THE UNIVERSITY OF MANITOBA

THE EFFECTS OF FEEDBACK AND RESPIRATION-ASSIST INSTRUCTIONS ON HEART RATE INCREASES IN LONG-DISTANCE RUNNERS AS COMPARED TO NON-RUNNERS

by

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ABSTRACT

The relationship of exercise (cardiovascular) history to learned heart rate (HR) increases was investigated in a 70 trial biofeedback session. Nine highly trained long-distance and nine beginning runners were compared under conditions of feedback (presence vs. absence) and type of instructions (with vs. without respiration assist) in a two phase single subject interaction design. Phase I assessed the efficacy of each variable alone while Phase II assessed the interaction between variables. The main conclusions of Phase I were that individuals can make explicit use of each of specific and breathing assist HR instructions as well as feedback to effect HR increases. Respiration assist instructions differentiated Runners and Non-runners with Runners generally demonstrating much larger increases in RR and somewhat larger increases in HR. While the HR and RR increases were both larger for Runners, the HR increases were somewhat smaller than the RR increases, suggesting that Runners were much better able to bring about RR changes. In Phase II, the addition of feedback to the two instructional strategies facilitated HR increases for Non-runners while the effects for Runners were mixed; feedback informed some Runners when the use of respiration was successful in effecting HR increases. The data support the notions that a) feedback/reinforcement generally serves to highlight effective vs. ineffective HR control strategies; b) the behavioral adjustments produced by voluntary control procedures are due to the combined influence of instructional and feedback variables; and c) that exercise history is an important variable for obtaining learned HR increases under respiration assist instructions.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	i
ABSTRACT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
INTRODUCTION	
The Nature of Biofeedback	1
Biofeedback in Historical Perspective	1
Three Theoretical Models of Cardiovascular Control in Biofeedback Research (Brener, Lang, and Schwartz)	3
Parameters of Learned Heart Rate Control	6
Individual Differences In Learned Heart Rate Control	8
Experimental Variables in Learned HR Control	16
Kind of Feedback or Reinforcement	16
Type of Instruction: Knowledge of Response by the Subject	19
Effects of Respiration Rate	23
Rationale for a Single Case Design	25
Purpose and General Design of the Experiment	27
Statement of the Hypotheses	30
METHOD	32
Subjects	32
Apparatus	33
Procedure and Training	34
Abbreviated Instructions to All Subjects	36

TABLE OF CONTENTS (CONTINUED)

RESULTS 37

Phase I, HR and RR Changes 37
A-B-A Series HR 37
A-B-A Series RR 39
A-C-A Series HR 39
A-C-A Series RR 40
A-B'-A Series HR 40
A-B'-A Series RR 41
Phase II HR and RR Changes 41
B-B'-B Reversal HR Changes 41
B-B'-B Reversal RR Changes 44
B-BC-B Reversal HR Changes 45
B-BC-B Reversal RR Changes 47
B'-B'C-B' Reversal HR Changes 47
B'-B'C-B' Reversal RR Changes 50

DISCUSSION 51

Phase I Effects 51
A-B-A Series 51
A-C-A Series 52
A-B'-A Series 52

Phase I Conclusions 54

Phase II Effects 54
B-B'-B Reversal Across Series 54
B-BC-B Reversal Across Series 59
B'-B'C-B' Reversal Across Series 65

Order Effects 68
B-B'-B 68
B-BC-B 69
B'-B'C-B' 70

Phase I-II Order Effects 70

Implications of a Single-Subject Design for Biofeedback Research 71

Considerations for Future Research on the Role of Feedback and Instructions 74

REFERENCES 77

APPENDICES
A. Mediation of Cardiovascular Responses 96
B. Models of Learned Cardiovascular Control 107
C. HR and RR Means and Standard Deviations for Groups of 3 Subjects Across Orders and Between Reversals: Phase I and II 144
D. Instructions to All Subjects 146
E. Rotter's I-E Scale 151
F. Post Experimental Questionnaire 156

LIST OF TABLES

		Page
1.	A Two Phase Design Illustrating the Independent Variables Alone (I) and in Interaction (II) Through Three Counterbalanced Reversals	29
2.	Cardiac - Motor Skills Ability Factor Parallels Based on Five Ability and Performance Factors Postulated by Fleishman (1966) for Motor System	120
A.	HR and RR Means and Standard Deviations for Groups of Three Subjects Across Orders and Between Reversals: Phases I and II. Means and Standard Deviations Represent Changes from Criterion.	145

LIST OF FIGURES

		Page
Figure 1.	Mean HR and RR Change Effects for Each Variable Alone Compared to Baseline HR and RR Across Orders and Between Subjects: Phase I Effects	38
Figure 2.	Mean HR and RR Change Effects of Breathing Assist Instructions Alone Across Orders and Between Subjects: Phase II B-B'-B Reversal Effects	42
Figure 3.	Mean HR and RR Change Effects of Feedback Upon HR Increase Instructions Alone Across Orders and Between Subjects: Phase II B-BC-B Reversal Effects	46
Figure 4.	Mean HR and RR Change Effects of Feedback Upon Breathing Assisted HR Increase Instructions Alone Across Orders and Between Subjects. Phase II B'-B'C-B Effects.	48

The Nature of Biofeedback

Biofeedback is a "term that refers to a group of experimental procedures in which an external sensor is used to provide the organism with an indication of the state of a bodily process, usually in an attempt to effect a change in the measured quantity" (Schwartz & Beatty, 1977; p. 1). This indication has been termed "feedback" (hence, biofeedback) or "reinforcement" as in the operant learning paradigm (see Peterson, 1982, for a behavioral analysis of the concept of feedback). A unique property of biofeedback procedures as tools for scientific investigation, is their capacity to generate highly specific changes within different physiological systems. As such, they have served as a means of gaining experimental control over specific physiological processes so as to explore the nature of their interrelationships and to explore their association with specific environmental and overt behavioral conditions. The current study investigated learned heart rate (HR) control and the relevant parameters affecting such control. However, in order to better appreciate the review of relevant parameters, we will first consider biofeedback in historical perspective.

Biofeedback in Historical Perspective

Biofeedback research has undergone several changes in experimental goals and theoretical positions. For example, where initial emphasis was focused on simply determining the possibility of operant control of autonomic nervous system (ANS) responses, researchers soon began to consider the theoretical and methodological implications of mediational contaminants of the "pure operant" response such as muscle potentials, mental imagery, and respiration (Crider, Schwartz & Schnidman, 1969;

Katkin & Murray, 1968). Researchers also attempted to produce large magnitude "voluntary" changes of clinical significance. However, Blanchard and Young (1973) concluded that the changes reported had been statistically rather than clinically significant. The resulting emphasis on clinical significance deemphasized the importance of mediational contaminants of biofeedback. Researchers became more concerned with controlling the desired response. Instead of viewing mediation as a contaminant, it was viewed as a potential facilitator of the desired response which resulted in the Mediation/Specificity controversy reviewed by Williamson and Blanchard (1979a). This controversy is concerned with whether an individual achieves direct operant control over a specific response, or whether he is controlling the response indirectly through cognitive and/or somatic mediation. Katkin and Murray (1968) suggested that one must distinguish between "conditioning" and "controlling" HR, which led to a subsequent change in emphasis to the psychophysiological mechanisms of learned HR "control". However, while many of the controlling variables for conditioned HR increases have been identified, and irrelevant variables ruled out, investigations of the underlying psychophysiological mechanisms have only just started (Williamson & Blanchard, 1979a).

Biofeedback researchers first studied predictors of HR control in the form of visceral, cognitive, developmental, and personality variables. Individuals were grouped according to these variables in an attempt to reduce intersubject variability and to select those individuals who could bring about large magnitude HR changes. While initial efforts centered on autonomic awareness, or whether "naturally occurring feedback" would be sufficient to obtain cardiac control (Bergman &Johnson, 1972),

subsequent efforts focused on such variables as age, gender, anxiety, locus of control (Rotter's internal-external locus of control, 1966) and other personality traits, in order to further reduce intersubject variability. However, autonomic awareness was also the first variable to be considered an indicator of individual differences in learned HR control (Williamson & Blanchard, 1979a). While individual differences in conditionability were initially considered as a form of "noise" or interference, certain researchers began to view individual differences as a potential source for achieving greater understanding of the complex mechanisms involved in biofeedback control (Levenson & Ditto, 1981; McCanne & Sandman, 1976; Williamson & Blanchard, 1979a). Such mechanisms were explored by studying individual differences in the patterning of physiological processes and their constraints (Schwartz, 1973, 1977), and individual differences in the development of instructional strategies to mediate ANS responses (Brener, 1974, 1977; Lang, 1974, 1975).

Three Theoretical Models of Cardiovacsular Control in Biofeedback Research (Brener, Lang, and Schwartz)

The experimental study of these mechanisms resulted in three theoretical models put forth by Brener (1974, 1977), Lang (1974, 1975) and Schwartz (1972, 1974, 1975, 1976, 1977) respectively. In general, each model suggests that learning to control HR, particularly HR acceleration, is akin to motor skills learning. Such a conceptual framework represents a move away from studying cardiovascular control within the general framework of instrumental conditioning (Kimmel, 1967, Miller, 1972). Each model emphasizes a different set of factors or

variables. For example, Brener (1974, 1975) has emphasized the discrimination of interoceptive sensations that are important for the development of voluntary control. In contrast, Lang (1974, 1975) has focused almost exclusively upon the feedback or consequence variables that differentially affect HR speeding and slowing. Schwartz's (1974, 1975) model is different in that it is primarily concerned with the learned control of response patterns. We will now briefly consider relevant details of each model.

Brener

Brener (1974, 1977) has proposed that the ability of subjects to discriminate the consequences of their actions is a prerequisite to the development of instructional control over these actions in the context of biofeedback training. He claimed that instructions (eg., increase HR) function to produce a very undifferentiated, nonspecific response pattern which is usually the result of subjects' previous learning experiences with the effects (eg., HR increase) reflected in the instructions. Such patterns are accompanied by interoceptive sensations that are related to the specific biological functions activated. In addition, the magnitude of exteroceptive feedback should also reflect changes in this response. Through associative learning processes or "calibration", the pairing of the exteroceptive and interoceptive stimuli results in the learned discrimination of the sensations associated with the desired response. Further, instructions that consistently precede the activation of these interoceptive stimuli also become associated with them so that eventually, the instructions function to activate this same set of sensations, called the response image, and the associated visceral response. Finally, after sufficient training, the individuals' ability

to discriminate the relevant interoceptive stimuli improves so that within biological limits, a more specific cardiac response develops.

Lang

Lang (1974, 1975) has dealt exclusively with the feedback variables related to learned HR control and he asserts that learned HR speeding should be conceptualized as the learning of a motor skill. On the other hand, he regards HR slowing as pure, visceral learning. Lang considers HR speeding to be dependent upon central mechanisms that couple somatic and autonomic systems, and suggests that most of the procedural variables found to systematically affect motor learning (eg., frequency of feedback, varied informational content; monetary incentives) also affect the acquisition of HR speeding. However, some of these variables have also been shown to affect HR slowing.

Schwartz

Schwartz (1974, 1975) has suggested that through biofeedback training, the specific response pattern learned is a function of two factors: 1) the specific feedback contingency; and 2) biological constraints. When individuals are given feedback information of a specific response pattern, e.g., raise HR and systolic blood pressure (BP), they can attain control over it except when such control is biologically constrained. Specifically, the model predicts that a specific response or response pattern will be learned only if feedback is contingent with the response. When two responses are naturally coupled, the second response will receive partial reinforcement and will be simultaneously learned as a part of the response pattern. Therefore, Schwartz's model predicts that specificity emerges only to the extent that naturally coupled responses can be differentially reinforced.

Each of the theorists emphasized a particular set of variables that are relevant to the learned control of HR functions. Williamson & Blanchard (1979b) in their review indicated that the most important of these variables can be categorized as: 1) instructions to the subject; 2) nature of the desired response; 3) biological constraints; and 4) feedback parameters. While each of the first three variables can be regarded as basic to all studies of learning, only when studying feedback variables does a prediction derived specifically from motor skills learning become relevant. One of the basic axioms of motor skills learning is that performance improves as a function of the amount of information provided by feedback (Bilodeau & Bilodeau 1958; Fitts & Posner, 1968). Moreover, Williamson and Blanchard (1979a,b), suggest that learned cardiovascular control is similar to the learning of a complex motor skill and that any comprehensive model must account for the interactions among the four variables discussed above.

Parameters of Learned Heart Rate Control

Parameters of learned HR control can be roughly classed into three kinds of variables: Individual Differences, Experimental and Mediational. The Individual Difference variable has so far been investigated through examination of variables such as gender, smoking behavior, exercise, locus of control, assorted personality variables, and internal autonomic awareness. These factors have been shown to influence the results of previous studies. However, the majority of HR control studies and theories were developed using "normal" subjects (Rayter, 1975). A different population of subjects might lead to different and perhaps new variables of HR control. The current study focused on a

comparison of athletes (long-distance runners) and non-athletes because of their differences in cardiovascular history as a function of running history.

The basic rationale for the experimental interest in long-distance runners is as follows. Runners are known to experience wide ranges of HR fluctuation during training (Robinson, 1968); i.e., they have specialized cardiovascular histories as a function of exercise. As well, Hollandsworth (1979) found that individuals who regularly engage in aerobic exercise develop sensitive awareness to physiological functioning which they may use to regulate their efforts during competion, and which transfers to quiescent states. Further, aerobic athletes (including runners) have been found to better discriminate HR sensations corresponding to HR changes (Jones & Hollandsworth, 1981; Whitehead, Drescher, Heiman and Blackwell, 1977). Since cardiavascular control is presumed to involve the discrimination of HR changes in particular, and cardiovascular activities in general (Brener, 1974), runners might reasonably be expected to show superior performance. Finally, given runners' skills in the discrimination of cardiovascular activities, and given the relationship between respiration rate (RR) and learned HR control (Holmes, Soloman, Frost & Morrow, 1980), runners might be better suited to learn HR increases under instructions to use their breathing. An additional arguement is that runners are experienced "motor-skills" athletes. If, as has been argued theoretically (Brener, 1974, 1977; Lang, 1974, 1975; Schwartz, 1974, 1975, 1977), HR control is a motor skill, runners might be expected to positively transfer their skills. This interest in cardiovascular history is expected to further our understanding of the underlying mechanisms of cardiovascular control.

Experimental parameters include those imposed by the experimenter such as the kind of feedback or reinforcement, and type of instructions that subjects receive. Mediational parameters, include respiration, muscle tension, and cognitive or ideational activity. The present study examined the use of respiration as a facilitator of learned HR control because it has been shown to facilitate cardiovascular control, and because long-distance runners were expected to achieve greater HR control through their breathing.

The present research examined the effects of individual differences as affected by two additional parameters of learned HR control. Specifically, we studied the effects of visual feedback and type of instructions upon learned HR increases in highly trained vs relatively untrained long-distance runners. Before examining the implications of the choice of these independent variables for runners, it will be necessary to review the research on these parameters, as it pertains to cardiovascular control.

Individual Differences in Learned Heart Rate Control

Individual differences refer to idiosyncratic or inter-individual factors of a developmental, personality, physiological, exercise, or employment nature that might strengthen cardiovascular control in relation to experimentally administered independent variables such as kind of feedback or instructions. In a sense, we are talking about an individual's cardiovascular history as represented by the above factors though in the current study, we are particularly concerned with exercise in the form of an individual's running history.

Several individual difference variables have been explored to a limited extent. Young and Blanchard (1972) reported that males appeared

to be "superior" to females in their ability to raise HR, but that there were no differences in ability to lower HR. As well, Whitehead et al. (1977) and Jones and Hollandsworth (1981) reported that males were more accurate cardiac discriminators than females i.e., more aware of heart rate both during and after exercise. With respect to age, Silverman and Campos (1973) reported no evidence of HR control in one and two year olds, while Lang (1975) reported significantly reduced HR control in a group of elderly subjects (mean age = 60.6) when compared to college age subjects (Introductory Psychology Students). Also, both positive (Elliot & Thysell, 1968) and negative (Irwin, 1971; Levenson & Ditto, 1981) effects of smoking upon HR control have been observed. Fortunately, effects of age, gender and recent smoking behavior can be readily controlled by matching for age and gender and instructing appropriately for smoking.

More relevant to the current study are the findings on autonomic awareness or ANS perceptibility. This was initially measured by the Autonomic Perception Questionnaire (APQ; Mandler, Mandler & Uviller, 1958), which had been used in an attempt to demonstrate a relationship between internal autonomic awareness and HR control. Bergman and Johnson (1971) hypothesized that HR perceptibility was related to the degree of HR control. However, they reported a greater degree of HR control by middle scoring subjects than by high and low scoring subjects who were equivalent in HR control. On the other hand, Blanchard, Young, and MacLeod (1972), Engel and Hansen (1966), and Green and Neilson (1966) reported greater cardiac control with low scoring subjects, suggesting that too much ANS awareness may interfere with cardiac control. A more recent study (Puente, Clark & Berman, 1980) reported that a shortened version of the APQ did not predict ability to control HR.

The rationale for expecting a positive correlation between autonomic awareness and cardiac control derived from studies Brener, Kleinman, & Goesling (1969), Young & Blanchard (1974), indicating that greater amounts of external feedback led to increased cardiac control. They reported that the degree of HR control was a direct function of the percentage of training trials upon which feedback was given. However, a link between internal autonomic awareness and external feedback was first suggested by Bergman and Johnson (1971).

McFarland (1975) attempted to clarify the somewhat confusing relationship between autonomic awareness and learned HR control by moving away from questionnaire responses (e.g., APQ). He chose a tracking test called heart activity perception (HAP) in which subjects attempted to shadow their heart rate by pressing a button in rhythm with their heart beats. McFarland reported a significant, positive correlation between HAP test results and HR increases which was independent of changes in either respiration rate or amplitude. Finally, a low observed correlation between the APQ and HAP tracking scores suggested that the two perceptual tests measured different attributes of subjects. McFarland concluded that individuals who have a more accurate perception of their heart activity are also best able to control that activity by using their "superior internal cardiac feedback" to produce the desired HR changes. Such speculation has also been the basis of Brener's (1974, 1977) model of learned cardiovascular control. He asserted, that if learning to discriminate the activities of the cardiovascular system were an important prerequisite to the control of those activities, then individuals trained to discriminate cardiovascular states would be better at controlling such states than individuals who were not provided with such training. In the current study, Runners and Non-runners were seen

respectively as trained and not trained in the discrimination of cardiovascular states based on their cardiovascular history as related to exercise.

Supportive evidence was obtained by Jones and Hollandsworth (1981) who found that male runners were more accurate cardiac discriminators than either tennis players or sedentary individuals. Cardiac discrimination was based on the subject's ability to accurately determine which of 35 10 sec HR feedback periods were true or false during rest and immediately following vigorous exercise. The finding of more accurate cardiac discrimination was true both at rest and immediately following vigorous exercise. Their study was based on an earlier study by Hollandsworth (1979) who found that individuals who regularly engage in aerobic exercise develop sensitive awareness to physiological functioning, which they may use to regulate their efforts during competition. Hollandsworth further suggested that this heightened awareness would transfer to quiescent states for the same individuals. A recent study of individual differences in heartbeat discrimination (Katkin, Morell, Goldband, Bernstein & Wise; 1982) confirmed the implication of the Jones and Hollandsworth (1981) results that most individuals are unable to discriminate their own heart beats without training, but they can learn. Current interest in studying perception of visceral events is a result of the hypothesized positive relationship between a) the capacities of individuals to discriminate HR and to control HR events (Brener, 1974, 1977; Ross & Brener, 1981); and b) HR discrimination and control where HR discrimination was based on an HR tracking test (McFarland, 1975; McFarland & Campbell, 1974).

Lang (1975) has investigated learned cardiovascular control through a motor skills learning paradigm. He stated that cardiovascular control

involves more than a single conditioned reflex; it requires "an organized set of activities, movements, and symbolic information", such as is involved in tennis or any other sport. Further, upon reviewing the different mechanisms involved in HR slowing and speeding, he concluded that the ability to speed HR on command appears to be a talent which is not distributed equally in the human population. Specifically, Lang noted that college age males were superior "autonomic athletes" relative to the elderly or to those with cardiac disorders. Similarly, upon noting that HR changes were obtained in a relatively short period of time (first session), Levenson (1976) suggested that subjects may vary pre-experimentally and that our experiments may be assessing only an individual's pre-experimental ability to control HR. It should be noted that it is typical to reach peak elevations in HR in the early phases of most experiments, with only very few studies (e.g., Blanchard et al., 1974; Colgan, 1971; Headrick, Feather & Wells, 1971) demonstrating a greater degree of cardiovascular control with prolonged biofeedback training. Thus, it is suggested that most experiments are tapping only pre-experimental abilities.

Lyon, Blankstein and Darte (1976) suggested that the ability to reduce HR can be construed as a stable response predisposition not unlike a personality trait. They reported that the ability to slow HR was consistent within subjects and stable between "good" and "poor" controllers, and that poor HR controllers did not show significant improvements even with multi-session biofeedback training. They concluded that the typical subjects used for learned HR slowing may well be made up of such poor visceral learners. This is a direct parallel to Lang's (1975) reference to "autonomic athletes", except that he dealt

with HR increases rather than decreases. Lyon et al. (1976) noted that relative to good controllers, poor HR slowers tended to be more trait anxious, less internal in locus of control, more introverted, lower in general sensation seeking, more coronary prone, and less inclined to give socially desirable responses. They viewed their results as consistent with Lang's suggestion that, "The fact that naive slowing is at least marginally related to personality factors may suggest that it is determined by temperamental, unconditioned factors, and perhaps for this reason less responsive to training" (Lang, 1975, p. 189).

Based upon the above reasoning, particularly that of Lang (1975) and Lyon et al. (1976) as well as the fact that HR decreases are generally difficult to obtain and maintain (Williamson & Blanchard, 1979a), the current study examined only learned HR increases. As well, athletes' generally lower than average resting HR (Robinson, 1968) mitigates against significant HR decreases.

McCanne and Sandman (1976) urged investigators to attend to individual differences, in theorizing about possible physiological mechanisms mediating operant HR changes. McCanne (1977) also stated that individual differences in physiological responding during operant HR control may account for some of the equivocal data on the mediation of such HR changes. Hopefully, such thinking will provide further understanding of the mechanisms underlying learned cardiovascular control. Ultimately, what may be required is further study of the individual subject using specifically tailored instructions incorporating cognitive-somatic strategies, and discrimination enhancing internal or external feedback, in line with McCanne's (1977) assertion that there may be fundamental differences among individuals in neurobiological

organization. The current study proposes to study individual differences with the use of specifically tailored instructions by incorporating RR instructions and the presence or absence of feedback. The merits of a single-subject design in this context will be discussed later. (pp 22 - 25).

The present study was partly a replication and extension of previous research by Rayter (1975) in which individual differences in HR variability were examined in a group of athletes. The study examined if individuals whose daily training routine involved experiencing wide ranges in HR variability (40 - 180 beats per minute b.p.m.) possessed differential abilities to effect HR changes and, if so, how would such potentially differing abilities manifest themselves? Athletes were selected because it is not uncommon for them to produce changes in HR from as low as 40 up to 180 b.p.m. during a day of training (Robinson, 1968). A group of endurance athletes and "normals", chosen on the basis of high, medium and low APQ scores, underwent three 1 hr. (48 trials) bidirectional biofeedback training sessions. Both groups were provided with HR feedback and bi-directional HR instructions while the magnitude of HR control (HR level attained) was measured. Subjects were told not to use their respiration to effect HR changes. While the study did not confirm the hypothesis as to athletes' superior ability to control HR, some differences were found between the two groups. With APQ level controlled, Normals raised their HR's significantly higher than the athletes but athletes tended to maintain HR increases for longer periods of time. This latter finding was in the predicted direction and was also supported by a study on exercise physiology (Holloszy, Skinner, Barry, & Cureton, 1964), in which well-trained endurance athletes maintained extremely high HR's for long periods of time during exercise.

