent variable.

8. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict abstract thinking ability using posttest mathematics test scores as the dependent variable.

9. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using pretest EMG tension readings as the dependent variable.

10. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using posttest EMG tension readings as the dependent variable.

ANALYSIS OF DATA

Hypotheses 1 - 6 in their null form were tested and reported in Chapter Four using the Student's "t" statistic for independent and dependent samples. Student's "t" is a statistic in which sample means are used to estimate population means. The "t" distribution is well suited from the standpoint of its ability to perform well when small "n" samples are used (Snedecor and Cochran, 1967, pp. 59-60). An alpha level of .05 was used as the level of significance for the "t" tests. This means that the null hypothesis can be rejected if the statistic ("t") is equal to or greater than the table value (two-tailed test) at the appropriate degree of freedom (df) and alpha level of (.05).

The null form of hypotheses 7 - 10 were tested using multiple regression. Multiple regression is a statistical procedure designed to produce an equation to predict a value of one variable (dependent variable) from values on two or more other variables (independent variables), to make such prediction, and to test the reliability of this prediction.

PRECAUTIONS TAKEN FOR ACCURACY

All statistical computations were done on the Sigma-7 computer on the campus of Montana State University utilizing the Student's "t" and Multiple Regression subprograms within the SPSS (Statistical Package for the Social Sciences).

SUMMARY

Chapter 3 presents the procedures used to collect supportive data of the notion that electromyographic feedback coupled with autogenic training of college student subjects can elicit statistically significant differences between an equal group of college students who have not received feedback or autogenic training. The population parameters have been described as well as the sampling procedure used to obtain a random sample of fifty students. It describes the procedure that will be used to insure the control and experimental group's equivalence.

The treatment is defined and source for the autogenic exercise is cited and use of the Autogen 1700 electromyograph proposed as the measuring device for muscle potentials and as the means of feedback for the subjects. Collection and organization of the data is outlined.

Hypotheses for the restatement of the problem and general questions are presented in their null form. Analysis of the data is discussed explaining that Student's "t" was used to test differences in H^0 1 through 6 and that multiple regression analysis was used to test the alleged relationships between selected dependent variables and independent variables in H^0 7 through 10.

Chapter 4

DATA ANALYSIS

Chapter Four presents the data analysis in two major sections. The first section presents the data and analyses of the Student's "t" statistic relating to the testing of hypotheses 1 through 6. The second section presents the data and analyses of a series of five variable multiple regression equations produced to test hypotheses 7 through 10. The chapter ends with a general summary of the findings and analyses.

SECTION ONE: STUDENT'S "t"

This section concerns all data collected to test statistical hypotheses 1 through 6 (see pp. 57 and 58). Section one relates the measures of difference between experimental and control group means of:

1) raw scores obtained on a mathematics test designed to yield measures of abstract thinking ability, and
2) test item tension indices recorded during the pre and post administration of the mathematics test utilizing an electromyograph (EMG).

Hypotheses 1 through 3 relate to mathematics test scores and hypotheses 4 through 6 relate to test item tension indices.

The following diagram represents the basic research paradigm used in the analysis of the data.

	Pretest	Posttest
Experimental Group		
Control Group		

Hypothesis 1, Table 3, is a Student's "t" test for independent samples and Hypothesis 2 and 3, Tables 4 and 5, are Student's "t" tests for dependent samples.

The following diagrams should simplify the relationship between the three hypotheses and their statistical table format.

Hypothesis 1/Table 3	Pretest	Posttest
Experimental Group		(E) POT
Control Group		(C) POT

Hypothesis 2/Table 4	Pretest	Posttest
Experimental Group	(E) PRT	(E) POT
Control Group		

Hypothesis 3/Table 5	Pretest	Posttest
Experimental Group		
Control Group	(C) PRT	(C) POT

The identical paradigms and statistical treatments also occur for Hypotheses 4 through 6.

Hypothesis 1

There will be no significant difference between control and experimental group posttest means based upon abstract thinking ability raw scores.

TABLE 3
t-Test: Independent Samples of Raw Scores of Abstract Thinking Ability Test/Posttest

		Experimental Group	Control Group
Number of Cases		25	25
Mean		12.84	10.72
Standard Deviation		3.51	3.74
Standard Error		.703	.749
F Value	1.133		
2-Tailed Probability	.761		
Pooled Variance Estimate			
t Value	2.06		
Degrees of Freedom	48		
2-Tailed Probability	.045		
Separate Variance Estimate			
t Value	2.06		
Degrees of Freedom	47		
2-Tailed Probability	.045		

When comparing means of independent samples given that their populations have unequal variances, a Student's "t" cannot be computed for the difference in sample means. Instead, an approximation to Student's "t" can be computed. However, the probability for Student's "t" may be approximated by treating it as "t" even though the statistic is not distributed as Student's "t". An F test of sample variances may be performed to ascertain whether the two sample means have the same variance (Nic, Hull, et al, 1979, pp. 269-270). The null hypothesis (sample variances are equal) with alternative (sample variances are not equal) and a significance level alpha is chosen. For purposes of this investigation the researcher has chosen .05 as alpha level. The F value is computed by dividing the larger sample variance by the smaller sample variance.

Should the probability for F be greater than the alpha, the null is retained and the Student's "t", based upon the "pooled variance estimate," is used to determine the significance of the difference between sample means. Should the probability for F be less than or equal to the alpha, the null is rejected and the Student's "t," based upon the "separate variance estimate" is used.

Table 3 displays an F value (1.133) whose probability (.761) is greater than .05 alpha. Therefore, the null is retained and the "pooled variance estimate" is used in the analysis.

The differences found between group means of the experimental and control groups yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. The probability of obtaining such differences by chance, between group means for 48 degrees of freedom is 4.5 times out of 100 times. Therefore, since the hypothesis was tested at the .05 alpha level the null hypothesis is rejected. In operational terms of this research study it can be stated that, based upon the evidence collected concerning Hypothesis 1, a significant difference in abstract thinking ability occurred between experimental and control group samples. It can be inferred from this evidence that the difference may most probably be the result of the "treatment" which consisted of autogenic relaxation exercises taught to the experimental group sample. Based on the data analyzed for Hypothesis 1, it can be stated that the experimental group scored significantly higher on the abstract thinking ability than did the control group.

Hypothesis 2

There will be no significant difference between the pretest and posttest group means of the experimental group based upon abstract thinking ability raw scores.

TABLE 4
t-Test: Dependent Samples of Raw Scores of Abstract Thinking Ability Test

Pre vs. Posttest/Experimental Group

	Pretest	Posttest
Number of Cases	25	25
Mean	9.60	12.84
Standard Deviation	3.77	3.51
Standard Error	.754	.425

Difference

Mean	-3.24
Standard Deviation	2.14
Standard Error	.429

Correlation

Correlation Coefficient	.829
2-Tailed Probability	.000
t Value	-7.54
Degrees of Freedom	24
2-Tailed Probability	.000

The differences which were measured between the experimental group sample's pretest mean and the posttest mean yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. This does not imply absolute certainty about the decision to reject or retain the null hypothesis. The alpha level is a sub-routine function of the SPSS program used in the computer analysis and prints the significance level to only three places to the right of the decimal. Any significant number past the third place does not appear on the printout. Therefore, with the available data, the probability of obtaining such group mean differences, by chance, for 24 degrees of freedom is .00 times out of 100 times. Therefore, since the hypothesis was tested at the .05 alpha level, the null hypothesis is rejected.

Operationally this means that, based upon the evidence collected concerning Hypothesis 2, a statistically significant increase in abstract thinking ability occurred as evidenced by the difference in means of the experimental sample's pretest scores and posttest scores. Table 4 shows an increase in group means from 9.60 to 12.84. It can be inferred from this evidence that the difference may most probably be the result of the "treatment" which consisted of autogenic relaxation exercises taught to the experimental group sample.

Based on the evidence collected for Hypothesis 2, it can be said that the experimental group scored significantly higher on the posttest administration of the abstract thinking ability than they had on the pretest administration.

Hypothesis 3

There will be no significant difference between the pretest and posttest group means of the control group based upon abstract thinking ability raw scores.

TABLE 5
t-Test: Dependent Samples of Raw Scores of Abstract Thinking Ability Test

Pre Vs. Posttest/Control Group

	Pretest	Posttest
Number of Cases	25	25
Mean	9.40	10.72
Standard Deviation	4.14	3.74
Standard Error	.828	.425

Difference

Mean	-1.32
Standard Deviation	1.79
Standard Error	.359

Correlation

Correlation Coefficient	.901
2-Tailed Probability	.000
t Value	-3.67
Degrees of Freedom	24
2-Tailed Probability	.001

The differences which were measured between the control group sample's pretest mean and the posttest mean yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. Based upon this statistical evidence concerning Hypothesis 3, a statistically significant increase in abstract thinking ability occurred. The probability of obtaining such group mean differences, by chance, for 24 degrees of freedom is .001 times out of 1000 times. Therefore, since the hypothesis was tested at the .05 alpha level the null hypothesis is rejected. Table 5 shows a significant increase in group means from 9.40 for the pretest to 10.72 for the posttest. This statistically significant difference in means between the control group pre and posttest was not anticipated as an effect by the investigator. Some increase in means was expected; however, an increase of statistically significant proportions was not expected. This increase may bring one to the conclusion that the two groups, both the control and experimental samples, were not "equal" in their abilities during the administration of the pretest. As is detailed in Chapter 3, Procedures, subsequent to the administration of the pretest to all subjects regardless of a division into control and experimental sample groups, each subject was then matched with another subject. The matching was based upon their pretest mathematical scores. In the case of multiple like scores, the average item tension indices were used to insure that both control and experimental samples displayed similar attributes over the two independent variables in the research investigation. A Student's "t" statistic for independent samples was calculated by the researcher between the mathematical raw score pretest means for both the control and experimental group samples. It was found that the difference between group means (experimental = 9.60 and control = 9.40) was not statistically significant. The calculations resulted in a Student's "t" of .866 with a two-tailed probability of .395, or 39.5 times out of 100 times such an observed difference in means could occur by chance. This difference does not meet the criteria set by the researcher of .05, or 5 times out of 100 times. The two distributions of raw scores of both the control and experimental groups yielded a Pearson Product Moment Correlation coefficient of .961 with a two-tailed probability of .000. This demonstrated, to the satisfaction of the researcher, that according to the two main dependent variable effects in this investigation, the control and experimental groups were successfully matched and that subsequent posttest measures of these two dependent variables would be accurate measures of increase or decrease of abstract thinking ability or skeletal muscle tension.

Relevant internal validity factors such as maturation and testing (Campbell and Stanley, 1963, p. 5 and p. 14) may in fact be the cause for the observed differences between control pre and posttest means. However, within the "pretest-posttest control group design" employed for this investigation, controls for internal validity regarding maturation and testing "are controlled in that they should be manifested equally in experimental groups and control groups" (Campbell and Stanley, 1963, p. 14).

Given the evidence of the experimental design's capability to control for the effects of maturation and testing, any differences between experimental group pre and posttest means and control group pre and posttest means are "manifested equally," that is to say, such effects manifest themselves equally in both control and experimental groups and do not abrogate any differences found between experimental and control groups. In this light, it can be observed that although there were statistically significant differences between experimental pre and posttest means and control group pre and posttest means, it does not necessarily cast doubt on the validity of differences observed between experimental and control group posttest means.

The following table shows the relationship between the group means of the experimental and control groups and the pre and posttest administration of the mathematical test of abstract thinking ability.

TABLE 6
Group Means: Raw Scores of Abstract Thinking Ability Test

	Pretest Mean	Posttest Mean	difference
Experimental Group	9.60	12.84	+3.24
Control Group	9.40	10.72	+1.32
difference	-.20	-2.12	

Hypothesis 4

There will be no significant difference between control and experimental group means based upon average posttest item tension readings.

TABLE 7

t-Test Independent Samples of Item Tension Readings/Posttest

		Experimental Group	Control Group
Number of Cases		25	25
Mean		2.36	3.08
Standard Deviation		.747	1.80
Standard Error		.149	.699
F Value	1.70		
2-Tailed Probability	.100		

Pooled Variance Estimate

t Value	-1.56
Degrees of Freedom	48
2-Tailed Probability	.124

Separate Variance Estimate

t Value	-1.56
Degrees of Freedom	47
2-Tailed Probability	.129

When comparing means of independent samples given that their populations have unequal variances, a Student's "t" cannot be computed for the difference in sample means. Instead, an approximation to Student's "t" can be computed. However, the probability for Student's "t" may be approximated by treating it as "t" even though the statistic is not distributed as Student's "t." An F test of sample variances may be performed to ascertain whether the two sample means have the same variance (Nic, Hull, et al, 1970, pp. 269-270). The null hypothesis (sample variances are equal) with alternative (sample variances are not equal) and a significance level alpha is chosen. For purposes of this investigation the researcher has chosen .05 as the alpha level. The F value is computed by dividing the larger sample variance by the smaller sample variance.

Should the probability for F be greater than the alpha, the null is retained and the Student's "t", based upon the "pooled variance estimate," is used to determine the significance of the difference between sample means. Should the probability for F be less than or equal to the alpha, the null is rejected and the Student's "t", based upon the "separate variance estimate" is used.

Table 7 displays an F value (1.70) whose probability (.100) is greater than .05 alpha. Therefore, the null is retained and the "pooled variance estimate" is used in the analysis.

The differences found between group means of the experimental and control groups yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. The probability of obtaining such differences, by chance, between group means for 48 degrees of freedom is 12.4 times out of 100 times. Therefore, since the hypothesis was tested at the .05 alpha level, the null hypothesis is retained.

In operational terms of this research investigation it can be said that, based upon the evidence, a statistically significant difference was not found between posttest group means of item tension measures of the experimental and control groups. It appeared that the treatment had no effect on skeletal muscle tension when experimental and control group posttest item tension indices are compared.

Hypothesis 5

There will be no significant difference between the pretest and posttest group means of the experimental group based upon average item tension readings.

