The Management of Blood Pressure Using Progressive Muscle Relaxation under Nonstressful and Stressful Conditions

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THE MANAGEMENT OF BLOOD PRESSURE USING PROGRESSIVE MUSCLE RELAXATION UNDER NONSTRESSFUL AND STRESSFUL CONDITIONS

by

A. Janelle Maldonado

A Thesis Submitted to the Faculty of the Graduate College in partial fulfillment of the requirements for the Degree of Master of Arts Department of Psychology

Western Michigan University
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Progressive muscle relaxation was assessed as a method for controlling blood pressure under stressful and nonstressful conditions using a multiple baseline across subjects design. Three borderline hypertensive subjects were trained in two experimental conditions, progressive muscle relaxation under resting conditions (PMR) and progressive muscle relaxation while performing time-limited tasks known to produce temporary increments in blood pressure (PMR + Math). Generalization of training effects to nontraining conditions was assessed in post-training, task only, sessions and in the home environment. Measures of changes in systolic and diastolic blood pressure as well as frontalis EMG were recorded once per minute for each condition. The results suggest that relaxation training under stressful conditions is superior to standard relaxation training in lowering blood pressure under stressful conditions.
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A. Janelle Maldonado
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CHAPTER I

INTRODUCTION

Hypertension is an American health problem of epidemic proportion. While in recent years we have seen a reduction in the incidence of contagious disease, there has been a dramatic increase in degenerative disorders such as coronary heart disease and hypertension (U. S. Department of Health, Education, and Welfare, 1978). It is estimated that there are twenty-three million American adults who suffer from some degree of diagnosed hypertensive vascular disease and these numbers may be growing with the identification of hypertensive individuals through blood pressure screening programs. Epidemiological research has demonstrated hypertension to be a robust predictor of several life-threatening disorders including myocardial infarction, congestive heart failure (Kanel, Castelli, McNamara, and Feinleib, 1972), chronic renal failure and blindness (Veterans Administration Cooperative Study on Anti-Hypertensive Agents, 1967, 1970, 1972). In addition, strokes occurring before age 65 are believed to be mostly a complication of hypertension (Second USA-USSR Joint Symposium, 1979). Research results from the ten year Framingham Study (Kanel et al., 1972) demonstrated that persons having high blood pressure are three times more likely to develop cardiovascular disease than normotensive individuals. These research findings have resulted in the designation of hypertension as one of the five major risk factors of coronary heart disease.
Hypertension occurs when blood circulates through the arteries at a pressure which is higher than normal. Actually, two blood pressures are involved. The systolic blood pressure is the pressure against the walls of the arteries when the ventricles are contracting and the diastolic blood pressure is the pressure against the walls of the arteries between ventricle contractions. While there is much disagreement regarding the definition of hypertension or what is blood pressure which is "higher than normal", blood pressure levels at or above 160 mmHg for systolic and 95 mmHg for diastolic are commonly accepted as hypertensive. Persons with blood pressure levels below 160/95 but above 138/88 may be considered borderline hypertensive (Smith, 1977). An individual is diagnosed as hypertensive if either or both the systolic and diastolic pressures remain in the high range for a period of a year or so. Untreated, hypertension may lead to severe physiological complications such as those mentioned earlier or even to death. Unfortunately, most cases of hypertension (80% in fact) fall under the heading of "essential" hypertension or hypertension for which there is no identifiable organic cause and thus no obvious organic defect to correct during treatment (Bech and Hilden, 1975). Consequently, extensive medical, pharmacological, and behavioral research has been directed at identifying effective treatments for essential hypertension.

Pharmacological treatments have been shown to effectively reduce blood pressure and other complications of hypertension including sudden death, advanced retinal changes, renal malfunction, strokes, myocardial infarction and congestive heart failure (Veterans Admin-
istrations Cooperative Study Group on Anti-hypertensive Agents, 1967, 1970, 1972). However, medication may be counter indicated as a treatment alternative for several reasons. One reason is that blood pressure medications have not been found effective in reducing borderline hypertension and thus physicians are reluctant to prescribe them. A second difficulty with pharmacological treatments is the problem of aversive drug side effects. Some side effects commonly associated with blood pressure medications are dermatitis, headaches, nausea, diarrhea, depression, weight gain due to sodium and fluid retention, loss of libido and sexual impotence (Page and Sidd, 1973).

A third problem is one of compliance. Patient compliance to hypertension regimens is notoriously poor (Agras and Jacob, 1979). It is the case that hypertension patients typically do not experience symptoms with increments in blood pressure and are usually placed on medication for life. The lack of symptoms, the drug side effects, and the expense of the medication combine to produce the high degree of noncompliance. Given these circumstances, effective nonpharmacological treatment alternatives for hypertension are needed.

Several relaxation techniques for managing blood pressure have been evaluated over the past forty years including: progressive muscle relaxation (Jacobson, 1939), metronome conditioned relaxation (Brady, Luborsky, and Kron, 1974), psychological relaxation (Stone and Deley, 1976), transcendental meditation (Benson, Resner, Marzetta, and Klemchuk, 1974), yoga exercises (Datey, Deshmum, and Dalvi, 1969, Patel, 1973), autogenic training (Luthe and Schultz, 1969), and hypnosis (Deabler, Gidel, Dillenhoffer, and Elder, 1973). Despite dif-
ferences in theoretical rationales, all of these techniques involve five common elements: a reduction in muscular tension; a covert device, such as a repetitive phrase; a passive attitude; a quiet environment; and in most cases, regular practice (Benson, Beary and Carol, 1974). Comparisons of blood pressure reduction reported in previously published articles yield no significant differences between techniques (Agras and Jacob, 1979). Relaxation produced blood pressure reductions of as much as 25/16 millimeters of mercury have been obtained in well controlled studies (Deabler et al., 1973).

Biofeedback is another technique which has been applied in the study of blood pressure control research. Two procedures have been examined, one where biofeedback equipment is used to directly measure and train blood pressure changes and second where EMG biofeedback is used to enhance relaxation. In either type of training, subjects typically are presented with a signal which amplifies small physiological changes (e.g., blood pressure or muscle activity). They are then instructed to try and make the signal change in a specified direction. The results of research in blood pressure and EMG biofeedback have demonstrated both as effective methods for reducing blood pressure. Reductions of as much as 21 millimeters of mercury in diastolic blood pressure and 16 millimeters of mercury in systolic blood pressure have been reported (Miller, 1972). Unfortunately, there are several disadvantages to using biofeedback as a standard training procedure for blood pressure management. The sophisticated biofeedback instrumentation generally limits training and practice to the treatment setting. A few studies have examined the use of biofeedback units in
the home environment (Goldman, Kleinman and Snow, 1975) but the use of such units may not become practical until they are more readily available, more reliable, and less expensive. Another possible disadvantage particular to EMG biofeedback is that training leads to control of only specific muscle groups (Burish and Horn, 1979). Relaxation programs on the other hand, may produce more general reductions in cardiovascular and autonomic arousal (Steptoe, 1978). Finally, the nature of biofeedback training may limit the degree to which training effects generalize to nontraining conditions. Generalization of biofeedback-produced blood pressure changes has not yet been studied (Seer, 1979). It may be that biofeedback training effects are specific to the particular laboratory setting and will therefore not be maintained in a nonlaboratory setting.

Relaxation techniques offer a number of advantages over biofeedback for controlling hypertension. In studies using relaxation techniques to control blood pressure, continued decrements have been reported in one year follow-up reports (Patel, 1975). While the reductions obtained using relaxation are as large as those obtained with biofeedback, practicing relaxation is convenient, requires no sophisticated instrumentation, and is inexpensive. Finally, individuals practicing relaxation have reported additional benefits such as improved sleep, general reduction in stress and fewer headaches (Deabler et al., 1973).