The results were discussed in terms of methodological shortcomings (e.g., questionable "athletic abilities") and several speculations regarding athletes' inability to demonstrate greater HR increases. The latter included athletes' difficulty in overcoming vagal (parasympathetic) influences and the possibility that the two groups utilized different mechanisms in obtaining HR increases. Specifically, it was suggested that athletes may rely more heavily on physiological or proprioceptive (interoceptive) kinds of feedback in order to attain and maintain HR control. If the athletes were relying mostly on proprioceptive feedback, it might not have been readily available, since they were asked to focus on external feedback, and thus, their performance would be correspondingly reduced. "Normals", on the other hand, were thought to rely more on external feedback in the form of a visual display of HR increases, a method demonstrated to be effective in biofeedback research. Further, athletes were thought to be able to utilize their breathing for more effective HR control; however, the instructions discouraged all subjects from changing their breathing rate or depth. Thus athletes may have been handicapped when compared to their non-athlete counterparts. It was suggested, in accordance with Ray (1974), that "an individual may possess a certain style for approaching a task physiologically in the same manner he [sic] demonstrated a cognitive style" (p. 354).

The present study assessed the above notion that athletes (i.e., long-distance runners) may rely more heavily upon internal or proprioceptive kinds of feedback by examining learned HR control in the absence, as well as the presence, of feedback. This reliance on internal feedback was also assessed by examining HR control with and without the use of

respiration instructions. Only very highly trained Runners were compared with Non-runners who had never before engaged in any form of routine exercise but rather who had only just begun a training program.

Experimental Variables in Learned HR Control

Kind of Feedback or Reinforcement

The present study also sought to examine the effects of HR feedback (or reinforcement) and instructions upon runners' ability to learn HR increases. The types of information used to facilitate HR changes can be classified into two categories (Bergman & Johnson, 1972): a) the type of feedback or reinforcement for cardiac responses, and b) specific information about such cardiac responses. The first category concerns the manner in which cardiac responses are interpreted and reinforced; i.e., feedback or reinforcement about the degree of success at meeting the criterion response. The second category consists of the kinds of information about the response of interest which is given to the subject through instructions. This latter variable will be discussed in the next section.

Feedback may be classified in terms of sensory modality e.g., (auditory visual, etc.), frequency of occurrence, and level of information (binary vs. proportional) the subjects receive. While auditory feedback has been presented in the form of tones of various frequencies (Brener & Goesling, 1969; Shearn, 1962), visual feedback has been more commonly employed. Examples include a light display (Brener & Hothersall, 1966; Engel & Chism, 1967a; Engel & Hansen, 1966; Hamano & Miyake, 1971; Levene, Engel, & Pearson, 1968), an oscilloscope (Donelson, 1966), and a

cardiotachometer for each of binary and proportional feedback studies. However, no statistical differences have been reported with respect to the different sensory modalities employed (Blanchard & Young, 1972), although Blanchard and Young (1972) and Blanchard et al. (1974) suggested that visual feedback was more effective than auditory feedback.

Feedback may also be classified in terms of its frequency of occurrence (temporal feedback factors). This issue really addresses the utility of feedback and also touches indirectly on the issue of the importance of instructions alone (i.e., no feedback) as a parameter of cardiac control. Frequency of feedback may range from no feedback whatsoever (Bergman & Johnson, 1971, 1972; Blanchard, Young, Haynes & Scott, 1975; Brener et al., 1969) through feedback at every five or 10 beats (Gatchel, 1974) or at various intervals of delayed time (Williamson & Blanchard, 1979c), to feedback following each trial (as in most studies). In the above studies, subjects were able to control HR best upon receiving feedback on a beat to beat basis and immediately following each beat, while only in the Bergman and Johnson (1972) study could subjects control HR without any feedback. A replication of Bergman and Johnson's study by Blanchard et al. (1975), with an increased number of training trials, supported the conclusion that instructional control over HR without exteroceptive feedback is possible. Similarly, Johnston (1976), Levenson (1976), and Stephens, Harris, and Brady (1972) suggested that their findings of immediate HR changes meant that feedback may not have been as important as believed and that instructional control of HR alone was worthy of further study. On the other hand, Young and Blanchard (1974) found that auditory feedback, after subjects were correctly informed of the response, aided subjects in raising HR relative to subjects

who received no feedback. However, the no-feedback group was contaminated by virtue of having initially been given instructions to control HR, therefore it was not possible to rule out effects due to prefeedback instructions. Only a very few studies (Bell & Schwartz, 1975; Colgan, 1977; Lang & Twentyman, 1974; and Whitehead, Drescher, Heiman & Blackwell, 1977) have included the proper control conditions for effects due to instructions alone. All of these studies have found that for HR speeding, feedback control was significantly greater than instructional control alone.

The variable of level of information refers to binary versus proportional feedback. With binary feedback the subject is automatically informed whether or not she or he has reached the criterion involving the period of HR for comparison (Brener & Hothersall, 1966; Engel & Chism, 1976b; Engel & Hansen, 1966). With proportional feedback (digital or analogue), a subject is given beat to beat feedback and told by how much she or he is above or below the criterion. Proportional feedback has been used by a number of researchers including Blanchard and Young (1972), Blanchard et al. (1974), Finley (1970), and Sroufe (1971). Stephens, Harris, Brady, and Shaeffer (1975) used complex combinations of different forms of both binary and proportional feedback. While the latter study reported large magnitude HR changes, the various feedback combinations made it difficult to determine which level of information (i.e., binary vs. proportional) was the most effective.

Manuck, Levenson, Hinricksen and Gryll (1975) investigated the role of feedback in HR control by manipulating the level of information that subjects received. While significant bidirectional HR changes were obtained there were no differences between the feedback conditions. This

indicated that not only were binary-proportional differences absent, but that HR contingent feedback was not a necessary condition for learned HR control. However, it was argued that the beneficial influence of feedback (particularly its presence or absence) may have been demonstrated with a larger sample size, protracted training, effective somatic restraint, or heightened subject motivation. Levenson (1967), Young and Blanchard (1974) and Shapiro, Tursky and Schwartz (1970) also reported no differences between binary and proportional (analogue) auditory feedback. Within the visual mode, however, both Lang and Twentyman (1974) and Blanchard, Scott, Young and Haynes (1974) found that proportional feedback was more effective than binary feedback but only for HR increases. These studies suffer from design and methodological idiosyncrasies that restrict comparison with other studies. For example, the feedback system employed by Lang and Twentyman (1974) was such that Colgan (1977) questioned whether it was truly equivalent to proportional feedback. Blanchard et al. (1974) also reported that neither of the feedback groups employed by Stephens et al. (1975) and Wells (1973) significantly improved control over the eight sessions. In other words, comparisons between binary and proportional feedback were based primarily on HR control during the first session. Colgan (1977) also reported that visual proportional feedback was clearly superior to visual binary feedback for bidirectional HR control, and that the addition of a binary signal to proportional feedback did not reliably enhance control.

Type of Instructions

Bergman and Johnson's (1972) second source of information to affect learned HR control is the type of instructions that the subject receives

about a response. Instructional set has been conceptualized in three different forms: No specific HR information, specific HR information, and augmented HR information. No specific HR instructions may consist of asking subjects to make a light go on and/or stay on as long as possible; in other words, they are presumably unaware that HR is the response of interest (Ascough & Sipprelle, 1968; Brener & Hothersall, 1966, 1967; Engel & Chism, 1967a; Engel & Hansen, 1966; Frazier, 1966; Levene, Engel & Pearson, 1968). With specific HR information, subjects have been asked to attend to and concentrate on their HR and hence were aware that HR changes were required. Both Bergman and Johnson (1971) and Brener, Kleinman, and Goesling (1969) found that this type of instructional set facilitated increases and decreases in HR. With augmented HR information, subjects receive cardiac information (unrelated to criterion HR level expected) as to correctness of response through one of the sensory modalities (auditory, visual) in addition to being told to attend to and concentrate on HR. Such information can be presented on an oscilloscope (Donelson, 1966), over a loudspeaker (Shearn, 1962), through earphones (Bergman & Johnson, 1972), via a meter (Lang, Stroufe, & Hastings, 1967; Stephens, Harris & Brady, 1972) or a light display (Brener & Hothersall, 1966; Engel & Chism, 1967a; Engel & Hansen, 1966; Hamano & Miyake, 1971; Levene et al., 1968).

In an attempt to assess the contribution of instructional set, Bergman and Johnson (1972) manipulated each of the three types across feedback and no feedback groups. Except for the no specific HR information group, all subjects were able to raise their HR. This suggested that awareness of the criterion response played a critical role in raising HR. These findings were in contrast to those of Engel and Hansen

(1966) who, after studying only HR decreases, suggested that knowledge of the learning contingency interfered with attempts to change HR. However, Bergman and Johnson (1972) suggested that such interference was a factor for HR decreases only, since in their own study awareness enhanced HR increases.

In contrast to the Bergman and Johnson (1972) interpretation, Blanchard, Scott, Young and Edmundson (1974) reported that correct knowledge of the response was found to facilitate HR decreases but not HR increases. However, Blanchard et al. (1974) also reported that feedback, rather than correct knowledge of the response was the critical factor in raising HR and only marginally significant in lowering it. They explained the discrepancies in results in terms of the type of feedback used, suggesting that the auditory feedback in the Bergman and Johnson study (1972) was not as effective as the direct visual feedback used in their own study. More recently, Bouchard and Granger (1977) sought to clarify the above discrepancies by replicating and extending these studies through increasing the mean duration of feedback training (from 13 to 30 min.). They predicted but were unable to confirm that continuous visual binary feedback would enhance the HR decrease performance of informed subjects in comparison to those who were originally instructed to change HR without knowledge of the response. While both of Bouchard and Granger's groups significantly lowered their HR's with instructions, the addition of feedback only tended towards significance in lowering HR. Thus, Bouchard and Granger (1977) corroborated Blanchard et al.'s (1974) finding that instructions, rather than feedback, facilitate learned HR decreases. In a related study, Bouchard and Granger (1980) corroborated their own earlier findings of the negligible effects of feedback, using monetary incentives with HR

decrease instructions. However, for HR increase instructions, Williamson and Blanchard's (1979a) thorough review of the "feedback" versus "instructional" control literature from 1973 -1979, concluded that the addition of feedback enhances the HR effect.

Colgan (1977) had supported Bergman and Johnson (1972); and Stephens et al. (1975) in finding that subjects could both increase and decrease HR simply on being told to do so. Thus, while instructions alone have been found to bring about bidirectional HR control, the effects of feedback (visual-proportional) alone have been more equivocal. One reason is that feedback has typically been manipulated simultaneously with instructions as to the nature of the required response. Yet, even the effects of instructions have been confounded by design and methodological shortcomings (Colgan, 1977). And while Colgan avoided a confound with the known inter-group variability in HR research by employing a within subjects design, the current study proposes to go one step further by implementing a single case design. Such a procedure will be more analytical in determining the effects of instructions and feedback singly and in combination.

In an attempt to determine if the mechanisms of HR control are different for Runners and Non-runners, two types of Instructions will be used: (1) specific HR information with RR controlled, as in the Bergman and Johnson (1972) study; and (2) breathing-assist, specific HR information; i.e., with additional instructions to utilize RR in controlling HR. Discussion of the rationale and research background for the respiration rate instructional manipulation follows below.

Respiration Rate

Colgan (1977) extended studies by Lang and Twentyman (1974) and Blanchard et al. (1974) in finding that RR was faster during HR increase trials. He asserted that such increases in respiration could be the major reason why HR increases are found in most studies. The mediational variable that has received the most attention, perhaps because it has been most easily demonstrated, has indeed been respiration. (See Appendix A for a full review of the mediation issue.) It has been well documented that changes in pressure exerted on the pressoreceptors in the lungs produce reflex tachycardia (HR speeding) and bradycardia (HR slowing) in both animals and humans (Neil & Heymans, 1962). Thus, from as early as Shearn's (1962) first report of detectable respiratory change, respiratory mediation of HR changes has been considered possible by virtually every investigator dealing with operant HR control. This form of mediation has been dealt with in various ways (See Blanchard & Young, 1973; Williamson & Blanchard, 1979a for a full review) ranging from simply monitoring respiration through statistical covariance analyses controlling for its effects, to the direct manipulation of respiration through instructions.

McCanne and Sandman (1976) stated that there are no studies which have shown that somatic mediation (RR or muscle tension) is necessary for learned HR control. They concluded that the current status of the research allows us only to suggest that respiratory changes may produce changes in operant HR under certain conditions, and that the precise relationship of RR to operant HR has yet to be determined. For example, Sroufe (1971) demonstrated that "respiration can be explicitly utilized to control heart rate" (p. 654), by providing subjects with respiratory

feedback. He also suggested that "the fact that cardiac control is possible with respiration experimentally controlled merely suggested that subjects can control heart rate independent of respiration, not that respiration is of minor importance." (Stroufe, p. 654; 1971). Obrist et al. (1975) demonstrated that the magnitude of HR change was directly proportional to the magnitude of muscle tension and respiratory change. A recent study (Holmes, Solomon, Frost & Moore, 1980) on the influence of respiratory patterns on HR increases, strongly suggests that individuals learn to control HR indirectly by controlling respiration. Instead of asking individuals to breathe in a particular fashion and subsequently monitoring HR and RR (Holmes, Solomon & Buchsbaum, 1979), Holmes et al. (1980) asked individuals to trace their own respiration pattern from an earlier phase of the same study. While tracing their own respiration pattern, HR changes were not requested, only monitored. The HR changes under both conditions was similar, suggesting that most of the variance accounting for HR change during biofeedback training is due largely to normally and easily achieved voluntary changes in respiration rather than to any new HR learning.

The current study was also concerned with an individual's use of RR to obtain and maintain learned HR control by using breathing-assist instructions. We were interested in determining whether or not athletes (i.e., long-distance runners) would be particularly prone to using RR since HR and RR are so integrally related to their training (Cooper, 1977). As will be recalled, athletes' previous difficulties in raising HR (Rayter, 1975) may have been due to their being explicitly requested not to use somatic mediation to bring about such HR changes.

Rationale for a Single Subject Experimental Design

Virtually all of the biofeedback research on HR has employed large-N group comparison designs (for an exception see Scott, Peters, Gillespie, Blanchard, Edmundson & Young, 1973). And as previously acknowledged, the magnitude of change reported has been 'statistically' rather than 'clinically' significant (Blanchard & Young, 1973). The lack of clinically significant results in large-N research has been tied by small-N researchers (e.g., Hersen & Barlow, 1976; Sidman, 1960) to three limitations of large-N research design: (1) averaging of results across subjects; (2) control of variability and (3) generality of findings.

The problem with averaging of results across subjects is that clinical effects for specific individuals are obscured in the group data. Some clients may demonstrate improvement with a particular intervention, while others may deteriorate, and still others may evidence no change. Yet all results are lumped together in a supposedly "representative" average. Since a complex pattern of individual difference variables is associated with each individual subject, consistency of results is not to be expected across subjects. Instead, effects specific to individuals or small groups of highly homogeneous subjects are more profitably examined with single-subject techniques. This is particularly true in the present biofeedback research where individual differences in cardiovascular history is a major focus of investigation.

Limitations of large-N group designs related to control of variability are of three kinds. First the focus on intergroup rather than intrasubject variability often leads to "weak" effects. Progress during treatment is typically assessed only once on a posttest. Since individual subjects may differ in magnitude or direction of effect, the

result is often minimum success. A second related problem is that within group variability, or error variance, is the statistical standard or baseline against which treatment effects are evaluated. Since error variance is largely a function of individual differences which are typically large, statistical significance may also be elusive.

The third limitation of large-N designs with respect to control of variability, is that emphasis is placed on statistical significance rather than on improved precision in controlling and manipulating independent variables. Variables are lumped together under the rubric of "chance" factors, rather than subjected to experimental analysis and control. Furthermore,while large-N statistics may indicate the presence of an interaction, they do not permit the precise analysis of combination effects present in sequential single subject designs. Single subject designs add and remove independent variables, so that separate and combined effects may be examined within the same subject (Hersen and Barlow, 1976, p. 213; Sidman, 1969, pp. 330 -340).

The above problems were clearly in evidence in previous research by the author on biofeedback with athletes (Rayter, 1975). Results which were clinically weak and at best marginally statistically reliable were obtained. Moreover, striking cardiovascular control, which was demonstrated by a marathon champion and several highly trained runners, was obscured in a statistical group average.

The third limitation associated with large-N research to be considered here concerns generality of results. Since findings from group studies do not represent, and hence generalize to, the individual client, they are of little value to the practicing clinician, in this case, the biofeedback specialist. Large-N solutions which attempt to

achieve increasingly homogeneous groups are destined for failure since, as increasing homogeneity is achieved, decreasingly successful inferences may be made to the target popluation, because the individual complexities in the population will not have been adequately sampled.

Small-N research strategy proposes a solution which includes rigorous and continuing analyses of the control of variability within specific individuals, eliminating the variability problems associated with large-N research. Individual data are analyzed by visual inspection eliminating the problem of group averages. Generality is achieved through replication of results in similar subjects with identical procedures (direct replication) or across a host of unrelated variables, e.g., setting, behavior change agents, etc. (systematic replication). Paradoxical as it may seem, Sidman (1960, p. 190) has cogently argued that precise experimental analysis and control of a single subject's behavior leads to a much greater ability to generalize than the "leaving to chance" technique of attempted statistical control. The latter samples a larger number of subjects, yet fails to achieve analytical control of variability which is the critical prerequisite to successful generalization.

Purpose and General Design of the Experiment

The experimental design has been briefly presented in this section to facilitate an understanding of the experimental hypotheses. The research investigated the relationship of individual subjects' running (cardiovascular) histories to control of heart rate. Of particular interest was a comparison of results between long-distance and non-runners. The independent variables of feedback (presence vs. absence)

and type of specific HR instructions (with vs. without respiration assist) were manipulated singly and in combination. A subsidiary interest was whether each variable alone was sufficient to induce HR increases. Two dependent measures of HR control were employed: (1) the magnitude of HR change above pre-trial HR and (2) the magnitude of RR change from pre-trial RR. Subjects were asked to raise HR as high as they could. The study involved testing of nine subjects within each runner category (long distance runner vs. non-runner).

Within each runner category the following single subject interaction design (cf. Hersen and Barlow, 1976, p. 213) was used. In this design, Phase I assessed whether any variable alone was sufficient to induce HR increases, while Phase II enabled the assessment of their interactions Subjects #1 - #3 received the following treatment order: A-B-A-B-B'-B-B-BC-B-B'-B'C-B', where A = adaption or baseline, B = specific heart rate instructions (without respiration-assist instructions), B' = respiration-assist specific HR instructions, and C = feedback. The order of conditions for subjects #4 - #6 was A-C-A-B-BC-B-B'-B'C-B'-B-B'-B; and for subjects #7 - #9 was A-B'-A-B'-B'C-B'-B-B'-B-B-BC-B. The design may be conveniently conceptualized in two phases as presented in Table 1. In Phase II, the order effects of each sequence are counterbalanced; e.g., B-B'-B appears in the first, third, and second positions of Phase II across subjects. Thus, the above two-phase design permits an analysis of the individual effects of the various conditions alone, the interaction effects of each pairing of conditions, and finally the effects of order of sequences.

TABLE 1

A Two Phase Design Illustrating the Independent Variables Alone (I) and in Interaction (II) Through Three Counterbalanced Reversals

Subjects	Phase I		Phase II	
1 - 3	A-B-A	B-B'-B	B-BC-B	B'-B'C-B'
4 - 6	A-C-A	B-BC-B	B'-B'C-B'	B-B'-B
7 - 9	A-B'-A	B'-B'C-B'	B-B'-B	B-BC-B

A = Baseline or Adaptation

B = Specific HR Instructions

B'= Respiration assist specific HR Instructions

C = Feedback

Statement of the Hypotheses

Phase I

HR Increase Instructions; A-B-A Series: Specific HR instructions alone were expected to lead to learned HR increases above pre-trial HR for both runners and non-runners. This prediction was based on findings by Bergman and Johnson (1972), Blanchard et al. (1975), and Colgan (1977), indicating that instructions rather than feedback was the critical variable responsible for learned HR increases. Runners were also expected to outperform their non-running counterparts based on the motor skills theory and research of Schwartz (1976, 1977) and Lang (1975) as well as Brener's (1974) model of cardiovascular control enhancement through learning to discriminate the activities of the cardiovascular system.

Feedback Alone; A-C-A Series: Feedback alone should result in small and moderate or large HR increases over pre-trial HR for Runners and Non-runners respectively, based on findings by Bergman and Johnson (1972), Blanchard et al (1974), Young and Blanchard (1974), Johnston (1976) and discussions by Colgan (1977). These studies reported that for Non-runners, feedback control was significantly greater than instructional control alone. However, there have been few attempts to examine the effects of feedback without instructions. Several studies did show that specific HR instructions were sufficient in the absence of feedback (Blanchard, Young, Haynes & Scott, 1975; Bouchard & Granger, 1980).

Breathing Assist HR Increase Instructions; A-B'-A Series: Respiration assist, HR increase instructions alone should result in HR increases above pre-trial HR for both groups but particularly for Runners

(Brener, 1974; Colgan, 1977; Obrist et al., 1975; Rayter 1975). The rationale for Runners' enhanced performance is based on the fact that RR and HR are integrally related in their training and further, that such somatic mediation has been shown to facilitate learned HR control (Obrist, Webb, Sutterer, & Howard, 1970; Obrist et al., 1975).

Phase II

Breathing Assist Plus HR Increase Instructions; B-B'-B Series

Respiration assist HR instructions were expected to significantly enhance HR increase performance over specific HR instructions for both Runners and Non-runners with an even more pronounced effect for Runners. This is based on observations and discussion by Brener (1974), Colgan (1977), Obrist et al. (1975) and Rayter (1975) that the use of somatic mediation facilitates learned HR control. As mentioned previously, this would be particularly true for runners for whom respiration and HR are integrally related in daily training (Rayter, 1975).

Feedback Plus HR Increase Instructions; B-BC-B Series: Feedback should enhance HR increase performance of specific HR instructed Non-runners (Blanchard et al., 1975; Bouchard & Granger, 1977; Colgan, 1977) but not of Runners since such external feedback apparently interferes with their own source (internal) of feedback (Rayter, 1975).

Feedback Plus Breathing Assist HR Increase Instructions; B'-B'C-B' Series: Feedback should enhance HR increase performance under respiration assist HR instructions for Non-runners but not for Runners. The rationale is identical to that of the B-BC-B series.

METHOD

Subjects

The subjects were 18 males ranging in age from 25 - 49 yrs. The mean ages of the Runners (35.5 yrs.) and Non-runners (37.5 yrs.) were matched as closely as possible. Long-distance runners were selected from demographic information contained in applications to the Manitoba Runners Association. Potential candidates were telephoned and asked to participate in a paid biofeedback experiment at a local university. Following a positive response, candidates were questioned as to the number of years in training as well as average weekly distances. A minimum of 10 yrs. training and 64 km. per week qualified a telephone candidate for mailing of Rotter's (1966) I-E scale (See Appendix E). Nine long distance Runners who scored as Internals (Ray & Strupp, 1974) were chosen for the study. Internals were chosen because of their propensity to do better at HR increases (Ray & Strupp, 1974).

Potential Non-runners were selected from respondents to sign-up sheets placed at the Reh-Fit Centre and Fit Stop Centre requesting beginning runners for a paid biofeedback study. The Reh-Fit Centre is a medical rehabilitation and fitness sports complex and the Fit Stop is a private health club in the community. Potential candidates were chosen on the basis of having just begun a running program and having never been involved in an ongoing training program before (i.e., no regular exercise or physical activity). They were then mailed Rotter's I-E scale and nine Non-runners who scored as Internals were chosen.

All subjects were free of cardiorespiratory ailments, the use of drugs, and were instructed to refrain from smoking and heavy exercise for at least 1 hr. prior to each session. All subjects were paid $15.00 for the session.

Apparatus and Materials

All physiological recording was done on a six channel Grass Model 7B polygraph. Electrocardiograms were recorded from disposable silver/silver chloride electrodes (3M Company; Red Dot Brand) applied to the subjects' right arm and left leg (Lead II) with the ground lead being applied with a clip to the subjects' left ear. Subjects sat in a recliner chair which was located in a sound-attenuated, radio-frequency shielded, air-conditioned room that contained a one-way glass window plus overhead lighting. The subjects' chair and feedback apparatus were in a copper caged enclosure with a door and were set on top of a plywood platform. The experimenter and the recording apparatus were in the adjoining room linked by an intercom and the window. The room was lit by a 15 watt desk lamp. Wiring passed through the rooms via matching panels on opposite sides of the brick wall.