TABLE 8
t-Test: Dependent Samples of Item Tension Readings

Pre vs. Posttest/Experimental Group

	Pretest	Posttest
Number of Cases	25	25
Mean	3.32	2.36
Standard Deviation	.365	.747
Difference		
Mean	.958	
Standard Deviation	1.917	
Standard Error	.383	
Correlation		
Correlation Coefficient	.078	
2-Tailed Probability	.710	
t Value	2.49	
Degrees of Freedom	24	
2-Tailed Probability	.020	

The differences which were measured between the experimental group sample's pretest and posttest mean yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. The probability of obtaining such group mean differences, by chance, for 24 degrees of freedom is 2 times out of 100 times. Therefore, since the hypothesis was tested at .05 alpha level, the null hypothesis is rejected.

Operationally, it can be stated that, based upon the evidence collected concerning Hypothesis 5, a statistically significant decrease in skeletal muscle tension occurred between the pre and posttest administration of the abstract thinking ability test. Table 8 shows a significant decrease in item tension readings between the pretest and the posttest experimental group mean which is most probably the result of the treatment.

Hypothesis 6

There will be no significant difference between the pretest and posttest group meansof the control group based upon average item tension readings.

TABLE 9

t-Test: Dependent Samples of Item Tension Readings

Pre vs. Posttest/Control Group

	Pretest	Posttest
Number of Cases	25	25
Mean	2.63	3.08
Standard Deviation	.796	1.80

Difference

Mean	-.450
Standard Deviation	3.37
Standard Error	.360

Correlation

Correlation Coefficient	.263
2-Tailed Probability	.203
t Value	-1.25
Degrees of Freedom	24
2-Tailed Probability	.222

The differences which were measured between the control group sample's pretest and posttest mean yields a Student's "t" statistic which is significant when tested at the .05 level using a two-tailed alternative. The probability of obtaining such group mean differences, by chance, for 24 degrees of freedom is 22.2 times out of 100 times. Therefore, since the hypothesis was tested at the .05 level, the null hypothesis is retained.

In operational terms of this research study it can be stated, based upon the statistical evidence, a statistically significant difference was not obtained between pre and posttest item tension readings. However, the difference did indicate an increase in skeletal muscle tension within the control group, which did not receive the autogenic relaxation exercise training. Table 9 shows this increase to be .450 units of tension from the pretest to posttest administration of the mathematics test.

SECTION TWO: FIVE VARIABLE MULTIPLE REGRESSION

This section presents the data and subsequent analysis of Hypotheses 7 through 10. Each hypothesis is analyzed using a multiple regression equation consisting of five independent variables. Section Two uses the following five (5) independent variables in the regression equations:

1. gender
2. age
3. marital status
4. undergraduate GPA
5. handedness

The following four (4) hypotheses (7, 8, 9, and 10) have two (2) sets of tables for each hypothesis. These tables are presented in the following formats.

Summary Table

Multiple-R	.XXX	Analysis of Variance	DF	SS	MS	F
R-Square	.XXX					
Standard Error	X.XX	Due to Regression	XX	X.XX	X.XX	X.XX
		About Regression	XX	X.XX	X.XX	
		Total	XX	X.XX		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
XXXXXXXXXXXX	X.XX	X.XX	X.XX	.XXX	.XXX
Constant: (X.XX)					

In the above Summary Table format example, there are two (2) divisions of the data. The first division deals with the dependent variable and its five (5) independent variables as if the problem were a bivariate correlation analysis. It is concerned with determining the strength of dependency or, equivalently, the amount of variation in the dependent variable that can be explained by linear dependence upon the five (5) independent variables operating jointly. Multiple-R and R-Square are interpreted as if they were the products of bivariate correlation analysis. The R-Square represents the percentage of variation within the dependent variable which could be accounted for by the five (5) independent variables operating jointly. The Standard Error is interpreted as being the average error in predicting a dependent variable value from the five (5) independent variables. The Standard Error represents the average deviation by predicted scores from actual scores. The use of the Analysis of Variance sub-routine allows for inferential analysis of the regression statistics. These statistics allow the researcher to apply statistical inference procedures in the determination of confidence limits for estimates and in testing hypotheses. This step was taken in the analysis to perform hypothesis testing, known procedurally as the "overall" test for goodness of fit of the regression equation. The "F" ratio allows one to determine whether or not R-square is zero (0) in the population from which the sample was drawn. "DF" is the degrees of freedom, "SS" is the Sums of Square, and "MS" is the Mean Square.

The second division of each multiple regression table deals with the influence of each independent variable on the dependent variable while holding constant the effect of the remaining four independent variables. The column labeled "Variable" contains the independent variables entered into the multiple regression equation. The column labeled "B" is the unstandardized regression coefficient. "Standard Error of Beta" is the amount of error that occurs between the sample's Beta and the population value of Beta due to sampling variability. "Student's 't'" is computed as a test of significance for Beta which is used as an alternative to examining the confidence interval. "Partial R" is a regression coefficient which expresses the relationship of the dependent variable and a selected independent variable when all other independent variables are held constant or otherwise controlled for. A partial regression coefficient stands for the expected change in the dependent variable with a change of one unit in a selected independent variable. "BETA" is the standardized regression coefficient, also referred to as the "beta weight." Beta weights are preferred as elements within a prediction formula because of their straightforward interpretation. The "beta weight" also allows the researcher to compare the relative effect on the dependent variable by each independent variable when the independent variables are comprised of different units of measure (i.e. age, sex, GPA).

The following Table 10 displays the mean, standard deviation, and number of cases of dependent variables (mathematical raw scores) entered into the multiple regression equation. (Hypotheses 7 and 8).

TABLE 10

Dependent Variable	Mean	Standard Deviation	Number of Cases
Pretest-Experimental	9.60	3.77	25
Pretest-Control	9.40	4.14	25
Posttest-Experimental	12.84	3.51	25
Posttest-Control	10.72	3.74	25

The following Table 11 displays the mean, standard deviation, and number of cases of dependent variables (item tension indices) entered into the multiple regression equation. (Hypotheses 9 and 10).

TABLE 11

Variable	Mean	Standard Deviation	Number of Cases
Pretest-Experimental	3.32	.365	25
Pretest-Control	2.63	.796	25
Posttest-Experimental	2.36	.747	25
Posttest-Control	3.08	1.80	25

The following Table 12 displays the mean, standard deviation, and number of cases for independent variables entered into the multiple regression equation. (Hypotheses 7, 8, 9, and 10).

TABLE 12

Independent Variables	Mean	Standard Deviation	Number of Cases
Gender	1.40	.49	50
Age	31.04	7.15	50
Marital Status	1.26	.47	50
Undergraduate GPA	2.96	.43	50
Handedness	1.14	.35	50

The values in Table 12 were encoded from the data sheets filled out by the researcher on each subject in the following manner.

Variable	Encoded Value Equivalents
Gender	1 = Male / 2 = Female
Age	Actual chronological age
Marital Status	1 = Married / 2 = Single
Undergraduate GPA	Actual grade point equivalents
Handedness	1 = Right Handed / 2 = Left Handed

The raw data summary may be more closely reviewed in Appendix I, page 192.

Hypothesis 7

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using pretest mathematical test scores as the dependent variable.

Multiple Regression: Pretest Raw Scores of Abstract Thinking Ability Test/Selected Biographical Independent Variables-Experimental and Control Groups

TABLE 13

Pretest-Experimental/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.469					
R-Square	.220					
Standard		Due to Regression	5	75.46	15.09	1.08
Error	3.745	About Regression	19	266.53	14.02	
		Total	24	342.00		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	-3.78	1.91	-1.98	-.414	-.501
Age	.16	.13	1.27	.280	.337
Marital Status	- .81	1.72	- .47	-.107	-.102
Undergraduate GPA	.40	2.07	.20	.044	.043
Handedness	- .08	2.74	- .03	-.006	-.007
constant: (9.564)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 1.08 is not equal to or greater than the "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict abstract thinking ability using experimental group pretest mathematical test scores as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of .220, it can be said that 22 percent of the variation in the pretest-experimental sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not diviate greater than 3.745 units on the mathematic test scale is .6826.

TABLE 14

Pretest-Control/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.615					
R-Square	.378					
Standard		Due to Regression	5	155.97	31.19	2.31
Error	3.670	About Regression	19	256.02	13.47	
		Total	24	412.00		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	-3.39	1.64	-2.06	-.427	-.409
Age	.02	.11	.19	.047	.037
Marital Status	-3.78	2.02	-1.87	-.393	-.373
Undergraduate GPA	3.36	1.70	1.97	.412	.385
Handedness	1.75	2.16	.81	.182	.158
Constant: (5.854)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 2.31 is not equal to or greater than the "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict abstract thinking ability using control group pretest mathematical test scores as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of .378, it can be said that 37.8 percent of the variation in the pretest-control sample group can be explained by the five independent variables operating jointly. The probability that an actual score will not deviate greater than 3.670 units on the mathematical test scale is .6826.

Hypothesis 8

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using posttest mathematical test scores as the dependent variable.

Multiple Regression: Posttest Raw Scores of Abstract Thinking Ability Test/Selected Biographical Independent Variables-Experimental and Control Groups

TABLE 15

Posttest-Experimental/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.488					
R-Square	.238					
Standard		Due to Regression	5	70.89	14.17	1.19
Error	3.452	About Regression	19	226.47	11.91	
		Total	24	297.35		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	-4.01	1.76	-2.28	-.463	-.570
Age	.21	.12	1.76	.375	.462
Marital Status	.10	1.59	.07	.015	.014
Undergraduate GPA	.58	1.91	.30	.069	.066
Handedness	.74	2.52	.30	.067	.070

Constant: (8.989)

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 1.19 is not equal to or greater than the "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict abstract thinking ability using experiment group posttest mathematical test scores as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of 238, it can be said that 23.8 percent of the variation in the posttest-experimental sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than 3.452 units on the mathematical test scale is .6826.

TABLE 16
Posttest-Control/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.674					
R-Square	.455					
Standard		Due to Regression	5	153.46	30.69	3.18
Error	3.108	About Regression	19	183.57	9.66	
		Total	24	337.03		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	-4.15	1.39	-2.98	-.564	-.554
Age	.02	.10	.20	.045	.037
Marital Status	-2.99	1.71	-1.74	-.370	-.325
Undergraduate GPA	2.93	1.44	2.04	.423	.372
Handedness	1.73	1.83	.94	.211	.173
Constant: (8.631)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 3.18 is equal to and greater than an "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables can jointly be used to predict mathematical test scores using control group posttest mathematical test scores as the dependent variable. Therefore, the null hypothesis is rejected. Given an R-Square of .455, it can be said that 45.5 percent of the variation in the posttest-control sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than 3.10 units on the mathematical scale is .6826.

Based upon the statistically significant "F" ratio for the Multiple-R, further investigation of the Beta coefficients shows that the variable "gender," given a two-tailed alpha level of .05 for 24 degrees of freedom, is statistically significant. The Student's "t" of -2.98 is greater than the "t" table value of 2.064 needed to be statistically significant at the .05 alpha level. No other independent variables are statistically significant.

<u>Hypothesis 9</u>

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using pretest EMG tension readings as the dependent variable.

Multiple Regression: Pretest Item Tension Indices of Abstract Thinking Ability Test/Selected Biographical Independent Variables-Experimental and Control Groups

TABLE 17

Pretest-Experimental/Summary Table

			DF	SS	MS	F
Multiple-R	.447	Analysis of Variance				
R-Square	.200					
Standard		Due to Regression	5	5.27	1.05	.95
Error	1.053	About Regression	19	21.08	1.10	
		Total	24	26.35		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	-.62	.53	-1.16	-.256	-.296
Age	.008	.03	.23	.052	.061
Marital Status	-.48	.48	-1.00	0.224	-.221
Undergraduate GPA	.82	.58	1.41	.307	.314
Handedness	-.06	.77	- .08	-.018	-.019
Constant: (1.831)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of .95 is not equal to or greater than an "F" ratio table value of 4.56 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict skeletal muscle tension using experimental group pretest item tension indices as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of .200, it can be said that 20 percent of the variation in the pretest-experimental sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than 1.05 units on the item tension indices scale is .6826.

TABLE 18

Pretest-Control/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.678					
R-Square	.460					
Standard		Due to Regression	5	7.00	1.40	3.24
Error	.657	About Regression	19	8.21	.43	
		Total	24	15.21		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	.89	.29	3.04	.572	.563
Age	.01	.02	.48	.109	.089
Marital Status	-.38	.36	-1.07	-.238	-.199
Undergraduate GPA	-.06	.30	- .21	-.048	-.038
Handedness	-.34	.38	- .89	-.199	-.161
Constant: (2.123)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 3.24 is equal to and greater than an "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables can jointly be used to predict skeletal muscle tension using control group pretest item tension indices as the dependent variable. Therefore, the null hypothesis is rejected. Given an R-Square of .460, it can be said that 46 percent of the variation in the pretest-control sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than .657

units on the item tension indices scale is .6826.

Based upon the statistically significant "F" ratio for the Multiple-R, further investigation of the Beta coefficients shows that the variable "gender," given a two-tailed alpha level of .05 for 24 degrees of freedom, is statistically significant. The Student's "t" of 3.04 is equal to and greater than the Student's "t" table value of 2.064 needed to be statistically significant at the .05 alpha level. No other independent variables are statistically significant.

<u>Hypothesis 10</u>

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using posttest EMG tension readings as the dependent variable.

Multiple Regression: Posttest Item Tension Indices of Abstract Thinking Ability Test/Selected Biographical Independent Variables-Experimental and Control Groups

TABLE 19

Posttest-Experimental/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.412					
R-Square	.169					
Standard		Due to Regression	5	2.27	.45	.78
Error	.765	About Regression	19	11.13	.58	
		Total	24	13.41		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	.47	.39	1.21	.267	.315
Age	.01	.02	- .55	-.126	-.151
Marital Status	.17	.35	.48	.110	.108
Undergraduate GPA	.45	.42	1.07	.238	.243
Handedness	-.30	.56	- .54	-.122	-.134
Constant: (.955)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of .78 is not equal to or greater than an "F" ratio table value of 4.56 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict skeletal muscle tension using experimental group posttest item tension indices as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of .169, it can be said that 16.9 percent of the variation in the posttest-experimental sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than .765 units on the item tension indices scale is .6826.