Over the years numerous investigations have reported that stress plays a significant role in the development of hypertension (Farris, Yeakel, and Medoff, 1945, Medoff and Bongiovanni, 1945, Shapiro and
Studies have shown that moderately stressful events similar to those of normal living, produce transient increases in blood pressure. These pressor events, believed to be part of the "fight or flight" emergency reaction (Cannon, 1914), may sustain hypertension if exposure to them is prolonged or repeated (Forsyth, 1969). Robert Eliot (1974) discusses the role of stress in the development of hypertension:

These physiologic, visceral responses to our environment evolved and stabilized many thousands of years ago. We still carry these visceral responses with us even though our environment has changed and is becoming more complex and unpredictable at an accelerating pace. The evolutionary visceral responses suitable then are inappropriate now and lead to a hypertensive response which is injurious to health. Since rapidly changing environmental conditions of modern life are not readily altered, better prevention and therapy of essential hypertension might be achieved by changing the response of an individual to his environment.

(p. 26)

This is the primary goal of relaxation training programs for hypertension: to change the subject's response to stressful events such that they will relax in the presence of stressful events of everyday living and in turn avoid frequent pressor reactions. Ironically, relaxation training is usually conducted only under quiet, non-distracting conditions rather than under the stressful, distracting conditions in
which relaxation exercises should ultimately be applied. Several researchers (e.g. Steptoe, 1978; Burish and Schwartz, 1980) have suggested that training which eventually included stressful or distracting conditions might enhance the generalization and maintenance of blood pressure changes.

In a recent study, Steptoe (1979) compared the effectiveness of biofeedback and relaxation in controlling blood pressure under stressful conditions. Twenty-four normotensive subjects either followed simple instructions to relax or received pulse-transit time (an indirect measure of blood pressure) feedback while engaged in an auditory choice or mental arithmetic task which produced pressor responses. The experimental results indicated that biofeedback and relaxation may vary in their effect on blood pressure control according to the conditions under which training is carried out. Biofeedback produced slightly larger increments in pulse transit time (decreases in blood pressure) under nonstressful training conditions than did relaxation. However, biofeedback was not significantly more effective than relaxation in producing blood pressure reductions under stressful training conditions (Steptoe, 1978).

The results obtained by Steptoe (1978) regarding relaxation may be misleading for several reasons. First, subjects were not actually trained to relax but simply instructed to relax in a general sense, while they attempted to perform stressful tasks. In contrast, subjects received biofeedback training while performing stressful tasks. Secondly, Steptoe did not examine whether or not relaxation training under quiet conditions would produce blood pressure reductions nor
did he assess relaxation training under stressful conditions. Finally, no evaluation was made of the generalization or maintenance of either relaxation or biofeedback produced blood pressure reductions to non-training conditions. It should be noted that, while several investigators have encouraged home practice of blood pressure control, few studies have assessed the actual generalization of blood pressure reductions to the natural environment (Frankel, Patel, Horowitz, Friedewald, and Gaarder, 1978).

The purpose of the present study was 1) to determine if traditional relaxation training under quiet conditions results in generalized blood pressure control under stressful conditions, 2) to determine if direct training of relaxation under stressful conditions will facilitate blood pressure management under stress, and 3) to evaluate the generalization of training in both stressful and nonstressful conditions to blood pressure control in the natural environment.
CHAPTER II

METHOD

Subjects

Three borderline hypertensive subjects, one male and two females, were recruited through advertisement. All subjects were found to have blood pressure ranging between 138 and 160 mmHg for systolic or between 88 and 95 mmHg for diastolic for ten consecutive readings in screening. None of the subjects were taking hypertensive medication during or within two years of the initiation of the study. Each subject obtained a physician's written approval for participation and agreed not to make any major alterations in their diet or exercise patterns for the duration of the study.

Subject 1

Subject 1 was a 51 year old female who was employed as a rehabilitation counselor at a local government agency. Her blood pressure at screening averaged 140/76. This subject had been diagnosed as borderline hypertensive three years prior to the study and had been on hypertensive medication two years prior to entering the program. During screening and throughout the study, Subject 1 reported she found her job extremely stressful and that her doctor had recommended that she learn to relax.
Subject 2

Subject 2 was a 34 year old female elementary school teacher. Her screening blood pressure averaged 133/94 mmHg. She was not receiving treatment nor was she experiencing excessive stress.

Subject 3

Subject 3 was a 47 year old salesman whose screening blood pressure averaged 154/98 mmHg. He had not been diagnosed as hypertensive prior to the study and was not taking hypertensive medication. This subject led a very active lifestyle but did not consider his daily routine to be overly stressful.

Apparatus

In-session and home blood pressures were taken using a Baum Hi/Lo 260 mmHg calibrated manometer and Bowles diaphragm stethoscope (W. A. Baum Co. Inc., Copiague, N.Y.). Calibrated V-LOK (Baum) adult size blood pressure cuffs were used for all three subjects. Frontalis muscle activity was monitored using a J & J electromograph (Model M55) and J & J digital score keeper (LGS Model 150). Time-limited math and anagram problems were presented using a Kodak carousel slide projector (Model AF). Slides were advance manually at pre-set intervals which were signaled by a Casio Card Time (Model PW 80). Tones signaling incorrect answers to problems were presented by depressing a telegraph key wired to a Hewlett Packard Audio Oscillator (Model 200 ABR) which was set to produce a 1,300 cycle/second tone with a sound pressure of 70 decibels. Relaxation instructions were presented by
cassette tape to standardize training across subjects.

Setting

Experimental sessions were conducted in a dimly lit 10x5.5x6 ft. room which was shielded to reduce interference from 60 cycle electrical artifacts. The room was located at Psychological Services Component, Western Michigan University. The subjects were seated in a non-reclining lounge chair, facing a wall on which slides were projected. Beeper tones for wrong answers were delivered from a six inch speaker attached directly behind the subject’s chair. The research assistant sat at a table to the left of the subject and recorded blood pressure and EMG measures. The experimenter stood directly across from the assistant and behind the subject to give instructions, present slides and deliver feedback on problem answers.

Procedure

Dependent Variables

Systolic and Diastolic Blood Pressure

Systolic and diastolic blood pressure were recorded once each minute during rest, training, and task periods in all phases. All blood pressures were taken manually. To standardize blood pressure measures, the cuff was deflated at a slow and constant rate of two millimeters of mercury per second. During slide presentations the assistant began inflating the cuff with the onset of the first slide after one minute had elapsed from the last blood pressure reading.
Approximately six slides were projected between each blood pressure reading in task conditions.

The research assistant was seated approximately two feet from the subject. The blood pressure cuff was placed on the subject's upper left arm so that the circle designating the location of the crystal microphone was placed directly over the radial artery. The cuff was then inflated to 10 mmHg above the subject's resting systolic blood pressure. Listening with a stethoscope, the assistant deflated the cuff at a rate of 2 mmHg per second. The assistant noted the first Kortokoff sound (systolic blood pressure) and the mercury level at the point just before the Kortokoff sounds disappeared (diastolic blood pressure). The cuff was then completely deflated. The assistant then waited until the beginning of a new minute, signaled either by a stop watch or the EMG display, to start the next reading. Each blood pressure reading took approximately 30 seconds to complete.

**Home Blood Pressure**

Subjects were supplied with home blood pressure units with which they recorded their own blood pressure at home three times per day. Home readings were to be taken at least three hours apart, preferably in the early morning, afternoon and evening. An individual training session was conducted to teach subjects accurate blood pressure measurement procedures prior to the initiation of home recording. In addition, each subject's accuracy in recording blood pressure was periodically checked following experimental sessions. An accurate reading was defined as $\pm 2$ mmHg of the experimenter's reading.
Frontalis EMG

Readings of frontalis EMG were taken once per minute during alternating task sessions and all training session. A digital read-out automatically displayed a value which represented the average EMG over each minute. The frontalis EMG measure served two functions. Most importantly, it was an independent measure of relaxation which allowed for the determination of the degree to which subjects were actually learning to relax during training. Secondly, by observing changes in EMG, it was possible to determine if the stressful tasks were actually stressful as evidenced by increments in frontalis muscle tension.

Percent Correct

Each subject's accuracy on the math and anagram problems was monitored by calculating the percent correct for each session. This measure allowed for the assessment of practice effects which might be correlated with blood pressure and/or EMG decrements.