The electrocardiogram signal was fed into the polygraph's cardiotachometer and then into the polygraph's HR monitor which converted the signal into HR on a beat to beat basis. The monitor output was fed into a specially constructed feedback comparator which determined whether the sample HR was above or below a subject's predetermined criterion (for feedback trials only). Feedback was provided to the subjects for HRs above criterion. This feedback criterion was determined during the rest period prior to each trial by counting heart beats based on R waves as read off the polygraph. The number of heart beats was multiplied by the appropriate factor (2.0 for 30 sec rest periods; 2.4 for 25 sec rest periods; 1.7 for 35 sec rest periods) so that a rate in beats per minute could be established as the criterion. Criterion HR was recorded in the rest periods prior to each feedback trial. Differential visual

proportional feedback was provided by a horizontal light bar which lit up as a progressively longer bar in proportion to the magnitude of HR change. As the bar lengthened to the right it indicated progressively larger HR increases above the feedback criterion. The light immediately to the left of the feedback bar was on to indicate a transition from above to below criterion during trial periods. It was also designed to come on during rest periods. The feedback bar device was placed on an oblong table (36cm x 91cm) approximately 1 m. in front of the subject, and 1.2 m from the floor.

Respiration rate and amplitude were monitored by a Beckman thermistor (Serial no. 98-53AH) placed inside the subject's right nostril, and recorded on a separate channel after being fed into a low level D.C. Pre-amplifier and then into a D.C. Driver Amplifier. Dummy electrodes for EMG, so that feedback only subjects (A-C-A; Phase I) did not know which internal response to control, were attached to the subjects' forearms using disposable silver/silver chloride electrodes. All lead wires were from Ingram and Bell and were 1.22 m long. All amplified signals (real only) were recorded on charted Grass polygraph paper running at a constant speed of 15 mm per second.

Procedure and Training

Upon entering the lab, all subjects were greeted and led to a seat in the experimental chamber. Then the purposes and functions of the experiment and electrodes respectively were explained. After application of the HR, respiration and dummy EMG electrodes, subjects were moved to a reclining chair, read the appropriate instructions and shown the feedback apparatus where appropriate to the condition (e.g., A-C-A).

Each long distance Runner underwent one 2 1/2 hr. session at either 9:00 a.m., 1:00 p.m. or 5:00 p.m. with their Non-runner counterparts receiving an identical session at the identical time but on another day. All sessions began with a 10.5 min. adaptation period which also constituted the first baseline treatment of Phase I. Both resting HR and criterion HR for the first feedback trial were determined by counting R waves and multiplying by 2.0 during the last 30 secs. of this period. Resting RR was also determined during the last 30 secs. of this period. The HR criterion was two b.p.m. above resting HR and constituted the level above which the subjects received beat to beat feedback when in a feedback condition. This level was set on the feedback comparator. A treatment combination (e.g., B or B'C) consisted of seven 60 sec. trials each followed by a rest period averaging 30 sec. in duration. Thus each series of treatments (e.g., B-B'-B) was of 31.5 mins. duration.

In the case of the adaption or baseline treatment (A), subjects were instructed to relax and become familiar with the equipment and surroundings. For the experimental sessions, the last 30 sec. pre-trial rest period constituted the pre-feedback period for the succeeding trial. In each trial, a new feedback criterion level was determined and set based on the HR reading during this pre-feedback period. Again, two b.p.m. above this criterion served as the new level above which feedback was given. A summary of the experimental design appears in Table 1 (p. 31). Phase I consisted of 7 trials while Phase II consisted of 63 trials, 21 for each reversal condition (e.g., B-B'-B).

The instructions for each treatment were presented via a tape-recorder which was started at the beginning of the adaptation period. At the completion of Phase I, the polygraph and recorder were stopped after

which the experimenter entered the chamber and read the instructions for Phase II. After reading the instructions, the polygraph and recorder were re-started, and there followed a brief re-adaptation period of 5 min.

Following the experiment, and after removal of the electrodes, each subject was given a post-experimental questionnaire (paper and pencil) to determine which strategies or techniques he may have used to effect HR changes. The questionnaire was adapted from Bergman (1972) and appears in Appendix F.

Abbreviated Instructions To All Subjects

All subjects were briefly informed about biofeedback techniques in general while their electrodes were being applied and any questions were also answered at this time. Subjects were requested to attend to the tape recorded instructions that requested either HR increases with no movement or breathing changes, or breathing-assist HR increases but still with no movements. Depending upon the series they were in (B, C, or B'), they were also explained the use and purpose of the feedback lights in front of them, either prior to Phase I (A-C-A Series) or prior to Phase II (A-B-A and A-B'-A Series). All subjects were told, upon hearing the words "Increase HR": "Try to raise your HR as high as you can for the next 60 secs. until you are instructed to 'Rest'". Upon hearing the words "Breathing-assisted increase" they were told: "You may change your breathing rate or depth to bring about HR increases". All subjects received two sets of instructions, one preceeding Phase I and the other preceeding Phase II. All subjects were also instructed how to contact the experimenter at any time, if it was necessary to interrupt the experiment. (Refer to Appendix D For Detailed Instructions.)

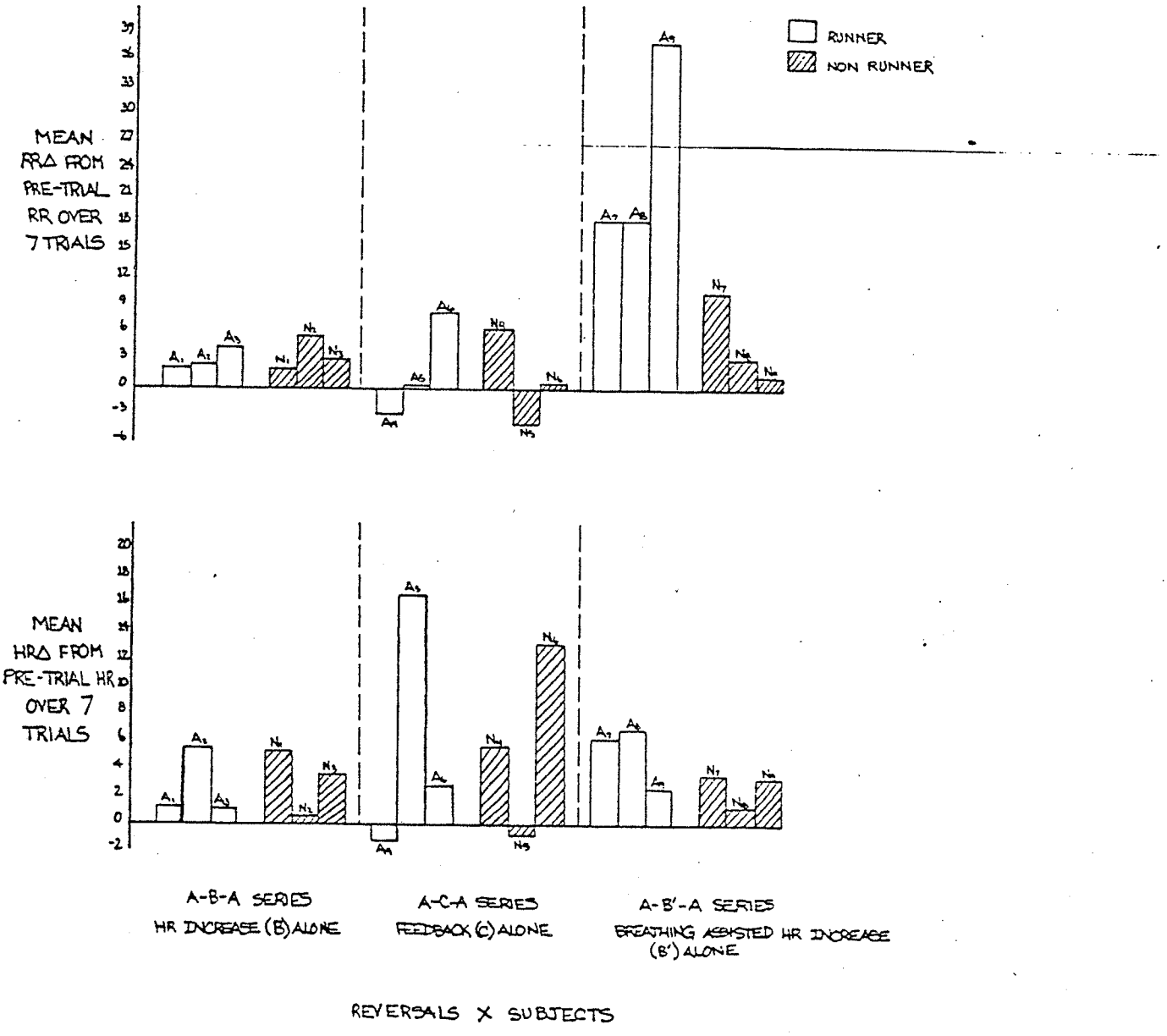
RESULTS

The data are presented for Phase I and Phase II in a manner that facilitates comparisons between groups (A = Runners; N = Non-runners) and across series (i.e., orders). There are four sets of graphs (Figures 1 - 4), each with two bar graphs illustrating the various reversals (e.g., B-B'-B) for each of the dependent variables of HR change (at the bottom of each figure) and RR change (at the top of each figure) respectively. Each set of graphs illustrates in histograph format, the within-series effects for all subjects. Thus, comparisons can be made between Runners (A's) and Non-Runners (N's) and across reversals as well as between HR and RR. For example, Figure 1 shows the Phase I effects of each of B, C, and B' alone (e.g., A-B-A Series). The bars of Figure 1 represent a subject's mean HR or RR change from pre-trial HR or RR over seven trials for each of the treatments alone in Phase I. Figures 2 - 4 which present data on the interaction of variables will be explained during the discussion of Phase II results. Each of the A's and N's are numbered and will heretofore be referred to as N_4 or A_6, for example, when a specified subject's performance is examined. For the purpose of consistency, small, moderate and large HR increases have been arbitrarily set at 0-3, 4-6, and greater than 6 beats per min.

Phase I, HR and RR Changes

A-B-A Series HR: The left-hand panel of the lower portion of Figure 1 shows the effects of specific HR instructions alone upon learned HR increases. As predicted, all of the A's and N's show HR increases above pre-trial HR demonstrating that specific HR instructions alone are sufficient to bring about HR increases. Mean increases ranged from one

Fig. 1 Mean HR and RR change (Δ) effects for each variable alone for baseline HR and RR across orders and between subjects : Phase I effects



to nearly six b.p.m. above pre-trial HR, with two of three N's and one of three A's demonstrating HR increases greater than 3 b.p.m.

The second hypothesis relative to the A-B-A series was not supported by the data. Runners were expected to demonstrate larger HR increases than N's when in fact two of three N's outperformed two A's. Further, the only N whose performance was low (N_2), had requested a bathroom break at the beginning of Phase II and had said that he had difficulty concentrating during the Phase I reversal. Had N_2's performance been greater, results completely opposite to the hypothesis may have been obtained.

A-B-A Series RR: The left-hand panel of the upper portion of Figure 1 illustrates RR changes for A's and N's during the A-B-A series where subjects were instructed not to use their breathing. Examination of RR changes across subjects indicates small differences between and within groups. The data suggest that despite instructions all subjects altered their RR somewhat in attempting to raise HR above pre-trial HR. Of note, however, are three subjects, A_2, N_1 and N_3 who show both the largest HR increases and smallest or near smallest RR changes. It appears that these three subjects effect relatively large HR increases with only slight RR increases. In contrast, N_2 shows a slight HR increase but relatively large RR increase.

A-C-A Series HR: The effects of HR feedback alone are shown in the middle panel of the lower portion of Figure 1. As in the A-B-A series, Figure 1 illustrates changes in HR from pre-trial HR.

During the feedback alone treatments one Runner (A_5) shows large HR increases, one shows moderate increases (A_6) and the third (A_4) shows HR decreases. Thus, the hypothesis that Runners will demonstrate negligible

HR increases was disconfirmed. In the case of the Non-runners, two show moderate (N_4) to large (N_6) HR increases and one (N_5) shows HR decreases from pre-trial HR, thus confirming the stated hypothesis for 2 of 3 Non-runners. For N_5 the hypothesis of moderate HR increases is not confirmed. Thus, for A_5 the effects of Feedback alone are inconsistent while for 2 of 3 N's, it apears that feedback facilitates HR increases.

A-C-A Series RR: The middle panel of the upper portion of Figure 1 contains RR changes for A's and N's during the A-C-A or feedback-alone series where subjects were also instructed not to use their breathing as an aid. As with HR changes during C alone, RR changes are highly variable between and within groups. Figure 1 shows that only two subjects (A_6, N_4) demonstrated large RR increases during periods of feedback alone. However, only N_4's large RR increase accompanied a moderate HR increase (5.9 b.p.m.). A_6's large RR increases accompanied a 2.6 b.p.m. HR increase. Subject N_6, on the other hand, showed a large HR increase (13.5 b.p.m.) and negligible RR changes (1 breath/min.). Subject A_5 shows the same relationship; an HR increase of 17 b.p.m. with a RR increase of 0.4 breaths/min. Subjects A_4 and N_5 show a direct relationship between HR and RR changes; HR decreases from pre-trial HR are accompanied by RR decreases from pre-trial RR.

A-B'-A Series HR: The effects of breathing-assist instructions (B') upon HR level attained are shown in the right-hand panel of the lower portion of Figure 1. As predicted, both A's and N's show HR increases above pre-trial HR. Also as predicted, A's generally demonstrated greater HR increases over pre-trial HR than N's. Actually, two of three A's (A_7, A_8) show larger HR increases than each of the N's, while two of

three N's (N_7, N_9) show slightly larger HR increases than the remaining A (A_9).

A-B'-A Series RR: The right-hand panel of the upper part of Figure 1 shows RR changes for A's and N's during the A-B'-A Series (breathing-assist instructions). In contrast to the B and C alone series, each of three A's effected large RR increases in breathing upon command. The larger RR which corresponds to their larger HR increases supports the hypothesis that A's are better than N's in using their breathing to effectively raise HR level above pre-trial HR. However, somewhat paradoxically, the largest RR increase (A_9) is also accompanied by the smallest HR increase even through the RR effect is still present.

Phase II HR and RR Changes

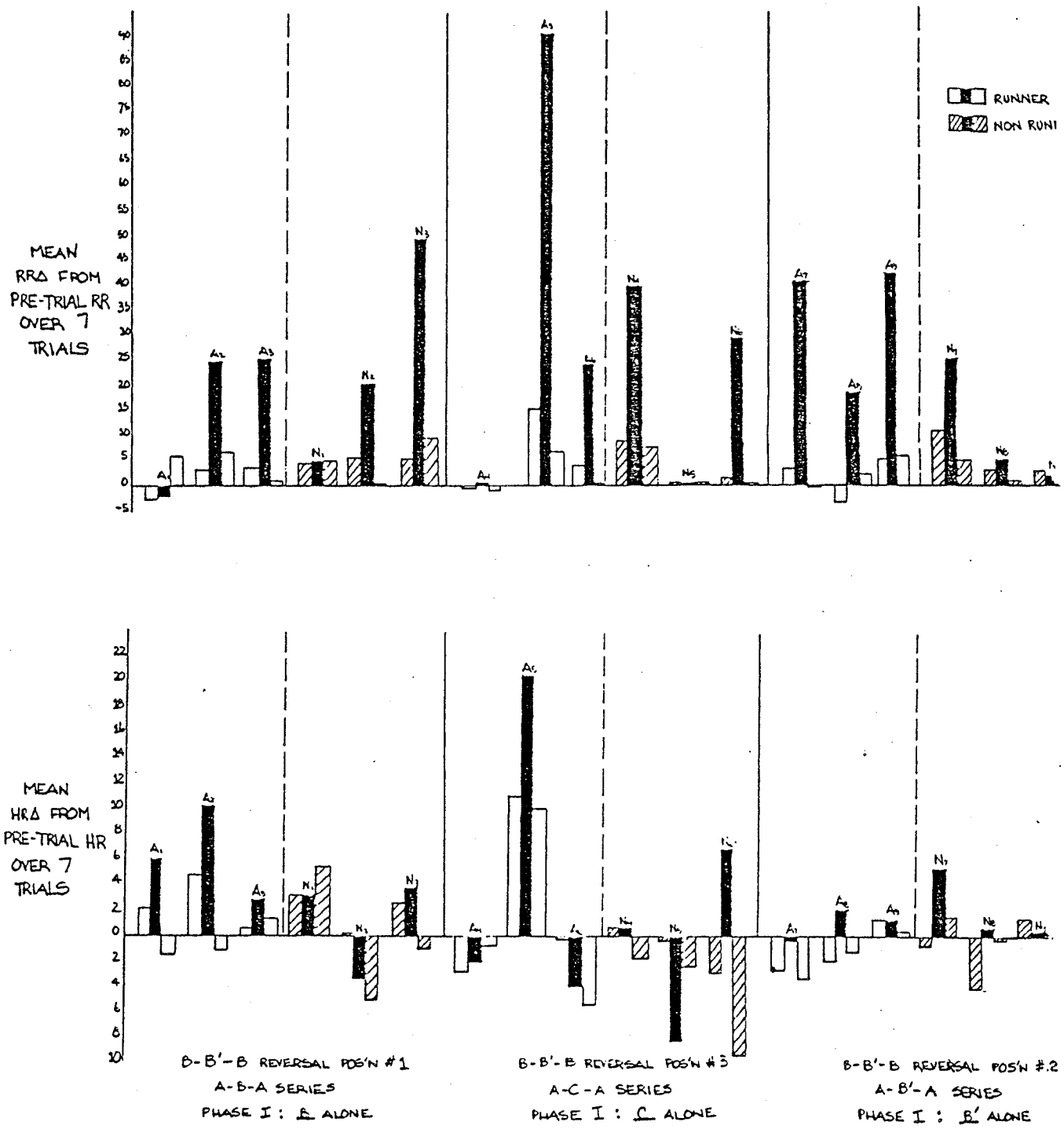
The data for Phase II, dealing with interactions between variables, are presented in Figures 2, 3 and 4. Figures 2 - 4 each illustrate one reversal (eg., B-B'-B) in each of the three different orders (i.e., series) involving 9 Runners (A) and 9 Non-runners (N). Thus, comparisons are made across orders (series) and between A's and N's. Each subject is represented by three bars, one for each of the treatment conditions of a three treatment reversal. For example, the first three bars of Figure 2 (bottom graph) represent average HR change from pre-trial HR over seven trials for HR increase instructions (B), breathing-assist instructions (B'), and finally, a return to HR increase instructions alone (B) respectively, all for A_1. The subjects are numbered 1 to 9 for each of A and N.

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B-B'-B Reversal HR

Figure 2 illustrates HR and RR changes respectively comparing specific HR increase and breathing-assist instructions across orders and

Fig. 2 Mean HR and RR change (Δ) effects of breathing assist instructions as compared to HR increase instructions alone across orders and between subjects: B-B'-B reversal effects



REVERSALS X SERIES X SUBJECTS

between subjects. The bottom half of Figure 2 shows that under breathing-assist instructions, all Runners improved HR performance over at least one of the HR increase instructions alone treatments. Specifically, all 3 A's for each of the A-B-A and A-B'-A series increase HR performance over both pre and post HR increase instructions alone treatments. However, the performance of A_7, though it improved over both baselines, is still below pre-trial HR. As well, A_9's performance increase over the pre-treatment mean is only 0.1 b.p.m. During the A-C-A series, only A_5 shows a large HR increase with breathing-assist instructions over HR increase alone instructions; A_4 and A_6 are consistently below pre-trial HR throughout the entire series though each demonstrates slightly improved performance over one of the baselines. Of the N's, 4 (N_3, N_6, N_7, N_8) attain a higher HR level under B' conditions, while only one N (N_5) evidences a complete deterioration in performance; the remaining 4 N's (N_1, N_2, N_4, N_9) equalled or outperformed only one of the baseline treatment conditions. Nearly all A's and most N's confirmed the hypothesis that breathing-assist HR increase instructions would result in higher HR levels when compared to HR level under specific HR increase instructions.

Runners were predicted to demonstrate larger HR increases than Non-runners. From Figure 2, Runners in Series A-B-A demonstrate a more pronounced breathing-assist effect than their non-running counterparts, while the two groups are more nearly equivalent during Series A-B'-A. During Series A-B'-A, all 3 Runners improved their performance over both baselines, while this was true for only 2 of 3 Non-runners. However, during the A-C-A Series both Runners and Non-runners showed difficulties increasing HR over criterion upon receiving breathing-assist

instructions. Only 2 subjects, A_5 and N_6, produced breathing-assist HR increases greater than obtained under HR instructions alone.

Order effects appear to be present as they occur in the B-B'-B reversal more often in Series A-B-A than either of the A-C-A or A-B'-A Series. That is, the B' effect is most clear when it is introduced in the first position, with B alone having occurred during Phase I. Runners not only use their breathing to increase HR, but they do so best when they do not experience HR feedback either in Phase I or before using their breathing during a latter part of Phase II.

B-B'-B Reversal RR changes

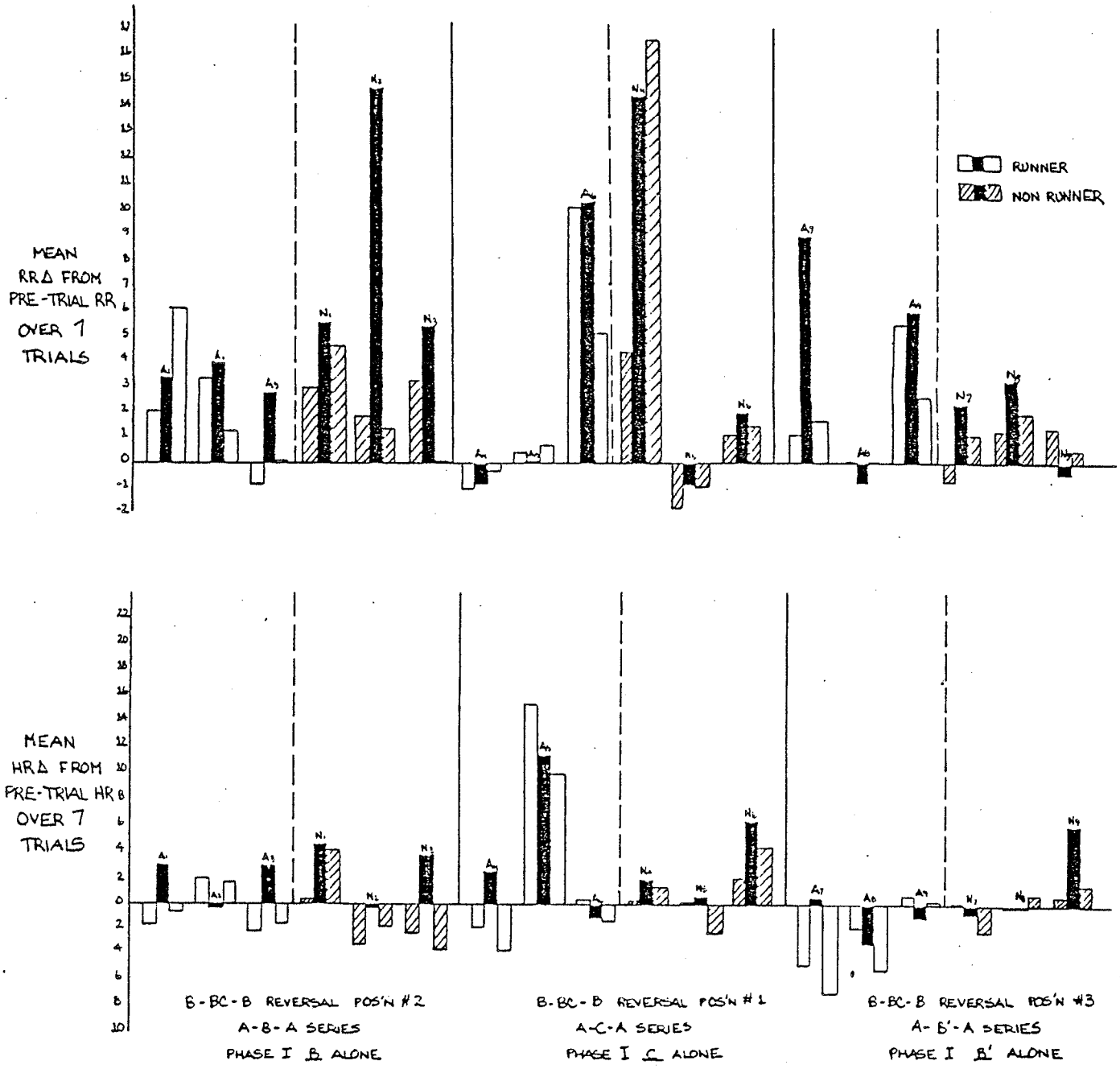
An examination of the top half of Figure 2 reveals the concomitant RR changes during the B-B'-B reversal and their relationship to HR changes during the various treatment reversals. Eight of 9 Runners (all but A_1) show clear RR increases during the breathing-assist instructions to increase HR reversal, while 7 of 9 of these Runners show measurable increases in HR during the same condition when compared to simply being instructed to increase HR. However, the 2 Runners (A_4, A_6) who could not effect corresponding HR increases over both baselines did show some improvement in performance over at least one of the baseline conditions. Of note is that both of these individuals do not raise HR over pre-trial HR during this reversal and for one of them (A_4) RR changes are negligible. In other words, one of the two subjects who does not improve HR increase performance with breathing-assist instructions also does not improve his breathing-assist performance. The other subject (A_6) does increase RR but with no concomitant improvement in his HR increase performance. Finally, of the above 7 of 9 Runners whose HR performance during B' improved over both Bs, 6 show a corresponding increase in RR.