TABLE 20

Posttest-Control/Summary Table

		Analysis of Variance	DF	SS	MS	F
Multiple-R	.530					
R-Square	.280					
Standard		Due to Regression	5	21.98	4.39	1.48
Error	1.721	About Regression	19	56.29	2.96	
		Total	24	78.27		

Variable	B	Standard Error of Beta	Student's "t"	Partial R	BETA
Gender	.96	.77	1.25	.275	.267
Age	.08	.05	1.57	.339	.336
Marital Status	-.14	.95	- .15	-.034	-.032
Undergraduate GPA	.10	.79	.13	.030	.028
Handedness	-.69	1.01	- .68	-.155	-.144
Constant: (-.312)					

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that an "F" of 1.48 is not equal to or greater than an "F" ratio table value of 2.74 needed to be statistically significant at the .05 alpha level. It can therefore be concluded that the five (5) independent variables cannot jointly be used to predict skeletal muscle tension using control group posttest item tension indices as the dependent variable. Therefore, the null hypothesis is retained. Given an R-Square of .280, it can be said that 28 percent of the variation in the posttest-control sample group can be explained by the five (5) independent variables operating jointly. The probability that an actual score will not deviate greater than 1.721 units on the item tension indices scale is .6826.

SUMMARY

Chapter Four presented the data analysis in two major sections. The first section dealth with Hypotheses 1 through 6 and the second section dealt with Hypotheses 7 through 10. Section one presented the Student's "t" statistics which were calculated on the measures of mean differences between the experimental and control sample groups. The Student's "t" statistics were calculated for differences in means of:

1) raw scores obtained on a mathematics test designed to yield measures of abstract thinking ability, and

2) test item tension indices recorded during a pre and post administration of the mathematics test utilizing and electromyograph (EMG).

Hypotheses 1 through 3 concern the data analysis of Student's "t" statistics calculated using the mathematics test scores and Hypotheses 4 through 6 concern the data analysis of Student's "t" statistics calculated using the average item tension indices.

The following table relates the findings of Hypotheses 1 through 6.

TABLE 21

Null Hypothesis	Table	Findings	Dependent Variable	Sample Group	Test Administration
1	3	Rejected	Math scores	Exp/Control	Posttest
2	4	Rejected	Math scores	Experimental	Pre/Post
3	5	Rejected	Math scores	Control	Pre/Post
4	7	Retained	Item Tension	Exp/Control	Posttest
5	8	Rejected	Item Tension	Experimental	Pre/Post
6	9	Retained	Item Tension	Control	Pre/Post

The criteria for rejecting or retaining all null hypotheses was the .05 alpha level using a two-tailed alternative.

Hypothesis 1

There will be no significant difference between control and experimental group posttest means based upon abstract thinking ability raw scores.

TABLE 22

Posttest Group Means Experimental	Control	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
12.84	10.72	2.06	48	2.008	.045	Rejected null

The data show that given a Student's "t" of 2.06 that the null hypothesis may be rejected at the .05* level using a two-tailed alternative. Operationally, it may be stated that the difference between posttest means of both the experimental and control sample groups was statistically significant. This may imply that because the posttest scores demonstrated significant differences when no significant differences were found between pretest means of both experimental and control sample groups (see page 63 for these findings) that the "treatment," or some other intervening variable, caused the two groups to score in a significantly different manner on the posttest than on the pretest.

It follows, then, that an examination of the pretest and posttest data from the administration of the mathematics tests should further indicate whether or not significant differences occurred within sample groups. Hypothesis 2 deals with the differences of means between pre and posttest math scores of the experimental group and Hypothesis 3 deals with the differences of means between pre and posttest math scores of the control group.

Hypothesis 2

There will be no significant difference between the pretest and posttest group means of the experimental group based upon abstract thinking ability raw scores.

TABLE 23

Experimental Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
9.60	12.84	-7.54	24	2.06	.000	Rejected null

The data show that given a Student's "t" of 7.54 that the null hypothesis may be rejected at the .05* level using a two-tailed alternative. Operationally, it can be stated that the difference between pre and posttest means of the experimental sample group was statistically significant. This, most probably, is evidence to support the notion that the "treatment" is the cause for the difference. Further investigation shows that the difference was an "increase" in the experimental group's mean math scores. This evidence supports the notion that autogenic relaxation exercises may have significantly contributed to the increase of scores.

Hypothesis 3

There will be no significant difference between the pretest and posttest group means of the control group based upon abstract thinking ability raw scores.

TABLE 24

Control Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
9.40	10.72	-3.67	24	2.06	.001	Rejected null

The data show that given a Student's "t" of 3.67 that the null hypothesis may be rejected at the .05* level using a two-tailed alternative. Operationally, it can be stated that the difference between pre and posttest means of the control sample group was statistically significant. This, most probably, is evidence that internal validity factors such as maturation or test wisdom are the chief causes in the significant difference between means, since the control group was not given the autogenic relaxation exercises between pre and post administration of the math test. Further investigation shows that the difference was an "increase" in the control group's mean math scores.

When a comparison of the two-tailed probabilities of each group's mean differences are looked at, the probability that such differences are the result of chance are relatively greater for the control (.001) than for the experimental group (.000).

Hypothesis 4

There will be no significant difference between control and experimental group means based upon average posttest item tension readings.

TABLE 25

Posttest Group Means Experimental	Control	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
2.36	3.08	-1.56	48	2.06	.124	Retained null

The data show that given a Student's "t" of 1.56 that the null hypothesis is retained at the .05* level using a two-tailed alternative. Operationally, it can be stated that the difference between posttest means of both the experimental and control sample groups was not significantly different. The evidence indicates that, based upon posttest measures, there was no significant difference in skeletal muscle tension between the experimental and control group.

It follows, then, that an examination of the pretest and posttest item tension indices should further indicate whether or not significant differences occurred within sample groups. Hypothesis 5 deals with the differences of means between pre and posttest item tension indices of the experimental group and Hypothesis 6 deals with the differences of means between pre and posttest item tension indices of the control group.

Hypothesis 5

There will be no significant difference between the pretest and posttest group means of the experimental group based upon average item tension readings.

TABLE 26

Experimental Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
3.32	2.36	2.49	24	2.06	.020	Rejected null

The data show that given a Student's "t" of 2.49 that the null hypothesis may be rejected at the .05* level using a two-tailed alternative. Operationally, it can be stated that the difference between pre and posttest means of the experimental sample group was statistically significant. This evidence supports the notion that autogenic relaxation exercise techniques coupled with biofeedback information should cause a significant drop in skeletal muscle tension produced during mental activity. Further investigation of the data shows that the average item tension indices of the experimental sample group not only dropped but also to a statistically significant degree.

Hypothesis 6

There will be no significant difference between the pretest and posttest group means of the control group based upon average item tension readings.

TABLE 27

Control Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
2.63	3.08	-1.25	24	2.06	.222	Retained null

The data show that given a Student's "t" of 1.24 that the null hypothesis is retained at the .05* level using a two-tailed alternative. Operationally, it can be stated that the difference between pre and posttest means of the control sample group was not statistically significant. This evidence supports the notion that without a means to "define" skeletal muscle tension (autogenic relaxation exercise techniques) coupled with the inability to physically (kinesthetically) monitor skeletal muscle tension, an increase in skeletal muscle tension should be produced during mental activity. Further investigation of the data demonstrates that the average item tension increased, however, not to the extent that the differences were statistically significant.

The following table related the findings of Hypotheses 7 through 10.

TABLE 28

Null Hypothesis	Table	Findings	Dependent Variable	Sample Group	Test Administration
7	13	Retained	Math scores	Experimental	Pretest
	14	Retained	Math scores	Control	Pretest
8	15	Retained	Math scores	Experimental	Posttest
	16	Rejected	Math scores	Control	Posttest
9	17	Retained	Item tension	Experimental	Pretest
	18	Rejected	Item tension	Control	Pretest
10	19	Retained	Item tension	Experimental	Posttest
	20	Retained	Item tension	Control	Posttest

The criteria for rejecting or retaining all null hypotheses was the .05 alpha level using a two-tailed alternative.

Hypothesis 7

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using pretest mathematical test scores as the dependent variable.

TABLE 29

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.469	1.08	2.74	Retained null
Control	.615	2.31	2.74	Retained null

When the "F" rates for the "overall" test of goodness of fit of the regression equations for both the experimental and control sample groups are analyzed, they show that neither group's abstract thinking ability as measured by the dependent variable, can be predicted by joint use of the five (5) independent variables identified in this investigation. The null hypothesis is retained.

Hypothesis 8

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using posttest mathematical test scores as the dependent variable.

TABLE 30

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.488	1.19	2.74	Retained null

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that the experimental group's abstract thinking ability, as measured by the dependent variable, cannot be predicted by joint use of the five (5) independent variables identified in this investigation. The null hypothesis is retained.

TABLE 31

Sample Group	Multiple-R	"F"	Table Value	Findings
Control	.674	3.18	2.74	Rejected null

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that the control group's abstract thinking ability, as measured by the dependent variable, can be predicted by the five (5) independent variables operating jointly. Upon further analysis of the betas of each independent variable, utilizing a Student's "t" statistic as a test of significance, only the variable "gender" was found to be statistically significant. The null hypothesis was rejected.

Hypothesis 9

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using pretest EMG tension readings as the dependent variable.

TABLE 32

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.447	.95	4.56	Retained null

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that the experimental group's skeletal muscle tension, as measured by item tension indices, cannot be predicted by joint use of the five (5) independent variables identified in this investigation. The null hypothesis is retained.

TABLE 33

Sample Group	Multiple-R	"F"	Table Value	Findings
Control	.678	3.24	2.74	Rejected null

When the "F" ratio for the "overall" test of goodness of fit of the regression equation is analyzed, it shows that the control group's skeletal muscle tension, as measured by item tension indices, can be predicted by the five (5) independent variables operating jointly. Upon further analysis of the betas of each independent variable, utilizing a Student's "t" statistic as a test of significance, only the variable "gender" was found to be statistically significant. The null hypothesis was rejected.

Hypothesis 10

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using posttest EMG tension readings as the dependent variable.

TABLE 34

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.412	.78	4.56	Retained null
Control	.530	1.48	2.74	Retained null

When the "F" ratio for the "overall" test of goodness of fit of the regression equations for both the experimental and control groups are analyzed, they show that neither group's skeletal muscle tension, as measured by item tension indices, can be predicted by the five (5) independent variables operating jointly. Therefore, the null hypothesis is retained.

Chapter Five will present the Conclusions and Recommendations of the researcher based upon the information and data presented in Chapters One through Four.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter Five presents a summary of Chapters One, Two, Three a second section which summarizes the conclusions related to the findings of Chapter Four, DATA ANALYSIS, and a third section which presents the researcher's recommendations for further possible research studies based on the findings of this investigation.

INTRODUCTION, REVIEW OF LITERATURE AND PROCEDURES SUMMARY

Introduction Summary

Chapter One presents the notion that there is a need to do educational research on the teaching-learning process. It presents evidence that, based on data collected over the past forty years, that "we are able to state decisively that no particular method of college instruction is measurably to be preferred over another, when evaluated by student examination of performances" (Dubin and Taveggin, 1968, p. 10). Given these findings, meangingful research on the teaching-learning process should focus on what "happens" during the mental processing of educational "data" and not upon a specific methodology (input) employed nor the process of evaluation (output) used to measure performance.

> We do, however, believe that anyone working or doing research at the college level of instruction can most readily make a useful contribution when this linkage between teaching and learning becomes

> the center of their attention. (Dubin and Taveggin, 1968, p. 8).

The "linkage" between teaching or methodology and learning or evaluation, then, is the focus of this study. Learning is defined as a determination of the ability to process educational data by examination performance. In this model, learning occurs when it can be externally verified by examination performance.

The approach used in this study to pursue the notion that the teaching-learning link should be investigated was to use electromyographic biofeedback as a physiological technique for verifying that the reduction of skeletal muscle tension should allow college subjects to perform better on a performance evaluation of an abstract thinking ability task. The logic of this investigation was that if a meaningful study were to be done on what occurs during the teaching-learning link, some verifiable, measurable internal indices should be monitored and analyzed statistically. Such an investigation would demonstrate concommitance with measures of skill performance levels. The measures of skill performance chosen by the researcher were a series of 20 mathematical problems consisting of addition, subtraction, multiplication, and division of fractions. Utilizing pre and posttest means, statistically significant differences in examination performance could be measured and verified. The "internal" indices chosen by the researcher were item tension readings which were taken on each subject by the use of an electromyograph (EMG). Utilizing pre and posttest item tension means, statistically significant differences in skeletal muscle tension during the performance of an abstract thinking ability task (mathematical test) could be measured and verified.

It was postulated, therefore, that if an experimental sample of a college student population could be instructed in the use of an EMG biofeedback device, their resultant posttest mathematic scores should be statistically significantly different from their pretest scores. Also, that posttest item tension readings should be statistically significantly different from their pretest item readings.

The notion, then, was to determine whether or not the use of biofeedback techniques could be utilized on an adult college student sample which would effect significant differences in their ability to think abstractly as well as to effect significant differences in their sample group pre and posttest item tension means. Five (5) independent variables were collected from each subject which were used to discover whether or not all variables or any combination of variables could be used to predict group abstract thinking ability or skeletal muscle tension. These five variables were gender, age, marital status, undergraduate GPA, or handedness (left or right).

Need for the Study

Given the premise that teaching methodology in and of itself, causes no measurable differences in examination performance by college students, there is then a need to pursue less "traditional" approaches to the improvement of the teaching-learning process. The first step is to identify what does make a difference in examination performance, if in fact, methodology does not, and the second step is to attempt to determine a means by which the teaching-learning process can be modified so that measurable differences in examination performance can be effected.

The study presents a summarization of personality and learning theory which asserts that physiological psychology gives this research study a paradigm from which "learning" can be defined in physiological terms and thus successfully be investigated. The discussion summarizes Behaviorist as well as Developmentalist points of view of the learning process. Where as Behaviorism's concept of learning is one in which the behavior (learning outcome) which one wishes to encourage or discourage is as much a function of the educational environment as well as or rather in spite of the methodology used to present the material or elicit the behavior, the Developmentalist's concept of learning is that learning is more a result of genetically inherited scheduling which ranges over developmental periods largely controlled by the physiological maturation of the organism.