Independent Variables

Relaxation Training

Subjects were given three sessions of instruction in progressive muscle relaxation (PMR) following the procedure outlined by Bernstein and Borkovek (1973). Subjects were instructed to tense and relax sixteen muscle groups in a sequential order (see Appendix A for the complete relaxation script). Each instruction specified a muscle
group, a method for tensing that group, and directions for releasing the tension. In the initial training session, the Experimenter model­led and instructed the subject in each muscle tensing exercise. Fol­lowing this, subjects were taken through an actual twenty minute ex­ercise. Relaxation instructions were delivered by casset recorder in subsequent sessions. The duration of the tape was approximately eighteen minutes.

Relaxation Training Plus Math

Relaxation training plus math (PMR + Math) was an abbreviated version of the instructions in the first procedure. Relaxation in­structions were alternated with the presentation of slides containing math problems. Each subject was given the same length of time to solve the problems as they received in task-only sessions. The termin­ination of each math slide was followed by the presentation of a blank slide and an instruction to tense and relax a specified muscle group. An instruction and a slide occurred with a thirty second in­terval. Thus, a subject who solved math problems in 5 seconds would re­ceive a relaxation instruction of approximately 25 seconds. The sequence would then repeat with a different problem and the next in­struction in the relaxation sequence.

Tasks

The time-limited tasks which produced temporary increments in blood pressure consisted of math problems and anagrams which were presented by a slide projector. The math problems, which were also
used in the PMR Plus Math training, were combinations of addition and subtraction operations. For example, one problem might be 62-9+13=?.

Only the correct solution was accepted as a correct response. Anagram problems consisted of five letter words which were scrambled. For example, the word STALE might be presented as ASTEL. Any correct word formed from the five letters was a correct answer (e.g., tales, slate, steal, etc.). A correct answer was required before a set amount of time elapsed. Failures to answer in time, or wrong answers were conseuated by a loud aversive beep. Correct answers were followed by a praising comment from the experimenter such as "right", "yes", or "good!".

The time limit for answering problems varied for each subject because the difficulty of the problems varied individually. A slide time which was long enough to allow subjects to answer problems but short enough to produce increments in blood pressure and EMG was determined in screening. This time interval was usually between five and eight seconds depending on the task and the subject. Following the presentation of each slide a blank slide (white screen) was presented for an equal time interval. Thus, a subject who performed anagrams in 5 seconds would be exposed to the following sequence; slide on 5 seconds, blank screen 5 seconds, slide on 5 seconds, etc., for seven minutes. The total number of problems solved per session varied between subjects due to the differences in time limits between subjects.

To minimize practice effects, several measures were taken. First, four series of slides were used for a total of 160 of each type of
problem. The slide series were alternated sequentially so that a subject should not go through any one series more than once every four sessions. Second, time limits for emitting answers were decreased after subjects made 10 consecutive correct responses, in an effort to hold the difficulty of the tasks constant.

Instructions were given prior to the beginning of a problem period which specified the type of problem and the time limit in effect (see Appendix B).

**Home Practice**

Subjects practiced relaxation at home at least twice daily after completion of their first relaxation training session. Each subject was given a cassette tape containing the same relaxation instructions used in training. The occurrence of home practice sessions were reported by each subject and verified by a child or spouse of the subject.

**Experimental Design**

**General Description**

Progressive muscle relaxation (PMR) was assessed as a method for controlling blood pressure under nonstressful and stressful conditions using a multiple-baseline-across-subjects design (see Figure 1.). The subjects were exposed to five experimental conditions: Baseline, PMR, Post-PMR, PMR + Math, and Post-PMR + Math. Maintenance of training effects was assessed in a two and six week follow-up session. Relaxation occurred during PMR and PMR + Math conditions. The remain-
Figure 1. Multiple-baseline-across-subjects design depicting the sequence of experimental conditions and the number of sessions in each condition for Subjects 1, 2, and 3. The X's within each of the conditions indicate sessions in which frontalis EMG measures were taken. The various dependent variables are listed on the ordinate and sessions numbers occur along the axis.
Figure 1. Multiple-baseline design
ing 3 conditions involved no formal training and were referred to as task sessions.

**Baseline Task Sessions**

Subjects received either three, five, or seven baseline sessions according to the multiple-baseline design. Initially the subject was seated in a lounge chair and the assistant placed the blood pressure cuff on the subject's upper left arm. If EMG readings were to be taken, the electrodes were placed at this time as well. The assistant then left the room and the subject rested quietly for 5 minutes. When the rest period had expired, the research assistant re-entered and took three resting blood pressure readings. Following this, the subject performed time-limited anagram problems for a period of seven minutes. A second 5 minute rest was given after which the assistant again took three resting blood pressure readings. The subject was then asked to perform time-limited math problems for a seven minute period. Blood pressure readings were taken once per minute throughout the baseline session, except during rest periods.

**PMR Training Sessions**

PMR sessions also began with cuff placement, a 5 minute rest and three resting blood pressure readings. However, no time-limited tasks were performed during PMR sessions. Instead, subjects received instruction in progressive muscle relaxation. Taped instructions were delivered under quiet, dimly lit conditions with distractions kept to a minimum. Each subject received a minimum of three PMR sessions.
Additional training sessions were conducted until the subject EMG readings in the final 3 minutes of relaxation were below their resting EMG for that day. Blood pressure readings were taken 1/min. except during the rest periods. Readings were not taken when subjects tensed the left bicep or chest muscles because doing so produced an inflated or inaccurate reading.

**Post-FMR Task Sessions**

The procedure for Post-FMR sessions was the same as that used in Baseline Task sessions with one change. Subjects were instructed to use the 5 minute rest period just before the math problem period to relax rather than rest. They were to do this by going through the exercise they had learned in the previous FMR Training sessions. Blood pressure readings were taken once per minute except during the initial rest and the relaxation periods. Frontalis EMG measures were taken on alternate sessions. Subjects attended a total of five Post-FMR Task sessions.

**FMR + Math Training Sessions**

FMR + Math sessions were sessions in which subjects were given progressive muscle relaxation instructions alternated with the presentation of time-limited math problems. The initial rest period and resting measures followed the same format as in previous training sessions. Following the rest period the subjects were informed that they would begin training in relaxation while performing math problems (see Appendix B for specific instructions). Blood pressure and EMG
measures were taken following the same procedure as used in PMR sessions. Subjects attended three PMR + Math Training sessions.

**Post-PMR + Math Task Sessions**

Post-PMR + Math sessions were conducted following the same procedure as in Baseline Task and Post-PMR Task sessions. Subjects were required to perform both anagram and math problems. During the 5 minutes prior to the math problem period, subjects were instructed to relax as they did in the Post-PMR sessions. In addition, subjects were instructed to try to relax during the math problem period. They were to do this by using the blank slide periods to scan their muscle groups for tension and then try to relax as they did in the PMR + Math Training session previously. Subjects attended a total of five Post-PMR + Math Task sessions. Blood pressure was recorded once per minute. EMG was recorded once per minute on alternate sessions.

**Follow-up Sessions**

Follow-up sessions were conducted two weeks and six weeks after the final Post-PMR + Math Task session. The procedure during Follow-up sessions was exactly the same as that used in Post-PMR + Math sessions.

A summary of the sequence of activities during the five experimental phases and Follow-up sessions is diagramed in Figure 2.
Figure 2. Summary of the sequence of session activities for each experimental condition and the approximate duration of each activity.
Figure 2. Sequence of session activities.
Data Analysis

Change From Baseline

Two procedures were used to assess changes in blood pressure and EMG produced by relaxation training. First, changes in systolic and diastolic blood pressure during training phases were compared to mean resting values during baseline for each subject. Training-produced blood pressure reductions were indicated by blood pressure reductions from baseline. Larger blood pressure reductions obtained during one training phase relative to the other allowed for a comparison of the effectiveness of PMR for reducing blood pressure under nonstressful or stressful conditions.