The one Runner (A_1) whose HR increase performance is in the predicted direction but did not show corresponding RR increases, altered his breathing by changing the depth rather than the rate (based on observation of the polygraph data and verbal report from the subject himself). These findings indicate that A's can use their breathing to effect HR increases upon command. Figure 2 also illustrates how all N's, except N_5, show greater RR increases during breathing-assist instructions as compared to one or both baselines, but how only 4 of them (N_3,N_6,N_7,N_8) demonstrate equivalent or greater HR increases during the same conditions. Overall, only 3 of 9 N's (N_6, N_7, N_8,) show moderate to large HR increases commensurate with large RR changes, while 7 of 9 A's show moderate to large HR increases commensurate with large RR changes (this is true if the large changes in respiratory depth for A_1 are considered).

B-BC-B Reversal HR

Figure 3 illustrates the effects, on each of HR and RR, of feedback in addition to specific HR instructions for Runners and Non-runners. As predicted, most N's (all but N_7, N_8) show enhanced HR increases under conditions of feedback when compared to specific HR increase instructions alone. This was true for all N's in the A-B-A and A-C-A Series, in particular the latter, but only for 1 of 3 N's (N_9) in the A-B'-A Series. The 2 N's (N_7, N_8) whose HR changes are not affected by feedback also show very small to negative HR changes during the baselines as well. Finally, the fact that those N's who performed best with feedback had feedback in Phase I (A-C-A series) parallels the finding that those A's who performed best with breathing-assist instructions, had those particular instructions during Phase I.

Fig. 3 Mean HR and RR change (Δ) effects of feedback upon HR increase instructions alone across orders and between subjects: B-BC-B Reversal effects



REVERSALS X SERIES X SUBJECTS

Under conditions of feedback, 4 of 9 A's (A_1, A_3, A_4, A_7) showed improved HR increases. Each of these A's, however, shows below criterion HR performance in both the pre-and post-experimental treatments. One of the Runners (A_2) even shows HR increases during the baseline but negative changes during feedback. Only one Runner (A_5) shows large HR increases during each condition of the B-BC-B reversal; in his case performance under feedback is less than that during the first baseline but greater than that during the second baseline. Thus, support for the hypothesis is equivocal.

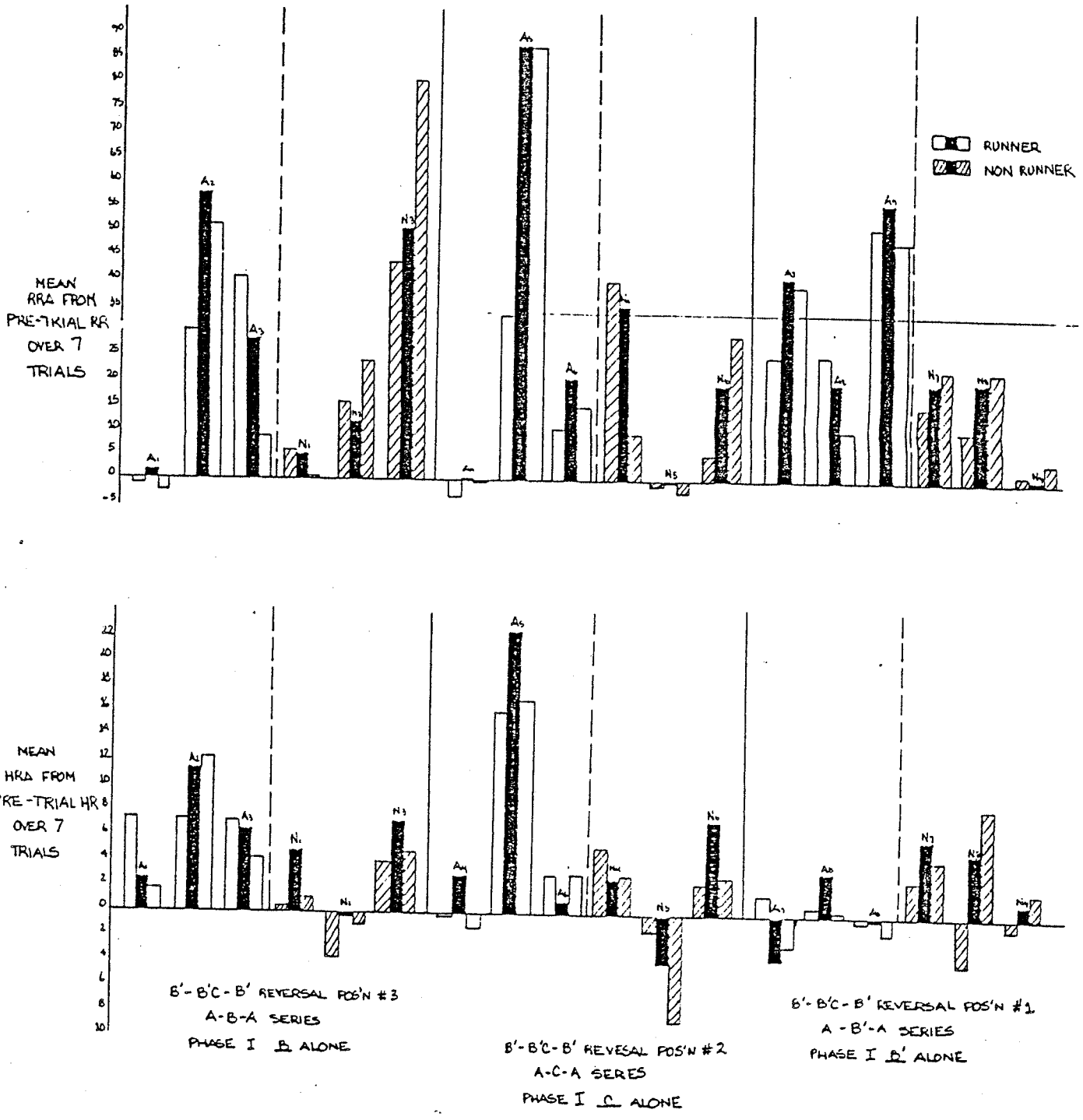
B-BC-B Reversal RR

The RR changes are shown in the top half of Figure 3. Even though RR changes were discouraged via instructions, 8 of 9 Non-runners (excluding N_9) showed greater increases in RR during feedback versus non-feedback conditions. Non-runners do not appear to show a consistent relationship between HR and RR changes. Seven of 9 Runners (excluding A_5 and A_7) showed greater RR increases during feedback versus non-feedback conditions with 2 of the those 7 (A_1, A_4) showing greater RR increases during either the pre or post feedback conditions, but not both. However, in 7 of 9 cases (excluding A_3, A_7), RR increases do not occur simultaneously with HR increases and conversely, small or negligible increases in HR occur simultaneously with large increases in RR.

B'-B'C-B' Reversal HR

Figure 4 presents the effects of the B'-B'C-B' reversal across orders and between Runners and Non-runners for each of HR and RR changes. The B'-B'C-B' reversal was designed to examine the effects of adding feedback to breathing-assist HR instructions and then removing it. For 5 of 9 Non-runners (N_1, N_2, N_3, N_6, N_7), the data confirm the hypothesis

Fig. 4 Mean HR and RR change (Δ) effects of feedback upon breathing assisted HR increase instructions alone across orders and between subjects



REVERSALS X SERIES X SUBJECTS

that feedback enhances HR increases under breathing-assist instructions. Of these 5 only one (N_2) does not raise HR above pre-trial HR, even though the HR level below pre-trial HR criterion is decreased. Of the remaining four Non-runners whose performance during B'C does not improve over both B' baselines, 2 N's (N_8, N_9) improve over the pre-treatment baseline and continue to do so during the post-treatment baseline; i.e., the data display a positive carryover effect. Of the final 2 N's, only N_5 shows a decline in performance that becomes more so in the post-treatment baseline; i.e., the data display a negative carryover effect. The remaining subject (N_4) was interrupted during the latter part of the reversal (i.e., second B') because of a "tingling sensation" he felt, which required a short break and a new warm-up period. In other words, his performance during this entire reversal may be unreliable. Thus, the hypothesis that feedback enhances HR increases under breathing-assist instructions for Non-runners is generally confirmed.

For Runners, the effects of feedback upon the breathing-assist baselines are more equivocal. Figure 4 illustrates that the performance of two Runners (A_6, A_7) declines with the introduction of feedback and is enhanced with its removal. The performance of three Runners (A_4, A_5, A_8) is enhanced with the introduction of feedback and subsequently reduced when feedback is removed. The performance of an additional two Runners (A_1, A_3) shows a decrease in HR increases with the introduction of feedback and a further decrease with its removal, representing a negative carryover effect. One Runner (A_2) shows a positive carryover effect; however, his performance was interrupted during the final baseline of the reversal due to "hyperventilation" and dizziness. The experiment was halted and restarted after a suitable warm-up period. Finally, A_9's

performance during the entire reversal is below criterion HR, even though A_9 shows a very small improvement with feedback.

B'-B'C -B' Reversal RR

While the top half of Figure 4 shows that most Runners (7 of 9) demonstrate increases in RR during B'C over both B's (A_3 and A_8 show increases over the second B' only), most N's (except N_5, where differences are negative or minimal) show decreases in RR from one or both of the baselines. One speculation to account for several A's (A_2, A_4, A_5, A_9) small to large increases in HR during B'C over B' is that they use the feedback as an indicator for the success of their joint HR-RR efforts; i.e., these Runners make greater use of RR. Thus, for some Runners, while feedback alone is found to interfere with HR increases, and breathing-assist instructions are found to facilitate HR increases, feedback plus breathing-assist instructions combine to jointly facilitate HR increases. That is, feedback informs certain Runners when their use of breathing is helpful and not only when HR change itself occurs. The N's whose use of breathing for increasing HR is not as critical, show reduced RR increases because they presumably are using the feedback itself as their measure of success. On the other hand, four N's (N_3, N_6, N_7, N_8) show both positive carryover effects of RR during return to B' treatment (upper portion of Figure 4) and positive HR effects; perhaps feedback also facilitates the use of breathing rather than exerting its influence singly. This may explain why these N's continue to breathe at a greater rate in the post treatment baseline, however, except for N_8, they cannot produce as large HR changes without feedback.

DISCUSSION

The discussion will focus upon the notion that HR and RR are integrally related during learned cardiovascular control, and how this is particularly true for long-distance runners as compared to non-runners. The strongest and most consistent HR effects occurred when breathing-assist instructions were involved. In fact, all predictions, with respect to the effects of breathing-assist instructions, were either wholly or partly confirmed. Further, Runners generally evidenced a greater use of their breathing and subsequently larger RR changes than non-runners. The current study supports the notions of pattern biofeedback learning (Brener, 1974; Magnusson, 1976; Schwartz, 1974, 1976) in the form of HR - RR integration; the notion that feedback/reinforcement generally serves to highlight effective vs. in effective HR control strategies (Brener, 1977; Lang, 1975; Schwartz, 1976); and the notion that the behavioral adjustments produced by voluntary control procedures are a joint function of instructional and feedback influences (Brener, 1974, 1975). While breathing-assist effects are a finding noteworthy in and of themselves, their significance serves to further reinforce the notion that both feedback and instructions lead to the final pattern of responses that an individual learns to regulate (Schwartz, 1976). Before discussing the Phase II reversal effects and their theoretical implications, a brief discussion of the results of each variable alone (Phase I effects), where initial clues to the differential importance of breathing effects are demonstrated, will be undertaken.

Phase I Effects

A-B-A Series: The first hypothesis, that specific HR instructions alone would lead to learned increases in HR for both Runners and Non-runners was confirmed. The second, that Runners would outperform Non-runners,

was not confirmed. Taken separately, the success of HR instructions alone supports the earlier findings (Bergman & Johnson, 1972; Blanchard et al., 1975; Colgan, 1977) that instructions are sufficient for learned HR increases. However, while instructions may have been sufficient for learning to increase HR, is it the case that instructions are necessary or critical? Can individuals increase HR with just feedback alone?

A-C-A Series: The current results, in partial support of the second hypothesis, seem to indicate that feedback alone can indeed result in learned HR increases. Most Runners and most Non-runners demonstrated not only learned HR increases, several also demonstrated the largest HR increases during the A-C-A Series than during either instructions or breathing-assist instructions alone. Perhaps feedback alone is sufficient for learned HR increases. As well, such feedback effects appear to meet the methodological requirements of Colgan (1977).

A-B'-A Series: The results of breathing-assist HR increase instructions provide the first indication of differential effects between Runners and Non-Runners. Not only did these instructions yield much larger RR changes than HR instructions alone, there were also greater HR increases for Runners over Non-runners. As predicted, Runners used their breathing more successfully than Non-runners to bring about large HR increases; Non-runners may be unable to bring about such rapid breathing and/or maintain it for 60 sec. periods. Long-distance runners, as the current study shows, are very good at obtaining large magnitude RR increases. And since those large magnitude RR increases are accompanied by proportionately similar HR increases in many subjects, we may conclude that there is a strong link between HR and RR; i.e., HR -RR integration (Schwartz, 1976). We may further conclude that HR and RR are already

integrated to a greater degree in long-distance Runners than Non-runners. This seems especially likely in view of their rapid acquisition time (only 7 breathing-assist increase trials) and the fact that Phase II results for breathing assist instructions never really bettered those of Phase I.

Now let us consider the Phase I results in the light of the study (Rayter, 1975) from which the current one was conceived, a previous study by the present author. The failure to confirm a Runner vs. Non-runner difference under HR instructions alone is actually a confirmation of speculations from the earlier study (Rayter, 1975) about why "athletes" could not effect greater learned HR increases than their "non-athletic" counterparts. Rayter (1975) hypothesized that athletes' previous difficulties in raising HR centered around their being asked not to use somatic mediation to effect HR changes; i.e., do not move or consciously alter your breathing pattern. He therefore speculated that by allowing athletes a freer use of somatic mediation, they would effect HR changes using mechanisms more akin to their typical cardiovascular routine. As such, subjects in the current study were instructed to use their breathing to implement HR increases and, as previously discussed, the initial hypothesis about Runners outperforming Non-runners in magnitude of HR change with breathing-assist instructions, was confirmed.

Rayter (1975) also speculated that athletes rely more upon proprioceptive or interoceptive vs. external kinds of feedback in order to obtain and maintain HR control. And, if this were true, such interoceptive feedback may not have been readily available, since the athletes were asked to focus on external feedback and thus, their performance may have been correspondingly reduced. In the current study,

Runners were able to draw upon the interoceptive feedback from respiratory changes as well as the HR changes themselves. That is, available interoceptive feedback could be focused on in the absence of external feedback. Since the Phase I effects occurred in a very short time span, only 7 trials, the significant breathing-assist effects likely arose from previously developed breathing habits of long-distance runners. The present study merely served as a format for eliciting their breathing skills in the service of cardiovascular control.

Phase I Conclusions

Several important preliminary conclusions can be drawn solely on the basis of the results of Phase I. The first is that individuals can make explicit use of each of specific and breathing-assist HR instructions as well as feedback to effect HR increases. The second is that long-distance runners are better able than Non-runners to effect HR increases only when breathing-assist instructions are used. A third conclusion, which receives additional support from Phase II results, is that individuals differ pre-experimentally in their ability to control HR. That is, certain individuals have existing patterns of integration between somatic and autonomic functions. Fourth and finally, based on the differential use of RR, individuals are differentially predisposed either through training or physiology to make use of internal versus external feedback for HR increase tasks.

Phase II Effects

B-B'-B Reversal Across Series

The B-B'-B reversal was designed to demonstrate the effects of adding breathing-assist HR increase instructions to HR increase

instructions alone. It was predicted and largely confirmed that both Runners and Non-runners would improve with breathing-assist instructions added. It was also predicted and only partly confirmed that Runners would improve even more so than Non-runners. The principal purpose underlying the B-B'-B reversal was the investigation of a potential cardiac-somatic relationship (Obrist, Galosy, Lawler, Gaebelein, Howard, & Shanks, 1975) for learned HR increases. In particular, long-distance runners were expected to evidence a cardio-respiratory relationship to a greater degree than Non-Runners. Though all Runners did not evidence improved performance with breathing-assist instructions, all of those that did, showed concomitant increases in respiration rate (or depth). With Non-Runners, on the other hand, HR - RR integration was not quite so well established as evidenced both by fewer subjects and a weaker relationship in those subjects who did show concomitant HR and RR changes (increases). In other words, Non-runners were less able to effectively employ RR changes to effect HR increases.

The most obvious conclusion to be drawn is that breathing-assist HR instructions did not assist all individuals equally; these instructions assisted only those individuals in whom HR and RR were already integrated, pre-experimentally. This conclusion is not unlike the B-BC-B reversal finding (to be discussed later) that feedback assisted those individuals who could successfully increase HR in the first place. Schwartz (1974, 1976, 1977) provides conceptual support for the above analysis. (The reader may consult Appendix B for a full review of Schwartz's theoretical approach.) Schwartz asserted that because individuals differ in their autonomic specificity and because different situations may evoke different patterns of responses (Lacey, 1967), there

is no cookbook approach as to the kind of feedback and/or instructions to use in order to evoke particular learning strategies. Schwartz (1974) suggested that if through instructions, individuals were allowed clear use of somatic strategies (both excitatory and inhibitory), it would lead to larger self-produced HR increases (and decreases) through feedback and reinforcement. That is, instructions can facilitate an individual's use of particular strategies in order to effect HR changes. Hence, the central dynamics for change lie in the instructions and subsequent strategies rather than in the feedback and reinforcement per se; the latter only serve to highlight the effective or ineffective strategies that the instructions induce. Thus, the critical question according to Schwartz becomes, "What combinations of instructions and contingency (i.e., feedback) will enable the subject to reach, or even exceed his effective range?" (1974, p. 425 - 426). Schwartz's conclusions are quite relevant and appropriate for the current results in as much as instructions, particularly breathing-assist, dictate the strategy, while feedback serves to highlight (for A's) the effective use of RR,i.e. a breathing-assist strategy. The criticality of applying the right combinations of variables for maximum effect underscores the importance of using a single-subject design to evaluate improvements in performance.

One reason that some Runners may not have shown HR increases without the use of RR strategies (i.e., specificity, Schwartz, 1974, 1975, 1976) may be the fact that HR is fully or partially integrated with vagal activity (vagal excitation --HR inhibition (decrease) and vagal inhibition -- HR excitation (increase)) which is in turn affected by somatomotor activity. For example, by instructing an individual to sit in a quiet, relaxed position and without resorting to respiratory or

muscular movement and by then asking him to raise his HR, he is put in a state that is clearly not optimal for raising HR. Sitting still in this fashion means reduced somatomotor activity and the associated peripheral somatic feedback. These very notions were suggested in a previous study by the author (Rayter, 1975) to account for 'athletes'' inability to outperform their 'non-athlete' counterparts. The current study, therefore, incorporated somatomotor adjustments in the form of RR instructions to test out the above notion. The current study sought to examine RR effects as an independent variable under the experimenter's control; i.e., to examine the degree to which RR could be controlled and subsequently, the degree to which controlling RR could control learned HR. Thus, by showing HR increases under conditions of breathing-assist instructions, we are at the same time accounting for at least one reason that Runners do not evidence sizable HR increases under HR increase instructions alone.

Brener (1974, 1977) also provides conceptual support for the B-B'-B reversal findings. He concluded that HR increase instructions lead to a general motor activation of all of its (HR's) attendant symptoms. Thus, we concluded similarly that breathing-assist HR increase instructions lead to a cardiac-somatomotor response unit, the strength of which is a function of having previous training in HR - RR integration or, in short, of one's cardiovascular history. Brener, attributed such a general motoric adjustment as being specified in terms of, and regulated via, the easily discriminable peripheral feedback available from the striate muscles. In other words, the voluntary characteristics of HR are supported not by feedback of cardiovascular activity per se, but rather by a feedback constellation derived from the behavioral complexes in

which HR responses are embedded which includes feedback from respiratory responses.

Lang (1974) also used the motor skills analogue in developing his model on the acquisition of heart rate control. He views somatic and muscle activity as response systems which often covary with the cardiovascular system and which facilitate visceral learning in intact individuals. He emphasized, also, the importance of continuous exteroceptive feedback in teaching voluntary control of vasomotor responses; a training technique similar to that used to teach motor skills. He used techniques which depend on orienting subjects to the discrimination of visceral changes, providing additional afferentation, and developing instructional sets or strategies. Implicit here is not that cardiovascular control involves a single conditional reflex, but rather that it requires an organized sequence of activities, movements and symbolic information. He speculated further, that subjects need only activate somatic behavior already in their repertoire to increase HR, a notion that is supported by the performance of the Runner's group. Thus, there is no new learning of specific visceral responses, but only a use of external feedback to confirm the appropriateness of recruiting a somatic-autonomic response unit which includes HR acceleration. This line of reasoning, as well as that of Brener, outlined earlier, lends credence to the current results which suggest that an HR - RR response unit can be reinforced as one, particularly if it has had extensive previous training. We may reason further, that feedback serves only to confirm, at least for A's in whom HR - RR integration occurs strongly, that breathing-assist is an 'appropriate' strategy, i.e., feedback confirms the appropriateness of recruiting a somatic-autonomic

response unit which includes HR acceleration. This line of reasoning will be explored further during the discussion of the B'-B'C-B' condition.

While in general there is merit in viewing cardiovascular control as a motor skill, (see Appendix B for critical reviews), it is particularly relevant for long-distance runners in whom there exist highly-trained somatic-autonomic response units. The reasoning behind the current study and its predecessor (Rayter, 1975) was that such a pattern of HR - RR integration already existed in athletes and would thereby facilitate greater cardiovascular control. It appears, in fact, that breathing-assist instructions provide for Runners a cardiovascular control strategy that would otherwise be unavailable with only specific HR increase instructions. Runners not only showed a greater degree of cardiovascular control, but were better at utilizing their breathing to do so than their non-running counterparts. The Non-runners, as we shall see in the following section, relied more typically on the exteroceptive feedback of the feedback lights. Runners, on the other hand, appear to have been better suited to rely on the interoceptive or proprioceptive feedback from well-trained somatic-autonomic response units called into play by breathing-assist instructions. Of course, this does not discount the Runners' use of feedback to reinforce appropriate HR increase strategies, including the use of RR.

B-BC-B Reversal Across Series

The B-BC-B reversal was designed to assess the differential effectiveness for Runners and Non-Runners of adding external feedback to HR increase instructions alone. It was predicted that the B-BC-B reversal, or the introduction of feedback to specific HR increase

instructions, would result in improved performance for Non-runners and poorer performance for Runners. The rationale was discussed in terms of an individual's use of external (N's) versus internal /proprioceptive (A's) feedback as a function of two variables; which type of feedback was available and whether or not the feedback was for specific (e.g., HR alone) or integrated (e.g., HR - RR) functions.