This study purports that, conceptually, both strands of learning theory are correct in that both environmental stress and genetic scheduling are factors in defining the teaching-learning process. The researcher acknowledges the environmental effect when choosing to measure skeletal muscle tension produced by the testing environment and also acknowledges the genetically inherited abilities to process afferent stimuli based upon the maturation of the organism as the basis for choosing adult, college level students who should, developmentally, be at the highest developmental level so that the research study findings are not confused by developmental differences in learning ability.

The study puts forth the notion that physiological psychology best provides an accurate and analagous model for learning in that it treats the process theoretically in physiological constructs and uses physiological entities, such as "neurons, cell assemblies," to define learning processes.

Research Questions

The study then summarizes the preceeding evidence and need for the study by formulating the following research questions.

1. Can a group of adult learners' ability to think abstractly be improved so that empirical validation can occur utilizing scores from a posttest designed to measure abstract thinking ability?

2. What will be the effect of the presence of absence of autogenic exercises on the abstract thinking ability scores when the group

means of both the control and experimental group are analyzed so as to reveal differences between pre and posttest administration?

3. Can the average muscle tension in the frontalis and trapezius muscle groups be made to decrease so that empirical validation can occur when average posttest tension readings from a biofeedback instrument (EMG) are used as indices of muscle tension?

4. What will be the effect of the autogenic exercises' presence or absence on the average level of muscle tension in the frontalis and trapezius muscle groups when group means of both the control and experimental group are analyzed so as to reveal differences between pre and posttest readings?

5. Can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the abstract thinking ability of adult learners when the raw scores from their pretest measures are used as the dependent variable?

6. Can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness by used to predict the abstract thinking ability of adult learners when the raw scores from their posttest measures are used as the dependent variable?

7. Can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from their

pretest EMG measures are used as the dependent variable?

8. Can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from the posttest EMG measures are used as the dependent variable?

General Procedures

Subjects were solicited from the Montana State University campus to participate in the research investigation. All subjects were pretested and then divided into two groups of 25 each. The dividing was accomplished by matching subject raw math scores utilizing mean item tension indices to determine matching when more than two subjects had the same score or when like scores were not possible to match. Each subject was assigned to either the control or experimental group. The experimental group was given biofeedback training techniques, autogenic relaxation exercises, and the control group was not given the "treatment." Both groups were then posttested with the same test items, and as in the pretest, correct or incorrect answers to the mathematics test were recorded as well as the average item tension readings for each item.

Using an Autogen 1700 electromyograph, average muscle potentials were recorded. The potentials, electrical impulses emitted by neurons, are indices of actual muscle activity and sub-muscle actuation activity . The latter can be interpreted as skeletal muscle tension. Two muscle groups were used to collect the skeletal muscle tension indices; the frontalis (facial muscles) and the trapezius (shoulder muscles). The tension readings were interpreted as indications of anxiety brought about by having to mentally solve a series of mathematical test items.

Twenty problems were presented to the subjects. They were presented in random order. The test was initially constructed to present assigned degrees of difficulty ranging from easy to very difficult. An administration of the test to a Montana State University college class was used to validate the assigned degrees of difficulty as well as verify that the verbal instructions and testing procedures were clear and adequate for the experiment.

Each subject was interfaced with the Autogen 1700 by a series of six electrodes. Three were attached to the frontalis muscle group and three were attached to the trapezius muscle group. The subjects were seated in a reclining chair and read the instructions by the experimentor. Each subject viewed the series of twenty problems, mentally solved the problems, and verbally gave the answer if the subject had been able to solve the problems. The correct or incorrect response to the test item and its average tension reading was recorded by the experimentor.

Both the control and experimental group were allowed to hear the audio feedback; however, only the experimental group was given the biofeedback training after the pretest and before the posttest. No explanation of the purpose of the experiment nor any findings were discussed with the subjects.

These data were then analyzed and interpreted according to the hypotheses and general research questions.

Limitations of the Study

The "pretest-posttest control group design" was used to collect the data from the experiment. This design was chosen for its ability to control for all of the major sources of internal invalidity, and because the use of a pretest activity allows for control group equivalency (Campbell and Stanley, 1963, p. 3). Population representation by the sample was elicited by advertising for volunteers and carefully screening them for meeting the population parameters. The procedure negated the possibility of selection of subgroups such as classes within the student population. While use of the randomized pretest-posttest control group design keeps to a minimum the effect of jeopardizing internal validity, there is some threat to external validity - specifically the question of generalizability. The author believes it is possible to delimit the scope of the population and thereby modify subsequent inferences by the knowledge that errors implicit within the sampling process may not allow an extensive scope of generalizability.

Given these limitations, however, the experimentor believes that the study needed to be done and that the knowledge gained would lead to further studies on the subject.

Historical Background

The author found evidence in current educational and professional literature to support the notion that the study of the teaching-learning process must become more sophisticated in that it takes advantage of current technology as well as current findings and understandings of human physiology. The literature documents a turning to the "organismic" model which represents the universe as a unitary, interactive, and developing organism (Knowles, 1973, p. 18). This trend towards an organismic view of learning theory may be compared to the more mechanistic model of learning theory in that the organismic model tends to emphasize the significance of process over product and qualitative over quantitative. The author presents the notion that physiological psychology incorporates the best aspects of both the mechanistic and organismic model. It also incorporates the current knowledge of human physiology with human psychology. This marriage of disciplines allows for a more extensive understanding of the equivalence of human phenomenon as they are interpreted both qualitatively and quantitatively.

Conceptual Background

Biofeedback allows the researcher to capitalize on both process and product, quantitative and qualitative aspects of human behavior. It allows the researcher to measure those proprioceptive physiological phenomena which, because of their nature, are not easily measured nor kinesthetically visible.

Eastern cultures often have arrived at the same conclusions, as have the Western cultures, concerning human behavior. The paths taken to those conclusions, however, have been divergent. As in a comparison of the mechanistic model to the organismic model of human psychology, we find a striking similarity in a comparison of Eastern and Western cultural paths to truth and knowledge about the human state and conditions. Eastern cultures tend to center on qualitative process aspects which are the "paths" to truth and knowledge. Western culture has tended to center on quantitative/product oriented aspects as the way of knowing the world. The author presents the notion that both ways are right. Physiological psychology is viewed, by the author, as a proper construct from which the study of the physiological basis of human behavior should begin. It is an amalgamation of the best aspects of both "ways of knowing." With the use of biofeedback, a researcher can investigate those areas of human behavior, of which human learning is one aspect, and discover those physiological processes which may very well be the cause for behaviors so deep within human physiology and that are not easily observed.

Biofeedback is an attempt to involve the organism in an "extensive body of transactions" (Ornstein, 1968, p. 17) which allows an individual trained in using biofeedback to "contribute to" and "modify" the body of transactions. Biofeedback provides for the investigative opportunity to pursue actual scientific inquiry within the area of the study of human consciousness and still maintain a balance between the empirical and intuitive ways of knowing.

Summary of Related Research

Frederich Courts in his article entitled "Relations Between Muscular Tension and Performance," summarized the research from 1930 up to and including 1942 in the area of changes in muscular states of tension accompanying performance by confirming that:

(1) In general, continuous mental work is accompanied by an increase in muscle tension as measured in various ways over the level maintained during rest (Davis, 1938; Freeman, 1931).

(2) Only rarely are individuals found who show no change or decrement from their resting tension when work is introduced (Davis, 1938).

(3) At the onset of work there is an initial increase in tension which rapidly drops to a level somewhat above that of the rest condition (Davis, 1938).

(4) There is an initial spurt of tension after which tension gra-

dually increases as work increases (Davis, 1938).

A number of attempts have been made to show that there is a demonstratable correlation between level of performance and muscular tension. Courts reports that Davis (1938) and Hadley,(1941) both have reported an increase in muscle potentials from the forearm and neck respectively, with increase in difficulty of arithmetical tasks. These findings were later confirmed by Shaw and Kline who concluded:

(1) When children attempted the solution of a series of arithmetic problems, muscle action potentials in their lower right arms increased as the problems increased indifficulty.

(2) When the problems were arranged to take account of the time, and of the number and kind of errors made in the solution of the problems the tendency for muscle action potentials to increase was more marked (Shaw and Kline, 1947, pp. 157-158). Davis also found that muscle potentials accompanying successes and failure reported and actual were not significantly different. The level of muscular activity for failure on a given problem was not significantly higher than that for success (Davis, 1938, p. 157). He also made an important discovery when he reported that muscular tensions are not evenly distributed over the organism during a period of labor. This finding is also reported by Shaw (Shaw, 1938). Davis found that the neck and arms to be most yielding of action potentials. In a later study reported by Greenfield and Sternback of a study which was done by R. Voas dealing

with generalization and consistency of muscle tension levels, it was confirmed that when mental work was the task, the areas which yielded the highest incidence of muscle potentials, based upon a test-retest situation, were the forearm extensors (.93), frontalis (.90), masseter (.87), and the trapezius (.69). Voas believed that these were the best choice for representative muscle potentials during mental work (Greenfield and Sternback, 1972, p. 339).

These researchers dealt mainly with observed changes in muscle tension of "motor groups." Another group of researchers pursued the concept of "single motor units" and their effect on skeletal muscles.

It was not, however, thoroughly understood what muscle action potentials were much less how to record them with any degree of accuracy until Jacobson utilized the electromyograph (EMG) to record the "spike waves" with paper and ink. It was not until the works of Harrison, Mortensen, and Basmajian and the advent of the oscilliscope that accurate "pictures" of the "spike" phenomenon was understood and measured with any degree of accuracy. Harrison and Mortensen found that single spike potentials (1) could be interpreted as muscular activity of single motor unit potentials, (2) that the activity of individual motor units could be identified and isolated to a variable degree by voluntary effort, (3) and that either auditory or visual feedback was essential to selection and controlled contraction of single motor units (Harrison and Mortensen, 1962, pp. 115-116). Basmajian further discovered that (1) single motor units not only can be recruited in isolation but also that in doing so, its neighboring units are inhibited, (2) subjects at first depend on aural and visual "feedbacks" from muscles, however, "the controls are learned so quickly, are so exquisite and are so well retained after artificial feedbacks are eliminated that one cannot help believe that fundamental processes are involved," (3) proprioceptors exist within the motor units which are sensory receptors that respond to stimuli from "within" the organism (Basmajian, 1963; Basmajian, 1967, p. 485). Basmajian's discovery that not only do recruited neurons (motor units) inhibit their neighbors but also that one can "learn" to control without biofeedback (artificial) systems leads one to the inescapable conclusion that much more control is possible over the bodily functioning than was previously anticipated. The concept of "proprioception" drives the creative possibilities of application of biofeedback training to even more complex conclusions. Basmajian demonstrated that not only can one learn to selectively control motor unit firings but also that these units respond to not just "external" stimuli but some "internal stimuli." The literal "thinking" of an act can and does trigger the motor unit "prior to conscious or kinetic awareness." This is called "proprioception." The work of Wagman, Pierce, and Burger further elaborates the function and role of the proprioceptive system and its essential sensory information for coordination of motor performance.

Three basic observations are herein reported (1) there is a demonstrated importance of peripheral input (actual muscle movement) in establishing control over individual motor units, (2) during any single training period, less and less effort from other muscles was necessary to activate specific units which were originally dependent in part on contraction, and (3) as the ability of a subject to control motor units became progressively refined and accurate, the subject was able to activate certain higher-threshold units by using less tension than had originally been required to activate the lowest threshold units (Wagman, Pierce, Burger, 1965, pp. 957-958).

In the selection of the problems and hypothesis, the research from both "strands" was considered. Both control of single motor units and the relation between skeletal muscle tension and abstract performance are important. The summarized research leads this author to these conclusions:

1. mental work is related to muscle tension;
2. the relationship of mental work and muscle tension is positively correlated; as work increases, tension increases;
3. mental work of varying degrees is related to muscle tension;
4. the relationship between mental work of varying degrees and muscle tension is positively related. As mental work becomes more difficult, muscle tension increases;
5. performance time is related to muscle tension;

6. the relationship of performance time to muscle tension is positively correlated. As more time is taken for performance, muscle tension increases;
7. if muscle tension "interferes" with mental performance, mental performance can be improved by lowering muscle tensions,

Population Description and Sampling Procedures

The sample used in this study was taken from the population of summer students at Montana State University. Summer students are defined as those who were enrolled in the 1977 Summer session at the University. The population contained both undergraduate and graduates. No attempt was made to stratify the sample to reflect the percentage of undergraduates to graduates.

The author began the week of July 18th to advertise for subjects who, in order to be used in the experiment, were required to meet the population parameters described above (see Appendix A). Fifty applicants were selected, those being the first fifty volunteers who met the population parameters. Fifty-three volunteers responded to the advertisement. Two did not meet the population parameters and lacking another volunteer to match, the remaining volunteer was not used. After the pretest had been given to all applicants, the sample was matched using the number of correct responses on the pretest and the average tension reading taken at rest prior to the pretest. In cases where there were more than two subjects with the same score on the pretest, the average tension reading was used to match the subjects.

Definition of Treatment

The treatment occurred when the experimental group of twenty-five subjects were identified, contacted by the experimentor, and scheduled for the treatment session . At the same time, the control group was scheduled for the posttest. This scheduling was done to insure that the time span was as close to being the same for the control group and experimental group with regard to the taking of the pre and posttest.

The treatment was administered in the Cortical Function Laboratory on the campus of Montana State University. The treatment consisted of autogenic exercises as outlined by Dr. Wolfgang Luthe, M. D. in his Volume I of the series "Autogenic Therapy" (Luthe, 1969), entitled Autogenic Techniques. The autogenic treatment consisted of an introduction to the method of relaxation, a portion of which was broken down into the following segments:

(1) reduction of afferent stimuli,

(2) training pattern and passive concentration,

(3) a standard exercise involving tension-relaxation of the frontalis and trapezius muscle groups.