Two baseline averages were required. The resting baseline was an average of blood pressure during the initial 5 minute rest periods in baseline sessions. This baseline value was compared to the average blood pressure during the last 3 minutes of all PMR sessions and all PMR + Math sessions. Change from resting baseline was determined by calculating the difference of training values minus the resting value. A negative difference indicated the amount of reduction in blood pressure resulting from training. A positive difference indicated the extent to which training produced an increment in blood pressure. For example, if a subject's systolic blood pressure averaged 140 during rest periods in baseline and 135 during the last 3 minutes of PMR sessions, then the change from baseline would be 135-140 = -5. This indicates a 5 mmHg reduction in blood pressure produced by PMR.

A task baseline was calculated so that changes in blood pressure
measures during Post-PMR, Post-PMR + Math, and Follow-up sessions could be determined relative to blood pressure during task periods in baseline. The task baseline values are separate averages of blood pressure during the 7 minute anagram and math periods in baseline. Similar averages were calculated for task periods in the Post-PMR and Post-PMR + Math phases. Change from baseline was then calculated as the difference of these task values minus the baseline values. Reductions in blood pressure evidenced in the two task phases relative to the task baseline indicated the maintenance of training effects to nontraining conditions.

**Task-produced Blood Pressure Increments**

Changes in systolic and diastolic blood pressure which occurred as a result of performing time-limited tasks were calculated for all experimental conditions. Blood pressure changes produced by anagram performance were determined by calculating the difference between the average blood pressure three minutes prior to anagram performance (the average of 3 readings) and the average blood pressure during anagram performance (the average of 7 readings). Note that the average blood pressure three minutes prior to anagrams is the same value used for the resting baseline in change from baseline. Difference values were calculated for each session and averaged within each experimental condition. Changes produced by math problems were calculated in the same fashion as for anagrams (i.e., the average blood pressure during math performance minus the average blood pressure three minutes prior to math performance. Note that the average blood pressure three min-
utes prior to math performance is not the same as resting baseline and thus the sum of math-produced increments and resting baseline values will not match the math task baseline. In addition to task-produced increments, the average change in blood pressure produced by tasks across all phases was calculated and the upper and lower range values were identified for each subject.

**Average Blood Pressure Across Phases**

Average systolic and diastolic blood pressure and frontalis EMG were calculated for all five experimental phases and follow-up sessions. A separate average was calculated for math and anagram periods in task phases, i.e., Baseline, Post-PMR, and Post-PMR + Math. Task averages were calculated from the seven reading during each task session problem period or 7 readings x 5 sessions = 35 readings per average value. Training averages from PMR and PMR + Math conditions were determined by averaging the measures of the last 3 minutes of all training sessions or 3 readings x 3 sessions = 9 readings per training value. The obtained phase averages were plotted in histogram form so that across-phase changes in blood pressure could be visually analyzed. Visual inspection of the histogram also allowed for analysis of covariation of systolic and diastolic blood pressure and EMG.

**Percent Correct**

Percent correct data were obtained by dividing the number correct responses to math or anagram problems by the total possible and multiplying that value by one hundred.
Home Blood Pressure

Values for average home blood pressure were calculated as the average of the three daily readings recorded by each subject.
RESULTS

Subject 1

Change From Baseline

Table 1 summarizes the change in average blood pressure from baseline for Subject 1. The average resting blood pressure for Subject 1 was 134.7/77.4 mmHg. Relaxation training under nonstressful conditions, PMR, produced a moderate reduction of 4.1 mmHg in systolic blood pressure (SBP) relative to the resting baseline value. PMR training produced a slight increment in average diastolic blood pressure (DBP) of +1.2 mmHg compared to baseline. During relaxation training under stressful conditions, PMR + Math, a much larger reduction in SBP was obtained, –10.0 mmHg. Diastolic blood pressure in this training condition was also lower than baseline by –4.2 mmHg. For both DBP and SBP, the reductions obtained in the PMR + Math phase were greater than reductions during PMR training.

Task-produced Blood Pressure Changes

Task-produced blood pressure changes are shown in the far left panel of Table 2 for Subject 1. Anagram problems produced slight increments in blood pressure in baseline sessions. Math problems produced moderate increments in both SBP and DBP in baseline. Following relaxation training, task-produced blood pressure increments declined and continued to do so in subsequent task sessions. A comparison of
Table 1. Change in systolic and diastolic blood pressure relative to baseline for Subjects 1, 2, and 3. Training-produced changes are listed in the upper part of the table and are to be compared with the resting baseline value. Blood pressure changes over task conditions are shown in the lower section of the table and are to be compared to the task baseline value. Changes in blood pressure are presented separately for math and anagram periods in task phases. Negative values indicate a reduction from baseline. Positive values indicate an increment from baseline.
Table 1.
Change from baseline.

<table>
<thead>
<tr>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RESTING</td>
<td>PMR TRAINING</td>
<td>PMR PLUS TRAINING</td>
</tr>
<tr>
<td>DBP</td>
<td>DBP</td>
<td>DBP</td>
</tr>
<tr>
<td>134.7</td>
<td>121.1</td>
<td>92.5</td>
</tr>
<tr>
<td>-4.1</td>
<td>+2.3</td>
<td>+2.8</td>
</tr>
<tr>
<td>+4.2</td>
<td>+6.9</td>
<td>+11.5</td>
</tr>
<tr>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>132.9</td>
<td>127.3</td>
<td>125.7</td>
</tr>
<tr>
<td>-5.6</td>
<td>+3.1</td>
<td>+5.2</td>
</tr>
<tr>
<td>-4.9</td>
<td>+5.1</td>
<td>+2.1</td>
</tr>
<tr>
<td>M</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>-1.7</td>
<td>+7.2</td>
<td>-2.8</td>
</tr>
<tr>
<td>-2.3</td>
<td>-1.4</td>
<td>-2.8</td>
</tr>
</tbody>
</table>
Table 2. Task-produced blood pressure changes for Subjects 1, 2, and 3 across phases. Separate values are listed for anagram and math tasks. The average task-produced change across all phases is indicated in the bottom section of the table along with the lower and upper ranges for each subject. Systolic and diastolic blood pressure changes are indicated below the S/D symbols.
Table 2.

Task-produced blood pressure changes.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Subject 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anagram</td>
<td>Math</td>
<td>Anagram</td>
</tr>
<tr>
<td>Baseline</td>
<td>S D</td>
<td>1.3 1.0</td>
<td>S D</td>
</tr>
<tr>
<td></td>
<td>4.4 3.2</td>
<td></td>
<td>5.2 4.2</td>
</tr>
<tr>
<td>Post-PMR</td>
<td>3.2 2.7</td>
<td>1.1 4.1</td>
<td>1.5 2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMR + Math</td>
<td>-11 -4.0</td>
<td>.2 2.4</td>
<td></td>
</tr>
<tr>
<td>Post-PMR + Math</td>
<td>-2.8 -3.0</td>
<td>.4 .2</td>
<td>-1.1 2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up (2wk)</td>
<td>-1.5 -4.1</td>
<td>-2.8-3.3</td>
<td>-1.0 6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up (6wk)</td>
<td>-8.0 -4.0</td>
<td>-2.1-3.7</td>
<td>1.6 .7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Average</td>
<td>-8.0 -4.1</td>
<td>-2.8-3.7</td>
<td>-1.1 .7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>-1.7 - .6</td>
<td>1.1 .1</td>
<td>-1.1 3.2</td>
</tr>
<tr>
<td>Upper</td>
<td>3.2 2.7</td>
<td>4.4 4.1</td>
<td>4.6 6.9</td>
</tr>
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<td></td>
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</tr>
</tbody>
</table>
average increment in baseline and the overall average increment across phases (shown at the bottom of the table) further demonstrates the declining effects of task presentation following PMR training and PMR + Math training.

Across-phase Changes

Across-phase changes in average blood pressure and EMG for Subject 1 are shown in Figure 3. The broken horizontal line delineates normal and borderline blood pressure ranges. As can be seen by the height of the bars across phases, SBP and DBP were reduced to lower normal levels during both PMR and PMR + Math. During the PMR + Math training phase, single white bar, DBP and SBP were lower than during the PMR training phase, black bars. Average EMG, however, remained lower during the PMR training phase. Blood pressure reductions during anagram problems, striped bars, occurred in only one phase, Post-PMR, and only for SBP. During math problems, white bars, SBP reductions were obtained in the Post-PMR phase and in both follow-up sessions. DBP showed almost no change during math and anagram problems over the task phases. Average EMG showed a reduction across task phases and follow-up sessions with slightly greater reductions during math periods.

Percent Correct

Figure 4 depicts the percent of correct responses to math and anagram problems for Subject 1. The graph clearly shows that accuracy on both types of tasks while highly variable, improved over the course of the study by as much as twenty percent.
Figure 3. The across-phase changes on average systolic blood pressure, diastolic blood pressure, and frontalis EMG for Subject 1. Blood pressure averages are presented in millimeters of mercury. EMG averages are presented in microvolts. The broken line on the blood pressure histograms represents the border between normal and borderline levels. Averages during task conditions are indicated by double bar showing levels during math problems (solid white bars) and anagram problems (striped bars). Standard relaxation averages are represented by the solid bars and relaxation under stressful conditions is represented by the single white bar in each histogram.
Figure 3. Across-phase changes.
Figure 4. The percent of correct responses to problems for Subject 1 across the three task phases (Baseline, Post-PMR, Post-PMR + Math and Follow-ups) and in the PMR + Math training phase. Percent correct values for anagrams are graphed as a function of sessions and are represented by the dark circles. Percent correct values for math periods are graphed as a function of sessions and are represented by the open circles.
Figure 4. Percent correct.

- ○ MATH TASKS
- ● ANAGRAM TASKS

SESSIONS: BASELINE  PMR  POST-PMR  PMR+MATH  POST-PMR+MATH  FOLLOW-UPS
Home Blood Pressure

Daily home blood pressure for Subject 1 is presented in Figure 5. Systematic reductions in blood pressure did not occur with the introduction of relaxation or in later phases. In the case of systolic blood pressure there appears to have been an increment in home blood pressure from about 138 mmHg to 142 mmHg in the final phases.

Subject 2

Change From Baseline

The center panel of Table 1 presents the change in blood pressure from baseline for Subject 2. Subject 2 had a resting baseline blood pressure of 121.1/82.3 mmHg. Both her SBP and her DBP were incremented with PMR training as well as PMR + Math training. Quite large increments occurred in DBP during PMR + Math training where there was a +10.5 change in baseline.

Subject 2 had a task baseline blood pressure of 127.3/86.5 for math and 125.7/84.7 for anagrams. Blood pressure increments occurred in all task sessions for this subject including Post-PMR, Post-PMR + Math, and follow-up sessions. The data also indicate that math problems produced slightly larger increments in both DBP and SBP than did anagrams.

Task-produced Blood Pressure Changes

Task-produced blood pressure changes are presented in the center panel of Table 2 for Subject 2. During baseline sessions, both math
Figure 5. Average home systolic and diastolic blood pressure (mmHg) as a function of days for Subject 1.
Figure 5. Home blood pressure.
and anagram problems produced moderate increments in blood pressure. Following PMR training the incremental effect of tasks declined for systolic and diastolic blood pressure. PMR + Math produced further reduction in the blood pressure increments produced by tasks. This trend continued in all subsequent sessions and in follow-up. In addition, the across phase average task-produced increment was well below the increments produced in baseline.

**Across-phase Changes**

Across phase changes in average SBP, DBP, and EMG for Subject 2 are presented in Figure 6. For both DBP and SBP, PMR training under non-stressful conditions resulted in lower averages than PMR + Math training. Conversely, average EMG was higher during PMR training than during PMR + Math training for this subject.

Inspection of task phase averages shows that during math and anagram performance, Subject 2 had an increment in her SBP which was well above her baseline condition. DBP was incremented from baseline across all phases during both math and anagram problems. The broken line on the SBP histogram indicates that Subject 2's blood pressure was well into the borderline range at the two and six week follow-ups. Her DBP increased into the borderline range much earlier, beginning with the Post-PMR phase and remaining above for all the following task phases. The lower histogram in Figure 6 reveals that average EMG for Subject 2 did not change by more than .5 microvolts across the training and task phases.
Figure 6. The across-phase changes on average systolic blood pressure, diastolic blood pressure, and frontalis EMG for Subject 2. Blood pressure averages are presented in millimeters of mercury. EMG averages are presented in microvolts. The broken line on the blood pressure histograms represents the border between normal and borderline levels. Averages during task conditions are indicated by double bars showing levels during math problems (solid white bars) and anagram problems (striped bars). Standard relaxation averages are represented by the solid bars and relaxation under stressful conditions is represented by the single white bar in each histogram.
Figure 6. Across-phase changes.
Percent Correct

Percent correct data for Subject 2 are presented in Figure 7. Accuracy in both math and anagram performance was largely improved over the experiment. Math accuracy increased from approximately 45% in baseline to 65% in Post-PMR + Math conditions. Accuracy of responding during anagram tasks increased from 40% to about 50% in Post-PMR + Math conditions. For both types of problems, improvement in performance increased in a highly variable manner.

Home Blood Pressure

Changes in home blood pressure for Subject 2 are presented in Figure 8. Clear reductions in home systolic blood pressure occurred just before the introduction of relaxation training. The reduction was from about 140 mmHg to about 125 mmHg. Home systolic levels increased slightly during relaxation training to 130 mmHg and then returned to the 125 mmHg level during the Post-PMR phase. Systolic blood pressure remained within this range for the remainder of the study but occasionally fluctuated to lower levels of 120 mmHg. Home diastolic blood pressure was at 90 mmHg for the duration of the study.

Subject 3

Change From Baseline

The right panel of Table 1 shows the change in blood pressure from baseline for Subject 3. Subject 3 had an average resting blood pressure in baseline of 147.6/92.5 mmHg. Progressive muscle relaxa-
Figure 7. The percent of correct responses to problems for Subject 2 across the three task phases (Baseline, Post-PMR, Post-PMR + Math and Follow-ups) and in the PMR + Math training phase. Percent correct values for anagrams are graphed as a function of sessions and are represented by the dark circles. Percent correct values for math periods are graphed as a function of sessions and are represented by the open circles.
Figure 7. Percent correct.
Figure 8. Average home systolic and diastolic blood pressure (mmHg) as a function of days for Subject 2.
Figure 8. Home blood pressure.
tion training produced decrements in SBP and DBP of -2.1 and -3.8 mmHg. Larger decreases from baseline were obtained with PMR + Math training where SBP was reduced -7.3 mmHg and DBP was reduced -5.8 mmHg.

Subject 3 had an average blood pressure of 159.4/103.6 during math and 157/101.4 during anagram tasks in baseline sessions. During Post-PMR math periods, this subject's SBP was -11.6 mmHg lower than in baseline. His DBP during math performance was reduced -9.4 mmHg from baseline. Similar reductions occurred during anagram performance in Post-PMR sessions. SBP was -8.0 mmHg lower than baseline and DBP was reduced by -7.6 mmHg.

Large blood pressure reductions were also obtained during Post-PMR + Math sessions for this subject. During anagram problems, DBP was -10.8 mmHg lower than baseline and SBP -7.0 mmHg lower. During math periods SBP and DBP were reduced -9.0 and 11.0 mmHg respectively. It is interesting to note that the largest change from baseline occurred in DBP during anagram performance. The follow-up data present reductions in average blood pressure which are as large or larger (-25.1 mmHg) than all previous task phases and baseline.

Task-produced Blood Pressure Changes

Task-produced changes in blood pressure are shown in the right panel of Table 2 for Subject 3. Both anagram and math problems produced large increments in systolic and diastolic blood pressure during baseline sessions. Relaxation training resulted in reduced increments in blood pressure during task performance. This effect was not enhanced by PMR + Math training but was maintained in subsequent phases and
in follow-up sessions. The reduced effect of task presentation is also indicated by the lower overall task-produced increment as compared to baseline averages.

**Across-phase Changes**

The across-phase change in DBP, SBP, and EMG for Subject 3 are presented in Figure 9. A comparison of average SBP during the two training phases indicates SBP was much lower during PMR + Math training than during PMR. For DBP, PMR + Math averages were again lower than the PMR average but the differency was not as great. For Subject 3, whose resting EMG was extremely low, average EMG during the two training phases did not differ. Average EMG was at 1.5 mV in both phases.

Visual inspection of the histograms for both SBP and DBP shows that for task phases (Baseline, Post-PMR, Post-PMR + Math) and follow-ups there was a downward trend in average blood pressure across phases. The average blood pressure during math problems was higher than during anagrams for the majority of Subject 3's task phases.

The broken line in the upper two histograms represents the border between borderline, high, and normal blood pressure levels. Subject 3 had a baseline task SBP which was very near the high blood pressure range. Blood pressure levels in subsequent phases are well below the high range during task performance as well as during relaxation. This subject's DBP was extremely high during baseline task sessions, reaching an average of 116 mmHg during anagrams and 105 mmHg during math problems. These DBP levels dropped to near borderline levels in sub-
Figure 9. The across-phase changes on average systolic blood pressure, diastolic blood pressure, and frontalis EMG for Subject 3. Blood pressure averages are presented in millimeters of mercury. EMG averages are presented in microvolts. The broken line in the blood pressure histograms represents the border between high and borderline levels. Averages during task conditions are indicated by double bars showing levels during math problems (solid white bars) and anagram problems (striped bars). Standard relaxation under stressful conditions is represented by the single white bar in each histogram.
Figure 9. Across-phase changes.
sequent task phases. Most notable are the DBP averages during follow-up sessions, where average DBP was well into the normal range during task performance.

Percent Correct

Percent correct on math and anagram problems as a function of sessions is presented in Figure 10 for Subject 3. During baseline, accuracy was at approximately 63% for math and 30% for anagrams. Over the experimental phases, math performance was fairly stable but increased to about 75% in the Post-PMR + Math phase. Anagram performance was highly inconsistent but appeared to improve to about 55% in the Post-PMR + Math phase. Interestingly, during the PMR + Math condition, accuracy of responses to math problems decreased somewhat before resuming the upward trend in the Post-PMR + Math condition.

Home Blood Pressure

Figure 11 shows average home blood pressure for Subject 3. Both systolic and diastolic blood pressure decreased significantly in baseline. Systolic blood pressure decreased from a level of 160 mmHg to approximately 145 mmHg. No changes in systolic blood pressure were evident with the introduction of either PMR alone or PMR + Math training. Daily systolic blood pressure remained within the low borderline levels of 140-145 mmHg for all phases after baseline. Diastolic blood pressure dropped in baseline from 102 mmHg to approximately 92 mmHg. Again phase changes did not produce systematic changes in diastolic blood pressure. Instead, diastolic blood pressure stabilized at 90 mmHg.
Figure 10. The percent of correct responses to problems for Subject 3 across the three task phases (Baseline, Post-PMR, Post-PMR + Math and Follow-ups) and in the PMR - Math training phase. Percent correct values for anagrams are graphed as a function of sessions and are represented by the dark circles. Percent correct values for math periods are graphed as a function of sessions and are represented by the open circles.
Figure 10. Percent correct.

- ○ MATH TASKS
- ● ANAGRAM TASKS

Percent correct

BASELINE PMR POST-PMR PMR+MATH POST-PMR+MATH FOLLOW-UPS

Sessions

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Figure 11. Average home systolic and diastolic blood pressure (mmHg) as a function of days for Subject 3.
Figure 11: Home blood pressure.

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CHAPTER IV
DISCUSSION

Training Effects

Effects of Standard Relaxation Training

Of the three subjects who participated in this study, only Subjects 1 and 3 achieved blood pressure levels during PMR Training sessions which were lower than resting levels in Baseline. However, the blood pressure reductions obtained were not as pronounced as those obtained in previous research (Agras and Jacob, 1979). Agras and Jacob (1979) point out that with relaxation training, subjects having higher baseline blood pressure obtain larger decrements in blood pressure than subjects with lower baseline blood pressure. The present results correspond to this observation. Baseline blood pressure for the three subjects in this study were in the borderline range or below during rest and the decrements obtained were modest. Subject 1 lowered her systolic blood pressure 4.1 mmHg during PMR Training but at the same time, there was a 1.2 mmHg increase in her diastolic blood pressure. Subject 3 lowered his systolic blood pressure by only 2.1 mmHg and his diastolic blood pressure by 3.8 mmHg during relaxation training. On the other hand, Subject 2, whose EMG data indicate she did not benefit from relaxation training under nonstressful conditions, actually experienced increments in her blood pressure during training. Her systolic blood pressure increased 2.1 mmHg but her diastolic blood pressure decreased 1.8 mmHg from her resting baseline. It may be that conditions which have been referred to as "nonstressful" were in some
way stressful for this subject and thus the results of training were confounded. Another possibility is that Subject 2's blood pressure was influenced by other, unknown, factors which hindered any effects of training. Taken together these results suggest that relaxation training under nonstressful conditions may facilitate the lowering of blood pressure under nonstressful conditions. However, for some individuals, standard relaxation instruction may not increase their ability to relax and thus has little impact on blood pressure levels in nonstressful conditions.

Standard relaxation training was found to facilitate blood pressure control in nontraining task sessions for Subjects 1 and 3 but not for Subject 2. Compared to her baseline, Subject 1's SBP during the Post-PMR task phase was 5.6 mmHg lower during math and 5.5 mmHg lower during anagram periods. The reductions achieved by Subject 3 were much larger for both SBP and DBP. During Post-PMR sessions, his SBP was 11.6 mmHg lower during math and 7.7 mmHg during anagrams. His DBP was 9.4 mmHg and 25.1 mmHg lower during tasks than in baseline. For these two subjects it appears that relaxation taught under nonstressful conditions may facilitate blood pressure control in untrained stressful conditions. For Subject 2, Post-PMR blood pressures were at levels 3 to 8 mmHg higher than in the Baseline task periods. This finding is not surprising since her training data showed no evidence of relaxation and thus generalization to task conditions was unlikely.
Effects of PMR Training Under Stressful Conditions

PMR + Math Training produced lower blood pressure averages than during math performance in Baseline for both Subjects 1 and 3. In fact, the largest departure from baseline levels occurred during this phase. Systolic blood pressure for Subject 1 was 10 mmHg lower than the resting baseline and diastolic blood pressure was 4.2 mmHg lower (See Table 1.). Similarly, Subject 3 had systolic levels 7.3 mmHg and diastolic levels 5.8 mmHg lower than Baseline. Note that although the subjects performed tasks in this phase, blood pressure levels, were lower than baseline rest levels where no tasks were performed. For these two subjects, relaxation training under stressful conditions clearly facilitated blood pressure control.

Subject 2 did not benefit from PMR + Math Training. Her SBP was 6.9 mmHg higher than her resting level in Baseline. Her DBP was 10.5 mmHg higher than baseline. It may be that the combination of rapid relaxation instructions and the presentations of math problems had a stressor effect on this subject which exceeded the effect of math problems alone. Such a situation would account for the large increments in blood pressure which resulted from PMR + Math Training. In at least one previous study, (Frankel, 1978), PMR training (combined with EMG biofeedback) failed to produce significant reductions in blood pressure within sessions. Unfortunately, changes in EMG were not reported and therefore it is uncertain whether relaxation also did not occur as seems to be the case for Subject 2. Further and more detailed analysis is necessary to determine what variables may
be responsible for the present changes in blood pressure and lack of change in EMG which resulted from both types of relaxation training for Subject 2.

Generalization of the effects of relaxation training under stressful conditions to blood pressure control in untrained task conditions was assessed by comparing reductions in blood pressure levels during Post-PMR sessions to those in Post-PMR + Math sessions. If blood pressure during anagram performance were lower during Post-PMR + Math sessions, then relaxation training in the presence of math problems may have produced a generalized improvement in blood pressure control during anagram performance. The results show very small reductions were obtained in blood pressure during anagram periods in the Post-PMR - Math phase. Only Subject 3 achieved a reduction in diastolic blood pressure of 3.2 mmHg from the Post-PMR phase. The moderate generalization of PMR + Math training effects is not unreasonable considering that training itself resulted in only moderate blood pressure reductions. The generalization of training would not be expected to exceed treatment effects. Thus it may be concluded that greater evidence of generalization of PMR + Math training may have occurred had the main treatment effect been more substantial.

Effects Of Training on Task-produced Increments In Blood Pressure

Across-phase change in task-produced blood pressure increments provide supporting evidence that standard relaxation training facilitates blood pressure management under stressful conditions. After PMR training, task presentation produced smaller blood pressure increments than in
baseline for Subject 2 and 3. Task effects were further diminished following EMR + Math training for Subject 1 (diastolic blood pressure only) as well as Subject 2 and 3. Contrary to expectations, there was not a larger decline in math-produced increments above those of anagram tasks. This was expected due to the fact that math problems were used in EMR + Math training. Thus, EMR + Math training effects were not specific to math performance.

Effects of Relaxation on Home Blood Pressure

The blood pressure reductions obtained within sessions were not correlated with reductions in home blood pressure. While both Subject 2 and 3 obtained reductions in their average daily home blood pressure, these reductions occurred before the introduction of relaxation of relaxation training. This finding suggests that changes in home blood pressure were due to some other variable, most likely, the reactive effects of self-monitoring blood pressure three times per day. It is also possible that the subjects began to relax in some fashion prior to training because they were all aware that relaxation would be part of the study (this was indicated in the recruiting advertisement).

Changes In Frontalis EMG

Careful examination of the changes in frontalis EMG during relaxation allow one to see that even in subjects who obtained large blood pressure reductions, very small reductions in average EMG occurred. This fact might lead to questions regarding the degree to which relax-
ation was responsible for blood pressure changes because large reductions in blood pressure were not paralleled by large reductions in EMG. Unfortunately, this finding cannot be compared with previous research because the available hypertension/relaxation literature contains no reports of correlated change in blood pressure and EMG. Only blood pressure data are reported, even in EMG biofeedback studies.

Two factors should be taken into consideration regarding the present EMG results. First, all three of the subjects had resting EMG levels which were normal or well below the relaxation criteria used in treating individuals with stress-related disorders (Stoyva, 1979). The presence of normally low EMG levels may preclude large reductions even with extensive relaxation training simply because there is a ceiling effect or limit in the degree to which normal EMG levels may be lowered. Given this situation, very small changes in normal EMG may be quite significant. A second consideration concerns the choice of the frontalis muscle as a reference for monitoring general muscle tension. The choice of the frontalis muscle may have been an unfortunate one because the use of the eyes tended to raise frontalis EMG levels above the level when the subjects were resting with their eyes closed. Remembering that the time-limited tasks were presented by slide projector, it is reasonable to see how actively observing the slides, frowning, or squinting may have inflated the EMG as a representation of overall body tension. The use of some other muscle, such as the forearm, may have allowed for more clearcut changes in EMG to be examined. Another consideration is that changes in EMG and blood pressure may be independent physiological processes and that something other than
reduced muscle tension was responsible for the changes in blood pressure which occurred for Subject 1 and 3.

Practice Effects

That the results obtained were due to a decrease in the stressfulness of the tasks rather than increased relaxation is not likely. The data indicated that repeated exposure to a limited number of tasks did improve accuracy of performance in all subjects. However, EMG or blood pressure reductions and increases in accuracy did not covary. For example, Subject 3 whose blood pressure was greatly reduced by PMR, did not have comparably large improvements in his task accuracy.

General Conclusions

The present study examined the effects of two relaxation training procedures on the management of blood pressure. For two subjects, both standard progressive muscle relaxation training and progressive muscle relaxation training under stressful conditions were found to facilitate the reduction of blood pressure within training sessions. In addition, present findings suggest that the effects of standard PMR training may result in generalized management of blood pressure under stressful conditions. Specific training of relaxation in the presence of stressful tasks did not result in enhanced blood pressure management during untrained task performance. Finally, neither type of relaxation produced reductions in the average blood pressure in the natural environment for any subject. Further investigations are recommended which will be directed at identifying relaxation training
procedures or practice contingencies which will promote generalized blood pressure management to nontraining situations. In addition, further research is needed to determine what specific factors are responsible for the treatment success obtained for Subject 1 and 3 which may have been lacking for Subject 2. Perhaps relaxation is ineffective for those with low resting EMG. Identifying such factors may provide a more widely accepted behavioral alternative to the treatment of hypertension which has not been forthcoming.
APPENDIX A

Script for Progressive Muscle Relaxation

Before beginning your relaxation exercise, review the guidelines for progressive muscle relaxation.

To begin relaxing, focus your attention on the muscles in your right/left hand and lower right/left arm. Tense the muscles in your hand and lower arm by making a tight fist NOW! Tight! Hold the tension. Notice the tightness of the muscles. Okay, relax... just let the muscles go limp, noticing the difference between the tension and the relaxation as you let the muscles relax further and further.

Again, tense the muscles in your hand and lower arm by making a tight fist NOW! Tight. Hold it. Notice the tension in your arm and hand. Feel the muscles tightening. Okay, relax..., letting the feeling of relaxation just flow through these muscles, noticing the difference between the tension and the relaxation, allowing the muscles to relax further and further, enjoying the pleasant feelings of relaxation as you continue to relax your hand and lower arm.

Now shift your attention to your right/left bicep. Tighten the muscles in your right/left bicep by pressing your elbow down and into your side NOW! Tight! Hard. Hold it. Feel the tension. Notice the muscles pulling in your arm. Okay, relax..., just letting the tightness flow out of your upper arm, noticing the difference between the tension and the relaxation.

Again, tense your right/left bicep NOW! Tight! Hold the tension. Feel the pull in your upper arm. Okay, relax..., allowing the muscles...
in your bicep to relax further and further, noticing the difference between the tension and the relaxation, enjoying the feelings of relaxation as your arm relaxes deeper and deeper, as you continue to relax your entire arm and hand.

(Repeat all of the above section for the left hand and lower arm and left bicep.)

Shift your attention to the muscles in your forehead. Tighten the muscles in your forehead by raising your eyebrows as high as you can NOW! Pull! Hard! Tight! Hold it. Feel the muscles pulling up. Notice the tension in your forehead. Okay, relax..., allowing the muscles in your forehead to become loose and relaxed, noticing the difference between the feeling of tension from before and the feeling of relaxation now. Allow the forehead to relax more and more as you enjoy the pleasant feeling of relaxation.

Again, tense the forehead muscles by raising your eyebrows as high as you can NOW! Hold it. Tight! Feel the tension. Notice the tightness in your forehead. Okay, relax..., letting the muscles completely relax, feeling the sensation of relaxation just flow into your entire forehead as you notice the difference between the tension and the relaxation. Continue to relax the upper facial muscles of your forehead as you enjoy the sensations of relaxation.

Next, focus your attention on the muscles in the central portion of your face around your eyes and nose. Tighten these muscles by squinting your eyes very tightly and wrinkling your nose NOW! Tight! Hold it! Feel the tension. Notice the pull around your eyes and
nose. Okay, relax..., just letting the muscles become very relaxed and loose, noticing the difference between the tension and the relaxation as the tightness flows out of these muscles and they relax deeper and deeper.

Again, tighten the muscles of the central portion of the face by squinting hard and wrinkling your nose NOW! Hard! Hold it! Tight as you can! Feel the muscles pull. Okay, relax..., just let go of the tension and allow the feeling of relaxation to spread throughout these muscles as you relax them more and more. Enjoy the pleasant feeling of relaxation around your eyes and nose. Go on relaxing the muscles in the central portion of your face until they are completely relaxed.

Move your attention down to the lower facial muscles around your mouth and jaw. Tense these muscles by biting down as you pull back the corners of your mouth NOW! Pull! Hard! Hold the tension. Feel the pull in the lower part of your face. Okay, relax..., letting your jaw become loose and relaxed, feeling the tension flow out of the muscles around your mouth as they become relaxed. Notice the difference between the tension and the relaxation as you go on relaxing your mouth and jaw.

Once again, tense the muscles in the lower face by pulling back the corners of the mouth as you bite down hard NOW! Tight! Hard! Pull the muscles. Notice the tension throughout your jaw. Okay relax..., feel the sensation of relaxation as the muscles smooth out. Let the muscles go more and more... allowing them to relax more and more deeply, enjoying the pleasant feelings of relaxation.
Continuing to relax the muscles in your upper, central, and lower face, shift your attention to the muscles in your neck. Tense the muscles in your neck by pulling your chin down toward your chest and back NOW! Tight! Hard! Feel the muscles tightening in the back of your neck as they counterpose. Notice the tension. Okay relax... allowing the muscles in your neck and throat to become loose and smooth, feeling the sensations of relaxation go through the back of your neck and spread around to the front neck muscles as you relax your neck muscles further and further.

Once again, tighten your neck muscles by pressing your chin down and back at the same time NOW! Pull back hard. Tight. Notice the tension in your neck. Okay, relax..., letting the tension go, allowing your neck muscles to smooth out and relax completely, thinking only of the pleasant feeling of relaxation in your entire neck. Continue to relax your neck muscles deeper and deeper.

Shift your focus now to the muscles of your chest and upper back. By taking a deep breath and holding it as you pull your shoulders back as far as you can, tense your chest and shoulder NOW! Pull your shoulders back! Hold it! Notice the tightness in your upper back and shoulders. Okay, relax..., just let these muscles go, noticing the difference between the tension and the relaxation, focusing on the feeling in this area as the muscles become more and more relaxed.

Once again, tense the muscles in your shoulders and upper back NOW! Hold it. Tight. Feel the tension. Notice the muscles pulling in your back and shoulders. Okay, relax..., releasing all the tension and allowing the calm, relaxed feelings move into your shoulders,
Continue to relax your upper leg more and more.

Turn your attention to your right/left calf. Pulling the toes upward so that they point towards your head, tighten your calf muscles NOW! Tight! Hard! Notice the pull in the calf area. Okay, relax..., just let the calf rest loosely on its support as the sensation of relaxation flows into your calf. Notice the difference between the tension and the relaxation.

Once more tense the right/left calf muscles NOW! Tight! Hold it! Feel the tension. Notice the pull. Okay, relax..., letting the muscles become more and more relaxed as you enjoy the pleasant feeling of deep relaxation. Continue to relax the calf more and more.

Focus now on your right/left foot. Turning your foot inward and at the same time curling your toes down, tense the foot muscles NOW! Hold it! Feel the tension in the ball and arch of your foot. Notice the muscles pulling slightly. Okay, relax..., letting the foot turn freely and the toes uncurl. Notice the difference between the tension and the relaxation as you allow the foot to relax more and more, letting the very pleasant feeling of relaxation just flow into this area, becoming completely relaxed.

(Repeat relaxation steps for upper, calf, and foot muscles of left leg.)

Now, continuing to relax, scan each of the muscle groups for any remaining tension. Notice the level of relaxation in your right hand and lower arm. Relax these muscles even further. Note any tension in your upper upper right arm. Allow any remaining tension to leave
chest, and upper back.

Focus on your abdominal or stomach region. Tense the muscles in your stomach by making your stomach as hard as you can as if you are bracing for a punch NOW! Tight! Hold it! Feel the muscles pulling inward. Notice the tension. Okay, relax..., just let the tightness flow out of your stomach, feeling the relaxed calmness move through these muscles. Notice the difference between the tension and the relaxation.

Again, tighten the stomach muscles, NOW! Tight! Hold it! Notice the hardness of the stomach. Note the tension. Okay, relax, just let the muscles completely loosen and become relaxed. Notice the difference between the tension and the relaxation as you go on relaxing the muscles further and further, enjoying the pleasant feeling of deep relaxation.

Turn your attention to your right/left upper leg. By counterposing the large top muscle with the two smaller ones underneath. Tighten your upper right/left leg NOW! Tight! Hold the tension. Notice the pulling sensation. Okay, relax..., just let your upper leg sink into its support as the muscles become more and more relaxed. Notice the difference between the tension and the relaxation as you enjoy the sensations of relaxation in these muscles.

Again, tense your upper right/left leg NOW! Tight! Hold it! Feel the muscles pressing against each other. Notice the hardness in your upper leg. Okay, relax..., allow the upper and lower thigh muscles to completely relax. Just think of letting the muscles go limp and relaxed as you enjoy the pleasant sensations of relaxation.
your upper right arm by relaxing it further and further. Now scan your left hand and lower arm by relaxing the muscles here deeper and deeper, removing any remaining tension. Now look for tension in the facial muscle groups. Allow these muscles to relax more and more as you eliminate any remaining tension. Relaxing the forehead further and further, relaxing the central facial muscles around your eyes and nose deeper and deeper, and relaxing the lower facial area of the mouth and jaw more and more completely. Let the muscles in your neck and shoulders become more relaxed than before, removing any remaining tension in this area. Notice the level of relaxation in your abdominal muscles. Relax any remaining tension in this area by allowing the tension to become loose and for the pleasant sensations of relaxation to flow into this area as it becomes completely relaxed. Briefly scan the muscles in your right leg, further relaxing the upper leg, further relaxing your right calf, relaxing your right foot deeper and deeper. Now scan the muscles in your left leg, relaxing further the upper left leg, continuing to relax the left calf, relaxing the left foot deeper and deeper.

Now notice the calm, peaceful feeling of complete relaxation throughout your body. Feel what it is like as the muscles become even more and more deeply relaxed. Continue to experience the very pleasant feeling of relaxation you have now achieved.
APPENDIX B

Session Instructions

Pre-task instructions

"Okay, now I am going to show you slides with math/anagram problems on them. You will have "X" seconds to answer each problem. If you are correct I will tell you by saying right or yes. If you are incorrect or take more than "X" seconds to answer, you will hear the beeper. Try to avoid the beeper as much as you can. Here is the first slide."

Post-PMR instructions for second rest period

"Today instead of your usual five minute rest period before doing math problems, I would like you to practice relaxation. Try to relax by going quickly through the exercise you learned in the last training sessions and on your tape. Okay begin."

PMR + Math pre-training instructions

"Today we will go through a relaxation exercise while you perform math problems. The problems will be just like those you worked before and you will have the same amount of time to answer them. If you answer correct I will say "correct", "right", "good", or "yes". If you are incorrect, you will hear the beeper. When the slide goes off to a blank screen, I will give you an instruction in relaxation similar to the ones on the tape but shorter. I will tell you what muscle to tense and give you the cue NOW! for tensing and "okay,"
relax" for releasing the tension. Then I will repeat the instruction. I will do this very quickly. Next you will try a new problem and I'll give you the next instruction in the series. We will continue until all the muscle groups have been relaxed twice. Do you have any questions? Okay, here is the first slide."

Post-PMR + Math instructions for second rest and math problems

Second rest instructions were the same as for Post-PMR sessions. "Today while you are attempting the math problems, I would like you to try and practice relaxing as you learned in the last training sessions where you relaxed while doing slides. I will not give you instructions this time. Use the blank slide time between each problem to relax and scan for tension. Do you have any questions? Okay, here is the first slide."
BIBLIOGRAPHY


Burish, T.G. & Horn, P.W. An evaluation of frontal EMG as an index of general arousal. Behavior Therapy, 1979, 10, 137-147.


Second USA-USSR joint symposium on hypertension, Hypertension in the USA and USSR: basic, clinical, and population research. Williamsburg, Virginia, 1979.

Shapiro, A.P., & Mechado, J. Observation on blood pressure and other physiologic and biochemical mechanisms in rats with behavioral disturbances. Psychosomatic Medicine, 1958, 20, 303.


Veterans Administration Cooperative Study Group on Anti-hypertensive Agents II. Results in patients with diastolic blood pressure averaging 90 through 114 mm Hg. Journal of the American Medical Association, 1970, 213, 1143-1152.