As predicted, most of the Non-runners showed enhanced HR increases under conditions of feedback. Those Non-runners whose HR changes were not affected by feedback also demonstrated very small to negative HR changes during the baseline periods as well. We concluded that the potentially enhancing effects of feedback are present only when there is an HR effect there to start. For Non-runners there was no pattern or relationship between RR changes and feedback/no feedback conditions.

While Runners were not expected to show enhanced HR increases under conditions of external feedback, nearly half demonstrated a slight to moderate (1 -3 b.p.m.) increase in HR. However, each of those Runners demonstrated below baseline performance in both the pre- and post-experimental phases, as well as an increase in RR changes during the feedback portion of the reversal. Thus, it appeared that these individuals could not increase HR on command or do so without the aid of a somatic-autonomic response unit in the form of RR. Rather, these individuals, upon receiving feedback, were able to use the feedback to indicate their success in incorporating a somatic-autonomic response unit in the form of a RR strategy. Or, that as Brener (1974, 1977) has suggested, the feedback served to "calibrate" the success of using RR which in turn provided additional afferentation in the form of internal/proprioceptive feedback about associated somatic-autonomic

response units. Brener refers to the additional afferentation as a feedback constellation.

Did feedback enhance the HR increase performance of Non-runners and did it also detract from or interfere with the same performance in Runners even though it may have indirectly enhanced the performance of several Runners? To answer this question, it is necessary to elucidate the various positions of Brener (1974, 1977) and Lang (1974, 1975) as to the role of feedback (and related instructions) in learned cardiovascular control.

Brener came to look at feedback processes by trying to analyze the instructional control of a voluntary act. Brener asserted that while we might accept that compliance with an instruction to execute an act does not depend upon being able to specify the efferent motor programs for that act; there are discriminable sensory consequences associated with the occurrence of all responses that we classify as voluntary. He asserted further, that one's ability to discriminate a current voluntary act is assumed to rest upon activation of interoceptive afferent pathways by the effectors involved in the act. Thus, when an individual is deprived of the above intrinsic (interoceptive/proprioceptive) feedback, he is also robbed of the illusion that he can voluntarily control responses of the effector (Laszlo, 1966; as cited in Brener, 1974). In Brener's model (1974), the initiation of such a voluntary act is based on James' (1890; as cited in Brener, 1974) notion of response image and its activation through some external (instructional) stimulus. (For a full explication of this model, refer to Appendix B.)

Brener also asserted that using exteroceptive feedback to help identify a desired performance goal should result in similar performance

changes, regardless of whether respiration or HR instructions are given. However, Brener found that exteroceptive feedback for HR performance greatly enhanced the HR control for individuals given HR instructions, but had practically no effect on the HR difference induced by respiration instructions. Perhaps RR feedback would have produced improvements in HR performance. He explained the above finding as follows: because RR responses are more easily discriminable than HR responses, there was a conflict between the instructionally specified behavioral goals and the exteroceptive feedback for HR responses. Runners in the current study, on the other hand, found breathing-assist instructions to enhance HR increases in the absence of feedback (i.e., during B-B'-B or B vs. B' alone). During the feedback and RR reversals (B'-B'C-B'), the Runners' performances uniformly deteriorated with the addition of feedback while the Non-runners performances were enhanced with feedback. How do we account for what happened here? Brener asserted that feedback can be the primary description of a desired activity especially in the absence of well formulated response images associated with a particular set of HR instructions. The current view, however, is that some individuals do possess such well formulated response images, and that they are more likely activated through breathing-assist instructions than HR instructions. Thus, for Runners, RR and HR feedback are not in conflict as Brener suggested, but rather in concert through pre-trained somatic-autonomic response units. Non-runners, on the other hand, more closely fit Brener's assertion that feedback can indeed be the primary description of the desired activity. During the feedback phase of the B-BC-B reversal, feedback was probably the primary description of the required HR increases since HR response images were not as yet well

formulated and thus performance was generally enhanced during the feedback portion. Similarly, during the feedback phase of the B'-B'C-B' reversal, Non-runners' performance improved over the breathing-assist instructions portion because, of the two possible response images (one from breathing instructions, the other from HR feedback), the latter predominant. That is, Non-runners had no cardiovascular history in the use of RR to alter HR; rather, it was the feedback that served to enhance HR increase performance.

Brener (1974) suggested and tested the following notion which was also supported by the current data. If learning to discriminate the activities of the cadiovascular system were an important pre-requisite to the control of such activities, then we might expect individuals trained to discriminate cardiovascular states to be better at controlling such states than individuals without such training. Specific additional research support for these notions on discrimination can be seen in the work of Carroll and Whellock (1981), Ross and Brener (1981) and Whitehead et al. (1977), each of whom suggested a relationship between HR perception skills and HR increase skills. The present author suggested that highly-trained long-distance runners are very good not only at discriminating cardiovascular states such as directional changes in HR, but the associated intrinsic feedback from such states as well. In fact, Jones and Hollandsworth (1981) reported that male distance runners were significantly more accurate HR discriminators at rest than tennis players or sedentary individuals. They related their results to Brener's (1974, 1977) ideomotor theory of visceral learning based on awareness of interoceptive feedback. Also, in a previous study, Hollandsworth (1979) asserted that individuals who regularly engage in aerobic exercise

develop sensitive awareness to physiological functioning which they use to regulate their efforts during competition. Further, Katkin et al. (1982) confirmed Whitehead et al.'s (1977) observation that most individuals are unable to discriminate their own heartbeats without training but that they can learn such a discrimination. Indeed, cardiovascular history plays a critical role in learned HR increases. More specifically, Runners have learned to disciminate cardiovascular states through intrinsic cardiovascular feedback from associated somatic-autonomic response units such as the RR - HR unit. When they do use external feedback, it is to calibrate and indicate their success at using available proprioceptive feedback.

Brener's notions of discrimination and calibration are not unlike the earlier predictions that individuals with higher levels of internal autonomic awareness (Mandler et al.'s APQ, 1958) would be better able to condition or control their HR's. Unfortunately, the data from these studies have been scanty and equivocal (see introductory section on Individual Differences). However, McFarland's (1975) attempt to determine the relationship between autonomic awareness and HR control produced more definite results. Using a more direct measure of cardiac awareness than an individual's opinion on a questionnairie (a HR tracking test, HAP test), he reported a significant positive correlation between his measure of cardiac awareness and degree of learned HR increases. He concluded that individuals with a more correct perception of their heart activity are also best able to control that activity using their "superior internal cardiac feedback", and therefore can more accurately determine what will produce the desired HR changes. Would our long-distance Runners be high HAP individuals? The above mentioned studies on

HR discrimination/perception corroborate Runners possessing "superior internal cardiac feedback". Future endeavors with Runners could directly assess the nature of the relationship, if any, between long-distance training, HAP scores, and control of HR.

Lang (1975) suggested that under certain conditions, an individual need only activate somatic behaviors already in his repertoire to increase HR. Thus, there is no new learning of visceral responses, but only a use of feedback to confirm the appropriateness of recruiting a somatic-autonomic response unit which includes HR acceleration. This in fact was suggested in the current study. Those runners whose performance was enhanced during feedback trials, used the feedback to confirm the appropriateness of having recruited a somatic-autonomic response unit; i.e., an HR - RR response unit. For a further analysis of the role of feedback in Lang's (1975) Model, the interested reader may consult Appendix B.

Of anecdotal importance is that upon post-experimental questioning, virtually every Runner stated that feedback interfered with his attempts to increase HR; that in general, it was distracting. Many, in fact, claimed to have closed their eyes during parts of the feedback sessions.

B'-B'C-B' Reversal Across Series

The results of the B'B'C-B' reversal are perhaps the most intriguing in that they incorporate the central dynamics of the three proposed models (Brener, Lang and Schwartz) and because the results illustrate how the use and role of feedback and instructions differ according to an individual's cardiovascular history. In this reversal, feedack and instructions exert their efffects in combination though not always in a synergistic fashion. The implications of the current results for the

various models will be examined briefly.

It was predicted that the effects of feedback upon breathing-assist instructions would parallel those of adding feedback to specific HR instructions only; i.e., enhance HR increases for Non-runners but not for Runners. However, since HR increases were enhanced for several Runners and not enhanced for several Non-runners during the B-BC-B reversal, it was not surprising to see a similar trend in the current (B'-B'C-B') reversal. For Non-runners the hypothesis was generally confirmed; the addition of feedback to breathing-assist instructions enhanced their HR increase performance. As well, all but one of the Non-runners showed a decrease in RR from one or both baselines, the implication being that they did not use breathing increases to effect HR increases once feedback was available. It is also suggested that for Non-runners, the external feedback highlights the effective use of HR increase strategies which did not include the use of RR. This is not unlikely since very few Non-runners consistently or effectively employed breathing rate to effect HR increases. Such reasoning is still consistent with the views of Schwartz (1974, 1977) and Brener (1974, 1977) in that feedback may be used to indicate the appropriateness of recruiting a somatic-autonomic response unit, even though in this case RR is not included.

For Runners, on the other hand, the effects of feedback upon the breathing-assist baseline were to highlight the effective HR increase strategies which did include the recruitment of an integrated unit consisting of HR and RR. The performance of the Runners was quite varied upon introducing feedback; five of the Runners improved with feedback and three did not improve. To interpret such results it is necessary to examine the HR and RR data together at least for those Runners whose

performance improved with feedback. Upon examining RR changes from one or both baselines, we can see that four of these five Runners showed increases in RR during B'C over B'. Thus, while feedback alone was found to interfere with the HR increases and breathing-assist instructions alone were found to facilitate HR increases, feedback plus breathing-assist instructions facilitated the effects upon HR increases of breathing-assist instructions. That is, the feedback informed the Runners when their use of breathing was helpful (if, in fact, it was helpful) and not only when HR change itself had occurred. The Non-runners whose use of breathing for increasing HR was not as critical, showed reduced RR increases because they were using the external feedback (or some other internal feedback) itself as their measure of success.

For some of the Runners, the external feedback likely served to calibrate the internal/proprioceptive feedback from the HR - RR (somatic-autonomic) response unit. Why then was this not the case for all Runners during the B'-B'C-B' reversal? Or, why did the external feedback for some of the Runners not indicate the success of their efforts? At this point, we can only speculate as to the occurrence of pattern learning and some form of pattern biofeedback. As Schwartz (1972) reported, feedback for integrating BP and HR (in this case HR -RR) produced somewhat larger effects and more rapid learning than feedback for either single function alone. Perhaps for some Runners the HR - RR unit was quite strong and feedback only served to reinforce it; or, perhaps there was minimal integration and feedback enhanced, as it did for Non-runners the HR increase strategies only. At this point, we do not know the specific effects of external feedback upon the mechanisms of HR increase performance in long-distance Runners.

Order Effects

Order effects refer to performance differences as a function of the order of presentation of a particular reversal; for example, receiving the B-BC-B reversal first (A-C-A Series), second (A-B-A Series) or third (A-B'-A Series). Order effects also refer to performance differences in Phase II as a function of which series an individual experienced during Phase I. It is noteworthy that several order effects coincide with the present hypotheses and with current theoretical models.

B-B'-B

Runners demonstrated their largest B-B'-B effects during the A-B-A series as compared to either of the remaining two (A-C-A, A-B'-A) series. In this A-B-A series, Runners not only experienced the B-B'-B reversal first, they also underwent B alone in the immediately preceding Phase I. Two implications follow from this: on the one hand, the Runners practised increasing HR in Phase I and thus already had in repertoire what was required immediately thereafter in Phase II. Alternately, or as well, the Runners did not have to deal with other procedural requirements such as feedback (A-C-A Series) or breathing-assist instructions (A-B'-A Series) before simple HR increase instructions (A-B-A Series). It is suggested that Runners may perform best upon first practicing with instructional demands (e.g., increase HR) and then upon adding instructions that include a RR component.

Non-runners also showed an order effect during the B-B'-B reversal. Their best B' performance occurred in the A-B'-A Series; with B' alone in Phase I and a reversal involving feedback (B'-B'C-B') immediately preceding the reversal in question. That is, such an effect occurred after the Non-runners recently experienced the opportunity to

receive feedback for HR performance following breathing-assist instructions. Having been thus "primed", "rehearsed", or reinforced the Non-runners subsequently demonstrated their best performance. Such differential preference for order of presentation between Non-runners and Runners further substantiates the relevant hypotheses as to the differences in means and degree of effecting learned cardiovascular control. Non-runners effect such control through experience with external feedback while Runners do so through experience with the use of respiration rate which, in turn, provides internal/proprioceptive feedback. The assertion that Runners use internal feedback from HR-RR response units does not preclude the use of external feedback to reinforce the appropriate recruitment of RR strategies for HR increases.

B-BC-B

During the B-BC-B reversal, both Runners and Non-runners demonstrated larger HR increase effects upon receiving feedback during the A-B-A Series than the remaining two series, though for Non-runners, the A-C-A Series effects were nearly as good. Such order effects reflect for Runners the opportunity to have had additional experience with HR increase instructions through B alone in Phase I, and both HR increase and breathing-assist HR increase instructions in the B-B'-B reversal immediately prior to the B-BC-B reversal in question. The order effects for Non-runners reflect their first opportunity to receive feedback for HR increase efforts, particularly after having been unsuccessful with breathing-assist instructions in the preceding B-B'-B reversal. In fact, upon receiving feedback in this B-BC-B reversal (i.e., A-B-A Series), the Non-runners demonstrated one of their largest and most consistent gains in HR increase performance during any reversal. Once again, it appears

that the order effects are consistent with the line of reasoning and theory development that reflects strategy differences between Runners and Non-runners in effecting cardiovascular control; the use of RR for Runners and the use of feedback for Non-runners.

B'-B'C-B'

During the B'-B'C-B' reversal, Non-runners showed their largest breathing-assist HR increase effects upon receiving feedback during the A-B'-A and A-B-A Series. It is difficult to determine for which of these series there are the largest breathing-assist HR increase effects because most subjects in the A-B'-A Series did not return to the B' baseline after the feedback was removed, though the B'C effects are nearly equivalent to those in the A-B-A Series. Because of this problem, it is similarly difficult to attribute the large B'C effects to either Non-runners having received feedback at the earliest opportunity (A-B'-A Series) or to having received feedback for two consecutive reversals after receiving none in the first (A-B-A Series). There were no order effects for Runners in the B'-B'C-B' condition.

Phase I - II Order Effects

Of note are two order related findings on the relationship between Phases I and II. Those Non-runners who performed best with feedback during the B-BC-B reversal, also received feedback alone in Phase I and those Runners who performed best with breathing-assist HR increase instructions during the B-B'-B reversal also experienced B alone in Phase I. There are two implications of such results: Firstly, that the effects of cardiovascular control strategies are enhanced by cumulative learning; and secondly, that there may be optimal sequences for the administration of each of instructions and feedback. In other words, the

effects of breathing-assist instructions, for example, are strongest when Runners first experience specific HR instructions without interference from feedback or other instructional strategies (e.g., breathing-assist HR instructions). Thus, individual differences in cardiovascular history such as being a long distance runner, and their associated somatic constraints (such as respiration), determine the degree and ordering of each variable so as to maximize optimum performance. Further, it seems more evident than ever, that feedback and instructional strategies combine to bring about the largest HR increase effects, which is in accordance with the motor skills learning positions of Schwartz (1974, 1976) and Brener (1974, 1975, 1977).

Implications of a Single-Subject Design For Biofeedback Research

One of the reasons (See pp 24 - 26) given in support of single subject designs was that individual effects are masked by group means, or that the variability between subjects can be large enough to hide large individual effects. Such variability was in fact evident and only through the single subject design were we able to draw attention to particularly large effects. For example, the two most successful individuals in terms of the use of breathing and feedback effects were the individuals, A_5 and N_6 respectively. Another reason for using a single subject design is shown by an earlier conclusion that feedback for Non-runners enhances performance only if there is a HR effect there in the beginning. This conclusion led to examining individual Runner's performances and the finding that, for several Runners, feedback indicates the successful use of RR rather than the successful use of HR strategies alone. A related finding was that for other Runners, feedback did not help when there were no initial HR effects at the start, and no

associated use of RR. The advantage of a single case design is that interrelationships between two variables are able to be extracted via individual data, thereby insuring that important conclusions about the associated models of cardiovascular control would not be overlooked.

An additional advantage of the single subject approach is the opportunity for observing clinically vs. statistically significant effects such as is found in the large magnitude effects of particular individuals. For example, A_5 demonstrates large (10 b.p.m.) and very large (20 b.p.m.) HR changes during the B and B' trials respectively, of the B-B'-B reversal. As well, this same individual shows increases of approximately 17 b.p.m. and 23 b.p.m. during the B' and B'C trials respectively, of the B'-B'C-B' reversal. The post-hoc questionaire reveals this Runner to be both highly motivated (see Kleinman, 1981, on the importance of motivation in biofeedback tasks) with respect to believing in bodily self-control and a very highly trained and disciplined Runner. This Runner not only ran more than 64 km. per week, but he was also trained in the practice of meditation techniques. Such an effect is certainly large enough to be considered of clinical significance based on earlier (Blanchard & Young, 1973) and recent (Williamson & Blanchard, 1979a) reviews. A final advantage is that the single subject perspective also permits a more precise analysis of combination and order effects (Sidman, 1960; p251) as opposed to averaging over counterbalanced orders. In fact the current design does permit the examination of interaction and order effects for instructional and feedback influences.

At this point, it is necessary to talk about the degree of reversability established; i.e., is it possible to demonstrate

reversability and hence experimental control over our independent variables. For example, it is evident that the subjects' post-treatment baselines show considerable variability from their pre-treatment baselines. One explanation for such reduced reversability is a positive or negative carryover effect in the absence of the treatment variable. For example, when subjects return to specific HR increase instructions after just having used their breathing to effect HR changes, some of them continued to use their breathing and thus experienced an increase over pre-treatment baseline. Similarly, some subjects seemed to show a negative carryover effect after the removal of feedback; i.e., HR performance was reduced below baseline treatment. However, a return to pre-treatment baseline may have occurred over a longer period of time. A second explanation is that due to the differential sequencing of a particular treatment (i.e., order effects), post-treatment baseline levels may vary depending on whether a treatment is experienced once or twice before, and alone vs. in combination with other treatment variables. For example, subjects who experienced the B-B'-B reversal in the second and third orders had access to more vs. less feedback and greater vs. fewer HR increase trials with and without breathing assist. Thus, all subjects in a particular reversal were not returning to baseline from the same point in cumulative training.

The phenomenon of reversability would more likely be demonstrated if all individuals experienced a series of three B-B'-B reversals and no Phase I effects; in effect, two replications of the one B-B'-B reversal. Not only would reversability more likely manifest itself, but any cumulative learning could be calculated as a proportion of performance on subsequent over earlier reversals.

Considerations For Future Research on the Role of Feedback and Instructions

Several alternate reversals need to be systematically explored to determine the relative roles of each of feedback and instructions. For example, what would be the differential effects on Runners and Non-runners of RR feedback for each of breathing-assisted HR increase instructions, HR increase only or RR increase only instructions. Does RR feedback enhance cardiovascular control because of HR - RR integration, particularly under RR instructions? Does RR feedback for Runners serve to highlight the effective use of an RR strategy as Schwartz has suggested? Further, does RR feedback serve to calibrate the HR response through its association with the related proprioceptive feedback as in Brener's model? Evidence in support of such a calibration model has been found by Williamson and Blanchard (1979C). Finally, is RR feedback as helpful to Runners as HR feedback is to Non-Runners? As Schwartz (1974) has stated, the extent to which two or more responses need to be behaviorally integrated in order for pattern learning to occur naturally, is not yet known nor does current theory explain how specificity of learning occurs from partially integrated systems. He suggested, and the current study supported the idea, that the pattern biofeedback approach offers a framework in which to determine the relative importance of feedback and instructions in producing the kinds of patterns that emerge both in basic and applied research settings. One thing is certain: "The simple assumption that by using an operant procedure, the learning will be specific is no longer justifiable" (Schwartz, 1974; p. 437). The exact nature of the biofeedback (for single or pattern responses) and the specific instructions used both contribute to the final pattern of

responses that the individual will learn to regulate. Depending upon the specific nature of the instructions, biocognitive strategies may vary as we presumably saw when RR instructions were added to HR increase instructions only.

Shapiro (1977) has also commented upon the interaction between feedback and instructions in cardiovascular self-control. "On the face of it, there is no reason to believe that any one unique effect achieved with biofeedback can not also be brought about through verbal instructions or vice versa. Feedback methods may work better and faster in some cases, and instructions may be better and faster in others. Clearly, some form of feedback is essential for learning, and externalized feedback displays facilitate the process" (Shapiro, 1977; p. 218). In the current study both variables were seen to contribute to the final response, although the effects of instructions were more easily discernable, since their impact was seen acting alone. Feedback, on the other hand, exerted its effect, for example, with most of the Non-runners (14 of 18) when they were given instructions (with or without breathing) to raise HR. That individuals, in particular long-distance runners, can produce cardiovascular increases without feedback supports earlier research (Bergman & Johnson, 1972; Blanchard et al., 1975; Colgan, 1977) showing the criticality of instructions. It appears that the relative importance of feedback and instructions is now also a function of an individual's cardiovascular history.

To the list of factors affecting individual differences in learned cardiovascular control skills, we can now add cardiovascular history in the form of extensive training in long-distance running. And, while the findings were not the same for every subject, the results generally support the notion that such Runners' cardiovascular history makes them

particularly amenable to the successful use of breathing-assist HR increase instructions. Cardiovascular history, or degree of integration and patterning as Schwartz identifies it, is really a constellation of psychophysiological/biocognitive variables for which biofeedback researchers need appropriate labelling and definition. To this effect, future endeavors need to focus on the construction of a more sensitive screening procedure for discriminating "good" and "poor" controllers (Lyon, Blankstein & Darte, 1976). Especially critical is some measure, preferably psychophysiological or of a motor skills nature, that determines the degree of integration between HR and other variables and that can be reinforced or instructed. In other words, we require a more direct measure of an individual's cardiovascular history as it relates to learned cardiovascular control, and particularly to the successful use of breathing-assist HR increase instructions. We require something like McFarland's (1975) HAP test which provides a direct measure of cardiac awareness by testing an individual's response to a HR tracking test. Testing Runners with the HAP test might prove a useful beginning.

In conclusion, it would appear that certain forms of exercise (e.g., running) are related to HR - RR integration and that further screening procedures along the lines of different exercise/training programs might help differentiate which individuals prefer which types of instructions and feedback. For example, underwater divers, gymnasts and ballet dancers all rely on being able to carry out and respond to fine "motor skills" and proprioceptive feedback, as well as to maintain careful control over breathing. Optimal instructional and feedback procedures might be constructed on the basis of these considerations with careful attention paid to monitoring and adaptation of programs for each specific individual.

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APPENDIX A

MEDIATION OF CARDIOVASCULAR RESPONSES

The Mediation Issue

In addition to the Experimental parameters of cardiovascular control such as kind of feedback and instructional set, there are a number of Mediational parameters or variables that contribute to learned cardiovascular control. Whereas mediational contaminants were initially viewed as a form of "noise" or as a disclaimer to operant control of the ANS, they are currently viewed as facilitative of, and/or contributory to, such learning. In this regard McCanne and Sandman (1976) have urged investigators who are concerned with the events that mediate operant HR changes, to attend to the individual differences that exist and to use such differences in theorizing about possible mediating mechanisms. A review of some of the theoretical, methodological, and practical aspects of the mediation issue follows.

Theoretical and Methodological Issues

Prior to 1960 investigators interested in the ANS had generally concluded that ANS functioning was modifiable by classical, but not by operant, conditioning techniques. This conclusion rested on the assumption that the ANS did not interact directly with the environment and hence, was not subject to environmental manipulation. Further, ANS functions were seen as involuntary and therefore as not interacting with the peripheral or central nervous systems. As such, the conditioning of ANS responses could not be accounted for by specific physiological or psychological mediating processes; i.e., skeletal muscle activity or implicit verbal activity, respectively. The failure of a number of experiments to condition GSR or peripheral vasoconstriction using operant techniques, led Kimble (1961) to conclude that "for autonomically

mediated behavior, the evidence points unequivocally to the conclusion that such responses can be modified by classical but not instrumental means" (p.100).

