THE EFFECTS OF FEEDBACK AND STRENGTH OF THE NERVOUS SYSTEM ON CARDIAC RATE CONTROL

by

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Abstract

The influence of two levels of visual feedback (continuous wave-form and no feedback) and three levels of extraversion (high, medium and low) on the ability to decrease heart rate were examined. Forty-eight college students served as subjects with each receiving five alternating three minute rest periods and self-control periods.

Heart rate and respiration rate were simultaneously recorded for all trials. Difference scores between the rest period and self-control period heart rates were subjected to analysis of variance which revealed a significant Trials X Feedback interaction. Paired comparisons revealed that subjects receiving feedback produced greater heart rate decreases on Trial 1 only. Personality differences and autonomic conditionability was discussed. The association between heart rate and respiration rate difference scores was found to be directional, but nonsignificant. Recommendations for future research with continuous wave-form feedback were presented.

The Effects of Feedback and Strength of the Nervous System on Cardiac Rate Control

by

William F. McDaniel[1]

Biofeedback paradigms have been successfully applied to clinical settings to raise and reduce blood pressure in essential hypertensive patients (Benson, Shapiro, Tursky, & Swartz, 1971), accelerate and decelerate heart rate in patients with premature ventricular contractions (PVCs) (Weiss & Engel, 1971), and to relieve tension headaches (Budzynski, Stoyva, & Adler, 1970). Many studies attempting to alter heart rate (HR) have indicated that HR increases were more reliably obtained than decreases (Engel & Chism, 1967; Headrick, Feather, & Wells, 1971; Johns, 1970; Levene, Engel, & Pearson, 1968; Stephans, Harris, & Brady, 1972).

Results of many experiments since the mid-1960's (Blanchard & Young, 1972; Brener, Kleinman, & Goesling, 1969; Donelson, 1966; Engel & Hanson, 1966; Johns, 1970; Lang, Sroufe, & Hastings, 1967) have demonstrated exteroceptive feedback as a necessary component of human cardiovascular control. Sensory feedback has, in all experiments, been used to notify the S of on-going autonomic behavior to ameliorate the monitoring of future cardiac responses. Blanchard and Young (1972) demonstrated that feedback presented through either visual or auditory sensory modalities had indistinguishable effects on facilitating cardiac control.

The three basic methods of sensory feedback presentation employed in cardiac control experiments have been 1) augmented or binary, 2) proportional, 3) continuous wave-form feedback. Augmented feedback refers to the procedural manipulation in which each interbeat-interval (IBI) is analyzed by logic circuits immediately following emission, as to whether or not it is significantly variant from the preset baseline IBI. Sensory feedback (light-on) is presented immediately contingent upon IBIs attaining criterion value. The S's goal is to increase the frequency with which the light flashes by controlling his HR. Blanchard and Young (1973) have more explicitly defined augmented feedback as binary feedback. Significant increases and decreases in HR have been demonstrated through the use of binary feedback (Brener, Kleinman, & Goesling, 1969; Brener & Hothersall, 1966, 1967; Engel & Chism, 1967; Engel & Hanson, 1966; Levene, Engel, & Pearson, 1967).

The second method of presenting sensory feedback is proportional feedback (Blanchard & Young, 1972; Blanchard, Young, & McLeod, 1972; Finley, 1970; Headrick, Feather, & Wells, 1971; Sroufe, 1971; Stephans, Harris, & Brady, 1972). The recent uses of proportional feedback have been variations of the original procedures employed by Hnatiow and Lang (1965) and Lang, Sroufe, and Hastings (1967) to reduce HR variability

in humans. In the original research, the baseline IBI was indicated by a red stripe on an opaque overhead projector. The position of a computer driven pointer indicated IBIs consonant with or variant from the preset IBI, while the S was typically instructed to keep the pointer in close proximity to the red stripe thus reducing HR variability. Blanchard, Finley, and Sroufe utilized voltage meters in which the baseline IBI was indicated as the midpoint on the meter range; variations from the baseline IBI were communicated by needle deflections to the left for HR decreases and right for increases. Headrick, et al. employed variations in tonal pitch as indications of HR increases and decreases. Continuous proportional feedback differs from binary feedback primarily in that the S is not only notified as to whether or not he is successfully performing the goal behavior, but also by how much.