The first segment (reduction of afferent stimuli) was in part accomplished by the physical environment in which the subjects were tested. The booth used for the experiment was sound-proofed so as to promote the reduction of afferent (in-coming) stimuli. This "closing off" of afferent stimuli from the physical environment is the essential first step in the reduction of tension. Without "turning off" external stimuli, the reticular activation system (RAS) will not allow an internal reduction of stimuli (Ornstein and Naranjo, 1971, p. 143). The booth brings the effect of stabilizing images to a degree that awareness of external stimuli can be reduced. Without the variety of visual stimuli normally available, large eye movements called "saccades" are reduced. These gross eye movements which are fixations at various points in the visual field along with very small involuntary movements called "optical nystagmus" help keep the retina in constant motion. The effect is that awareness of afferent stimuli is maintained at a level sufficient to keep the body and mind at a steady state of readiness (Ornstein and Naranjo, 1971, pp. 165-167). There is a documented contiguity between stabilization of visual images and the production of alpha rhythms. Alpha rhythms are:

> . . . usually though of as representing a state of decreased visual attention to the environment. It is increased almost always when the eyes are closed or when the eyes are rolled up into the head - when vision is turned down. (Ornstein, 1971, p. 165).

Lehmann, Beeler, and Fender in their investigations into brain states evoked by stabilizing images (Lehmann, et al, 1967) found that the alpha rhythm was likely to appear at the time when the subject reached a state of visual stabilization. Other ways to produce this reduced state of awareness are closing the eyes or concentration on a patternless visual field called a "ganzfeld" (Ornstein and Naranjo, 1971, p. 166).

The second segment of the treatment called for the establishment of a training pattern and passive concentration. This simply means that a pattern be established which can be used by the subjects when they employ the autogenic exercises to reduce muscular tension or anxiety. Passive concentration is the application of the training pattern or regimen so that unconsciousness does not occur. If, as in segment one, the subject reduced all afferent stimuli, sleep or unconsciousness would occur. This, for obvious reasons, is not a desirable state for the experiment when a specific degree of alertness will be required to solve the mathematical problems. The use of the training pattern keeps the subject "alert" enough so as complete (unconsciousness) relaxation does not occur.

The third segment (muscle exercises) is designed to focus on the specific muscle group or groups which are identified for intensive and deep relaxation. This process involves "tension-relaxation" of each muscle group. Each subject was asked to tense and relax the two muscle groups (frontalis and trapezius), first each muscle group separately and then together. These structured exercises are designed to increase the subjects awareness of what tension and relaxation "feels" like relative to each specific muscle group. During the tension-relaxation exercises the subject was "hearing" the analogue feedback from the two muscle groups so that aural as well as kinetic feedback heightened the experience.

Utilizing these three segments, the subject's feedback was "shaped" by using an audio threshold-selector on the Autogen 1700. This device allows the experimentor to adjust the audio threshold level of the incoming signal (muscle potentials). When activated, the Audio Feedback Threshold Selector determines the minimum or maximum absolute level of EMG activity required for any of the audio feedback signals to be present. Shaping is then performed by either raising or lowering the absolute level of EMG required to produce the audio feedback signal.

Method of Collecting Data

As the subjects arrived at the laboratory, they were given an explanation of the general procedures of the pre and posttest sessions. They were not told the specifics of the research design nor were they given the hypothesis or research questions. This procedure was followed so that such knowledge would not bias their response to the experiment. Each subject was then asked to read and fill out the waiver and data sheet supplied by the experimentor (see Appendix F). The subject was then placed in the booth and seated in an overstuffed reclining chair and given the instructions for the pretest. These were:

(1) mentally solve the mathematical problems given you on each

3 X 5 card. I will hold the cards for you.

(2) you have twenty seconds to solve each problem.

(3) respond with your answer or if you cannot solve the problem, give no response.

(4) I will not verify the answers for you.

(5) the problems are addition, subtraction, multiplication and division of fractions. Each problem will vary in degree of difficulty.

(6) a rest period will be observed between each problem.

(7) do not make unnecessary movements during the solution period.

(8) do you have any questions concerning the directions I have just given you?

An attempt was made to not vary the presentation of directions nor the subsequent test procedures by using an experiment checklist (see Appendix E) designed by the experimentor.

Method of Organizing the Data

The data are presented in graphic and tabular form under two main divisions in Chapter Four. The first division concerns all data related to the statistical hypotheses which concern measures of differences and the second concerns the statistical hypotheses which analyze the results of the multiple regression analysis. This division facilitates the presentation in that a differing statistical treatment of each division will precipitate a particular format for each treatment.

The first division shows different graphs and tables while the second division displays graphs and tables dealing with multiple regression values.

Statistical Hypotheses

The problem statement when transformed into statistical hypotheses is:

1. There will be no significant difference between control and experimental group posttest means based upon abstract thinking ability raw scores.

2. There will be no significant difference between the pretest and posttest group means of the experimental group based upon abstract thinking ability raw scores.

3. There will be no significant difference between the pretest and posttest group means of the control group based upon abstract thinking ability raw scores.

4. There will be no significant difference between control and experimental group means based upon average posttest item tension readings..

5. There will be no significant difference between the pretest and posttest group means of the experimental group based upon average item tension readings.

6. There will be no significant difference between the pretest

and posttest group means of the control group based upon average item tension readings.

7. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict abstract thinking ability using pretest mathematics test scores as the dependent variable.

8. Selected biographical independent variables (gender, age marital status, undergraduate GPA, or handedness) cannot be used to predict abstract thinking ability using posttest mathematics test scores as the dependent variable.

9. Selected biographical independent variables (gender, age marital status, undergraduate GPA, or handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using pretest EMG tension readings as the dependent variable.

10. Selected biographical independent variables (gender, age, marital status, undergraduate GPA, or handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using posttest EMG tension readings as the dependent variable.

Analysis of Data

Hypotheses 1 - 6 in their null form were tested and reported in Chapter Four using the Student's "t" statistic for independent and dependent samples. Student's "t" is a statistic in which sample means are used to estimate population means. The "t" distribution is well suited from the standpoint of its ability to perform well when small "n" samples are used (Snedecor and Cochran, 1967, pp. 59-60). An alpha level of .05 was used as the level of significance for the "t" tests. This means that the null hypothesis can be rejected if the statistic ("t") is equal to or greater than the table value (two-tailed test) at the appropriate degree of freedom (df) and alpha level of (.05).

The null form of hypotheses 7 - 10 were tested using multiple regression. Multiple regression is a statistical procedure designed to produce an equation to predict a value of one variable (dependent variable) from values on two or more other variables (independent variables), to make such prediction, and to test the reliability of this prediction.

DATA ANALYSIS CONCLUSIONS

Student's "t"

Chapter Four presented the data analysis in two major sections. The first section reports the findings related to Hypotheses 1 through 6. The second section reports the findings related to Hypotheses 7 through 10.

Section one presented Student's "t" statistics which were calculated on the measures of mean differences between the experimental and control sample groups. The Student's "t" statistics were calculated for differences in group means of:

1) raw scores obtained from a mathematics test designed to yield measures of abstract thinking ability, and

2) test item tension indices recorded during the pre and post administration of the mathematics test. The indices were collected using an Autogen 1700 electromyograph.

Hypotheses 1 through 3 relate to the mathematical test raw scores and hypotheses 4 through 6 relate to the test item tension indices.

The table below summarizes the findings of Hypotheses 1 through 6.

TABLE 35

Null Hypothesis	Table	Findings	Dependent Variable	Sample Group	Test Administration
1	3	Rejected	Math scores	Exp/Control	Posttest
2	4	Rejected	Math scores	Experimental	Pre/Post
3	5	Rejected	Math scores	Control	Pre/Post
4	7	Retained	Item Tension	Exp/Control	Posttest
5	8	Rejected	Item Tension	Experimental	Pre/Post
6	9	Retained	Item Tension	Control	Pre/Post

The criteria for rejecting or retaining all null hypotheses was the .05 alpha level using a two-tailed alternative.

Hypothesis 1

There will be no significant difference between control and experimental group posttest means based upon abstract thinking ability raw scores.

TABLE 36

Posttest Group Means Experimental	Control	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
12.84	10.72	2.06	48	2.008	.045	Rejected null

The data show that the null hypothesis was rejected. Operationally, it may be stated that the differences between posttest means of both the experimental and control sample groups were statistically significant. The conclusion which may be drawn from the data is that the posttest scores of the experimental group and those of the control group were different to a statistically significant degree because of the treatment which the experimental group received. This evidence supports the notion that biofeedback and autogenic exercises cause statistically significant differences between group mean scores of abstract thinking ability of college adults.

Hypothesis 2

There will be no significant difference between the pretest and posttest group means of the experimental group based upon abstract thinking ability raw scores.

TABLE 37

Experimental Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
9.60	12.84	-7.54	24	2.06	.000	Rejected null

The data show that the null hypothesis was rejected. Operationally, it may be stated that the differences between pre and posttest means of the experimental sample group were statistically significant. The conclusion which may be drawn from the data is that the observed differences between pre and posttest means of the experimental sample group were because of the treatment received by this group. The evidence supports the notion that biofeedback and autogenic exercises cause statistically significant differences between pre and posttest mean scores of abstract thinking ability of college students. Abstract thinking ability seems to increase to a significant degree when biofeedback and autogenic exercises are used by college adults.

Hypothesis 3

There will be no significant difference between the pretest and posttest group means of the control group based upon abstract thinking ability raw scores.

TABLE 38

Control Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
9.40	10.72	-3.67	24	2.06	.001	Rejected null

The data show that the null hypothesis was rejected. Operationally, it may be stated that the differences between pre and posttest means of the control sample group were statistically significant. The conclusion which may be drawn from the data is that the observed difference between pre and posttest means of the control sample group was because of factors of internal validity such as maturation or test wisdom since the control group did not receive the biofeedback training and autogenic exercise training. The evidence shows that with or without the treatment that abstract thinking ability scores improved significantly; however, the experimental group achieved a higher score than did the control group. Furthermore, the posttest group mean differences between control and experimental group were also statistically significant.

Hypothesis 4

There will be no significant difference between control and experimental group means based upon average posttest item tension readings.

TABLE 39

Posttest Group Means Experimental	Control	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
2.36	3.08	-1.56	48	2.06	.124	Retained null

The data show that the null hypothesis was retained. It may be stated operationally that the differences between posttest means of both the experimental and control sample groups were not significantly different. The conclusion which may be drawn from the data is that the observed difference between posttest item tension indices means of the control and experimental groups was not statistically significant.

The treatment did not cause significant differences of average skeletal muscle tension between both groups of college adults when performing abstracting thinking tasks.

Hypothesis 5

There will be no significant difference between the pretest and posttest group means of the experimental group based upon average item tension readings.

TABLE 40

Experimental Group Means Pretest	Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
3.32	2.36	2.49	24	2.06	.020	Rejected Null

The data show that the null hypothesis was rejected. It may be stated operationally that the difference between pre and posttest means of the experimental group was statistically significant. The conclusion which may be drawn from the data is that the observed difference between pre and posttest item tension indices means of the experimental group was significant and most likely due to the treatment. Biofeedback training and autogenic exercises did cause the average skeletal muscle tension of college adults to significantly decrease when performing abstract thinking tasks.

Hypothesis 6

There will be no significant difference between the pretest and posttest group means of the control group based upon average item tension readings.

TABLE 41

Control Group Means Pretest	Control Group Means Posttest	Student's "t"	DF	Table Value*	Two-Tailed Probability	Findings
2.63	3.08	-1.25	24	2.06	.222	Retained null

The data show that the null hypothesis was retained. It may be stated operationally that the difference between pre and posttest means of the control group was not statistically significant. The conclusion which may be drawn from the data is that the observed difference between pre and posttest item tension indices means of the control group was not significant and most likely due to the group not receiving the treatment. When a group of college adults perform abstract thinking tasks without the treatment, the average skeletal muscle tension shows no significant difference between pre and posttest task administration.

Multiple Regression

Section two of Chapter Four presented a series of "five variable" multiple regression equations related to Hypotheses 7 through 10. Five independent variables were used to predict the mathematical scores and item tension. Those variables were: 1) gender, 2) age, 3) marital status, 4) undergraduate GPA, and 5) handedness.

The following Table 42 displays the mean, standard deviation, and number of cases of dependent variables (mathematical raw scores) entered into the multiple regression equation. These data are related to Hypotheses 7 and 8.

TABLE 42

Dependent Variable	Mean	Standard Deviation	Number of Cases
Pretest-Experimental	9.60	3.77	25
Pretest-Control	9.40	4.14	25
Posttest-Experimental	12.84	3.51	25
Posttest-Control	10.72	3.74	25

The following Table 43 displays the mean, standard deviation, and number of cases of dependent variables (item tension indices) entered into the multiple regression equation. These data are related to Hypotheses 9 and 10.

TABLE 43

Variable	Mean	Standard Deviation	Number of Cases
Pretest-Experimental	3.32	.365	25
Pretest-Control	2.63	.796	25
Posttest-Experimental	2.36	.747	25
Posttest-Control	3.08	1.80	25

The following Table 44 displays the mean, standard deviation, and number of cases of independent variables entered into the multiple regression equation. These data are related to Hypotheses 7, 8, 9, and 10.

TABLE 44

Independent Variables	Mean	Standard Deviation	Number of Cases
Gender	1.40	.49	50
Age	31.04	7.15	50
Marital Status	1.26	.47	50
Undergraduate GPA	2.96	.43	50
Handedness	1.14	.35	50

The values in Table 44 were encoded from the data sheets filled out by the researcher on each subject in the following manner.

Variable	Encoded Value Equivalents
Gender	1 = Male / 2 = Female
Age	Actual chronological age
Marital Status	1 = Married / 2 = Single
Undergraduate GPA	Actual grade point equivalents
Handedness	1 = Right Hand / 2 = Left Hand

The raw data summary may be more closely reviewed in Appendix I, page 192.

The following table relates the findings of Hypotheses 7 through 10.

TABLE 45

Null Hypothesis	Table	Findings	Dependent Variable	Sample Group	Administration
7	13	Retained	Math scores	Experimental	Pretest
	14	Retained	Math scores	Control	Pretest
8	15	Retained	Math scores	Experimental	Posttest
	16	Rejected	Math scores	Control	Posttest
9	17	Retained	Item tension	Experimental	Pretest
	18	Rejected	Item tension	Control	Pretest
10	19	Retained	Item tension	Experimental	Posttest
	20	Retained	Item tension	Control	Posttest

The criteria for rejecting or retaining all null hypotheses was the .05 alpha level using a two-tailed alternative.