Since that time, successful operant conditioning has been reported for a wide variety of ANS responses including HR, salivation, GSR, peripheral vasconstriction and dilation, sytolic and diastolic intestinal contractions, and urine production (See Katkin and Mur- 1968; Kimmel, 1967; Miller, 1969, for reviews). This increase in the number of reports of successful operant modification of ANS responses prompted Katkin & Murray to produce a critical review of the literature that had accumulated between 1961 and 1967. McCanne and Sandman (1976) amplified and extended this review up to 1976. It was the latter's contention that much of the inquiry into possible mediators of operant HR change had been overly simplistic and did not generate the data necessary to build a model of ANS functioning during operant HR conditioning.

In their review of the earlier human studies, Katkin and Murray (1968) reported respiration artifacts (Shearn, 1962), high positive correlations between subjects' reports of their voluntary actions and HR changes (Engel & Chism, 1067b; Engel & Hansen, 1966), and cardiac control mediated by learned changes in muscle tension (Brener & Hothersall, 1966, 1967; Frasier, 1966; Hnatiow & Lang, 1965). Several studies were also criticized on the basis of involving potential classical conditioning paradigms (Brener & Hothersall, 1966, 1967; Frasier, 1966; Hnatiow & Lang, 1967).

Katkin and Murray (1968) also reviewed a series of animal studies by Miller and his colleagues in which the drug curare was used in an attempt to experimentally control for the above sources of mediation. Curare is

a drug that paralyzes all peripheral nervous system activity (Miller, 1969) thereby allowing conclusions as to the independence of learned HR control from any of the above mediators. Katkin and Murray found this series of studies "the only true evidence of instrumental conditioning of ANS responses independent of possible mediators" (p.65). It was also felt that the curare studies supported other studies in which a particular visceral response (eg. GSR, RR) could be conditioned without interference from, or aid of other visceral responses (Birk, Crider, Shapiro & Tursky, 1966; Crider, Schwartz & Shnidman, 1967; Gavalas, 1967; Shapiro, Crider & Tursky, 1964; Snyder & Noble, 1968). However, Miller and Dworkin (1974) reported major difficulties in replicating their curare work with rats, leaving some questions about the effect that curare exerts on ANS responding and about whether HR changes can be conditioned in artificially respirated animals. Further, because instrumental conditioning of the ANS was demonstrated in curarized animals only, Katkin and Murray (1968), along with Black (1966), concluded: Although theoretically, autonomic conditioning is possible, practically, one must distinguish between conditioning and controlling the ANS where controlling connotes potential mediation.

Respiration Rate Effects and Their Control

The mediational variable that has received the most attention, perhaps because the effects have been most easily shown has been respiration. It has been thoroughly demonstrated that changes in pressure exerted on the pressoreceptors in the lungs produce reflex tachycardia (HR speeding) and bradycardia (HR slowing) in both animals and humans (Neil & Heymans, 1962).

From as early as Shearn's (1962) first report of detectable respiratory changes, respiratory mediation of HR changes has been considered possible by virtually every investigator dealing with operant HR control. The problem of assessing RR effects upon HR has been dealt with in various ways (Blanchard & Young, 1973; Williamson & Blanchard, 1979a) ranging from simply monitoring respiration to statistically controlling for effects. For example, Brener and his colleagues (Brener & Hothersall, 1966, 1967; Brener et al, 1969) reported that conditioned operant HR acceleration generally has been accompanied by faster and more erratic respiratory cycles than has conditioned operant HR deceleration. However, Brener and Hothersall (1966) noted that operant conditioning produced similar HR changes in all subjects, whereas respiratory changes were dissimilar between subjects and were highly idiosyncratic. They concluded that it was unlikely that the dissimilar changes in respiration could have mediated the similar HR changes noted. However, simply monitoring RR changes is a relatively ineffectual, correlational, means of studying HR control effects.

A second approach, although also relatively ineffectual, was to instruct subjects not to change their breathing pattern from normal (Blanchard & Young, 1972; Engel & Chism, 1967b; Engel & Hansen, 1966; Ginsberg, 1972; Levene et al., 1968). Its ineffectiveness became apparent in the Levene et al. study where in spite of being told not to alter breathing, some subjects did so without awareness. Levene et al., therefore, used what might be considered a third approach to dealing with concommitant respiratory responses: the subject was instructed to pace his baseline respiration rate with something like a metronome or rhythmic puff of air. Levene et al. (1968) paced two of their five subjects to

fast and slow breathing and reported no significant changes in HR. However, Brener and Hothersall (1967) demonstrated that subjects who had been trained to maintain their respiratory frequency at a constant rate could still significantly alter HR during training. Successful cardiac changes using the pacing technique were reported by Engel & Chism (1967a), Sroufe (1969), Stern and Anschel (1968) and Themis (1970). Sroufe, however, pointed out that the ability to control HR deteriorated when control over another variable such as respiration was required.

It has been demonstrated that changes in respiratory depth affect both HR level (Engel & Chism, 1967; Stern & Anschel, 1968) and HR variability (Engel & Chism, 1967b); deep breathing resulted in faster more variable HR while shallow breathing had the opposite effect. Stern and Anschel (1968) added that the acceleratory component of HR was related to depth of inspiration, whereas the deceleratory component was related mostly to decreased breathing rate; an interaction between respiration (i.e., depth and rate) and direction of change was suggested. On the other hand, Headrick (1971) noted a lack of correlation between changes in respiratory depth and operant HR change and Wells (1973) found that the magnitude of operant HR changes was not accounted for by the magnitude of changes in respiratory depth. Wells also suggested that changes in respiratory depth may have been a necessary but not sufficient condition for changes in operant HR.

The fourth approach to potential respiratory mediation has been to monitor, analyze, and control statistically, through covariance analyses, any systematic variation in respiration. This procedure has been used by Finley (1971), Headrick et al. (1971), Hnatiow and Lang (1965), and Lang et al. (1967), none of whom found a direct significant relationship

between HR and respiratory changes. McCanne and Sandman (1976) concluded that the current status of the research allows us only to suggest that respiratory changes may produce changes in operant HR under certain conditions, and that the precise relationship of respiration to operant HR is yet to be determined. For example, Sroufe (1971) demonstrated that "respiration can be explicity utilized to control heart rate" (p. 654), by providing subjects with respiratory feedback. However, he also concluded that "the fact that cardiac control is possible with respiration experimentally controlled merely suggests that subjects can control heart rate independent of respiration, not that respiration is of minor importance" (Sroufe, 1971; p.654). This is very similar to Katkin and Murray's (1968) comment that one must distinguish between conditioning and controlling heart rate.

Somatic-Muscular Mediation

Many investigators have questioned whether operant modification of ANS functions can be mediated by centrally initiated muscular changes which are subject to environmental control (e.g., Brener, 1974; Katkin & Murray, 1968; Miller, 1969; Obrist et al, 1970b). In this particular form of mediational model, changes in somatic-muscular activity are assumed to result in changes in HR. While the curare research (Miller, 1969) was originally conceived as a means of controlling the effects of muscular activity in HR, the difficulty in replicating those animal studies (Miller & Dworkin, 1974) leaves the problem of somatic-muscular mediation unresolved by this approach. McCanne and Sandman (1976) also added that the major criticism of research studying somatic-muscular mediation, has been the lack of direct monitoring of somatic-muscular

variables during operant HR conditioning.

There are two studies that not only address the concerns of McCanne and Sandman but also provide support for the somatic-muscular mediation position. In a study by Magnusson (1976), three groups of subjects received the following instructions and contingencies: 1) Increase HR with continuous feedback of performance while tensing the right forearm muscles 20% of maximal voluntary contraction; in the last session only HR feedback was used; 2) HR feedback only; 3) tense muscles only for the first two sessions, and for the last session, increase HR with feedback only. Results indicated that the first group was superior in performance during the first two sessions, but the performance in the third session deteriorated significantly to the level of the other two groups. Magnusson concluded that the addition of somatic activity to the feedback seemed especially beneficial for producing a larger number of reinforcible responses during the first two sessions and, that in acordance with Obrist, Galosy, Lawler, Gaebelin, Howard and Shanks (1975), HR and somatic coupling occurred. He suggested further, that such coupling may manifest itself peripherally through one central process as in the work of Black (1974), Brener et al. (1974), and Goesling & Brener, (1972). Of interest was the lack of transfer of the previous (sessions one and two) interaction between HR feedback and somatic mediation to the final session. It is interesting to speculate whether such transfer of cardiac-somatic coupling would be both present and present to a greater degree in individuals or groups of individuals with a previous history of repeated couplings. If so, perhaps such individuals or groups would exhibit a greater degree of learned HR control.

Further to the Magnusson (1976) study and the above speculations on cardiac somtic coupling, is a similar study by Lynch, Schuri and D'Anna (1976). Lynch et al. had subjects perform two isometric exercises at three levels of exertion while HR, respiration rate and amplitude, finger pulse amplitude and skin temperature were monitored. While pulse amplitude and skin temperature were significantly reduced due to the exercise, HR significantly increased with the magnitude of the cardiovascular effect varying in proportion to the magnitude of the exercise. They also reported that cardiovascular reactions to isometric exercises were not mediated by respiratory variations. Lynch et al. suggested that the results clearly indicate that static muscular contractions at moderate exertion levels, which involve no actual body movement, and which might remain undetected under other circumstances, can result in rapid, large magnitude changes in finger pulse amplitude, skin temperature and HR. They suggested further that somatic muscles play a central role in mediating such cardiovascular responses and that biofeedback researchers should monitor as many EMG locations as possible for sources of static muscle tension that can lead to cardiovascular changes. Based on the potential mediating role of somatic muscles, a source of individual differences worth investigating would be the cardiovascular history of such muscle control athletes as gymnasts.

Central Mediation of Heart Rate and Somatic Responses

Several investigators (Brener, 1974; Obrist et al, 1970b) have suggested that both cardiac and somatic events are mediated by a common CNS effector and that the two are "coupled" to one another by this central mediator. Thus it is not changes in muscle tension that cause HR

changes, but rather both of these responses are caused by CNS activity and therefore both are utilized in making inferences about CNS activity. Based on evidence concerning cardiac-somatic coupling during exercise (Rushmer, 1962, 1965), Obrist et al. speculated that HR and somatic events are peripheral manifestations of a common central event. However, McCanne and Sandman (1976) criticized this position as follows: 1) The contentions of Obrist and his colleagues rest on somatic coupling of tasks that demand a minimum of motor activity; and 2) the magnitude of the correlations between HR and muscular activity though statistically significant, are still modest. However, recent data by Schwartz and his colleagues (1976, 1977), strongly suggest patterns of interaction between the cardiovascular system, striate musculature and CNS responses that make it difficult to maintain a position of independent operant HR control.

Cognitive Mediation of Cardiovascular Responses

"Can cognitive processes elicit or 'mediate' patterned physiological changes?" (Schwartz, 1975; p.22). The idea that cognition was an epiphenomenon, either unimportant or interferring, was long held by both behavioral and biofeedback researchers. In their review and critique of operant conditioning of ANS responses, Katkin and Murray (1968) asserted that cognitive events could be held responsible for mediating "true" instrumental conditioning of an autonomic response. In reply, Crider, Schwartz & Shnidman (1969) pointed out that there was little experimental data to support the notion that cognitive events could influence discrete physiological responses in the first place. They asserted that "to account for such results, a cognitive mediation hypothesis would have to

posit a different cognitive event (or class of events) for each visceral response pattern resulting from operant conditioning" (Crider et al., 1969; p.548). Kimmel (1974) held similarly unsupportive views on cognitive mediation.

It appears that a number of studies (Bell & Schwartz, 1975; Jones & Johnson, 1978; May & Johnson, 1973; Schwartz, 1975; Shapiro, 1977; Valins, 1970) suggest that cognitive activity can elicit physiological responses. However, the question still remains whether there is any experimental evidence that classes of cognitive events can elicit specific patterns of physiological responses corresponding to those regulated by biofeedback. And, if so, are we therefore justified in concluding that such strategies reflect underlying neural mechanisms involved in regulating the physiological changes. Although there has been a great deal of interesting data, conclusions are tentative, relying upon subjective, speculative interpretations. An answer to the question of cognitive mediation will have to await further experimental study.

Brener's (1974, 1977) understanding of the cognitive processes in biofeedback procedures (1974, 1977; see Appendix B for a review of this model) is perhaps more helpful since it permits experimental analysis. He stated that "if any individual can learn to appropriately label the sensory consequenses of a response, then he will be able to comply with instructions to execute that response" (Brener, 1977; p.37). Thus, cognitions are useful and effective to the degree that they serve as appropriate labels of sensory consequences. He argues further, that it is instructions that serve to determine the descriptions that subjects apply to their activities. Put another way, instructions lead individuals to draw upon previously learned cognitive strategies.

APPENDIX B

MODELS OF LEARNED CARDIOVASCULAR CONTROL

Pattern Biofeedback and Motor Skills Learning (Schwartz)

Further to the renewed interest in the mechanisms and constraints underlying learned cardiovascular control, Schwartz (1975) and his colleagues have coined the term "pattern biofeedback" and have developed a theory to account for the learned control of response patterns in the human cardiovascular system. By tracing the development and expansion of this position, it is clear that the variables of instructional set and individual differences have taken on new dimensions and the need for further study. The direction of Schwartz's work is perhaps best indicated by his statement: "the simple assumption that by using an operant procedure, the learning will be specific is no longer justifiable" (Schwartz, 1974; p.437). In other words, biofeedback procedures may actually be reinforcing a more general response or set of responses than was expected. Thus, training an individual to control HR may actually result in the learned control of HR, BP, RR, and an assortment of muscle group responses; i.e., the training of response patterns. Specificity of learning may require an altogether different set of training procedures.

Development of the Model

In his earlier work, Schwartz (1973) considered some of the important issues and problems arising out of the clinical application of biofeedback techniques to the individual patient. Initially, he looked at specificity of learning through the BP and HR studies of Shapiro and Schwartz and their colleagues (Schwartz, 1972; Shapiro & Schwartz, 1972; Shapiro, Tursky & Schwartz, 1970a,b). He viewed these findings on specificity of learning as important prerequisites to the clinical

application of biofeedback training, since the alleviation of symptoms was desired without corresponding side effects, such as those sometimes produced by drugs. On the other hand, the clinician may be concerned with what else is changing when a person is provided with feedback for a given condition; i.e., "patterns of responses" rather than a specific response. Thus, it becomes important not only to be able to predict under what conditions side effects may occur, but how one might produce them in specific cases. Schwartz (1973) asserted that the degree to which learned specificity or patterning occurs, is a function of the interrelationships among bodily functions over time, as well as of the exact nature of the contingency (i.e., feedback for responding) involved. However, he added, such control is limited or restricted by physiological and associated cognitive constraints.

Schwartz (1972) found that subjects could more easily learn to make their systolic BP and HR go together than to make them go apart. He also found that feedback for integrating these functions produced somewhat larger effects and more rapid learning than feedback for either single function alone. Altogether, it appeared that in the process of trying to understand and extend biofeedback techniques to patterns of responses, the research uncovered more information about the nature of the physiological systems themselves and their relationship to cognition than about feedback itself. Schwartz (1975) later stated that biofeedback and related cognitive procedures provide a unique and powerful research tool for investigating both the interrelationships among physiological systems and the role of patterns of physiological responses in the generation of subjective experience.

A treatment implication of such a behavioral-biological approach is

that the clinician should carefully evaluate how he or she is to administer feedback to an individual patient so that what the patient will and will not learn is more precisely controlled. For example, if a patient is receiving analogue feedback for beat by beat changes in HR and has sinus arrythmia (HR rising and falling with each breath), he or she will be simultaneously receiving feedback for respiration and thus may modify it accordingly. One has to question if such learning is desirable. Secondly, given that individuals differ in their autonomic specificity, and that different situations may evoke different patterns (Lacey, 1967), biofeedback should be viewed as but one approach to the treatment of the "total person". For example, to cure hypertension requires more than attempting to control BP; i.e., constraints of different sorts exist in such a schema. Rather, "personality and individual differences make it impossible to provide a simple "cookbook" approach to questions such as 'what should I tell the patient?' or 'what kinds of incentives should I provide?' On the other hand, to the extent that specific instructions direct a patient's attention to certain aspects of his behavior or lead him to utilize certain strategies in learning control, it can be speculated that what the patient is told, and what he is asked to do, may depend on both the specific nature of the desired function(s) to be changed and the personality of the patient" (Schwartz, 1973; p.672)

It is within the above framework that we find implications for individual differences and instructional control through cognitive and somatic strategies. Schwartz (1974) asserted that if through instructions, individuals were allowed clear use of somatic strategies (both excitatory and inhibitory) there would result larger self-produced

HR increases and decreases through feedback and reward. In other words, instructions that elicit an individual's use of idiosyncratic strategies, would also enhance their ability to bring about larger self produced changes in HR through feedback and reward. Hence, the central dynamics are actually in the instructions and subsequent strategies rather than in feedback and reward per se. The latter only serve to highlight the effective or noneffective strategies that the instructions induce. Schwartz (1974) therefore asked: Given that effective range constraints can operate and thereby influence the magnitude of learned HR control, "what combinations of instructions and contingency will enable the subject to reach, or even exceed his effective range?" (p.425-26).

Theoretical Speculations

By expanding the general concepts of contingency and constraints and systematically applying them to two or more functions (e.g., HR, BP), it is possible to provide an initial framework for predicting and controlling patterns of cardiovascular activity through feedback and reward. Specifically, Schwartz (1974) has suggested that both the qualitative and quantitative nature of learned pattern control are largely determined by the interaction of three factors: 1) the characteristics of the interrelationships between bodily functions over time; coupled with 2) the exact nature of the contingency involved; in the context of 3) biological, cognitive and environmental constraints. For ease of discussion, the first two factors will be considered in combination, followed by an analysis as to how they interact with different constraint conditions.

Interrelationships and Contingencies

Different characteristics of the feedback (contingency) may affect the degree to which different patterns of response are learned. For example, analogue meter feedback for beat-by-beat changes in HR can also act as feedback for respiratory inhalation and exhalations in sinus arrythmia. On the other hand, digital feedback for changes in rate above a certain criterion may reduce the relationship between respiration and HR. This is especially true if the feedback is so deliberately programmed that half the time, criterion HR changes are reinforced when the subject is breathing in, and half the time when the subject is breathing out (assuming that the relationship between phasic changes in HR and breathing is not perfect). In this case, the end result would be to provide partial, although contingent reinforcement for HR, and at the same time to provide some form of random reinforcement for respiration.

However, if under the above experimental circumstances it were found that respiration still changed, then it would suggest that underlying central connections linking HR and respiration were in operation. One strategy for directly exploring these mechanisms was to test subjects for their ability to directly integrate vs. differentiate their HR and respiration through the use of pattern feedback and reward. If integration were easy to obtain and differentiation quite difficult, then it would provide strong support for a causal link between phasic HR and respiratory changes. The HR-RR relationship is further complicated, however, since phasic changes and tonic changes may reflect different mediating processes, both neural and hormonal. When a subject is given analogue feedback for HR per se, he or she is in fact receiving complex integrated information about vagal, sympathetic, and hormonal influences.

Clearly, though, through the use of specific drugs and surgical procedures, it may be possible to uncover the exact mechanism that the subject is using to control his rate (Weiss & Engel, 1971). However, what happens if it is desirable for a subject to learn to directly control only one of these processes, or some specific pattern? The theory would suggest that it is necessary to make the feedback more directly integrated with the underlying neural and/or hormonal processes. Schwartz (1974) outlined several physiological and pharmacological techniques by which this could be accomplished. However, he stated that ideally, through proper response definition, it should be theoretically possible to compute what aspect of the total signal reflects a given process, and to provide the subject with such feedback directly, without resorting to physiological or pharmacological intervention. Schwartz outlined several methods, each with its unique problems but concluded that such concepts are useful to the extent that they illustrate the potential for systematically evaluating the interaction of contingency variables with ongoing physiological changes, and are open to direct empirical test. He holds similar views for biological constraints which are discussed below.

Constraints

In the same way that a person can handle different physical loads depending upon the muscle groups used, different components of the cardiovascular system probably have different capabilities for change. By classifying constraints into four different categories (state, neural circuitry, organ, and reward) it is possible to speculate as to how such constraints will influence learning in the cardiovascular system.

By state constraints are meant the effects of such factors as time

of day, drugs, situation and instructions on the physical and physiological "state" of the organism. For example, by instructing a subject to sit in a quiet, relaxed position and without resorting to respiratory or muscular movement, then asking him to raise his HR, he or she is put in a state that is clearly not optimal for raising HR. As well, drugs like curare clearly influence state (eg., by eliminating pheripheral somatic feedback), which may have specific effects on cardiovascular control. To the extent that state variables can change the levels and variability of cardiovascular responses, and to the extent that they can possibly alter their interrelationships, they will alter the kinds of patterns of responses that will be acquired. For this reason, state variables are considered crucial to the prediction and control of patterns of responses.

State effects operate because of specific brain structures and their interconnections or what is referred to as neural circuitry. The purpose of isolating neural circuitry constraints is to highlight a specific process such as homeostasis that can influence the development of cardiovascular control. Similarly, the extent to which HR is centrally integrated with the somatic system is an important neural circuitry constraint, since it helps explain why HR increases under resting conditions are so readily obtained. Less obvious is the fact that state and task demands may change cardiovascular relationships in very specific ways. For example, the relationship between HR and mean BP depends in part on the kind of exercise (eg., isotonic vs isometric) performed. This observation is very important, not only because it illustrates how task demands may effect relative changes in two systems, but also because it provides an avenue to possible mechanisms for learned differentiation

of BP and HR under different states. For example, it is predicted that if subjects were tested for degree of voluntary control of patterns of BP and HR under two different exercise conditions, they would be better able to produce the specific exercise-related differentiations than a generalized integration of these functions. This conclusion is opposite to the findings previously generated for "resting" conditions (Schwartz, 1972).

Organ constraints refer to the relative maximum and minimum changes across all different situations. Whereas state constraints restrict the total range possible for a given organ (here called the effective range), the concept of organ restraint refers to Lykken's notion of range correction for determining true peak and through values of the individual per function (Lykken et al. 1966 as cited by Schwartz, 1974). However, "true" peak and through values still involve some neuro-circulatory constraints, since maximum HR increases for example, are limited by a normally functioning vagal control system and sinoatrial pacemaker. If this were changed through injury, disease, or drugs, the peak (and trough) values would change accordingly.

Finally, reward constraints refer to the biological implications of different types of rewards for learning specific bodily processes. For example, one can speculate what effects warm versus cold feedback stimuli might have on the voluntary control of peripheral vasodilation and constriction, the hypothesis being that the former would enhance control of vasodilation, while the latter would inhibit voluntary vasodilation but enhance vasoconstriction.

In conclusion, Schwartz (1974) stated that the extent to which two or more responses need to be behaviorally integrated in order for pattern

learning to occur naturally, is not yet known; nor does current theory explain how it is possible for specificity of learning to occur from partially integrated systems when long-term training procedures are employed. However, one strong conclusion that seems justified at this time is that the systematic appliction of operant-biofeedback patterning procedures can help make it possible to determine the nature of autonomic and central nervous system constraints and their modification in the intact organism. It is suggested that this theoretical approach may offer a framework in which to determine the relative importance of feedback and reward in producing the kinds of patterns that emerge both in basic and applied research settings. As previously emphasized, "The simple assumption that by using an operant procedure, the learning will be specific is no longer justifiable" (Schwartz, 1974; p.437). Schwartz's thesis addresses the scores of studies that have failed to bring about specific results as planned, as well as the numerous contradictions and contraversies surrounding the significance of assorted variables for cardiac control.

Rayter (1975) suggested that perhaps pattern learning (i.e., integration) already occurs to a significant degree in particular individuals such as certain types of athletes. He suggested that athletes were unable to demonstrate specificity, in the form of learned HR control, as a result of what Schwartz termed neural circuitry constraints. Heart rate may have been fully or partially integrated with vagal activity. In other words, vagal activity, in the form of HR inhibition through vagal excitation, may have been the constraint that prevented successful HR control for the athletes. In his work on the analysis of the final common pathway for HR conditioning (i.e., classical

conditioning) Cohen (1974) demonstrated that both the vagii and sympathetics contribute to the conditioned HR response with vagal inhibition being predominant. He also stated that the primary component in HR conditioning is the release of vagal inhibition, consistent with the typical observation of HR adjustments during exercise.