The third method of presenting cardiac rate information, continuous wave-form feedback, has been utilized by Donelson (1966) in one experiment to aid the synchronization of a pulse generator output rate with HR and in another experiment to aid the synchronization of HR with a predetermined pulse generator output rate. Feedback was continuously presented on the visual display face of an oscilloscope individually monitored to respond only to the high voltage R waves of the EKG wave complex. Training with oscilloscopic

HR feedback was found to be essential in the synchronization of the pulse generator with HR and to a slight extent beneficial in the synchronization of HR with a constant pulse generator rate when feedback was not available to the S.

The perennial issue pertaining to whether cognitive or somatic mediators are reinforced by the presentation of immediate HR feedback has been proposed as crucial to the therapeutic applications of instrumental autonomic conditioning (Swartz, 1973). Swartz has suggested that in cases such as essential hypertension, an understanding of the function of cognitive and somatic mediators of decreased blood pressure may prove beneficial to the modification of this autonomic behavior; i.e. the goal of decreasing blood pressure may be facilitated by simultaneously reinforcing cognitive mediators of muscular relaxation as well as the attainment of the decreased blood pressure goal. Engel (1972) and Kimmel (1974), on the contrary, have been unable to demonstrate consistent cognitive mediating factors through posttraining questionnaires given Ss successfully attaining autonomic control.

Hnatiow and Lang (1965) and Lang, Sroufe, and Hastings (1967) have reported a high degree of intersubject variability in the ability to learn HR control. Bergman and Johnson (1971) and Blanchard, Young, and McLeod (1972) demonstrated that variability could be predicted by determining pretrial

scores on the Mandler Autonomic Perception Questionnaire (APQ). Bergman, et al. found that middle range scores were predictive of better autonomic conditioning. Blanchard, et al. found Ss low in awareness of autonomic functioning successful in raising and reducing their HRs and Ss high in awareness unable to significantly alter their HRs while not examining middle range scores.

Eysenck (1957) proposed that one major source of individual differences in Pavlovian and Hullian conditioning paradigms was attributable to differences in the excitation-inhibition balance of the central nervous system (CNS). Extraverts are postulated to slowly generate weak excitatory potentials while rapidly generating strong reactive inhibition that dissipates slowly. Introverts, on the other hand, are postulated to rapidly generate strong excitatory potentials while slowly generating weak reactive inhibition that dissipates quickly. Research by Eysenck (1960a, 1960b) and Vogel (1961) has produced data supporting Eysenck's hypothesis that individual differences in human respondent conditioning are discernible by a pretrial administration of the Maudsley Personality Inventory (MPI) Introversion-Extraversion (I-E) scale. Gray (1967) suggested that the I-E scales may also be applicable to the understanding of individual differneces evident in human instrumental conditioning.

Since self-mediated decreases in HR are desirable in clinical settings as treatment for paroxysmal arrythmia, hyperthyroidism, A-V shunts and PVCs, it was considered imperative to examine conditions through which lowered HR may be learned. It was predicted that HR control varies as a function of discriminable external or internal information and that continuous feedback would maximize control by informing the S of HR performance on each IBI. Futhermore, it was predicted that discriminability and control would accrue as a function of training. No attempt was made to determine the somatic and cognitive mediators of decreased HR, but rather, both were assumed to be simultaneously reinforced by providing feedback contingent only upon the chronotropic function of the heart. In the present experiment, somatic mediators were maximized by the continuous wave-form feedback while cognitive mediators were maximized by instructions suggesting the relationship between cognitive set and HR physiology.

As in any medicinal or behavioral therapy, individual differences in the patients influence the extent to which a therapy will be effective. Therefore a secondary purpose of this experiment was to examine the applicability of the MPI I-E scale to instrumental HR conditioning. Through this procedure it may be possible to accurately predict the conditions under which autonomic conditioning will be maximized for specific individuals in the clinical setting.

Method

Subjects

From a group of 150 college students of both sexes enrolled in undergraduate psychology courses at Appalachian State University, 48 were selected on the basis of their scores on the MPI I-E scale. Sixteen Ss classified as either high extravertive (HE), middle-range extravertive (ME), or low extravertive (LE) and randomly assigned to two feedback conditions constituting six groups of eight Ss each.

Questionnaire

The pretrial measure of introversion-extraversion was the Maudsley Personality Inventory, Form A (see Appendix). The MPI contains an extraversion index consisting of 24 items interspersed within the 56 item questionnaire. The extraversion scale correlates highly with the Guilford r scale of introversion (.85) and the Taylor Manifest Anxiety Scale of neuroticism (.89). Following 150 administrations of the MPI, scores were ranked and divided into one-fifths. The lower one-fifth was utilized as the LE group (range: two to nine, $\overline{X} = 6.53$), the third-fifth was considered the ME group (range: 12 to 13, $\overline{X} = 12.56$), and the highest fifth was utilized as the HE group (range: 16 to 20, $\overline{X} = 17.68$). Subjects within these divisions were randomly selected for each group of 16 Ss.

Apparatus

The feedback display apparatus consisted of a triggerable oscilloscope (Heathkit Model 10-14) connected in parallel circuit with the pen motor of an E & M Physiograph IV which was driven by the amplified signal of an E & M Hi-gain pre-amplifier. The physiograph was situated outside of the S's view. The oscilloscope was individually triggered to respond only to the high voltage R wave of the EKG wave complex. The distance between R wave indicators (spikes on the oscilloscope) provided the continuous wave-form feedback available to Ss. An illuminated retilinear gradiant, 10cm X 5cm with divisions of 1cm was superimposed over the display face indicating the HR associated with increments of distance on the gradiant. The S sat directly in front of the oscilloscope at a distance of approximately 105cm. A seven and one-half volt light stimulus behind a polyethylene green shield was the cue to decrease HR; the light-off stimulus was the cue to emit a normal resting HR. Time intervals for all trials were recorded by the timer on the physiograph and the cues were activated by E.

The EKG was recorded from silver plate electrodes dampened with a 20% solution of sodium chloride connected to the volar surfaces of the left and right wrists. Respiration was monitored by silver plate surface electrodes and sodium chloride attached to the rib cage approximately in the area of the sixth and seventh vertebrosternal ribs. These were coupled with an impedance pneumograph transducer (E & M Instrumant Co., Inc.) which drove a pen motor on the physiograph and printed a permanent record of inhalation-exhalation skin resistance changes.

Design

A three-factor mixed factorial with repeated measures on trials was the design employed. The between S variables consisted of three levels of personality (LE, ME, HE) and two levels of feedback (continuous wave-form, CW, and no feedback, NF). The within S variable was the five trials each consisting of a 3minute cue-off (rest period) followed by a 3minute cue-on (self-control period). The HR difference score between the two cue condition mean HRs within each trial was the response measure employed. Respiration rate (RR) was also recorded for purposes of examining the association between HR alterations and RR variability.

Procedure

Upon entrance to a physiology laboratory, Ss were told the purpose of the experiment, their goal, and instructed in the use of feedback when applicable. Instructions were adapted from those employed by Bergman and Johnson (1971) (see Appendix).

After Ss were comfortably seated in a recliner, electrode sites were scrubbed with isopropanol and electrodes connected. Ss were again instructed in the use of oscilloscopic feedback and told that they would observe alternate light-off-light-on conditions. During the light-on conditions, Ss were to decrease their HRs in any manner possible with the exceptions of breathing manipulations and muscular movements. During the light-off conditions they were to relax and not concentrate on HR decreases. Subjects experiencing discomfort were allowed movement after notifying the E, but in no case were such trials included in the study. Stereo headphones were employed to reduce equipment and other extraneous uncontrollable noise. Subjects remained seated and motionless until five light-off and five light-on trials had been recorded.

Data Analysis

The mean HR in bpm from each rest period trial and decrease trial served as the data for each S. These data were reduced by the E. In order to avoid the overall trend of decreasing HR over the course of the experiment reported by Brener and Hothersall (1967) and Brener, Kleinman, and Goesling (1969) and to remove some of the intersubject variability in baseline HR, differences between rest period HR and self-control period HR were calculated for each individual trial. The difference scores served as data for the experiment.

The mean RR in cycles per minute (cpm) was also calculated for each rest period trial and self-control period. Differences between rest period RR and decrease period RR were calculated for each of the five trials. The difference scores, with appropriate sign, were the data for examining associations between HR and RR difference scores.

Results

The mean HR difference scores for groups in the two feedback conditions collapsed across personality conditions for each trial are presented in Figure 1. The data for the two feedback groups and three personality groups were subjected to an analysis of variance with repeated measures on trials.

Insert Figure 1 about here

There were no significant main effects for Feedback, Personality, and Trials. However, there was a significant Trials X Feedback interaction ($F = 2.37$, $df = 4/168$, $p < .05$), indicating that the CW and NF groups were responding with significantly variant decreases on one or more trials. The significant interaction was reduced to paired comparisons analysis which indicated that the CW groups responded with greater HR decreases than the NF groups only on Trial 1 ($t(23) = 2.045$, $p < .05$). Figure 1 indicates that on Trials 2 through 5, the

NF groups responded with slightly greater, but nonsignificant, HR decreases than the feedback groups.

Insert Table 1 about here

In addition to the preceeding analysis, a four-factor mixed analysis of variance was performed on the raw data which indicated that HR under both stimulus cues decreased consistently as a function of trials. The main effect of personality, while nonsignificant, indicated that ME groups tended to produce slightly greater HR decreases than the LE groups ($t(15) = 2.044$, $p < .08$).

Total RR and HR difference scores with appropriate sign for four Ss with interpretable RRs over the five trials were subjected to a Pearson Product-Moment Correlation. Results indicated a nonsignificant, but directional association between HR and RR ($r_{22} = .3873$, $p < .07$).

Discussion

Results from this study indicate that Ss are able to decrease HR from an immediately preceeding rest period HR in the presence and absence of continuous wave-form feedback on some trials. Subjects receiving feedback produced greater HR decreases on Trial 1, but not on Trials 2 through 5.

These findings initially appear to conflict with much of the research previously cited suggesting discriminable feedback as a necessary component of cardiac control. They are supported by the findings of Headrick, Feather, and Wells (1971) using proportional auditory feedback and Johns (1970) using binary auditory feedback. Blanchard, Young, and McLeod (1972) and Finley (1971), on the other hand, have demonstrated proportional visual or auditory feedback as a condition necessary for HR decreases to exceed those of Ss receiving either no feedback or inaccurate feedback.

The data at this point is inconsistent and deserving of research to explain these conflicting results. Two explanations for the conflicts are tenable. The first is that HR feedback may not have been equally discriminable in all studies. In other words, HR decreases may have been difficult for the Ss to interpret in the present and supporting studies and therefore arousing to Ss attempting to produce the decrease HR goal. The second explanation is that the instructional sets may have been inconsistent between studies. In the present experiment, instructions were given concerning cognitive processes that may facilitate cardiac control. Therefore, Ss in both feedback conditions may have been given information sufficient for producing the decrease HR goal.

It is recommended that research be conducted to explore the influences of instructions containing cognitive self-control clues and various forms of discriminable external feedback upon the production of HR decreases.

The question of discerning autonomic conditionability by a pretrial administration of the MPI has received moderate support from this study. Perhaps if the MPI score ranges had been more widely separated, differences in conditioning may have been more evident. As reported, the HE and ME groups tended to reduce HR slightly more than the LE groups. This seemingly contradictory finding may in fact support Eysenck's (1957) hypothesis of conditioning in introverts. In view of the fact that the NF groups tended to produce slightly greater, but nonsignificant HR decreases, _S_s attending to feedback may have been frustrated by indiscriminable feedback and therefore more physiologically aroused. Introverts, being more preoccupied with "social duties" and achievement (Eysenck, 1957) may have been more aroused than other _S_s by a conflict between the response desired and indiscriminable feedback presented.

Future research with continuous wave-form feedback should utilize and overhead projector to magnify the oscilloscope display face and therefore ameliorate discriminability. In addition, more training sessions should be utilized to

maximize the acquisition of self-control since learning to discriminate internal feedback of autonomic function is probably the crucial factor in learning autonomic control.

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Footnote

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Figure Captions

Fig. 1. Mean HR difference scores for Ss in CVW and NF groups.

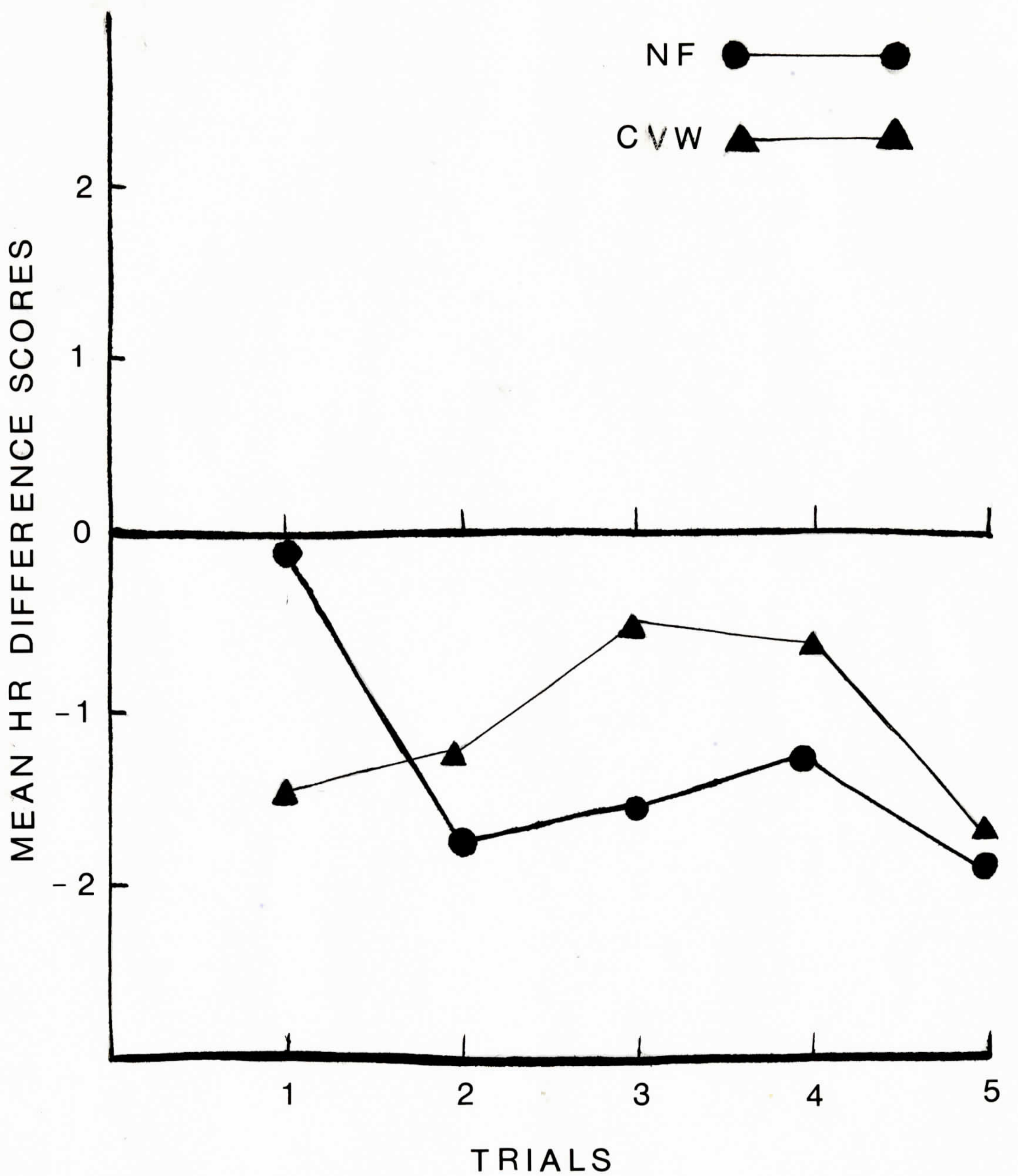

TABLE 1

Summary of analysis of variance of HR difference scores

Source	df	MS	F
Between Ss			
Personality (P)	2	26.59	2.73
Feedback (F)	1	2.14	< 1.00
P X F	2	.49	< 1.00
Error b	42	9.74	
Within Ss			
Trials (T)	4	7.72	1.72
T X P	8	4.68	1.04
T X F	4	10.64	2.37*
T X P X F	8	3.95	< 1.00
Error w	168	4.50	

*$p < .05$

Appendix

1. Do you often long for excitement?
2. Do you often need understanding friends to cheer you up?
3. Are you usually carefree?
4. Do you find it very hard to take no for an answer?
5. Do you stop and think things over before doing anything?
6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?
7. Does your mood often go up and down?
8. Do you generally do and say things quickly without stopping to think?
9. Would you do almost anything for a dare?
10. Do you suddenly feel shy when you want to talk to an attractive stranger?
11. Once in a while do you loose your temper and get angry?
12. Do you often do things on the spur of the moment?
13. Do you often worry about things you should not have done or said?
14. Generally, do you prefer reading to meeting people?
15. Are your feelings rather easily hurt?
16. Do you like going out alot?
17. Do you occassionally have thoughts and ideas that you would not like other people to know about?
18. Are you sometimes bubbling over with energy and sometimes very sluggish?
19. Do you prefer to have few but special friends?
20. Do you daydream alot?
21. When people shout at you, do you shout back?
22. Are you often troubled about feelings of guilt?
23. Are all your habits good and desirable ones?
24. Can you usually let yourself go and enjoy yourself alot at a gay party?
25. Would you call yourself tense or "highly-strung"?
26. Do other people think of you as being very lively?
27. After you have done something important, do you often come away feeling you could have done better?
28. Are you mostly quiet when you are with other people?
29. Do you sometimes gossip?
30. Do ideas run through your head so that you cannot sleep?
31. If there is something you want to know about, would you rather look it up in a book than talk to someone about it?
32. Do you get palpitations or thumping in your heart?
33. Do you like the kind of work that you need to pay close attention to?
34. Do you get attacks of shaking or trembling?
35. Would you always declare everything at the Customs, even if you knew that you could never be found out?
36. Do you hate being with a crowd who plays jokes on one another?
37. Are you an irritable person?
38. Do you like doing things in which you have to act quickly?

39. Do you worry about awful things that might happen?
40. Are you slow and unhurried in the way you move?
41. Have you ever been late for an appointment or work?
42. Do you have nightmares often?
43. Do you like talking to people so much that you never miss a chance of talking to a stranger?
44. Are you troubled by aches and pains?
45. Would you be very unhappy if you could not see lots of people most of the time?
46. Would you call yourself a nervous person?
47. Of all the people you know, are there some whom you definitely do not like?
48. Would you say that you were fairly self-confident?
49. Are you easily hurt when people find fault with you or your work?
50. Do you find it hard to really enjoy yourself at a lively party?
51. Are you troubled with feelings of inferiority?
52. Can you easily get some life into a rather dull party?
53. Do you sometimes talk about things you know nothing about?
54. Do you worry about your health?
55. Do you like playing pranks on others?
56. Do you suffer from sleeplessness?

Instructions

Feedback groups

This study deals with controlling your HR. The majority of people can decrease their HR when they are given a signal to do so. Decreasing your HR is possible if you concentrate on your heart and try very hard to make it go slower. There are many reasons for exploring this kind of learning when one considers the large numbers of persons with heart problems currently on drugs with adverse side effects. In this experiment, you will see this light beside the scope come on lasting for three minutes. During the time the light is on, I want you to try to make your HR slower. There will be five times that the light is on and five equal times that the light is off. You may find that your HR is slower from trial to trial.

By looking at this scope (E pointing to the scope) you will be able to see a spike each time your heart beats. The greater the distance between these spikes, the slower your HR. By looking at the numbers on the scope face you should be able to interpret your own HR on each spike. Once again, try to make the distances between spikes as large as possible while the light is on.

There is one thing you must do to insure that you are using concentration to decrease your HR. You must refrain from deliberately manipulating your breathing patterns and making gross muscular movements.

You probably realize that there are some thoughts that can alter your HR. For example, by thinking about exciting things such as sex, you can increase your HR. When you think about quiet things such as a walk along a deserted beach, your HR has a tendency to decrease its beating rate. You may use thoughts to help you decrease your HR in addition to the feedback.

<u>No feedback groups</u>

This study deals with controlling your HR. The majority of people can decrease their HR when given a signal to do so. Decreasing your HR is possible if you concentrate on your heart and try very hard to make it go slower. There are many reasons for exploring this kind of learning when one considers the large numbers of persons with heart problems currently on drugs with adverse side effects. In this experiment, you will see this light beside the scope come on lasting for three minutes. During the time the light is on, I want you to try to make your HR slower. There will be five times that the light is on and five equal times that the light is off. You may find that your HR is slower from trial to trial.

Some people can see their HR on the scope in front of you, but in your case I wish to find out if you can control your HR without knowing its rate.

There are two things you must do to insure that you are using concentration to decrease your HR. You must refrain from

deliberately manipulating your breathing patterns and making gross muscular movements.

You probably realize that there are some thoughts that can alter your HR. For example, by thinking about exciting things such as sex, you can increase your HR. When you think about quiet things such as a walk along a deserted beach, your HR has a tendency to decrease its beating rate. You may use thoughts to help you decrease your HR in addition to any internal feedback you may be able to sense.

Cell Means and Standard Deviations

		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
HE, CVW	M	-2.575	-0.712	-0.913	-0.675	-0.650
	SD	4.111	1.238	2.266	1.365	3.054
HE, NF	M	-0.838	-1.625	-1.200	-1.125	-2.163
	SD	0.823	1.688	2.503	1.853	2.726
ME, CVW	M	-1.750	-1.588	-1.050	-1.525	-2.637
	SD	2.508	1.823	2.086	3.127	3.569
ME, NF	M	-0.900	-2.625	-2.087	-0.825	-2.163
	SD	1.865	1.345	2.538	1.578	2.382
LE, CVW	M	-0.038	-1.287	0.413	0.225	-1.425
	SD	3.166	1.690	2.611	2.230	1.703
LE, NF	M	1.575	-1.287	-1.063	-1.787	-1.000
	SD	2.467	1.762	3.667	1.734	1.336