Hypothesis 7

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using pretest mathematical test scores as the dependent variable.

TABLE 46

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.469	1.08	2.74	Retained null
Control	.615	2.31	2.74	Retained null

The data show that the null hypothesis was retained. Neither the experimental nor control group's abstract thinking ability can be predicted by joint use of the five (5) independent variables using pretest mathematical test scores as the dependent variable.

Hypothesis 8

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict abstract thinking ability using posttest mathematical test scores as the dependent variable.

TABLE 47

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.488	1.19	2.74	Retained null

The data show that the null hypothesis was retained. The experimental group's abstract thinking ability could not be predicted by joint use of the five (5) independent variables, using mathematical test scores as the dependent variable.

TABLE 48

Sample Group	Multiple-R	"F"	Table Value	Findings
Control	.674	3.18	2.74	Retained null

The data show that the null hypothesis was rejected. The control group's abstract thinking ability can be predicted by joint use of the five independent variables using posttest mathematical test scores as the dependent variable. Furthermore, it was found that the independent variable, "gender," was statistically significant. Gender can be used to predict abstract thinking ability utilizing posttest mathematical test scores as the dependent variable.

Hypothesis 9

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using pretest EMG tension readings as the dependent variable.

TABLE 49

Sample Group	Multiple-R	"F"	Table Value	Findings
Experimental	.477	.95	4.56	Retained null

The data show that the null hypothesis was retained. The experimental group's skeletal muscle tension could not be predicted by joint use of the five independent variables using pretest EMG tension readings as the dependent variable.

TABLE 50

Sample Group	Multiple-R	"F"	Table Value	Findings
Control	.678	3.24	2.74	Rejected null

The data show that the null hypothesis was rejected. The control group's skeletal muscle tension can be predicted by joint use of the five (5) independent variables using pretest EMG tension readings as the dependent variable. Furthermore, it was found that the independent variable, "gender," was statistically significant. Gender can be used to predict skeletal muscle tension utilizing pretest item tension indices as the dependent variable.

Hypothesis 10

Selected biographical independent variables (gender, age, marital status, undergraduate GPA, and handedness) cannot be used to predict average muscle tension in the frontalis and trapezius muscle groups using posttest EMG tension readings as the dependent variable.

TABLE 51

Sample Group	Multiple-R	"F"*	Table Value	Findings
Experimental	.412	.78	4.56	Retained null
Control	.530	1.48	2.74	Retained null

The data show that the null hypothesis was retained. Neither the experimental nor control group's skeletal muscle tension could be predicted by joint use of the five (5) independent variables using posttest EMG tension readings as the dependent variable.

Summary

The following section relates all statistical findings to the original research questions postulated in Chapter One, pages 12 and 13.

Research Question 1

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, can a group of adult learners' ability to think abstractly be improved so that empirical validation can occur utilizing scores from a posttest designed to measure abstract thinking ability?

The data collected from Student's "t" statistical analysis of Hypotheses 2 and 3 show that adult learners can so increase their abstract thinking ability. Both experimental and control groups significantly increased their mean posttest score. However, the experimental group increased their mean score from 9.60 on the pretest to 12.84 on the posttest while the control group increased their mean score from 9.40 on the pretest to 10.72 on the posttest.

Research Question 2

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, what will be the effect of the prescence or absence of autogenic exercises on the abstract thinking ability scores when the group means of both the control and experimental group are analyzed so as to reveal differences between pre and posttest administration?

The data collected from Student's "t" statistical analysis of Hypotheses 1, 2, and 3 show that adult learners who had the autogenic exercises taught to them did increase their abstract thinking ability to a statistically significant degree. Although the group who did not learn the relaxation exercises also increased their scores significantly, the difference in group means was greater in the group who did have the relaxation exercises taught to them. Also, the posttest mean difference of both groups was statistically significant.

Research Question 3

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises can the average muscle tension in the frontalis and trapezius muscle groups be made to decrease so that empirical validation can occur when average posttest tension readings from a biofeedback instrument (EMG) are used as indices of muscle tension?

The data collected from Student's "t" statistical analysis of Hypotheses 5 and 6 show that adult learners can decrease their average skeletal muscle tension in the frontalis and trapezius muscle groups. The experimental group decreased their average muscle tension to a statistically significant degree from a pretest mean of 3.32 to a posttest mean of 2.36. These units are expressions of skeletal muscle tension measured in milli-volts of electricity. The control group increased their average muscle tension from a pretest mean of 2.63 to a posttest mean of 3.06. This difference, however, was not statistically significant.

Research Question 4

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, what will be the effect of the autogenic exercises' presence or absence on the average level of muscle tension in the frontalis and trapezius muscle groups when group means of both the control and experimental group are analyzed so as to reveal differences between pre and posttest readings?

The data collected from Student's "t" analysis of Hypotheses 4, 5, and 6 show that adult learners who were taught the autogenic relaxation exercises decreased their skeletal muscle tension to a statistically significant degree. The group which did not receive the training were unable to decrease muscle tension. In fact, the mean test item tension index increased, although not to a statistically significant degree. The mean difference between control and experimental group posttest scores was not statistically significant.

Research Question 5

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the abstract thinking ability of adult learners when the raw scores from their pretest measures are used as the dependent variable?

The data collected from multiple regression analysis of Hypothesis 7 show that the selected biographical variables of gender, age, marital status, undergraduate GPA, and handedness cannot be used to jointly predict adult learners' abstract thinking ability using pretest mathematical test scores as the dependent variable.

Research Question 6

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the abstract thinking ability of adult learners when the raw scores from their posttest measures are used as the dependent variable?

The data collected from multiple regression analysis of Hypothesis 8 show that the selected biographical variables of gender, age, marital status, undergraduate GPA, and handedness cannot be used to jointly predict the experimental group's abstract thinking ability using posttest mathematical test scores as the dependent variable. Conversely, the selected biographical variables can be used to jointly predict the control group's abstract thinking ability using posttest mathematical test scores as the dependent variable. The variable "gender" was the main contributor to this effect and was the only statistically significant independent variable.

Research Question 7

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from their pretest EMG measures are used as the dependent variable?

The data collected from multiple regression analysis of Hypothesis 9 show that the selected biographical variables of gender, age, marital status, undergraduate GPA, and handedness cannot be used to jointly predict the experimental group's skeletal muscle tension using pretest item tension indices as the dependent variable. Conversely, the selected biographical variables can be used to jointly predict the control group's skeletal muscle tension using pretest item tension indices as the dependent variable. The variable "gender" was the main contributor to this effect and was the only statistically significant independent variable.

Research Question 8

In a laboratory environment utilizing biofeedback instrumentation and autogenic relaxation exercises, can selected biographical variables such as gender, age, marital status, undergraduate GPA, or handedness be used to predict the average muscle tension level in the frontalis and trapezius muscle groups of adult learners when the average tension readings from the posttest EMG measures are used as the dependent variable?

The data collected from multiple regression analysis of Hypothesis 10 show that the selected biographical variables of gender, age, marital status, undergraduate GPA, and handedness cannot be used to jointly predict adult learners' skeletal muscle tension using posttest item tension indices as the dependent variable.

Given these findings, the following list of conclusions are presented by the author.

1) Abstract thinking ability among adult learners can be signifi-

cantly increased by the use of biofeedback and autogenic relaxation exercises.

2) The increased ability to think abstractly can be measured and verified utilizing conventional methods of evaluation of adult learner performances.

3) Skeletal muscle tension among adult learners can be significantly decreased by the use of biofeedback and autogenic relaxation exercises.

4) Electromyography in conjunction with autogenic relaxation exercises, proved to be efficient methods of decreasing skeletal muscle tension, thus reducing "test anxiety." This allows for more accurate measures of adult learner performance.

5) The variable "gender" plays a significant role in predicting adult learner posttest abstract thinking ability.

6) The variables gender, age, marital status, undergraduate GPA, and handedness can jointly predict adult learner abstract thinking ability.

7) The variable "gender" plays a significant role in predicting adult learner pretest skeletal muscle tension.

8) The variables gender, age, marital status, undergraduate GPA, and handedness can jointly predict adult learner skeletal muscle tension.

RECOMMENDATIONS

Section three of this chapter presents the researcher's recommendations for further possible research studies based upon the findings of this investigation. They are presented in no particular order so as to constitute priorities. Instead, the recommendations presented are an attempt to enlarge the scope of the investigation as well as to define areas of possible research which developed out of the process of analysis of the data.

It became clear to the author, when formulating the problem statement for this study, that unless a succinct application to an adult education learning environment be made that a major premise of "applied research" would have been violated.

Research, in general, is a systematic attempt via disciplined inquiry to provide answers to questions. The answers may be abstract and not often provide immediate usable information for altering the environment. This is often the case in "basic research." "Applied research" calls for a great deal of highly concrete and specific answers to questions and often becomes a further test of a "product" of basic research. Applied research becomes the "test" or "tryout" that includes systematic evaluation. This study is clearly a case of applied research whose "product" was essentially the basic research done by Basmajian, Davis, Forrest, Freeman, and Jacobson. These "products" were the findings of their research which defined models of neuronal activity, skeletal muscle tension, and the concommitance between those physiological phenomena and mental work. This author has attempted to provide answers to questions whose source is the adult learner's classroom environment.

Recommendation 1

As defined in the problem statement and research questions (see pages 6, 7, 12, and 13) the use of volunteers within a laboratory environment precludes a direct application of the findings of this study to an "intact" classroom environment. The author believes that further studies should be done, using actual classrooms of adult learners to test the stated hypotheses of this study. Other research questions which could be postulated are:

1) Can test anxiety be reduced among adult learners so as to achieve more accurate student performance measures?
2) Can autogenic relaxation exercises and biofeedback be used to increase an adult learner's ability to form "neural synapses" or "neural impresses?"
3) Can autogenic relaxation exercises and biofeedback be used to increase the creative or intuitive mental process among adult learners?

Recommendation 2

Should a replication of this study be pursued, the author would encourage the researcher to expand the biographical variable used to predict skeletal muscle tension. This expansion of variables could provide the basis for a formulation of a "profile" of those adult learners most likely to be susceptible to skeletal muscle tension. This profile could usefully serve a teacher of adult learners in the diagnostic process.

Recommendation 3

Further studies should be done which do not delimit the population to adult learners. It is fair to ask such questions as: when is the appropriate point in the development and continuum of human learning that students should be taught a more "exquisite" control over their own neuronal activity? Is this an appropriate skill to be taught? What are the measurable and verifiable benefits of such activities? These questions, as well as others, could form the basis for research done with other than college level adult learners as the population.

Recommendation 4

The author would also encourage studies which are longitudinal in nature. These longitudinal studies could provide data on the relationship between learning developmental stages and skeletal muscle tension.

This chapter has summarized the study in these major sections.

The first section provided an overview of Chapters One through Three, the second section summarized the findings and conclusions of Chapter Four and the third section provided a series of recommendations for further research based upon the research questions postulated for this study.

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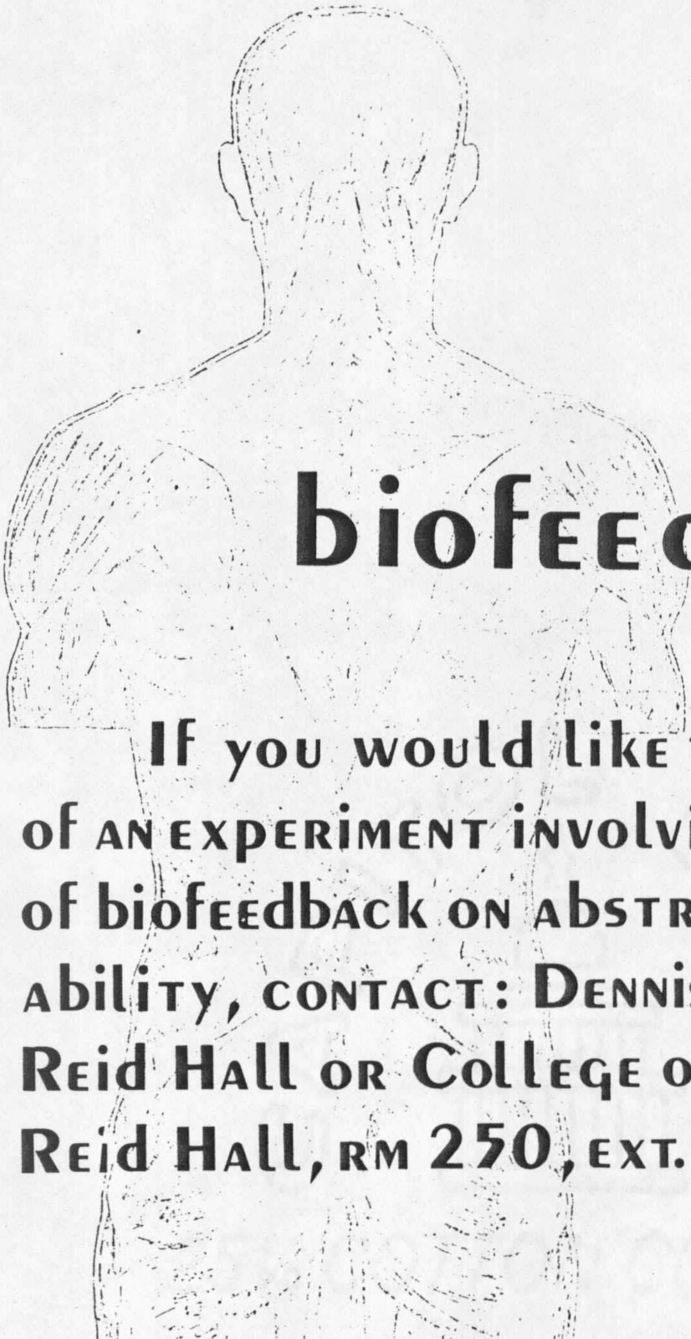
APPENDIXES

APPENDIX A

EXPERIMENT ADVERTISEMENT



biofeedback

If you would like to be a part of an experiment involving the effect of biofeedback on abstract thinking ability, contact: Dennis Weems, rm 113 Reid Hall or College of Education, Reid Hall, rm 250, ext. 4731.

APPENDIX B

MATCHED PAIRS DATA

SUBJECT PRETEST
RAW DATA

Pair Number	Subject Number	Raw Score	Item Tension (Microvolts)	Subject Number	Raw Score	Item Tension (Microvolts)
1	45	16	.97	48	15	.79
2	28	14	1.07	17	14	1.04
3	10	14	.98	37	14	1.00
4	22	14	.95	40	14	.85
5	39	14	.63	35	14	.84
6	15	13	1.25	6	12	1.03
7	38	13	.65	33	13	.69
8	3	12	.88	7	11	.83
9	20	11	1.25	18	11	1.00
10	30	10	1.00	2	11	.94
11	47	10	.90	43	12	.82
12	1	11	.80	41	11	.81
13	46	9	.93	44	9	.87
14	4	8	1.08	23	10	.97
15	24	10	.87	21	10	.92
16	32	10	.84	31	10	.83
17	13	8	.93	11	7	.91
18	36	8	.78	26	8	.85
19	50	7	.82	42	9	.87
20	5	7	.81	19	6	.88
21	16	6	.98	25	6	.95
22	49	7	.87	12	4	.70
23	27	4	.66	34	2	.76
24	14	3	.65	9	2	.85
25	8	1	1.91	29	0	.85

APPENDIX C

AUTOGEN 1700 MANUAL EXCERPT

I. INTRODUCTION

A. The Electromyogram - The activity of the skeletal muscles is triggered by a complex pattern of electrical impulses originating in the central nervous system. These impulses travel from the brain and spinal chord through motor nerve pathways which terminate in the muscle fibers. Innervation of the muscle fibers, and consequent muscular contraction, is brought about when a significant number of motor nerves in a given area are emitting repeated electrical discharges. Muscular relaxation occurs when the electrical discharge rate of the motor nerves decreases. The electrical activity which accompanies muscle action is called the electromyogram, or EMG, and is commonly detected by metal electrodes attached to the surface of the skin. EMG activity is generally expressed in integral average microvolts (millionths of a volt). At any given location, this microvolt level is a function of:

1. the number of motor neurons firing in the vicinity of the electrodes.

2. the rate of firing (discharge) per neuron

3. proximity of the discharging neurons to the electrodes.

Since muscular tension is proportional to the degree of electrical discharge stimulating the muscles, the EMG is a direct physiological index of muscular contraction or relaxation (the lower the microvolt level of EMG activity, the more relaxed the monitored muscle).

B. Feedback Electromyography - Feedback electromyography is the process of monitoring and displaying to an individual the ongoing EMG activity generated by his muscle action. In feedback electromyography, the EMG activity is first amplified, then rectified, integrated and rendered in the form of auditory patterns and/or visual displays.

This audio and visual "feedback" informs the learner of the relative tension or relaxation of the muscle(s) being monitored. Feedback also enables the learner to recognize and discriminate subtle changes in muscular activity which are frequently outside the domain of normal sensory awareness. With time, this learning process generally results in the individual's ability to exercise substantially greater control over the specific muscle activity than had previously been possible. This control is of particular value in the attainment of deep muscular relaxation, the recovery of functionality in atrophied muscles, etc.

C. Introduction to the Autogen 1700

The Autogen 1700 Feedback Myograph offers a significant number of training-oriented features and monitoring capabilities which have previously been unavailable in electromyograph instrumentation. To derive maximum benefit from the instrument, ASI recommends that you study this manual carefully to develop a thorough understanding of the many unique features and modes of operation of the Autogen 1700. In addition, ASI recommends that professionals train with the instrument to become thoroughly familiar with its use.

This section will provide a capsule summary of the features and control functions of the Autogen 1700 and a general overview of its operation. Detailed operating instructions and explanations of control functions are provided in Section II of this manual.

1. Front Panel Functions of the Autogen 1700

a. Electrode Input Connector ("Input A", "Input B") - Accepts the plugs at the end of the EMG electrode cables.

b. Input Weighting Control ("Weighting") - Determines which of the two electrode inputs will be monitored at any given time; also enables one to perform weighted combinations of EMG information from the two inputs.

c. Power/Test Switch ("Power") - Used to turn the power to the instrument on and off. When switched to the appropriate position, this control also activates the battery strength and electrode impedance (attachment quality) test functions.

d. EMG Bandpass Selector ("Bandpass Hz.") - Determines the frequency bandpass over which the EMG activity is monitored. Bandpasses of 100-200 Hz., 400-500 Hz., 100-1000 Hz., and 20-1000 Hz. may be selected.

For most general EMG applications, the recommended bandpass is 100-200 Hz.

e. EMG Activity Meter - Provides a visual display of instantaneous or time-averaged EMG activity expressed in integral average microvolts, selectable over seven scales (0.05-1uV, 0.15-3uV, 1.5-30uV, 5-100uV, 15-3-uV, and 50-1000uV). When switched to the appropriate test mode, the meter also measures battery strength and electrode impedance (attachment quality).

f. Meter Scale Selector - ("Meter Scale") - Selects one of the seven available scales of EMG activity to be displayed on the EMG Activity Meter.

g. Instantaneous/Average Meter Readout Selector ("Meter, Avg." push-button) - Determines whether the EMG Activity Meter reading reflects instantaneous or time-averaged information. When switched to the "Avg." mode (push-button in), the meter reading will reflect the average EMG level over the running time interval selected by the Meter Averaging Time Selector ("Avg. Time").

h. Meter Averaging Time Selector ("Avg. Time") - Selects the running time interval over which the EMG information is averaged when the meter is switched to the "Avg." Mode. Time intervals of 10, 20, 50, 100, 200, 500, and 1000 seconds are available.

i. Audio Output Connector ("Audio") - Accepts the connector plug from either an external speaker or a set of stereo headphones. (To receive audio feedback, a high efficiency external speaker or set of stereo headphones is required. Any set of stereo headphones may be used, but only a high-efficiency speaker carried or recommended by ASI should be used.)

j. Audio Feedback Volume Control ("Volume") - Controls the volume of the audio feedback signal.

k. Feedback Threshold Selection ("Threshold")-Sets the upper or lower EMG microvolt limit at which audio feedback will be activated. Also determines threshold limits for the analog light feedback.

l. Threshold On/Off Switch ("Threshold, On" push-button) - Used to activate the Audio Feedback Threshold Selector. When the threshold selector is not activated, audio feedback will be present over the entire meter scale.

m. Threshold Logic Switch ("Threshold, Above" push-button) - Determines whether the audio feedback will be present below or above the selected threshold level. When this switch is depressed, audio feedback will be present above threshold; otherwise, it will appear below threshold.

n. Audio Feedback Mode Selector ("Audio Feedback") - Selects one of eight possible forms of audio feedback: variable pulsated analog tone ("AN. 1"), continuous analog tone ("AN. 2"), steady pulsated analog tone ("AN.3"), click feedback ("CL"), bi-tone derivative feedback ("DR"), positive derivative feedback ("DR+"), negative derivative feedback ("DR-"), direct audio feedback ("DA"), and external feedback through battery-operated tape recorded ("EXT").

o. Feedback Response Control ("Response") - Enables the EMG information which drives the audio feedback, light feedback, and instantaneous meter feedback to be "smoothed" or slightly averaged over a short variable time interval of 0-5 seconds.

p. Feedback Expansion Switch ("Feedback, Expand" push-button) - Allows one to expand the resolution of the audio feedback signal around a selected microvolt level. This switch is used in conjunction with the Audio Feedback Threshold Selector.

q. Light Feedback - Consists of four lights which provide visual feedback for EMG fluctuations in either the analog or derivative mode.

r. On/Off Switch for Light Feedback ("Lights, On" push-button) - When depressed, the feedback lights on the front panel of the instrument will be activated. They should be switched off when not desired to avoid unnecessary battery drain.

s. Light Feedback Mode Selector ("Lights, Deriv." push-button) - When depressed, the light feedback will operate in the derivative mode. Otherwise, the light feedback will operate in the analog mode.

2. Accessories for the Autogen 1700

In addition to the Autogen 1700, the following accessories are required for operation (Items a, b, c, and d are included with the purchase of each unit).

a. EMG Electrode Assemblies - Two EMG electrode assemblies are provided with the purchase of each Autogen 1700. Each electrode assembly consists of three silver/silver chloride electrodes, each embedded in a plastic insulator disc and attached to a shielded cable. The connectors at the end of the electrode cables are inserted into the front panel connectors labeled "Input A" and "Input B."

b. EMG Electrode Attachment Discs - These discs, which incorporate an adhesive material on both sides, are used to attach the electrodes to the skin surface.

c. Electrode Contact Medium - This electrical conductive substance facilitates EMG electrode contact. A small amount is squeezed into each electrode cup before attaching the electrode discs to the skin surface.

d. Input Termination Plug - If only one of the two electrode input connectors on the Autogen 1700 is used, input termination plug is inserted into the unused connector. This human-engineering feature prevents possible environmental noise pickup from the unused connector in cases where the input Weighting Control is not rotated completely to the position corresponding to the input connector used.

e. High Efficiency External Speaker or Stereo Headphones- To receive audio feedback, a high-efficiency external speaker or a set of stereo headphones is required (both available through ASI). Any set of stereo headphones may be used, but only an external speaker carried or recommended by ASI should be used. The external speaker is generally preferred over the headphones, since some individuals may find wearing headphones uncomfortable or distracting. The speaker or set of headphones is plugged into the audio connector on the front panel of the instrument.

3. Rear Panel Functions of the Autogen 1700

   a. Instrumentation Outputs - These outputs are used to interface the Autogen 1700 with external data acquisition devices such as the Autogen 5100 Digital Integrator, or accessory items, such as a remote EMG meter. For information concerning the electrical characteristics of these output functions and instructions on their use, please refer to the Appendix of this manual.

   b. External Audio Feedback Input ("Ext. Audio In") - This connector accepts an audio cable from a battery operated tape player. Do not use this connector for any other purpose.

   c. Connector for Isolated Power Supply ("To MA 50/51") - Used to interface the Autogen 1700 with the MA-51 Isolated Power Supply or the MA-50 Rechargeable Battery Pack. Do not use this connector for any other purpose.

   d. Battery Compartment - Contains the two nine-volt batteries which power the unit.

4. Initial Hookup/Operating Procedures

   This section provides an abbreviated set of operating instructions for the Autogen 1700 and is intended to give an initial overview of the operation of the instrument. (Detailed operating instructions covering the many functions and capabilities of the unit are provided in Section II of this manual).

   a. Take one of the two electrode sets and attach the electrodes to the forearm extensor muscle, as outlined in Section II-B, pages 10 to 14. (In particular, refer to Figure 6d, page 13).

   b. Plug the attachment cable from this set of electrodes into the front panel connector marked "Input A", making certain that the plug clicks into place.

c. Take the second set of electrodes and attach it to the forearm flexor muscle, as outlined in Section II-B, pages 10 to 14. (In particular, refer to Figure 6e, page 14).

d. Plug the attachment cable from this set of electrodes into the front panel connector marked "Input B", making certain that the plug clicks into place.

e. Plug the connector from the external speaker or a set of stereo headphones into the front panel connector marked "Audio."

f. Turn on the power to the unit and test the battery strength and electrode impedance (attachment quality) of each of the two sets of electrodes. These test procedures are outlined in Section II-D, page 17.

g. Return the power switch of the unit ("Power") to the "On" position after completing these test functions.

h. Rotate the Input Weighting Control ("Weighting") completely counterclockwise to the "A" position. This will cause the instrument to monitor the EMG activity from Input A, the first set of electrodes.

i. Rotate the EMG bandpass Selector ("Bandpass Hz." to the 100-200 Hz. position.

j. Rotate the Meter Scale Selector ("Meter Scale") to the position which causes the meter needle to deflect as closely as possible to the center of the meter scale when the monitored muscle is relaxed.

k. Rotate the Audio Feedback Mode Selector ("Audio Feedback") to the "AN 2" (Analog Feedback) position, and adjust the Feedback Volume Control ("Volume") to a comfortable listening level.

l. Rotate the Feedback Response Control ("Response") to 1 second.

m. Set the Meter Averaging Time Selector ("Avg. Time") to 20 seconds.

n. Activate the Derivative Light Feedback by depressing the "Lights On" and "Deriv." switches.

o. Make certain that there are no switches depressed other than those indicated in the previous 14 steps.

p. Now observe the performance of the instrument. As you tighten the forearm extensor muscle ("Input A"), the meter needle will deflect to the right and the pitch of the audio feedback tone will increase. As you relax this muscle, the meter needle will deflect to the left and the pitch of the audio feedback tone will decrease.

If the meter needle is too near the end of the scale in either direction, the Meter Scale Selector ("Meter Scale") should be readjusted to a point where the meter needle deflects as closely as possible to the center of the scale.

Now observe the light feedback and its correlation with the meter and audio feedback. In the derivative mode, only the two center lights will be activated. As the EMG activity decreases, the "decrease" light will come on.

q. Depress the Instantaneous/Average Meter Readout Selector ("Meter Avg."). The meter reading will now reflect the running average of EMG activity over a twenty second time base.

r. Note the meter reading when switched to the "Avg." mode. Set the Audio Feedback Threshold Selector ("Threshold") to a point where its numerical reading corresponds approximately to the above meter reading. For example, if the time-averaged EMG level displayed by the meter is 2.5, rotate the "Threshold" knob to 2.50.

s. Activate the Audio Feedback Threshold by depressing the "Threshold, On" switch. Return the meter to its in-stantaneous mode of operation. Return the "Lights, Deriv." switch to its original position. This will cause the Light Feedback to function in the "analog" mode.

t. Now observe the performance of the instrument. When the EMG level drops below the selected threshold value, the audio feedback signal will be present. When the EMG activity rises above this level, the audio feedback will not be present.

u. Rotate the Input Weighting Control ("Weighting") completely clockwise to the "B" position. This will cause the instrument to monitor the EMG activity from Input B, the second set of electrodes.

v. Now rotate the Input Weighting Control to the "O" position, halfway between "A" and "B". This will cause the instrument to monitor combined EMG activity from the two muscle groups.

II. DETAILED OPERATING INSTRUCTIONS

A. Operating Precautions

1. Do not connect the Autogen 1700 Feedback Myograph to any external electrical apparatus that is not battery operated without using an optical isolation accessory especially designed by ASI for this purpose. If the instrument is connected to an AC (powerline) operated device which is faulty or improperly grounded, shock to the user and serious damage to the unit may result. (The unit may, of course, be connected to battery-powered accessory instruments such as the Autogen 5100 Digital Integrator).

2. When removing old batteries or inserting new batteries, make certain that the power switch to the unit is turned off.

3. The Autogen 1700 should be used only under the supervision of a medical, paramedical, psychological or education professional.

APPENDIX D

DATA SHEET EXAMPLE

SUBJECT____________________

DATE______________ TIME__________

RESTING mV READING__________

METER SCALE READING__________

PRETEST ☐
POSTTEST ☐

GROUP
Control ☐
Experimental ☐

TEST ITEM NUMBER	TIME (sec)	mV	PROBLEM RESPONSE
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			

DATA SHEET

NAME: ____________________ MALE ☐

FEMALE ☐

BIRTH DATE: ______________ BIRTH PLACE: ______________

Check one (1):

Right-handed ☐

Left-Handed ☐

Both ☐

MARRIED ☐

SINGLE ☐

RACE, Check one (1):

Hispanic ☐

Amer. Indian ☐

White ☐

Black ☐

Asian ☐

Other ☐

OCCUPATION:

Full-time student ☐

Part-time student ☐

Occupation: ______________

UNDERGRADUATE GPA: ______________

ACADEMIC AREA: ______________

EDUCATIONAL STATUS:

Non-degree prog. ☐

Degree program

Undergrad ☐

Masters ☐

Doctoral ☐

Post-Doc ☐

APPENDIX E

EXPERIMENT CHECKLIST

EXPERIMENT CHECKLIST

1. Order the Mathematics Test cards according to the Random Ordering Sheet.

2. Explain the (pretest/posttest/treatment) procedure to the subject.

3. For the pretest/posttest, give instructions:

   a. mentally solve the mathematical problems given you on each 3 X 5 card. I will hold the cards for you.

   b. you have twenty seconds to solve each problem.

   c. respond with your answer or if you cannot solve the problem, give no response.

   d. I will not verify the answer for you.

   e. the problems are addition, subtraction, multiplication, and division of fractions. Each problem will vary in degree of difficulty.

   f. a rest period will be observed between each problem.

   g. do not make unnecessary movements during the solution period.

   h. do you have any questions concerning the directions I have just given you?

4. Attach the electrodes to the subject.

5. Perform the battery test.

6. Check the settings on the Autogen 1700 for the following:

   a. plug in the electrode connectors,

   b. power on,

   c. set Meter Averaging Time Selector to 20 seconds,

   d. set Audio Feedback Mode Selector to AN 1,

   e. for pretest - turn volume <u>off</u>,

f. for posttest - adjust volume for subject,

g. engage the following settings:

   1. Threshold On/Off switch to <u>On</u>,

   2. Threshold Logic switch to <u>Below</u>,

   3. On/Off switch for Light Feedback to <u>Off</u>.

7. Begin the experiment with the micrometer centered.

8. Record the Meter Scale reading on the Data Sheet.

9. Record the test data on the Data Sheet.

10. After the pretest, posttest, detach the electrodes.

11. Turn the Autogen 1700 off.

12. Verify the next appointment with the subject.

APPENDIX F

WAIVER FORM

This study is an attempt to collect data from college students about the relationship between muscle action potentials and the ability to think abstractly. The experiment involves the use of an electromyogram (EMG) as the measuring device for muscle potentials and a mentally solved mathmatical test with varying degrees of item difficulty which will be used to determine achievement.

As a participant in the experiment, you have the right to confidentiality of the data obtained from you. All analysis of the data will be done in a group manner so that individual measurements will remain as anonymous as possible. The results will be available to you in the University Library and the Dean of Education's office upon the completion of the dissertation.

Dennis Weems

Dennis Weems

I give my permission to the experimentor to use the data collected from me within his dissertation as stipulated by the above conditions of confidentiality. I also give my permission to perform the electromyographic measurements, the process of which has been explained fully to my satisfaction.

Date | Signature

APPENDIX G

MATHEMATICAL PROBLEMS

MATHEMATICS TEST USED TO MEASURE ABSTRACT THINKING ABILITY

1) 7/9 ÷ 8/15 =

2) 7/15 ÷ 5/18 =

3) 7/9 - 3/4 =

4) 3/4 X 6/5 =

5) 6/12 ÷ 3/4 =

6) 1/2 ÷ 1/8 =

7) 2-1/3 - 1/4 =

8) 5/6 - 3/4 =

9) 3-3/4 - 5/6 =

10) 5/9 - 1/6 =

11) 3 ÷ 2/3 =

12) 2-1/2 X 2-1/4 =

13) 1/6 X 3/8 =

14) 3/6 X 5/7 =

15) 2/3 + 5/6 =

16) 3/4 + 2/9 =

17) 2/10 X 50/100 =

18) 2/6 + 3/6 =

19) 4-5/8 + 3-1/4 =

20) 4-5/8 + 3-1/4 =

APPENDIX H

RANDOM ORDERINGS OF MATHEMATICAL PROBLEMS

Random Ordering of Mathematical Problems

Subject	Random Ordering																			
1	8	10	5	3	18	20	2	12	1	14	16	9	11	6	17	7	19	13	15	4
2	14	20	13	1	12	10	8	17	7	5	9	3	6	15	19	16	4	2	18	11
3	12	18	6	19	9	8	7	10	14	20	16	11	5	4	1	15	2	3	17	13
4	5	11	7	19	18	17	3	8	2	6	16	1	4	9	20	12	13	10	14	15
5	12	13	10	19	7	17	1	11	9	14	4	3	8	5	16	20	6	15	18	2
6	2	15	14	13	17	8	18	1	5	12	19	4	11	6	16	9	10	7	20	3
7	17	19	16	13	20	6	11	7	14	18	5	9	8	10	1	3	4	15	2	12
8	4	15	18	9	11	17	19	16	6	10	8	7	5	20	1	14	13	2	12	3
9	15	18	17	5	2	4	11	10	8	7	16	9	20	13	6	14	3	12	19	1
10	18	2	16	19	6	11	10	9	4	7	15	13	17	14	1	20	8	5	12	3
11	10	11	19	15	20	7	6	14	2	3	4	12	18	16	9	8	17	1	13	5
12	15	7	5	12	6	14	11	4	8	2	18	19	20	10	1	13	9	3	17	16
13	7	19	20	6	2	15	18	13	12	3	8	5	4	17	1	10	9	16	11	14
14	11	1	9	14	20	17	5	19	2	8	6	16	10	13	4	15	3	18	12	7
15	8	2	6	19	3	13	20	9	15	12	4	5	17	1	14	11	16	7	10	18
16	2	10	7	13	17	12	16	14	4	20	18	1	11	6	9	8	5	3	19	15
17	15	17	8	16	7	19	9	14	12	13	18	10	1	3	20	11	5	2	4	6

Subject	Random Ordering																			
18	4	13	1	12	6	9	2	19	17	15	11	7	5	8	14	20	3	16	18	10
19	7	11	5	13	15	12	19	8	20	14	16	6	18	9	17	3	2	1	10	4
20	10	8	5	17	18	15	9	1	16	4	14	7	6	3	19	2	20	11	12	13
21	4	6	3	2	16	12	14	13	15	10	1	19	7	11	5	17	8	18	9	20
22	2	7	12	9	8	14	15	20	1	17	13	6	10	19	4	3	11	16	5	18
23	2	10	20	12	19	6	7	14	4	17	9	8	1	3	15	11	13	16	5	18
24	20	17	11	9	19	16	4	13	5	14	6	15	1	10	7	18	2	3	8	12
25	10	11	1	9	8	5	3	19	16	17	4	13	2	7	20	18	15	12	14	6
26	4	12	15	6	2	19	16	10	9	18	1	20	14	8	13	17	3	11	5	7
27	7	17	2	1	6	14	11	4	20	12	8	10	19	16	9	18	3	15	13	5
28	2	8	15	19	3	4	20	10	9	17	14	18	6	12	7	13	1	11	16	5
29	8	2	9	4	1	12	5	14	3	13	15	18	11	6	7	10	20	19	17	16
30	6	15	14	10	19	8	18	2	16	20	3	7	9	5	13	4	11	12	1	17
31	17	13	2	18	20	9	12	10	16	1	11	8	3	6	7	4	15	19	5	14
32	3	16	13	12	2	18	10	20	9	5	14	1	17	8	4	15	11	6	19	7
33	18	9	13	14	6	10	2	5	12	11	1	15	16	20	19	17	4	8	7	3
34	17	16	2	10	8	1	15	3	5	4	20	9	6	13	14	7	19	18	11	12
35	12	6	9	19	14	1	15	18	11	13	5	16	8	4	17	3	10	2	20	7
36	3	2	5	15	6	18	20	1	7	9	13	11	4	14	12	10	19	17	8	16
37	9	14	7	19	20	12	18	11	6	15	1	5	13	4	10	3	8	16	2	17

Subject	Random Ordering																			
38	14	9	7	8	13	19	20	3	17	2	1	4	11	12	10	16	5	15	18	6
39	14	9	10	19	5	16	18	2	12	15	3	7	6	13	20	1	4	17	11	8
40	19	5	1	3	13	17	14	6	11	8	15	20	2	10	7	12	9	4	16	18
41	16	11	7	8	3	14	4	9	2	6	18	12	20	15	5	13	10	17	19	1
42	9	10	2	3	18	6	5	14	19	11	15	13	20	8	7	16	17	1	12	4
43	8	16	9	5	13	20	3	19	12	17	18	15	10	2	11	4	1	6	7	14
44	12	5	9	8	6	7	16	1	19	11	14	18	4	2	20	13	10	3	15	17
45	18	20	15	13	6	19	4	12	8	2	14	9	10	11	7	1	5	17	16	3
46	2	1	9	10	14	13	12	20	11	6	4	8	7	16	17	3	18	5	15	19
47	4	14	6	17	5	3	9	11	12	13	16	20	1	18	2	7	8	15	10	19
48	6	8	19	5	3	10	17	11	1	18	2	7	4	20	12	13	14	15	16	9
49	4	1	13	11	8	12	14	2	19	3	17	15	5	9	18	16	7	20	10	6
50	8	3	5	4	17	15	14	18	9	10	13	7	6	12	16	11	2	19	20	1

APPENDIX I

RAW DATA SUMMARY

EXPERIMENTAL GROUP

Pair #	Test Score Pre	Test Score Post	Item Tension Pre	Item Tension Post	Gender	Age	Marital Status	Undergrad. GPA	Handedness
1	16	16	5.36	1.59	1	39	1	3.25	1
2	14	18	2.78	2.92	2	50	2	3.00	1
3	14	16	2.74	1.92	1	27	1	2.90	1
4	14	15	2.61	2.15	2	35	1	2.70	1
5	14	16	4.24	2.26	1	33	1	2.70	1
6	13	16	4.80	4.12	1	30	1	2.56	1
7	13	16	3.05	2.26	1	30	1	2.40	1
8	12	13	1.58	1.52	1	31	1	2.30	1
9	11	15	3.58	2.41	1	21	1	3.50	2
10	10	13	2.22	1.25	1	22	1	2.92	1
11	10	11	2.77	4.20	2	27	2	3.70	1
12	11	15	10.79	1.86	2	46	1	2.86	1
13	9	11	1.34	1.38	1	32	2	3.00	1
14	8	15	1.85	1.69	1	25	2	2.30	1
15	10	12	2.87	2.08	1	22	1	2.85	1
16	10	11	2.36	2.14	2	30	1	3.00	1
17	8	11	2.67	2.37	1	33	1	3.00	1
18	8	14	3.44	2.86	1	24	2	2.75	1
19	7	11	2.31	2.15	1	25	2	2.85	2
20	7	16	2.95	2.30	2	42	1	3.65	1
21	6	11	4.58	2.71	1	29	1	3.52	1
22	7	11	2.93	2.59	2	25	2	3.40	2
23	4	7	2.70	2.32	2	29	2	2.50	1
24	3	9	3.34	2.28	2	38	1	2.50	1
25	1	2	3.10	3.61	2	38	1	2.95	1

CONTROL GROUP

Pair #	Test Score Pre	Test Score Post	Item Tension Pre	Item Tension Post	Gender	Age	Marital Status	Undergrad. GPA	Handedness
1	15	13	2.53	2.65	2	33	1	3.80	1
2	14	16	3.07	3.08	2	31	1	3.75	1
3	14	15	2.50	2.33	1	24	1	3.50	1
4	14	15	1.75	1.85	1	29	1	3.10	1
5	14	14	2.02	1.81	1	25	2	2.80	2
6	12	17	1.94	2.73	1	26	1	2.98	1
7	13	12	2.15	1.62	1	25	1	3.75	1
8	11	10	2.39	2.43	1	29	1	2.25	1
9	11	14	2.49	1.68	1	30	1	2.80	1
10	11	11	2.65	2.62	1	30	1	2.80	1
11	12	12	2.41	2.18	1	37	1	3.00	1
12	11	10	2.69	19.05	2	44	1	3.17	1
13	9	9	4.21	4.20	2	35	1	3.80	1
14	10	13	2.05	2.53	1	21	1	3.25	1
15	10	9	4.87	3.96	2	28	1	2.59	1
16	10	13	2.62	1.98	1	47	1	2.27	1
17	7	9	1.53	1.34	1	34	1	2.59	2
18	8	11	1.99	2.64	1	22	2	3.30	2
19	9	11	2.87	3.09	2	39	1	2.50	2
20	6	7	3.62	5.32	2	30	1	3.00	1
21	6	9	1.78	2.69	1	24	2	2.50	1
22	4	7	3.56	7.56	1	37	1	2.85	1
23	2	5	3.28	3.04	2	40	2	3.50	1
24	2	3	2.00	2.30	2	26	2	2.50	1
25	0	3	2.94	2.38	2	23	1	3.00	1