Cox and McGuiness (1977) have further explored the effects of vagal activity on HR changes by studying groups of anxious and non-anxious individuals. They noted a marked ability for highly anxious subjects to self-induce HR increases while low anxious subjects could only self-induce HR decreases. In earlier studies by McFarland and Coombs (1974) and a Pavlovian study by McGuiness (1973), it was hypothesized that highly anxious subjects may have been prone to vagal inhibition which maintains heart rate increases once HR levels are elevated. And conversely, low anxious subjects were viewed as prone to vagal excitation. McGuiness (1973) offered the explanation that following stimulation, the increased circulatory level of adrenaline may have been more prolonged in highly anxious subjects.

Motor Skills Learning

Despite the abundance of research on self regulation techniques, there has been little effort to explain exactly how self regulation develops or what the underlying psychobiological mechanisms and constraints are (Schwartz, 1975). Schwartz asserted that most research treats only single responses or response systems and fails to address the more normal but complex phenomenon of voluntary coordination of multiple physiological processes. Alternatively, he stated that biofeedback and related cognitive procedures can provide a unique and powerful

research tool for investigating both the interrelationships among physiological systems and their constraints in the intact human, and the role of patterns of physiological responses in the generation of subjective experience. In order to adequately explore these underlying psychobiological mechanism, Schwartz (1976) adopted an alternative perspective, in which cardiovascular self regulation is conceptualized from the perspective of skill learning, or more specifically, motor skills learning.

Recently, biofeedback researchers such as Brener (1974) and Lang (1975) have emphasized specificity of motor skills learning and its interaction with biofeedback. (The reader may consult Williamson, 1979b, for a review of the motor skills based models of Brener, Schwartz and Lang.) Schwartz, Young, and Volger (1976) stated that biofeedback research which has appeared thus far, has tended to concentrate primarily on the variables of feedback and instructions. Further, to date, little attention has been directed towards specifying the more precise nature of the visceral skills required by the task. They attributed this to the fact that we have not drawn explicit parallels between the structures of motor skills learning and visceral self control.

Schwartz et al. (1976) have found it fruitful to apply Fleishman's (1966) model of complex motor skills learning to visceral self regulation. The model posits that motor skills are conceptually separate from being abilities with complex skills comprised of a finite number of distinct, underlying abilities. For example, in tennis, the ability to move one's arm and legs (underlying abilities) is different from the trained (or learned) skills necessary to execute an inwardly curving topspin serve (complex skill). Fleishman's model also predicts that a

positive correlation (i.e., transfer of learning) will be found between performance on any pair of complex, integrated skills to the extent that they share a similar constellation or pattern of underlying abilities. However, the basic abilities are themselves viewed as relatively separate components involving distinct learning processes.

Several of the motor abilities outlined by Fleishman (1966) can be applied to visceral learning, although the differences in effector organs in the somatic and visceral systems make direct comparisons difficult. In attempts to construct parallels between the two systems, Schwartz et al. (1976) asserted that it is of heuristic value to use hypothetical properties of neural activity as a common ground in attempting the translation, even though a translation using single neural innervation of a positive nature is oversimplified when applied to visceral responses. In other words it is well known that visceral responses are often dually innervated by the sympathetic and parasympathetic divisions of the ANS, and the two components may become differentially involved in learning depending upon the nature of the skill involved (eg., HR up versus HR down; Lang, 1974). The basic translation is illustrated in Table 2.

Fleishman's (1966) model describes five basic components of complex motor skills: strength (S), endurance (E), steadiness, control precision and reaction time (RT). Biofeedback studies have typically used a combination of S and E paradigms in which the experimental task is to change HR as much as possible (S) and for a given interval of time (E). According to Fleishman, the degree of transfer of training between two tasks (addressing different skills) should be a function of the component abilities which they have in common.

TABLE 2

Cardiac-motor skills ability factor parallels
based on five ability and performance factors postulated
by Fleishman (1966) for the motor system
Schematized neural activity regulating these abilities is also illustrated
To apply this analysis to parasympathetic (vagal)
as opposed to sympathetic innervation of heart rate,
maximum neural firing should be equated with min HR
and vice versa (see text for details)

Neural Activity	Motor Activity	Cardiac Activity
max/min firing	strength	max/min HR
maintenance of max/min firing overtime	endurance	holding max/min rate
stable rate of firing	steadiness	minimum variability
regulation of firing rate in specific temporal order	control precision	cardiac control precision
quick onset of firing to a required level	reaction time	cardiac reaction time

From Schwartz et al., 1976, p. 307

Schwartz et al. (1976) chose to develop a task which would measure and train a cardiac RT ability and then compared performance on this task with performance on a more typical S-E paradigm. It was predicted that the performance on one task would not improve following training on the other, despite the fact that all subjects would receive training in controlling their HR. Performance would be task-specific for the skill for which feedback training was given. Subjects were pre and post tested with instructions alone for degree of cardiac S-E control (maximally increase or decrease HR and sustain it for one minute) and degree of cardiac RT control (produce a small, three second burst of increased or decreased HR as quickly as possible at the onset of a trial). All subjects received HR biofeedback during training, with half practicing S-E and the other half RT control. The results indicated that S-E training led to improved S-E control accompanied by a slight decrement in RT control. Conversely RT training led to markedly improved RT control accompanied by a small decrement in S-E control.

Schwartz et al. (1976) viewed their data as supporting the conceptalization of cardiovascular self regulation from the perspective of skill learning. Their study also extended the specificity of learning notion by demonstrating specificity of cardiac skill learning. It extends further previous research demonstrations of specificity across biological systems and for different parameters within the same biological system. The ability to perform the specific task for which the subjects were given feedback, transferred only to the particular task the subjects were requested to practice even though at a gross level, both tasks required the production of a change in HR and the maintenance of this change. When these complex skills were reduced to their

component abilities and the relative contribution of each component was evaluated, it became apparant that the S-E and R-T tasks were not dependent upon one another. Based on their data the authors also ruled out fatigue and interference as significant factors in the failure to improve on the non-trained tasks.

Three things can be inferred from the above study: 1) that specificity of skill learning exists within a single autonomic effector; 2) that instructions and feedback to control a specific response, or a component of a response that is independent of another, can lead to control of only that response with no transfer of training; 3) that HR control, whether it is viewed as a complex skill or as an operant response, is composed of separate or component abilities, some of which may be independent of one another.

Altogether, it appears that the nature and extent of learned specificity or patterning of cardiovascular reponses depends initially on 1) the precise nature of the relationships between various responses over time, and 2) the exact manner in which biofeedback is administered (i.e., for single responses, or more explicity for patterns of responses, Schwartz, 1977). For example, in the numerous blood pressure studies of Schwartz and his colleagues, subjects were given minimal instructions about the task at hand. Further, when subjects were specificially instructed to control their HR, they demonstrated immediate cardiovascular self regulation, even in the absence of feedback (Bell & Schwartz, 1975; Brener, 1974). However, Schwartz (1977) has asserted, it is a mistake to conclude that instructional control is identical to regulation gained through biofeedback. Whereas single system biofeedback leads to learned specificity, instructions (particularly with extensive

training) often result in more complex patterns of responses. Hence, the verbal instruction to control systolic BP can lead to the immediate and simultaneous control of HR as well, whereas single system biofeedback for systolic BP with minimal instructions can lead to the development of learned BP regulation in the absence of HR control.

It thus follows that the exact nature of the biofeedback and the specific instructions used both contribute to the final pattern of responses the individual will learn to regulate. Further, we should not be surprised to recognize that instructions can differentially influence peripheral cardiovascular effectors in a biofeedback setting, since the average adult brain can draw on a variety of neural strategies in its conscious repertoire to regulate the feedback. Depending upon the specific nature of the instructions, the biocognitive strategies will vary accordingly.

Future Directions

"The general thesis slowly emerging from biofeedback research is that patterns of physiological processes can be both generated and processed by the brain, producing unique cross-system interactions and perceptual gestalts that make up a significant component of human behavior and subjective experience" (Schwartz, 1977; p.215). "Research on biofeedback and the regulation of combinations of responses extends the emergent nature of patterning by providing a new paradigm for investigating physiological relationships. Self regulation as a general research strategy can be useful to the extent that it enables researchers to isolate component parts of systems and then examine how they combine to provide unique physiological and associated subjective states" (Schwartz, 1977; p.216). Schwartz emphasized the importance of viewing

visceral self regulation in psychobiological perspective without destroying the importance of instructional, cognitive, or personality variables in biofeedback.

Instructional Control Over Cardiovascular Responses (Brener)

The General Model

Brener (1974, 1977) has developed a general model of voluntary control which he applied to the phenomenon of learned cardiovascular change. The model attempts to account for the processes underlying the development of instructional control of motor activities. And, in line with the general theme of the literature relating to learned motor control, and to cardiovascular control in particular, he assumes that feedback processes are fundamental to the development of voluntary control.

Brener (1974) posits that the traditional view of a structurally based operant-respondent dichotomy is no longer tenable, since the biofeedback literature shows that the cardiovascular system displays easily demonstrable voluntary as well as involuntary characteristics. Thus, the terms voluntary and involuntary refer only to the conditions under which a given instance of a response is observed and have little to do with the structural attributes of the response apparatus in question. Rather, Brener defines a voluntary response as one that is systematically influenced by instructions, with the development of instructional control being dependent upon the execution of certain training procedures. An involuntary response, on the other hand, is defined as the reliable consequence of a narrowly delineated class of eliciting stimuli. This form of control is assumed to be independent of any other prior

conditions. Thus, given instances of the same topographically restricted response may be classified as voluntary or involuntary, depending on the procedures employed for the demonstration of those particular instances. Brener proposes that these terms represent two independent dimensions in the classification of behavior, rather than opposite poles of a linear continuum. Further, in principle, all responses, regardless of their structural attributes, are amenable to both voluntary and involuntary control. The task of investigators is thus seen as the specification of the conditions under which the voluntary characteristics of cardiovascular behavior may be reliably demonstrated.

The means of studying voluntary cardiovascular control is determined by the model of functioning underlying voluntary control processes. While the terms "operant conditioning" and "voluntary control" or "feedback" are used interchangeably, the associated analytical models differ significantly. (See Black, Cott, & Pavloski, 1977 for further discussions.) Whereas the strict operant conditioning approach posits the response contingent event (i.e., reinforcing stimulus) as the final cause of behavioral change, the feedback approach attempts to account for the processes by which response contingent events lead to behavioral change. In other words, the principle of reinforcement which is axiomatic in the conditioning approach is derived from more basic axioms in the feedback approach. According to Brener the feedback approach permits a finer-grain analysis of the voluntary control process, suggesting feasible lines of inquiry into the structural basis of such control processes.

The Initiation of a Voluntary Act

Brener defines a voluntary response as one that is amenable to

control via verbal self-instruction; i.e., "compliance with instructions forms the basis of my belief that I can voluntarily control the response in question" (Brener, 1977; p.30). The assumption underlying this definition is that a response that is amenable to control via self-instruction will also be amenable to control via instructions delivered by a second party. Brener points out that although an individual may have the capacity to comply with an instruction to perform a response, he or she may not manifest this capacity because he or she does not want to do so. Thus certain responses may be classified as nonvoluntary that, under other conditions, may meet the criterion for classification as voluntary. The issue is resolved by adopting an approach from traditional learning theory as follows: the capacity to comply with an instruction is viewed as the consequence of associative (learning) processes, whereas the manifestation of this capacity is viewed as a performance process, and, as such, is determined by the interaction of learning and motivational factors.

At an introspective level, Brener (1974) asserts that we may accept the notion that compliance with an instruction (emanating from one's self or someone else) to execute an act does not depend upon being able to specify the efferent motor programs for that act. However, there are discriminable sensory consequences associated with the occurrence of all responses that we classify as voluntary. Our ability to discriminate the current voluntary act is assumed to rest upon activation of interoceptive afferent pathways by the effectors involved in the act. When individuals are deprived of such intrinsic feedback from an effector, they are also robbed of the illusion that they can voluntarily control responses of the effector (Laszlo, 1966; as cited by Brener, 1974).

In Brener's (1974) model, the conception of initiation of a voluntary act is based on James' (1890; as cited by Brener, 1974) notion of response image (RI) and its activation through some external (instructional) stimulus. The topographical dimensions and intensive characteristics of a response are very precisely defined in terms of the interoceptive feedback array contingent upon the response. Thus, James proposed that with repeated elicitation, the afferent information consequent upon a response is stored centrally as the RI. Both the RI and the immediate sensations contingent upon its occurrence are functions of the afferent systems serving the effector involved in that response. The RI is, therefore, simply a stored represention of the pattern of afferent stimulation produced by past occurrences of the response. An individual's ability to identify a given response in his repetoire is assumed to depend on a comparison of the immediate feedback upon the response with the established image for that response.

Brener (1974) proposed that instructional stimuli, as a function of certain procedures, acquire the ability to elicit an RI and that activation of the RI leads to a state of nervous system imbalance, resulting in the production of the response specified by the image. The RI is assumed to represent the standard against which neural feedback from the periphery is compared. In general terms, the model proposes that compliance with an instruction to execute an act depends upon the ability of the instruction to evoke a memory (image) of the sensory consequences of that act. This ability in turn is assumed to rest upon the prior pairing of the words denoting the act with the internal sensations consequent upon the act. Finally, completion of the act is assumed to rely upon the comparison of sensations arising from present

instances of the act with the image (memory) of previous instances of such sensations. Rephrased in terms of Brener's proposed model, a voluntary act is initiated through the activation of an RI by some external (instructional) stimulus. Activation of the RI produces a specific pattern of activity in some central motor controller. This pattern of activity leads to the occurrence of effector action and consequent interoceptive feedback. The interoceptive afferent signals are compared to the pattern of excitation specified by the RI. If they are in accord, the act is completed; if not, additional motor signals are generated until a comparator achieves a null state.

The Voluntary Characteristics of Heart Rate

In order to demonstrate the voluntary characteristics of HR through the influence of verbal instructions only, Brener referred to an earlier experiment in which subjects were able to increase and decrease their HR in the absence of any special feedback conditions (Brener et al., 1969). The results were explained by drawing the inference that subjects had developed appropriate HR response images. This in turn assumed availability of interoceptive feedback associated with cardiovascular activity to the central sensory integrator and also the past calibration of such feedback in terms of the labels "heart rate increase and decrease". However, rather than RI's based on cardiovascular feedback, Brener assumed that the "increase" "decrease" instructions activated motor programs that were directed towards producing those sensations (striate muscle, respiratory, etc.) previously identified as "heart rate increases" during increase trials, and motor programs directed at eliminating such sensations during decrease trials. Regardless of the

basis of the observed control, Brener felt that the evidence supported the classification of HR as a voluntary response based on his criterion that it was influenced by instruction.

Since HR adjustments are generally embedded in a complex of other activities including vigorous somatomotor adjustments, and since the subjects in the Brener et al. (1969) experiment were instructed not to move or breathe irregularily, Brener suggested that they were receiving antagonistic instructions in addition to being deprived of the most discriminable element of the peripheral feedback associated with the tachycardiac response complex; i.e., a high level of proprioceptive stimulation. To test this possibility, subjects were instructed to increase and decrease HR in the absence of exteroceptive feedback and without verbal constraints on movement. Results were twice the magnitude of those obtained in the earlier study in accordance with Obrist et al. (1974) who reported that the greater the verbal constraints placed on somatomotor activity during learned HR control, the poorer the control. Obrist et al. also reported a close correlation between somatomator activity and the observed HR changes. Brener thus assumed that the instructions to increase HR led to a general motor activation of all of its attendant symptoms and, the instruction to decrease HR led to a general motor quiescence. The general motoric adjustment was specified in terms of, and regulated via, the easily discriminable peripheral feedback available from the striate muscles. This mode of parallel somato-cardiovascular regulation had previously been suggested by Smith (1967).

Because the instruction to control HR leads to a general behavioral adjustment of which HR is only one component, it might be expected that

instructions to control other components of the general response would lead to similar adjustments with a similar HR effect. Thus, Brener (1974) examined the influence on HR of instructing subjects to control respiratory activity and found a mean HR of eight bpm higher when hyperventilating than when hypoventilating. In view of the similarity in degree of HR change with respiration instructions, it might be concluded that similar response images and consequent motoric adjustments are produced by respiration and HR control instructions. Thus, although HR does display the characteristics of a voluntary response in the absence of any special conditions, it would appear that its voluntary characteristics are supported not by feedback of cardiovascular activity per se, but rather by a feedback constellation derived from the behavioral complexes in which HR reponses are embedded.

It should also follow that the provision of exteroceptive feedback, identifying a desired performance goal, would result in similar performance changes, regardless of whether respiration or HR instructions are given. Rather, upon testing this view, it was found that exteroceptive feedback of HR performance greatly enhanced the HR control for subjects given HR instructions, and had practically no effect on the HR performance induced by respiration instructions. Brener explained these unexpected results as follows. Relative to HR responses, respiratory responses are easily discriminable. Therefore, in the case of the group receiving respiration instructions and HR feedback, the behavioral goals specified by the RR instructions on the one hand and by the exteroceptive HR feedback on the other were in conflict. That is, since the response images associated with RR instructions are not as well formulated due to a lack of specific calibration of the intrinsic

feedback associated with this response, exteroceptive feedback was the primary description of the desired activity and therefore did not lead to a substantial enhancement of HR control. The RR instructions provided the subjects with no tangible cues or stimuli for HR changes. However, the facilitative role of exteroceptive feedback in the case of HR instructions can be explained in one of two ways. It may have have served to calibrate the available intrinsic feedback through defining the internal sensations associated respectively with high and low HR's. Or, it may have substituted for a lack of available intrinsic feedback. Support for the former view was accumulated by Brener et al. (1969) who found that the amount of HR control was a direct function of the amount of exteroceptive feedback provided during training (100% vs 50% vs 0%). With respect to the calibration model, the data suggested that the subjects who had the most exteroceptive feedback learned to distinguish the feelings associated with high and low HR's and were, hence, best able to control their HR's in the absence of such feedback.

Finally, Brener suggested and tested the following notion: if it were true that learning to discriminate the activities of the cardiovascular system were an important prerequisite to the control of these activities, then we might expect individuals trained to discriminate cardiovascular states to be better at controlling such states than individuals who are not provided with such training. Two additional studies reported in Brener (1974), supported this hypothesis. It was found that exteroceptive feedback served to calibrate and thus discriminate intrinsic feedback associated with HR changes and that such calibration led to subsequent enhancement of HR control. The data indicated that the behavioral adjustments produced by voluntary control

procedures were a joint function of instructional and feedback influences. Brener's notions of discrimination and calibration are not unlike the earlier predictions that subjects with high levels of internal autonomic awareness (as measured by Mandler et al's' (1958) Autonomic Perception Questionnaire) would be better able to condition or control their HR's. Unfortunately, as was discussed earlier (see Individual Differences), the data from these studies have been scanty and equivocal, but for a study by McFarland (1975) in which autonomic awareness was measured by a HR tracking test.

The Role of Instructions

More recently, Brener (1977) articulated the role of instructions in facilititating voluntary visceral control. He asserted that the acquisition of meaning, by words that are used to describe variations in visceral activity, may be viewed as the fundamental process of voluntary visceral control. His position is an attempt to articulate the nature and function of instructions (the initiating conditions for voluntary responses) and response feedback (the means by which compliance with the instruction is assessed).

Either implicity or explicity, instructions transmit information of a motivational nature. Further, instructions serve to designate a particular state of affairs that the individual is required to achieve - they describe a goal, or in feedback language, a set point. Instructions vary in the complexity of the behavioral goals they specify from broad classes of activity (eg., "move" or "stop") to more specific responses (eg., "Move your right index finger"). In cardiovascular research, we typically employ simple instructions cast in the form of imperative

sentences which are comprised of a verb (e.g., "raise" or "lower") and a noun phrase (e.g., "your heart rate" or "your blood pressure"). The verb describes the direction of the required behavioral adjustment, and the noun phrase, the effector system in which the directional request is to be fulfilled.

It follows that in order to comply specifically with an instruction to execute an act, an individual must understand the nature of the behavioral requirements specified in the instruction. In particular, he or she must be able to recognize acts of the class referenced in the instruction, implying an ability to discriminate the sensory state associated with the performance of the act. He or she must also possess the ability to label the sensory state appropriately. However, since most individuals have not received specific training in the verbal labelling of sensations associated with variations in visceral activity, it is likely that they will interpret instructions to perform visceral responses in idiosyncratic and inaccurate ways. Such ambiguity may be reduced by designating the occurrence of an external stimulus as the goal; for example, "Make this light become as bright as possible and for as long as possible" where the external stimuli are programmed to occur when the individuals HR increases. While some instructions specify external stimulus changes as the goal, others imply the occurrence of an internal stimulus as the goal, both of which are viewed by Brener as functionally equivalent. However, it is generally the case that instructions specifying behavioral goals require more specific behavioral adjustments than those specifying an external stimulus change as the goal (e.g., make a light come on). With instructions of the latter sort, the behavioral means of achieving the goal is unspecified, where the

behavioral means itself is the goal specified by instructions of the former type. However, all instructions to execute acts are reducible to instructions to produce stimulus changes in either some internal or external sensory modality and sometimes in both modalities.

By examining the behavioral adjustments produced by instructions that specify a behavioral goal rather than an external stimulus, it is possible to infer what individuals understand by such concepts as "increases in heart rate" or "decreases in blood pressure". It is assumed that under appropriate motivational conditions, individuals will comply with instructions they understand. The instruction specifies the behavioral goal to be achieved, and feedback from the internal and external receptors provides information that permits an assessment of whether or not the required sensory state is achieved. Therefore, instructionally produced activity is of a regulatory nature - its' "purpose" is to achieve a sensory state similar to that represented by the central neural circuits which previously gave rise to it and were activated by the instructional stimulus. Thus an individual who is motivated to comply with an instruction to increase his HR will continue his efforts until such time as he achieves a state that he recognizes as an "increase" in "heart rate". Appropriate response feedback will terminate the behavioral control process. Further, if it can be demonstrated that external feedback was necessary for the development of instructional control over a particular response, and if the control was maintained following the withdrawal of the feedback, it may be inferred that the external feedback has served a calibrating function. In other words, feedback made available during training enabled the individual to employ internal feedback stimuli to identify the behavioral goal demanded

by the instructions. Evidence of calibration, therefore, implies that discriminable internal feedback is associated with the occurrence of the response in question. The simple hypothesis that derives from this understanding of voluntary control, is that if an individual can learn to appropriately label the sensory consequences of a response, he will be able to comply with the instructions to execute that response.

In support of the above hypothesis, Brener cited a number of studies in which naive subjects, without any special training and in the abscence of any special feedback conditions, reliably complied with instructions to increase and decrease their HR's (Bergman & Johnson, 1971, 1972; Blanchard et al, 1974; Brener et al., 1969; Ray, 1974). The reliable influence on HR of the "increase" and "decrease" components of instructions has been demonstrated independently in two investigations using similar techniques (Bouchard & Corson, 1976; Brener & Goesling, 1968). These experiments contained procedures for investigating the pretreatment influences of the directional requirement component of instructions (e.g., producing high pitched tones indicated HR increases). The results suggested that the effects of the increase and decrease components of the verbal instructions were more profound than those produced by specific effector referents. That is, by designating an external stimulus change as the goal they controlled for the influences of specific effector referents. The influence of directional requirements is assumed to operate by establishing reponse sets in individuals that may vary in terms of their compatibility with the behavioral adjustment required by other aspects of the training procedure. Thus, instructions to increase and decrease either HR or BP or RR reliably lead to equivalent changes in HR, irrespective of the

specific effector referent.

The dominant effect of this instructional component may be attributed to the tendency of individuals to respond in a predictable but nonspecific manner to instructions that incorporate the commands "increase" or "decrease". These types of responses imply that individuals may meet the requirements of instructions to perform particular responses without being able to detect instances of the activity referenced by the instructions. In other words, comprehension of the directional requirement may enable behavioral compliance with an instruction, irrespective of the individual's ability to identify and label responses of the exclusive class designated by the effector referent. This latter ability is considered to be a determinant of the specificity of voluntary visceral control rather than a criterion to be used in assigning responses to the class of voluntary or nonvoluntary.

These results and interpretations do not discount the possibility of obtaining learned changes in other effector referents (e.g., EMG, BP) besides the one specified in the verbal instructions. In other words, it is possible that individuals have learned to label variations in EMG activity as "heart rate increases and decreases" but not as "blood pressure increases and decreases", resulting in substantial EMG changes even though only heart rate changes were referenced in instructions.

An earlier statement by Brener (1977) serves to summarize the previous discussion: "the acquisition of meaning by words that are used to describe variations in visceral activity may be viewed as the fundamental process of voluntary visceral control" (Brener, 1977; p.42). When an individual acquires the ability to comply reliably and specifically with the instruction to produce a particular variation in

visceral activity, it may be asserted that he has learned the meaning of the instruction. In order to determine if our procedures have been effective in establishing meaning in a set of instructions it is necessary to probe the meaning of the instruction prior to and following the training procedure. The broader the spectrum of activities used to investigate the influence of instructions, the more precise activities used to investigate the influence of instructions, the more precise will be our inferences regarding the individual's interpretation of these instructions. This suggestion has also been made by Shapiro (1977) who stated that it could be revealing to compile some "physiological dictionaries by finding out about the particular physiological changes associated with particular verbal labels and particular people" (p.218). Brener also noted that instructions influence not only what individuals will do in the experimental situation, but also what they will say they are doing and experiencing as indicated by their post-hoc self-reports. As a result, he is doubtful as to the utility of such post-hoc reports.

Shapiro (1977) commented further on the interaction between feedback and instruction in cardiovascular self control: "Although biofeedback may be conceived of as a kind of instruction, it is apparently not the same as the instruction inherent in particular verbal labels, such as those derived from physiological knowledge per se, or some other frame of reference that may or may not be pertinent to the individuals past experience or conditioning." (p.218). Shapiro refers to the work of Brener (1974) and his associates showing "fascinating variations in patterns of heart rate, diastolic blood pressure, chin EMG, and respiration with different combinations of feedback and instruction." (p.218). He adds, "On the face of it, there is no reason to believe that

any one unique effect achieved with biofeedback can not also be brought about through verbal instructions or vice versa. Feedback methods may work better and faster in some cases, and instructions may be better and faster in others. Clearly, some form of feedback is essential for learning, and externalized feedback displays facilitate the process." (Shapiro, 1977; p.218).

A Model on the Acquisition of Heart Rate Control (Lang)

In Lang's (1974) model, he stresses the need to emphasize such things as the individual set, the optimal characteristics of the feedback display, the effect of social motivation on performance and the role of individual differences. He also sees the need to consider the role of language mediators (cognitive control) and somatic muscle activity, not as something to be ignored or eliminated, but as response systems which often covary with the cardiovascular system and which facilitate the visceral learning of intact individuals.

Lang's (1975) research program has been prompted by three clinical concerns which have shed light on the intricacies of learned cardiovascular control, especially for the parameters of instructional set and individual differences: 1) to forge a tool for directly testing the interactions between physiological and behavioral responses; 2) to examine the feasibility of learned visceral control as a treatment for anxiety and phobias; 3) to provide information relevant to the etiology and treatment of cardiac disease. Specifically, "We are interested in relationships between psychological determination of heart rate and the presence of heart disease and in the possible development of instructional control as a treatment for disorders of heart rhythm" (Lang, 1974; p.170).

A review of the data on instrumental conditioning of visceral responses in animals led Lang (1975) to suggest that some modification of the animals' viscera through instrumental conditioning was possible; however, the effects were much smaller than previously suggested, less persistent, and apparently more narrowly dependent upon unique details of precedures than was previously supposed. As an alternative approach to traditional instrumental conditioning techniques, he looked to the work of Lisina (1958; as cited by Lang, 1975) whose procedures emphasized the importance of continuous exteroceptive feedback in teaching voluntary control of vasomotor responses; a training technique more closely resembling those techniques that are used to teach motor skills. Her procedures involved providing "additional afferentation" in the same fashion that Brener's (1974, 1977) exteroceptive and interoceptive feedback and instructions facilitated the discriminability of activities associated with the response the individual was being asked to control voluntarily. Specifically, Lang (1975) adopted techniques similar to Lisina "which depend on orienting subjects to the discrimination of visceral changes, providing 'additional afferentation', and the development of instructional sets or strategies which the subject can use to mediate the correct autonomic response" (p.173). Once again, this approach assumes that the acquisition of voluntary control over a viscus is a skill. It also assumes that cardiovascular control involves not only a single conditional reflex, but also that it requires an organized sequence of activities, movements, and symbolic information, such as that required to play darts, or to hit a tennis ball accurately. Thus, the body of literature most relevant to Lang's program is not research on the instrumental conditioning of animals but research on the acquisition of

motor skills and the performance theories of Fitts and Posner (1968) and Bilodeau and Bilodeau (1969). The distinction between these two approaches is one of type of feedback. In the instrumental paradigm HR information is typically provided in binary form. The subject is cued when his performance exceeds a preset criterion HR, and this signal is absent or replaced with a different cue, when the subject fails to achieve criterion. Thus, subjects only knew if they were correct or incorrect, with almost no additional afferentation. When information is presented in an analogue form, as with Lisina's approach, subjects attend to a signal which is continuous with beat by beat changes in HR. Further, if the target or criterion level is part of the display, there is proportional representation of relative performance, resulting in analogue feedback of both performance and organ activity. A review of the literature (see section on Kind of Reinforcement) including work by Lang and Twentyman (1974) and Gatchel (1974) revealed that analogue feedback was clearly superior for instructed HR speeding. For HR speeding, an increasing monotonic function of performance existed from low information to high information, whereas for HR slowing, there was no performance gradient; binary or low information frequency subjects did just as well as the analogue group.

Together, Lang (1975) viewed these results as suggesting that instructed HR speeding and slowing depend upon different mechanisms. Further, he stated that it "is tempting to speculate that HR speeding is dependent on some central coupling between somatic and autonomic innervation systems" (Lang, 1975; p.181) in line with the views of Obrist, Webb, Sutterer, and Howard (1970). In conjunction with the data from an earlier study (Lang and Twentyman, (1974), Lang (1975) speculated

that "perhaps subjects need only activate somatic behaviors already in the repetoire to increment heart rate. In this case we presume no new learning of visceral responses, but only a use of feedback to confirm the appropriateness of recruiting a somatic-autonomic response unit which includes HR acceleration. The very rapid acquisition observed in speeding sessions (near maximum performance on the first two trials) is consistent with this view" (p.628). This view is also consistent with that held by Rayter (1975) that particular subject populations (in this case athletes) might be better able to bring about and maintain cardiovascular control (See section on Individual Differences).

Continuing with Lang's analysis, HR slowing developed slowly over a session (i.e., there was a significant trials effect) with a lower absolute change in beats per minute than for increases. As well, there was little evidence of transfer of training to no feedback trials. These facts, according to Lang (1975), are suggestive of a different innervation pattern, leading to the speculation that HR slowing is closer to true visceral learning, perhaps involving a modification of vagal firing and vascular changes which are relatively independent of centres that control somatic activity.

Further differences between speeding and slowing were uncovered in a study using cardiac disease patients. Lang et al. (1975) employed three groups of subjects: patients diagnosed as having a myocardial infarction or unequivocal angina pectorus (mean age equal 58.05 yrs.); an age matched group free of any known cardiac disease (mean age equal 60.60 yrs.); and a third, control group of college students. All students received experimental sessions; in HR control (one speeding between two slowing) followed by sessions with a tracking task as a control for HR

changes attributable to the stimulus properties of the display. While no difference was found between groups in tracking performance, there was a significant groups effect for instructed HR change regardless of the direction of change; performance was best for college students, next best for age-matched controls, and poorest for the patients with heart disease. However, when HR task performance relative to tracking was considered, speeding-slowing differences were apparent. Patients as well as normals displayed the same pattern, with significantly greater slowing during the HR feedback task than when tracking the computer generated display. On the other hand, only the college students showed a significantly faster HR than that obtained during the psychomotor tasks; neither of the older groups increased HR significantly more than during tracking. Lang (1975) interpreted these "surprising" results as follows. If the acquisition of instructional control over HR speeding is analogous to the learning of a psychomotor task, and possibly based on related neurophysiology, it is reasonable to expect that it would be similarily influenced by age and disease. That is, performance would be deleteriously affected by both of these variables. From his earlier studies with students, Lang added that the degree of instructed speeding was related to the variability and responsivity of the individual's cardiovascular system. Research in gerontological physiology (Thompson & Nowlin, 1973; cited by Lang, 1975) indicated that a diminution of reactance and variability of the cardiovascular system is a reliable consequence of the aging process. It would appear that instructed HR speeding follows a similar course.

Lang (1975) concluded that the ability to speed HR on command appears to be a talent which is not distributed equally in the human

population. College age males are superior "autonomic athletes" relative to the elderly or those with a cardiac disorder. On the other hand, it remains unclear why instructed HR slowing fails to convary with variables that traditionally modify performance. Lang suggested that the problem may lie in the nature of the task itself as it affects a dually innervated organ like the heart. Low HR's are achieved in a state of low arousal; e.g., just after walking in the morning. Watching a visual display and processing feedback require an organismic state which makes obvious cardiovascular demands. In effect, the unconditioned sympathetic effects of the task may block rate reduction, with the degree of their reciprocal inhibition proportional to the potency of the variable. Thus, the sympathetic activation of the heart prompted by the task would exactly counter efforts to train greater vagal (para-sympathetic) inhibition of cardiac rate. This argument suggests that refined control of HR slowing is not likely to be achieved through a direct attack but rather through first training multiple but related behaviors and then returning to direct instructional control (Lang, 1975).

APPENDIX C

TABLE A

HR AND RR MEANS AND STANDARD DEVIATIONS FOR GROUPS OF THREE SUBJECTS ACROSS ORDERS AND BETWEEN REVERSALS: PHASE I AND II MEANS AND STANDARD DEVIATIONS REPRESENT CHANGES FROM CRITERION

TABLE A

Heartrate and Respiration Rate Means and Standard Deviations for Groups of Three Subjects across Orders and Between Reversals: Phase I and II Means and Standard Deviations Represent Changes from Criterion

		HR (beats/minute)				RR (breaths/minute)			
		A		N		A		N	
PHASE I		$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
B ALONE		2.6	2.7	3.4	2.1	3.0	1.1	3.8	1.6
C ALONE		6.0	7.7	6.3	5.8	2.3	4.7	1.8	4.4
B' ALONE		5.3	1.9	3.0	1.1	25.4	9.1	5.0	3.9
PHASE II									
		B-B'-B Reversal Across Series							
	B	2.0	1.1	1.8	3.4	1.0	2.4	4.4	1.0
A-B-A Series	B'	6.5	5.0	1.4	3.2	16.3	13.0	25.2	18.8
	B	-0.6	1.2	-0.1	5.1	4.4	3.8	4.6	3.3
	B	2.8	5.8	-0.8	1.2	6.5	6.7	3.7	3.7
A-C-A Series	B'	4.4	11.1	-0.1	6.1	38.8	37.4	23.5	17.0
	B	1.3	6.5	-4.3	3.0	2.3	4.0	3.0	3.1
	B	-1.1	1.7	-1.1	2.3	1.7	3.6	5.4	3.5
A-B'-A Series	B'	1.0	1.0	2.5	2.3	33.4	11.3	11.0	10.4
	B	-1.6	1.7	0.6	0.8	2.5	2.3	2.2	1.5
		B-BC-B Reversal Across Series							
	B	-0.6	1.2	-1.6	1.4	1.6	1.7	2.7	0.6
A-B-A Series	BC	1.8	1.5	2.7	2.2	3.5	0.5	8.5	4.9
	B	-0.3	1.1	-0.4	3.2	2.8	2.7	2.0	1.6
	B	4.7	7.8	0.7	0.8	3.1	5.0	1.3	2.4
A-C-A Series	BC	4.7	5.3	3.1	2.6	3.2	5.0	5.2	6.8
	B	1.6	6.0	1.1	2.7	1.8	2.3	5.6	7.8
	B	-1.4	2.5	0.3	0.5	2.2	2.4	0.6	0.9
A-B'-A Series	BC	-0.8	1.5	1.9	3.0	4.7	3.6	1.8	1.5
	B	-3.8	3.1	0.3	1.7	1.4	1.1	1.1	0.6
		B'-B'C-B' Reversal Across Series							
	B'	7.5	0.2	1.1	3.3	23.6	18.2	22.5	16.3
A-B-A Series	B'C	7.3	3.7	4.1	3.1	29.7	23.4	23.1	20.4
	B'	4.6	5.7	2.0	2.5	19.2	23.4	35.5	33.3
	B'	6.4	7.0	2.3	2.9	14.3	15.2	15.3	18.8
A-C-A Series	B'C	9.4	9.8	2.2	4.7	38.4	37.2	16.6	12.6
	B'	6.6	7.9	-0.8	5.5	33.9	30.4	12.9	13.3
	B'	0.8	0.8	-0.7	2.4	34.5	12.6	9.1	5.5
A-B'-A Series	B'C	-0.2	3.0	4.2	2.0	40.5	15.4	14.1	9.3
	B'	-1.2	1.1	5.1	2.8	33.9	17	16.2	8.6

APPENDIX D

INSTRUCTIONS TO ALL SUBJECTS

Pre-Experimental Instructions

For the next two and one half hours you will be taking part in a biofeedback experiment. Biofeedback is a technique used to help people gain control over their internal functions by mental means only. To help us with our measurements, and to at times provide you with feedback as to your success in controlling your internal functions, I will be attaching several surface electrodes to your arms, legs, nose and chest. I will explain the purpose of each to you.

Experimental Instructions

Phase I

A-B-A Series (specific instructions alone). The experiment consists of two phases. I will give you the instructions for Phase I presently, and in approximately 32 min., I will enter the chamber to provide you with instructions for Phase II. In this part of the experiment you are to try to raise your HR by mental means only. When I leave the room there will be a 10.5 min. adaptation period during which your only task will be to sit in a comfortable position and relax so that you may become used to your surroundings. When you hear the words "Increase HR" from this tape-recorder (pointing), try to raise your HR as high as you can for the next 60 secs. until you are instructed (pointing) to "Rest". At this point, do not attempt to raise your HR; you are only to relax for the next approximately 30 secs. until you are again instructed to "Increase HR". The rest periods will vary in length around 30 secs. During the rest period, this red light (pointing) to the middle bar will go on to indicate that you must rest. This cycle of increase HR and rest will be repeated seven times. I cannot tell you how to go about

increasing your HR since each subject seems to have his or her own method. However, you are not to attempt to increase your HR by intentionally changing your breathing rate or depth, or by changing your muscle tension. Attempt to raise your HR by mental means only. Are there any questions?

There is an intercom here which is connected to the next room. If you wish to speak to us or to stop the session, simply call out. Remember, concentrate on raising your HR as high as you can be mental means only.

A-C-A Series (feedback alone). Instructions will be the same as those for the A-B-A Series except for the following. In this part of the experiment, you are to try to raise the level of an internal response. So that you can control your bodily processes solely through mental means, we are not telling you what the response is. As the level of the internal response increases, this bar (pointing to bar on right) will light up and become progressively longer in proportion to the degree that you raise the level of that internal response. This is called feedback, and will serve as an accurate indicator of how successful you are in raising the level of the internal response. You will hear the word "Increase" on the tape recorder.

A-B'-A Series (Respiration-assist Instructions). Instructions will be the same as those for the A-B-A Series except for the following. In this part of the experiment, you are to try to increase your HR. Each subject seems to use different techniques to increase his HR and you will have to discover your own. However, in addition to whatever techniques you choose to use, we would like you to use your breathing pattern to bring about HR increases. In other words, you may change your breathing

rate or depth to bring about HR increases. You will hear the words "Breathing-Assisted HR Increase" on the tape recorder.

Phase II

In will now give you instructions for the remainder of the experiment. During this phase, there will be an additional nine treatments, each with seven trials of 60 secs. duration followed by seven rest periods of 30 secs. duration. During each treatment you will be instructed to increase your HR above a preset criterion, with additional instructions as to the means by which you are to do this. As well, you will be receiving at different times, feedback as to success or failure at increasing HR. Here are the instructions you will be hearing over the tape-recorder:

-"Increase HR": Increase the level of your HR by mental means only. Do not change your breathing rate or depth of muscle tension.

-"Breathing-Assisted HR Increase": We want you to increase the level of your HR by using your breathing rate and/or depth in addition to whatever mental means you may have discovered in Phase I. However, you must not change your muscle tension. Any questions?

Now I would like you to turn your attention over to the light meter or bar (pointing). (Those in the A-C-A Series will be told to "look again" since its use will have been explained in Phase I). These are your feedback lights and they are designed to tell you how successful you are at raising your HR under instructions to do so. However, they will not always be available to you, as this too is part of the experiment. The middle of the bar (pointing) will be lighted during the rest periods at which time you will not be required to raise your HR and you will not

be receiving feedback. Upon being asked to raise your HR, either with or without breathing assist, the light bar to the right of centre will light up and become progressively longer in proportion to the amount that you raise your HR above a preset criterion. Remember, your goal is to make the bar on the right as long as possible until you are told to rest and the middle bar lights up. At this point, simply relax, stop trying to increase your HR, and wait until you hear your next set of instructions. If the bar does not light up for you, this means that your HR is below your criterion level.

At no time are you to change your muscle tension in an attempt to alter your HR. If you must move, restrict it to the rest periods. Remember, use either mental means and/or your breathing when the instructions allow it.

This last phase will last approximately 1 1/2 hours. The intercom is on at all times should you need to call out or wish to stop the experiment.

Thank you.

APPENDIX E

ROTTER'S I-E SCALE

SOCIAL OPINION SURVEY

This is a questionnaire to find out the way in which certain important events in our society affect different people. Each item consists of a pair of alternatives lettered a or b. Please select the one statement of each pair (and only one) which you more strongly believe to be the case as far as your concerned. Be sure to select the one you actually believe to be more true rather than the one you think you should choose or the one you would like to be true. This is a measure of personal belief: obviously there are not right or wrong answers.

Your answers to the items on this inventory are to be recorded on a separate answer sheet. Please answer these items carefully but do not spend too much time on any one item. Be sure to find an answer for every choice. Find the number of the item on the answer sheet and black-in the space under the number 1 or 2 which you choose as the statement more true.

In some instances you may discover that you believe both statements or neither one. In such cases, be sure to select the one you more strongly believe to be the case as far as you're concerned. Also try to respond to each item independently when making your choice; do not be influenced by your previous choices.

1. a. Children get into trouble because their parents punish them too much.

   b. The trouble with most children nowadays is that their parents are too easy with them.

2. a. Many of the unhappy things in people's lives are partly due to bad luck.

   b. People's misfortunes result from the mistakes they make.

3. a. One of the major reasons why we have wars is because people don't take enough interest in politics.

   b. There will always be wars, no matter how hard people try to prevent them.

4. a. In the long run people get the respect they deserve in this world.

   b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries.

5. a. The idea that teachers are unfair to students is nonsense.

   b. Most students don't realize the extent to which their grades are influenced by accidental happenings.

6. a. Without the right breaks one cannot be an effective leader.

   b. Capable people who fail to become leaders have not taken advantage of their opportunities.

7. a. No matter how hard you try some people just don't like you.

   b. People who can't get others to like them don't understand how to get along with others.

8. a. Heredity plays the major role in determining one's personality.

   b. It is one's experiences in life which determine what they're like.

9. a. I have often found that what is going to happen will happen.

   b. Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.

10. a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.

    b. Many times exam questions tend to be so unrelated to course work that studying is really useless.

11. a. Becoming a sucess is a matter of hard work, luck has little or nothing to do with it.

    b. Getting a good job depends mainly on being in the right place at the right time.

12. a. The average citizen can have an influence ingovernment decisions.

    b. This world is run by the few people in power, and there is not much the little guy can do about it.

13. a. When I make plans, I am almost certain that I can make them work.

    b. It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.

14. a. There are certain people who are just no good.

    b. There is some good in everybody.

15. a. In my case getting what I want has little or nothing to do with luck.

    b. Many times we might just as well decide what to do by flipping a coin.

16. a. Who gets to be the boss often depends on who was lucky enough to be in the right place first.

    b. Getting people to do the right thing depends upon ability, luck has little or nothing to do with it.

17. a. As far as world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.

    b. By taking an active part in political and social affairs the people can control world events.

18. a. Most people don't realize the extent to which their lives are controlled by accidental happenings.

    b. There really is no such thing as "luck".

19. a. One should always be willing to admit mistakes.

    b. It is usually best to cover up one's mistakes.

20. a. It is hard to know whether or not a person really likes you.

    b. How many friends you have depends upon how nice a person you are.

21. a. In the long run the bad things that happen to us are balanced by the good ones.

    b. Most misfortunes are the result of lack of ability, ignorance, laziness, or all three.

22. a. With enough effort we can wipe out political corruption.

    b. It is difficult for people to have much control over the things politicians do in office.

23. a. Sometimes I can't understand how teachers arrive at the grades they give.

    b. There is a direct connection between how hard I study and the grades I get.

24. a. A good leader expects people to decide for themselves what they should do.

    b. A good leader makes it clear to everybody what their jobs are.

25. a. Many times I feel that I have little influence over the things that happen to me.

    b. It is impossible for me to believe that chance or luck plays an important role in my life.

26. a. People are lonely because they don't try to be friendly.

    b. There's not much use in trying too hard to please people, if they like you, they like you.

27. a. There is too much emphasis on athletics in high school.

    b. Team sports are an excellent way to build character.

28. a. What happens to me is my own doing.

    b. Sometimes I feel that I don't have enough control over the direction my life is taking.

29. a. Most of the time I can't understand why politicians behave the way they do.

    b. In the long run the people are responsible for bad government on a national as well as on a local level.

APPENDIX F

POST EXPERIMENTAL QUESTIONNAIRE

Name:_____

POST-EXPERIMENTAL QUESTIONNAIRE

People usually try different approaches or techniques in order to control their heart rate. Some approaches seem to be more successful than others depending upon the individual. Below, are questions pertaining to how YOU tried to control your heart rate during the experiment. Please check-off and fill-in the answers relevant to how you controlled your heart rate. There are no right or wrong answers and we are interested in the ways in which you tried to control your heart rate.

1. Concentrated on the sound or pulsing of your heart beat,

yes ( ) no ( )

2. Concentrated on changing, or increasing your heart beat,

yes ( ) no ( )

3. Thought of various things which were: Check off as many as were applicable, and if checked, give examples.

exciting ( ) _____

frighening ( ) _____

enjoyable ( ) _____

stimulating ( ) _____

dangerous ( ) _____

distasteful ( ) _____

unenjoyable ( ) _____

physically exerting ( ) _____

_____ ( ) _____
other

_____ ( ) _____
other

4. Did you find yourself becoming tense, or tensing your muscles?

yes ( ) no ( )

Is so, when? _____

5. Did you have difficulty keeping your breathing at a steady or constant rate when asked to do so?

yes ( ) no ( )

6. Where you able to make use of your breathing when asked to do so?

yes ( ) no ( )

How did you do so?

_____

7. Did you try to cheer-on ( ), rood ( ), or give pep talks ( ) to your heart? Yes ( ) No ( ). If you did, what did you "say" to yourself or your heart?

_____

_____

8. How successful do you think you were at increasing your heart rate? Place an "x" on the line below to indicate your answer.

_____

not at all moderately extremely

9. Were there any changes in how you increased your heart rate from the beginning to the end of the experiment?

yes ( ) no ( )

If so, what were they? _____

10. Did you use the feedback lights?

yes ( ) no ( )

11. Did you experience any "sensations" during the training trials?

yes ( ) no ( )

If so, of what nature? _____

12. Do you believe that internal control over autonomic functioning is possible?

yes ( ) no ( )

13. Do you think that physical training is helpful in raising your heart rate?

yes ( ) no ( )

If so, how? _____

14. Do you believe what you were told as to the purpose of this experiment?

yes ( ) no ( )

If not, what do you think the purpose was? _____

_____

COMMENTS: