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## The Effects of Feedback and Knowledge of Response on the Voluntary Acceleration of Heart Rate

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THE EFFECTS OF FEEDBACK AND KNOWLEDGE OF RESPONSE  
ON THE VOLUNTARY ACCELERATION OF HEART RATE

by

Sharon A. Moskowitz

A Thesis Submitted to the Faculty of the Graduate School  
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## VITA

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## INTRODUCTION

The question of whether responses mediated by the autonomic nervous system may be modified through operant conditioning has claimed the attention of researchers for many years. Most early investigators believed that autonomic responses are not subject to operant conditioning (Kimble, 1961; Miller & Konorski, 1928, cited in Kimmel, 1974; Skinner, 1953). This belief was challenged by Miller (1969), whose work with animals suggested that the conditioning of visceral responses was possible. Recent research has also suggested that humans may learn to control physiological processes under the control of the autonomic nervous system when they are given feedback about these processes (see Kimmel, 1974).

In such research with human subjects, individuals are presented with biofeedback indicating changes in a specific autonomic response. The biofeedback may be presented visually or auditorily and may be either binary or proportional. Binary feedback provides information as to whether or not subjects have produced a change in the specific response beyond a criterion level, but gives no information regarding the magnitude of the change. For example, a tone may sound or a light may go on when the subject has exceeded a criterion. Proportional feedback

provides information regarding the magnitude of change in the response, as well as information about whether a criterion has been met. For example, subjects may view a meter indicating various levels of the response, in which the pointer continuously moves to show the current level. Using these techniques, studies have shown that individuals can learn to control responses such as heart rate, blood pressure, muscle potentials, and vasomotor activity. These demonstrations have led to the use of such procedures in the treatment of psychological, psychosomatic, and physiological disorders (see Blanchard & Young, 1974; Shapiro & Schwartz, 1972; Winer, 1977).

Heart rate is one autonomic response which has received considerable attention in biofeedback research. Many early studies demonstrated that individuals can increase or decrease heart rate when they are provided with feedback indicating heart rate performance (Brener & Hothersall, 1966, 1967; Engel & Chism, 1967; Engel & Hansen, 1966; Levene, Engel, & Pearson, 1968). While the magnitude of change reported in these studies was small, later research has shown that subjects may produce large magnitude heart rate accelerations or decelerations after participation in many training sessions (Headrick, Feather, & Wells, 1971; Stephens, Harris, & Brady, 1972; Wells, 1973).

While all of these researchers reported that sub-



jects exhibited significant control of heart rate, the majority of the studies did not utilize control groups (Brener & Hothersall, 1966, 1967; Headrick et al., 1971; Levene et al., 1968; Stephens et al., 1972; Wells, 1973). The two studies which did include control groups used yoked controls (Engel & Chism, 1967; Engel & Hansen, 1966). Each control subject received the same feedback as was provided to an experimental subject, so that they were actually receiving false feedback regarding their own performance. This may have interfered with their performance so that the comparison of experimental subjects and yoked controls yielded spuriously large effects. Therefore, it is not possible to determine whether the reported changes in heart rate were actually due to the provision of feedback, or whether they were the result of some other aspect of the experimental situation, such as instructional set.

Because of their failure to include sufficient controls, these early studies leave a number of questions regarding the use of heart rate biofeedback unanswered. First, there is the question of whether the provision of biofeedback is actually a necessary prerequisite for learning to control heart rate. The relative contributions of feedback and instructions for learning self-control are still unclear. Many later studies have tried to determine whether the provision of instructions and feedback leads

to a greater ability to increase or decrease heart rate than the provision of instructions alone, but the results have not provided definitive answers. Another question relating to the effects of instructions is whether subjects should be informed of the nature of the response which they are to control. Some of the early researchers informed their subjects, while others did not. The effect of knowledge of the target response has been examined in later studies, but without conclusive findings. A third question regarding the use of biofeedback techniques is whether subjects can transfer the self-control acquired during the provision of feedback to situations in which feedback is no longer available. This has particular importance for the use of biofeedback techniques as clinical procedures. The generalizability of learned self-control has been examined in only a few recent studies.

This thesis examined the effects of biofeedback and of knowledge of the specific response to be controlled on learning voluntary heart rate acceleration. The ability to transfer the self-control acquired with the provision of feedback to a condition in which feedback was not available was also examined.

## REVIEW OF RELATED LITERATURE

### Feedback and Instructional Effects

Many early studies demonstrated that subjects can control cardiac functions when they are provided with feedback on their performance. These researchers assumed that feedback was a prerequisite to learning self-control of heart rate. However, since the effects of feedback and instructions were confounded in these studies, it is not possible to determine whether feedback is actually necessary for learning voluntary control or whether individuals have the ability to exert such control without the provision of feedback.

Evidence that heart rate control may occur without feedback was presented as early as 1885, when Tarchanoff (1973) described his studies with individuals who were able to voluntarily produce large magnitude heart rate accelerations. Two of the early biofeedback studies also suggested that subjects may be able to increase heart rate without feedback. Brener and Hothersall (1966) and Stephens et al. (1972) reported that subjects could immediately increase heart rate on the first trial. More recently, researchers have systematically examined the assumption that feedback is necessary for the control of heart rate.

The first two studies which examined this assumption used subjects who were instructed to increase and decrease heart rate without the provision of feedback. Brener, Kleinman, and Goesling (1969) conducted a one session study in which subjects were instructed to increase and decrease heart rate in response to two different stimuli. They found significant differences between mean heart rate on increase and decrease trials for these subjects who did not receive feedback. The mean difference ranged from one to three beats per minute. However, Brener et al. did not assess the magnitude of heart rate change in either direction, as compared to resting rates or to a noninstructed control group.

Bergman and Johnson (1971) studied female subjects for one session. One group received instructions to increase heart rate, one group received instructions to decrease heart rate, and a third group received no instructions but served as a control for the effects of adaptation and of the stimuli signaling the trials. Bergman and Johnson found that subjects instructed to increase had significantly higher heart rates than the control group, while subjects who received decrease instructions showed significantly lower rates than the controls. These results were replicated for heart rate acceleration but not for deceleration.

These studies suggest that individuals may volun-

tarily control heart rate when they are instructed to do so, without biofeedback. However, neither study used a condition in which feedback was provided, so it is not possible to determine whether the magnitude of heart rate change would have been greater if both feedback and instructions were available. Brener et al. (1969) stated that the magnitude of heart rate change for their subjects was less than had been reported in studies which utilized feedback.

Other studies have reported findings concerning the effects of feedback with subjects who participated in both feedback and no feedback conditions. Ray (1974), Stephens, Harris, Brady, and Schaffer (1975), Colgan (1977), and Haynes, Blanchard, and Young (1977) all found that subjects could increase and/or decrease heart rate when they were instructed to do so prior to the provision of feedback, but the subsequent provision of feedback led to a greater magnitude of heart rate change. Blanchard, Young, Scott, and Haynes (1974) compared interspersed feedback and no feedback trials of heart rate acceleration and also found that feedback led to consistently greater heart rate increases. However, Levenson (1976) found no effect of feedback for either heart rate acceleration or deceleration in a comparison of prefeedback and feedback trials, while Bell and Schwartz (1975) found that the provision of feedback led to greater heart rate decreases but not increases.

All of these studies concur with the findings of Brener et al. (1969) and Bergman and Johnson (1971) that subjects are able to increase heart rate without feedback, and all but one (Bell & Schwartz, 1975) report that subjects are able to decrease heart rate without feedback. Therefore, feedback does not seem to be necessary in order for informed subjects to learn the response of heart rate acceleration or deceleration. Most of these studies do suggest that feedback may enhance control of heart rate. However, these studies do not provide a clear examination of the effects of feedback due to their use of within subject designs. When no feedback trials are presented prior to the provision of feedback, the effects of experience and practice are confounded with the effects of feedback. Furthermore, when no feedback trials are presented in between feedback trials, the researchers may be measuring generalization of a feedback effect, rather than obtaining a pure measure of the ability to control heart rate without feedback.

A more appropriate method of examining the effects of feedback is through the comparison of a group of subjects who receive feedback with a group that does not receive feedback, with both groups participating in all phases of the experiment. Many researchers have utilized a no feedback control group.

One group of studies was conducted by Blanchard and his associates. Blanchard and Young (1972), Young and Blanchard (1974), and Blanchard, Scott, Young, and Haynes (1974) examined the relative efficacy of various types of feedback and utilized no feedback control groups. Both male and female subjects were used, and the number of sessions ranged from two to eight in the different studies. Experimental subjects were instructed to increase and decrease heart rate in response to two stimuli. Proportional and binary, visual and auditory feedback were utilized in various sequences and combinations. Trial heart rate was compared with heart rate during each pretrial rest period, and all of these studies found that proportional feedback groups showed significantly greater heart rate increases than no feedback groups. The provision of auditory binary feedback also led to a greater ability to increase heart rate (Young & Blanchard, 1974), while the provision of visual binary feedback did not (Blanchard, Scott, Young, & Haynes, 1974). No form of feedback had any effect on the ability to decrease heart rate. Blanchard and Young (1972) reported that the mean heart rate increase was 4.1 beats per minute greater for the feedback groups than for the no feedback control, while the mean difference for heart rate decreases was 1.1 beats per minute.

Another study by Blanchard and his associates examined both the effects of feedback and of knowledge of the

target response (Blanchard, Scott, Young, & Edmundson, 1974). The results concerning the effects of feedback will be the focus here, and the results concerning awareness of the response will be discussed in a later section of this review. As part of this study, Blanchard et al. compared a group of subjects who were instructed to increase and decrease heart rate and received visual proportional feedback with a group who received the same instructions but no feedback. Trial heart rate was compared with pretrial resting rates, and the feedback group was found to produce significantly greater heart rate acceleration on increase trials than the no feedback group during the two sessions of the study. For heart rate deceleration, the feedback group produced significantly larger decreases than the no feedback group during the first session, but not during the second session.

All of the studies by Blanchard and his associates found that the provision of feedback significantly affected heart rate acceleration, while it had little or no effect on heart rate deceleration. However, a number of other studies have found no effect of feedback on either the ability to increase or to decrease heart rate.

Manuck, Levenson, Hinrichsen, and Gryll (1975) studied male and female subjects for one session. All subjects were instructed to increase and decrease heart rate in response to two stimuli, and three groups of



subjects received various forms of binary or proportional feedback while one group received no feedback. When trial heart rate was compared to resting rates, all subjects were found to be able to increase and decrease heart rate. Feedback had no effect on either the magnitude or consistency of heart rate acceleration or deceleration.

Levenson (1976) studied male and female subjects who participated in one session of heart rate increase and decrease trials. All subjects were informed of the target responses, and two groups received visual proportional feedback while one group did not receive feedback. Levenson also found significant increases and decreases in heart rate relative to resting rates for all subjects, while feedback did not affect the magnitude or consistency of heart rate acceleration or deceleration.

Holmes, Frost, and Bennett (1977) conducted a one session study with male and female subjects. One group was instructed to increase heart rate and one group was instructed to decrease heart rate. Half of each group received visual proportional feedback, while the other half did not receive feedback. When heart rate on the final trial was compared to baseline heart rate, feedback was not found to be more effective than instructions alone for either heart rate acceleration or deceleration.

In a study of the effects of instructions, strategy suggestions, and feedback, Lacroix (1977) used three

sessions of heart rate increase and decrease training. The results indicated that instructions to control heart rate were sufficient to generate reliable bidirectional heart rate differences, while feedback had no significant effect on performance.

Bouchard and Granger (1977) examined heart rate deceleration. Male and female subjects participated in two experimental sessions. All subjects were instructed to produce heart rate decreases, and one group also received visual binary feedback while the other group was not provided with feedback. No differences between these groups were found. The mean decrease in heart rate from pretrial resting rates was less than one beat per minute for both groups.

Two other studies examined both the effects of feedback and of knowledge of the target response. Again, only the effects of feedback will be considered here.

Bergman and Johnson (1972) studied heart rate acceleration with female subjects who participated in one experimental session. Some subjects received instructions to increase heart rate and visual binary feedback, while others received increase instructions alone. The provision of feedback had no effect on the ability to increase heart rate. Johns (1970) studied female subjects for one experimental session under conditions of paced respiration. Subjects were instructed to increase and decrease heart rate in

response to two stimuli, and one group also received auditory binary feedback, while another group did not receive feedback. Using the change from preexperimental heart rate levels, Johns found that the provision of feedback produced an overall increase in heart rate throughout all phases of the session, but did not affect the difference in performance between increase and decrease trials.

A number of other studies have also examined the effect of feedback through a comparison with no feedback controls, but have included additional control groups in their studies. The additional controls have either been instructed to sit and rest throughout the experimental sessions or have been presented with feedback displays and instructed to monitor them. The first type of control group (adaptation control) is used to assess the effect of habituation, in order to determine whether the changes found in the heart rates of experimental subjects are any greater than what would result from rest alone. This is particularly important in the assessment of heart rate deceleration. The second type of control group (tracking control) is used to assess the effects of habituation and of attention to a stimulus.

Two studies by one group of researchers (Bennett, Holmes, & Frost, in press; White, Holmes, & Bennett, 1977) compared groups instructed to increase heart rate, groups instructed to decrease heart rate, and adaptation control

groups. Some of the subjects in each experimental group received visual proportional feedback, while others received no feedback. Each study consisted of one session and male and female subjects were used. Using analyses of residualized heart rate scores, both studies found that feedback had no effect on the ability to decrease heart rate and that none of the instructed subjects showed greater deceleration than the adaptation controls. For heart rate acceleration, all instructed subjects were found to exhibit significant heart rate increases as compared to the adaptation controls, but the provision of feedback had no effect on heart rate. It should be noted that increase instructions with or without feedback did not lead to an actual increase in heart rate relative to pretraining levels. Heart rate tended to decrease over the course of the session for all subjects, and the increase groups just showed less of a decline than the adaptation controls.

Another series of studies examined the effect of feedback on the ability to control heart rate with the use of adaptation control groups. Rupert and Holmes (1978) studied anxious male psychiatric patients. One group of subjects was instructed to increase heart rate and another group was instructed to decrease heart rate for four sessions. Some of the subjects in each group were provided with visual proportional feedback, while others did not receive feedback. Using residualized heart rate scores,

feedback was found to have no effect on the ability to decrease heart rate, and neither of the instructed groups showed greater deceleration than the adaptation control group. For heart rate acceleration, the feedback group produced significantly larger heart rate increases than either the no feedback group or the adaptation control group, who did not differ from each other. The mean increase for the feedback group was four beats per minute. Rupert and Schroeder (Note 1) also studied anxious male psychiatric patients. All subjects were instructed to increase heart rate for two sessions and to decrease heart rate for two sessions, and half of the subjects received visual proportional feedback while the others did not receive feedback. No differences were found between the feedback group, the no feedback group, and the adaptation control group for either heart rate acceleration or deceleration. No subjects increased heart rate relative to baseline levels, and while subjects were able to decrease heart rate from baseline levels this seemed to be due to the effects of adaptation.

Lott and Gatchel (1978) studied the effects of feedback with experimental subjects who were compared to a tracking control group. Male and female subjects participated in two experimental sessions, one in which they were instructed to increase heart rate, and one in which they received decrease heart rate instructions. Half of the

experimental subjects received visual proportional feedback, while the others received no feedback. Performance on training trials was compared to baseline levels, and both experimental groups were found to exhibit significant heart rate increases and decreases as compared to the tracking controls. The feedback and no feedback groups did not differ from each other on either heart rate acceleration or deceleration.

To summarize these results, all of the studies which compared instructed feedback and no feedback groups found that feedback had no greater effect on the ability to decrease heart rate than the provision of instructions alone. The few studies which included an adaptation control group also found that no subjects showed greater heart rate deceleration than subjects who merely sat and rested throughout the session (Bennett et al., in press; Rubert & Holmes, 1978; White et al., 1977; Rupert & Schroeder, Note 1). Therefore, the value of biofeedback techniques for teaching heart rate deceleration is highly questionable. The results regarding heart rate acceleration are not as consistent. A number of researchers have reported that the provision of feedback results in a greater magnitude of heart rate increase than is found with instructions alone (Blanchard, Scott, Young, & Edmundson, 1974; Blanchard, Scott, Young, & Haynes, 1974; Blanchard & Young, 1972; Rupert & Holmes, 1978; Young & Blanchard,

1974). However, the majority of the previously described studies reported no effect of feedback on heart rate acceleration (Bennett et al., in press; Bergman & Johnson, 1972; Holmes et al., 1977; Johns, 1970; Lacroix, 1977; Levenson, 1976; Lott & Gatchel, 1978; Manuck et al., 1975; White et al., 1977; Rupert & Schroeder, Note 1).

The conflicting results regarding the effect of feedback on the ability to increase heart rate can not be accounted for by the type of feedback provided, sex of subjects, or type of data analysis used. However, the amount of heart rate training which subjects received may provide a possible explanation for the differences in results. All of the studies which consisted of one session of increase training found no effect of feedback (Bennett et al., in press; Bergman & Johnson, 1972; Holmes et al., 1977; Johns, 1970; Levenson, 1976; Lott & Gatchel, 1978; Manuck et al., 1975; White et al., 1977), while five of the seven studies which utilized more than one session reported a significant feedback effect (Blanchard, Scott, Young, & Edmundson, 1974; Blanchard, Scott, Young & Haynes, 1974; Blanchard & Young, 1972; Rupert & Holmes, 1978; Young & Blanchard, 1974). Despite the problems in the studies which used a within subject design to examine the effects of feedback, it is worth noting that the amount of heart rate training provided to subjects also seemed to influence the results. All of the within subject studies which used a number of training sessions reported a signif-

icant effect of feedback for heart rate acceleration (Blanchard, Young, Scott, & Haynes, 1974; Colgan, 1977; Haynes et al., 1977; Stephens et al., 1974), while only one of the studies which utilized one session found a feedback effect (Ray, 1974). Instructions may be the most important component of early heart rate training, while feedback facilitates the ability to produce large heart rate increases only after additional training.

#### Knowledge of the Target Response

Another question relating to the effect of the instructions used in biofeedback techniques is whether subjects should be informed of the nature of the response which they are to control. Some researchers routinely inform their subjects, while others do not. The difference of opinion concerning whether subjects should be informed stems from the early results of Engel and his associates (Blanchard & Young, 1973). Engel and Hansen (1966) reported a post hoc finding that the five subjects in their study who learned to decrease heart rate did not infer the nature of the response being conditioned, while four of the five nonlearners guessed the correct response. And in another study which used uninformed subjects, Levene, Engel, and Pearson (1968) reported that the two subjects who guessed that a cardiovascular response was involved had difficulty in learning to decrease heart rate.



These findings have been interpreted as indicating that knowledge of the response-reinforcement contingency causes poorer performance.

A number of researchers have reported significant control of heart rate in subjects who were not informed of the nature of the target response (Brener & Hothersall, 1966, 1967; Engel & Chism, 1967; Engel & Hansen, 1966; Levene et al., 1968; Shapiro, Tursky, & Schwartz, 1970). The type of feedback provided, sex of the subjects, number of experimental sessions, and type of data analysis varied from study to study. This research suggests that it is not necessary to inform subjects of the nature of the response which they are to control. However, most of these studies only compared performance between increase and decrease trials or between groups who received feedback for the production of either increases or decreases, without utilizing any comparison with resting rates. Therefore, it is not possible to assess the magnitude of heart rate change which occurred, and whether the reported differences were due to the ability to increase heart rate, decrease heart rate, or both. In addition, these studies either used yoked controls or did not use any control group, leading to further difficulties in interpreting the results.

Thus, while studies have reported successful heart rate training of uninformed subjects, they contain methodological problems. And the two studies which suggest that

knowledge of the target response may even result in a decrement in performance utilized post hoc findings. In order to determine whether informing subjects results in a difference in heart rate performance, informed and uninformed groups which are composed on an a priori basis should be compared. A number of studies have done so.

McCanne and Sandman (1976) studied male and female subjects, half of whom were instructed to produce heart rate accelerations and decelerations in response to two different stimuli. The other half were told only that two different physiological responses were to be produced during the stimulus presentations. Subjects participated in one experimental session and all received visual binary feedback. Informed subjects were found to produce significant heart rate increases during increase periods and significant heart rate decreases during decrease periods, when trial heart rate was compared with pretrial resting rates. The mean increase was 2.4 beats per minute and the mean decrease was 1.1 beats per minute. Uninformed subjects showed heart rate deceleration during both increase and decrease periods. Thus, uninformed subjects were unable to learn to increase heart rate and the deceleration shown on decrease trials may have been solely the result of habituation.

Three other studies compared groups of informed and uninformed subjects and also examined the effect of the

provision of feedback. The results concerning the effect of feedback have been described previously. In their study of heart rate acceleration, Bergman and Johnson (1972) used female subjects who participated in one experimental session. One group of subjects was instructed to increase heart rate, a second group was instructed to increase heart rate and also heard their actual heart beats through earphones, and a third group was instructed to control an internal response. Half of each group received binary visual feedback and half received no feedback. Both of the informed groups showed significantly higher heart rates on training trials than did the uninformed group, whether or not feedback was provided. The uninformed group was unable to increase heart rate.

Johns (1970) also studied female subjects for one experimental session. One group of subjects was instructed to increase and decrease heart rate in response to two stimuli, while the other group was not instructed to modify their heart rate. Half of each group received auditory binary feedback and half received no feedback. Johns examined the change in heart rate from baseline to trial levels, and found that all of the informed subjects showed a significant difference in heart rate change on increase and decrease trials. The uninformed subjects could not increase or decrease heart rate, whether or not they received feedback.

Blanchard, Scott, Young, and Edmundson (1974) compared Uninformed Feedback, Misinformed Feedback, Informed Feedback, and Informed No Feedback groups who participated in two experimental sessions. The uninformed subjects were instructed to increase and decrease an internal response, the misinformed subjects were instructed to increase and decrease skin resistance, and the informed groups were told to increase and decrease heart rate. Both male and female subjects were used, and feedback groups received visual proportional feedback. Trial heart rate was compared to heart rate during pretrial rest periods. The Informed Feedback group was found to show significantly greater heart rate deceleration on decrease trials than the Uninformed Feedback group. However, knowledge that heart rate was the target response had no effect on heart rate acceleration.

Thus, the studies which directly compared groups of informed and uninformed subjects all reported that awareness of the target response led to a greater ability to decrease heart rate. However, conflicting results were found regarding heart rate acceleration. Three of the studies reported that informed subjects showed significantly better performance than uninformed subjects on heart rate increase tasks (Bergman & Johnson, 1972; Johns, 1970; McCanne & Sandman, 1976), while the other study reported no difference between these groups (Blanchard,

Scott, Young, & Edmundson, 1974). These conflicting results may be due to differences in the specific instructions used, the type of feedback provided, or the number of sessions in each study. In terms of differences in instructions, in the first three studies the informed group was instructed to increase and/or decrease heart rate, while the uninformed group was told to "control" an internal response. Thus, the informed group was told the nature of the response and the appropriate direction of change, while the uninformed group did not receive either piece of information. In the study by Blanchard et al., both the informed and the uninformed groups were told the direction of change, and differed only in the knowledge of the specific response involved. Thus, the superior performance of the informed groups in the first three studies may have been due to the instructions to "increase," rather than to the effect of awareness of the specific response involved. Differences in results may also stem from the fact that Blanchard et al. used proportional feedback while the other studies used binary feedback, or from the fact that this study utilized two experimental sessions while the other studies consisted of one session each.

#### Generalization of Learned Heart Rate Control

An important question regarding the effectiveness

of biofeedback techniques is whether subjects who are trained to control heart rate with feedback can continue to do so after feedback is withdrawn. The maintenance of control is essential for the clinical use of biofeedback, since individuals must be able to transfer the acquired self-control from the clinic to an environment where feedback is no longer available. In order to assess the effectiveness of heart rate biofeedback, it is necessary to determine whether subjects who have undergone prior feedback training show greater heart rate control without feedback than subjects who received the same instructions but were never provided with feedback.

Many researchers have found that subjects who received instructions to control heart rate and biofeedback continued to show heart rate changes after feedback was withdrawn or on interspersed no feedback trials or sessions (Bell & Schwartz, 1975; Blanchard, Haynes, Young, & Scott, 1977; Blanchard, Young, Scott, & Haynes, 1974; Colgan, 1977; Haynes et al., 1977; Lang & Twentyman, 1974; Wells, 1973). However, these studies did not compare the performance of their subjects with that of instructed subjects who had never received feedback.

Brener, Kleinman, and Goesling (1969) did compare the performance of groups who received feedback with a no feedback control group on trials during which none of the subjects received feedback. Subjects participated in two

sessions consisting of increase and decrease trials. During three blocks of trials in each session, no subjects received feedback. During the rest of the session, one group of subjects received proportional auditory feedback on 100 percent of the trials, one group received such feedback on 50 percent of the trials, and a third group received no feedback. All subjects were informed of the target responses. The mean differences between increase and decrease trials during the three no feedback trial blocks in each session were analyzed, and the 100 percent feedback group was found to exhibit significantly greater control of heart rate than the no feedback group. The performance of the 50 percent feedback group fell between that of the other two groups, but did not differ significantly from either one. The mean difference between increase and decrease trials was two to three beats per minute greater for the 100 percent feedback group than for the no feedback group. Scores were not analyzed relative to resting rates, so it is not possible to determine whether the reported differences between the groups were due to differences in the ability to increase heart rate, to decrease heart rate, or both.

Of those studies which reported a significant difference between feedback and no feedback groups during training trials, only one utilized a subsequent phase in which no subjects received feedback. As was previously

reported, Rupert and Holmes (1978) found that subjects who received feedback showed significant heart rate increases as compared to a no feedback group and to an adaptation control group. However, when feedback was withdrawn, these subjects could not produce greater heart rate acceleration than either of these other groups.

Thus, only two studies utilized no feedback control groups to examine the generalization of learned heart rate control, and they reported conflicting results. Brener et al. (1969) found that the prior provision of feedback led to a greater ability to control heart rate without feedback. However, this was only demonstrated for relatively brief trial periods which were presented in between training trials, and it is not clear whether subjects could increase heart rate, decrease heart rate, or both. Rupert and Holmes (1978) found that subjects could not maintain their heart rate increases when feedback was withdrawn after training trials. Thus, no conclusions can be drawn regarding the ability to generalize heart rate control exhibited during biofeedback training.

### Conclusions

The previously reported studies which examined the effects of feedback and of knowledge of the target response have yielded consistent findings regarding heart rate deceleration. All of the studies which utilized appropriate



comparison groups found that information regarding the response being conditioned led to a greater ability to decrease heart rate, while the provision of feedback had little or no effect on heart rate deceleration for informed subjects. However, no clear conclusions can be drawn regarding heart rate acceleration. Conflicting results have been reported regarding both the effect of feedback and the effect of awareness of the target response on the ability to produce heart rate increases. Also, no conclusions can be reached regarding the ability to generalize heart rate control exhibited during the provision of feedback, due to the scarcity of studies in this area which utilized control groups.

#### Purpose of the Study and Hypotheses

This thesis examined the effects of biofeedback and knowledge of the specific response being conditioned on the self-control of heart rate acceleration. This study was a partial replication of the study by Blanchard, Scott, Young, and Edmundson (1974) which examined both of these factors. Informed No Feedback, Informed Feedback, and Uninformed Feedback groups were used in the current study. Blanchard's design was extended through the addition of a Transfer phase during which no subjects received feedback, in order to determine whether any differential effects of feedback

could be sustained once feedback was withdrawn. Two experimental sessions were again conducted in order to determine whether the facilitory effects of feedback become apparent only after increased training.

Based on an examination of previous research, biofeedback and knowledge of the response are hypothesized to affect the learning and generalization of heart rate acceleration in the following manner.

Hypothesis 1). Knowledge of the target response is the most important element in early heart rate training. Subjects who are not informed must learn by trial and error to use cognitions which informed subjects may immediately draw upon. The provision of feedback has little effect during this beginning stage. Thus, in the current study it is predicted that both Informed groups will show significantly higher heart rates than the Uninformed Feedback group during the Acquisition phase of the first experimental session. The performance of the Informed Feedback and Informed No Feedback groups will not differ.

Hypothesis 2). Feedback affects the magnitude of heart rate acceleration only after a greater amount of training. Subjects require an extended period in order to utilize the information provided by feedback regarding which response strategies are actually effective. Thus, in the current study, subjects in the Informed Feedback and Uninformed Feedback groups will show significantly higher

heart rates during the Acquisition phase of the second session than during the Acquisition phase of the first session. No major differences between sessions are predicted for the Informed No Feedback subjects. In addition, due to the improvement in performance of feedback groups after increased training, it is predicted that the Informed Feedback group will show significantly higher heart rates than the Informed No Feedback group during the Acquisition phase of the second session. The performance of the Informed No Feedback and Uninformed Feedback subjects will not differ.

Hypothesis 3). Subjects who have received feedback are able to generalize their learned heart rate control to a condition in which feedback is not available. Thus, the same differences in performance among the three groups are predicted for the Transfer phase as for the Acquisition phase. During the Transfer phase of the first session, the Informed Feedback and Informed No Feedback groups will show significantly higher heart rates than the Uninformed Feedback group, but will not differ from each other. During the Transfer phase of the second session, the Informed Feedback group will show significantly higher heart rates than the Informed No Feedback group, while the Informed No Feedback and Uninformed Feedback subjects will not differ.

No specific predictions are made regarding changes in performance across the trials within each session. Differences across trials will be examined in order to determine whether a learning curve occurs for all subjects and to assess when differences between groups begin to emerge.

## METHOD

### Subjects

Subjects were eighteen female undergraduate and graduate students, who volunteered to participate in this study. All subjects reported that they were in good health and were not taking any medications. Subjects were randomly assigned to the Informed No Feedback, Informed Feedback, and Uninformed Feedback conditions. Three uninformed subjects guessed that heart rate was the response being conditioned and were removed from the experiment. Thus, data from fifteen subjects were used in the analyses, with five subjects in each experimental group.

### Apparatus

Heart rate was detected with two silver cup electrodes attached to the right collar bone and the fourth intercostal space on the left side. A ground electrode was attached to the left earlobe. Each subject's electrocardiogram (EKG) was recorded on a Grass Model 5 polygraph, which was located in a control room adjacent to the experimental room and could not be seen by the subject. In addition, photoelectric plethysmographic transducers were attached to the forehead and right middle finger of each subject, and a standard blood pressure cuff was placed on

each subject's right arm. These additional response systems were monitored so that the actual response being conditioned would not be readily apparent to the uninformed subjects. These additional data were not analyzed for the present study.

An auxiliary biofeedback device which consisted of a Schmitt trigger level detector and a digital counter was constructed. This device detected the R spike of each EKG waveform from the output of the polygraph preamplifier, and counted the number of ventricular contractions which occurred during consecutive twenty second intervals. Feedback consisted of a numerical display every twenty seconds of the number of heart beats which had occurred during the previous twenty seconds. Thus, subjects in feedback conditions received numerical proportional feedback at fixed time intervals.

A panel containing a signal light and the feedback display was located in front of the subject. The feedback display was activated only during the Acquisition phase for subjects in the two feedback conditions.

### Procedure

Subjects were tested individually in an experimental room, separated from the control room which contained the physiological recording devices. Each subject was seated in a reclining chair with the signal light and

the feedback display directly in front of her. At the beginning of the first session, each subject was told that the purpose of this experiment was to examine the ways in which individuals could learn to control their internal physiological responses, and that specific instructions would be given to her later in the session. Electrodes, plethysmographic transducers, and the blood pressure cuff were then attached to each subject. At the beginning of each phase in the study, the experimenter entered the experimental room and gave specific instructions to the subject. The experimenter then returned to the control room and observed the subject through a one way mirror throughout the phase.

The first phase of the experiment consisted of a ten minute adaptation period, during which subjects were instructed to sit and rest. The signal light and the feedback display were activated during the last three minutes of the adaptation period for subjects in both feedback groups, in order to allow habituation to the stimuli and to record initial twenty second heart rate.

The second period of the experiment was the Acquisition phase. During this phase, subjects in the Informed No Feedback group were instructed to increase heart rate whenever the signal light was on and to just sit and rest when the light was off. The Informed Feedback group received the same instructions and were also told that they



would receive feedback in order to help them increase heart rate. They were told that a number would be displayed every twenty seconds while the signal light was on, and that as the number increased it meant that their hearts were beating faster. Each subject was told the number which corresponded to her current mean heart rate for a twenty second period and instructed to produce numbers higher than this initial level and as high as possible. Subjects in the Uninformed Feedback group were instructed to increase an internal response whenever the signal light was on and to rest when it was off, and were told that they would receive feedback in order to help them with their task. The feedback display was explained in the same manner, but they were told that the numbers corresponded to the level of an internal response. The feedback provided was of actual heart rate. All subjects were instructed to use only mental means of producing increases, and not to change their breathing rate, tense their muscles, or move around.

The Acquisition phase of the study consisted of eight two minute increase trials, during which the signal light was on. Each trial was preceded by a one minute rest period. Blood pressure was recorded during the fourth and eighth rest and trial periods.

The final period of the experiment was the Transfer phase. At the beginning of this phase, subjects were



told that the same procedure would continue, and Informed Feedback and Uninformed Feedback subjects were also told that they would no longer be provided with feedback. The Transfer phase consisted of four two minute trial periods, each preceded by a one minute rest period. Blood pressure was recorded during the final rest and trial periods.

All subjects participated in two experimental sessions held on two consecutive days at the same time of day. The same procedure was followed during each session. At the end of the second session, all subjects were questioned regarding the strategies they had employed to produce increases, and all uninformed subjects were asked to describe the response they had been trying to control. The design of the study was explained to all subjects following these inquiries and any questions they had were answered.

## RESULTS

### Data Reduction and Analyses

Heart rate for each subject during all artifact free epochs of each two minute trial period was directly measured from the EKG record, and expressed as mean number of beats per minute. Mean heart rate in beats per minute was also calculated for each subject for the sixth and seventh minutes of the first session adaptation period (the final two minutes of adaptation before the stimuli were presented). These heart rate scores were used in the following analyses.

Initial levels of heart rate have been found to influence the magnitude of subsequent heart rate responses (i.e., the "law of initial values"; Lacey, 1956; Wilder, 1962). Therefore, analyses of covariance were used, in order to control the influence of subjects' initial levels of heart rate on their trial heart rate scores (Benjamin, 1967; Cronbach & Furby, 1970). Mean heart rate for each subject on each trial was the dependent variable in the following analyses, and mean heart rate for each subject during the initial adaptation period was the covariate.

Two analyses of covariance were computed. The first was a 3 (Groups) X 2 (Sessions) X 8 (Acquisition Trials nested within Sessions) analysis with repeated

measures over the last two factors. The second was a 3 (Groups) X 2 (Sessions) X 4 (Transfer Trials nested within Sessions) analysis of covariance with repeated measures over the last two factors. Orthogonal planned comparisons of both Informed groups versus the Uninformed group and of the Informed Feedback and Informed No Feedback groups were also used.

### Acquisition Phase

The 3 X 2 X 8 analysis of covariance on heart rate during the Acquisition trials revealed a trend towards a difference in heart rates among the three groups of subjects,  $F(2,11) = 3.66$ ,  $p < .06$ . The mean heart rate scores for each group during the Acquisition trials of each session are presented in Table 1. A planned comparison indicated that the Informed Feedback and Informed No Feedback groups exhibited higher mean heart rates on Acquisition trials than the Uninformed group, after adjustment for the covariate,  $F(1,11) = 6.88$ ,  $p < .05$ . No differences were found in a planned comparison of the Informed Feedback and Informed No Feedback groups. Thus, knowledge of the specific response to be controlled led to a greater ability to increase heart rate. However, the provision of feedback did not affect heart rate performance.

A near significant Groups X Sessions interaction was also found,  $F(2,12) = 2.93$ ,  $p < .09$ , indicating that

Table 1  
Mean Heart Rates of Experimental Groups

Group	Initial Heart Rate	Session 1		Session 2	
		Acquisition	Transfer	Acquisition	Transfer
Informed No Feedback	73.90	72.78	70.55	75.28	74.15
Informed Feedback	77.00	77.17	75.52	77.65	75.37
Uninformed Feedback	74.70	72.98	70.40	69.26	67.90

the different experimental conditions tended to affect the patterns of performance between the two sessions. Inspection of the means indicated that the Informed No Feedback group exhibited a higher mean heart rate on Acquisition trials during the second session than during the first session, the Uninformed Feedback group showed a lower mean heart rate during Session 2, and the Informed Feedback group evidenced no difference in mean heart rate for the two sessions. Thus, the provision of feedback did not lead to better performance during the second session. Only the No Feedback subjects showed any increase in heart rate over the course of training.

One additional finding was a significant main effect for Trials within Sessions,  $F(14,168) = 3.59$ ,  $p < .01$ . Inspection of the data indicated that heart rate decreased from Trial 1 to Trial 8 of each session. This general decline in heart rate occurred for each group of subjects and seems to reflect adaptation to the experimental situation. The mean heart rate scores for each group on each Acquisition trial are presented in the Appendix.

### Transfer Phase

The 3 X 2 X 4 analysis of covariance on heart rate during the Transfer trials revealed a trend towards a difference in heart rates among the three groups of subjects,

$F(2,11) = 2.73$ ,  $p < .10$ . The mean heart rate scores for each group during the Transfer trials of each session are presented in Table 1. Planned comparisons indicated that the two Informed groups showed significantly higher mean heart rates than the Uninformed group during Transfer trials, after adjustment for the covariate,  $F(1,11) = 5.24$ ,  $p < .05$ . The Informed Feedback and Informed No Feedback groups did not differ significantly in performance. These results are consistent with the findings for the Acquisition phase. Information regarding the specific response to be controlled facilitated heart rate acceleration, while the prior provision of feedback had no effect.

No significant differences in Transfer trial heart rate between the two sessions or during the trials within each session were found for any group of subjects. The mean heart rate scores for each group on each Transfer trial are presented in the Appendix.

## DISCUSSION

This study examined the effects of biofeedback and knowledge of the specific response being conditioned on the learning and generalization of heart rate acceleration. It was hypothesized that knowledge of the target response would be the most important component of early training, whereas the provision of feedback would facilitate the production of heart rate increases only after a greater amount of training. It was also hypothesized that subjects who had received feedback would be able to maintain their heart rate control after feedback was withdrawn.

The results of this study supported the hypothesis concerning the early stages of heart rate training. During the Acquisition phase of the first session, the Informed Feedback and Informed No Feedback groups showed significantly higher heart rates than the Uninformed Feedback group, but did not differ from each other. Thus, in early training, instructions to increase heart rate facilitated the production of increases, whereas the provision of feedback did not. The prediction that feedback would facilitate heart rate acceleration during the latter stages of training was not supported. The performance of the feedback groups did not improve over the course of training, and during the Acquisition phase of the second session

the Informed Feedback and No Feedback groups continued to show significantly higher heart rates than the Uninformed group, but did not differ from one another.

The results found during the Transfer phase were consistent with those of the Acquisition phase. Information regarding the target response had a significant effect on heart rate performance, while the prior provision of feedback had no effect. It should be noted that the Transfer phase was included in the design of this study in order to determine whether any differential effects of feedback could be sustained when feedback was withdrawn. However, since no differences between feedback and no feedback groups were found even during the provision of feedback, the question of transfer of a feedback effect is no longer relevant.

The results of this study indicated that knowledge of the target response led to significantly better performance on tasks of heart rate acceleration. It should be stressed that this study, and all prior studies which utilized appropriate comparison groups, provided no support for the assumption that information regarding the response leads to a decrement in performance. The results of this study concur with the findings of McCanne and Sandman (1976), Bergman and Johnson (1972), and Johns (1970), but are not consistent with the results of Blanchard, Scott, Young, and Edmundson (1974) who found no



difference between Informed and Uninformed Feedback groups. It was suggested earlier that the differences between Blanchard's results and those of the other three previous studies may have been due to differences in the specific instructions used, the type of feedback provided, or the number of sessions in each study. The current study attempted to control these factors. Both this study and Blanchard's study used two sessions, proportional feedback, and instructions to the uninformed subjects regarding the appropriate direction of change. Yet these results still support the other previous research.

In terms of the effects of feedback, the results of this study indicated that the provision of biofeedback had no effect on learning to increase heart rate. These results are consistent with those of many other studies which found that the provision of feedback had no greater effect on heart rate acceleration than the provision of instructions alone (Bennett et al., in press; Bergman & Johnson, 1972; Holmes et al., 1977; Johns, 1970; Lacroix, 1977; Levenson, 1976; Lott & Gatchel, 1978; Manuck et al., 1975; White et al., 1977; Rupert & Schroeder, Note 1). A number of previous studies reported that the provision of feedback did lead to a greater magnitude of heart rate acceleration than instructions alone (Blanchard, Scott, Young, & Edmundson, 1974; Blanchard, Scott, Young, & Haynes, 1974; Blanchard & Young, 1972; Rupert & Holmes,

1978; Young & Blanchard, 1974). The suggestion that this was due to their use of a longer period of training was not supported by this study. The current feedback subjects showed no increase in the ability to accelerate heart rate over the course of training. In fact, only the No Feedback group showed any evidence of a learning curve.

Two uncommon features in the design of this study should be examined, in order to determine whether they may have influenced the failure to find a feedback effect. First, only female subjects were used in this study. Bergman and Johnson (1972) and Johns (1970) studied only female subjects, but the other studies in this area used groups of males or both sexes. So the possibility of sex differences in the ability to produce heart rate increases should be examined. Females were found to produce greater heart rate accelerations than males in one study (White et al., 1977), males were found to produce greater accelerations than females in another study (Young & Blanchard, 1972), and no sex differences were found in two other studies (Levenson, 1976; Manuck et al., 1975). Thus, no consistent sex differences have been reported across studies which examined this factor. Furthermore, there is no reason to believe that female subjects have a specific inability to utilize feedback while still being able to produce heart rate increases as the result of instructions.

The effect of the specific type of feedback which was used in this study should also be examined. Numerical proportional feedback which was presented at fixed time intervals was utilized. Numerical feedback has been used previously and has not been found to differ from other types of proportional feedback (Levenson, 1976; Manuck et al., 1975). The effect of fixed time feedback was examined in two previous studies. Twentyman and Lang (1977) found that the presentation of feedback at six second intervals led to greater heart rate acceleration than the presentation of feedback at each heart beat, and in an additional experiment found no difference between feedback presented at eight second and half second intervals. However, Gatchel (1974) found that the presentation of feedback at each interbeat interval led to greater heart rate increases than the presentation of feedback after intervals of five and ten beats. Thus, the effects of fixed time feedback are still unclear. It could be argued that a feedback effect would have emerged in this study if subjects had been presented with feedback at shorter time intervals. However, in response to this argument, it should be stressed that the finding of no effect of feedback is consistent with the results of many previous studies which utilized continuous proportional feedback (Bennett et al., in press; Holmes et al., 1977; Levenson, 1976; Lott &

Gatchel, 1978; Manuck et al., 1975; White et al., 1977; Rupert & Schroeder, Note 1).

The amount of heart rate acceleration produced by the current subjects may be assessed through a comparison of their heart rates during experimental trials with their preexperimental heart rates. During the Acquisition phase, the mean increase in heart rate from initial levels was less than one beat per minute for each of the Informed groups, while the mean heart rate change for the Uninformed subjects was a decrease of  $\bar{-}3.5$  beats per minute. During the Transfer phase, all groups showed a decrease in heart rate from initial levels. Both Informed groups showed a mean change of  $\bar{-}1.55$  beats per minute, while the Uninformed Feedback group had a mean change of  $\bar{-}2.88$  beats per minute. Thus, while the Informed groups showed better performance than the Uninformed group, they did not exhibit heart rate acceleration as compared to preexperimental levels. They just seem to have been able to reduce the general decline in heart rate which occurs with adaptation, while the Uninformed subjects could not do so.

The comparison of trial heart rate with initial levels provides a very conservative estimate of the ability to increase heart rate, since general heart rate levels decrease over the course of a session. In order to control for this decline in heart rate, many researchers have compared performance during trial periods with heart

rate during interspersed rest periods. This procedure has problems as well, because there is no way to be certain that resting heart rate is not affected by the preceding experimental conditions. In order to accurately determine whether any groups of subjects produce significant heart rate acceleration, either of two procedures seem more appropriate. The first is the use of an extended adaptation period, in order to be certain that subjects have reached baseline heart rate levels before the trials begin. The other procedure involves comparing the performance of experimental subjects with the performance of an adaptation control group who merely sit and rest throughout the session. Such a comparison controls for the general decline in heart rate across subjects. An adaptation control group was not included in this study, but it is recommended that this control be utilized in further studies of biofeedback. This will also serve to determine whether instructions to increase heart rate result only in an ability to reduce the effects of adaptation, as the current results and those of two previous studies suggest (Bennett et al., in press; White et al., 1977).

In summary, this study and many previous studies strongly suggest that the most important component of heart rate biofeedback training is the instructions given to subjects. Biofeedback per se does not seem to facilitate

learning the response of heart rate acceleration or even affect the magnitude of heart rate change.

Before concluding that heart rate biofeedback has no utility, two areas may warrant further research. The first area is the examination of whether heart rate biofeedback techniques are effective only with specific types of subjects. Personality factors may influence the ability to control heart rate, so that certain personality types are able to control heart rate at will, others are able to do so only with feedback training, and others are unable to do so at all. Whether cardiovascular changes are a subject's characteristic autonomic response to stress may also influence his or her ability to control heart rate. The effects of factors such as anxiety and motivation levels may also be examined.

Another direction for future research is to focus on the use of biofeedback techniques with the clinical populations who may be expected to benefit from such procedures. These individuals may need biofeedback in order to learn to control the autonomic responses which are involved in their disorders, even if the usual experimental subject, the healthy college student, does not.

## SUMMARY

This study examined the effects of biofeedback and knowledge of the response being conditioned on the learning and generalization of heart rate acceleration. The results indicated that specific instructions to increase heart rate had a significant effect on performance, whereas the provision of feedback did not affect heart rate acceleration. These results are consistent with those of the majority of the previous studies in this area which utilized appropriate control groups. No support was found for the hypothesis that information about the response is the most important component of early heart rate training, while feedback facilitates heart rate control after an increased amount of training. Subjects who received feedback showed no increase in the ability to accelerate heart rate over the course of two sessions.

Thus, this study provides no support for the assumption that feedback is necessary for learning the response of heart rate acceleration, or even facilitates the production of heart rate increases of larger magnitude. Instructions seem to be the most important component of heart rate biofeedback training, and the value of feedback for learning to control heart rate is questionable.

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#### REFERENCE NOTES

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## **APPENDIX**

# APPENDIX

## MEAN TRIAL HEART RATES OF EXPERIMENTAL GROUPS

	Groups		
	Informed No Feedback	Informed Feedback	Uninformed Feedback
Session 1			
Trials			
Initial Level	73.90	77.00	74.70
Acquisition			
1	74.00	78.80	76.40
2	73.80	78.30	75.40
3	73.00	79.70	74.50
4	72.90	75.10	71.70
5	72.40	77.00	71.70
6	71.20	76.60	71.90
7	72.40	76.60	71.70
8	72.50	75.30	70.50
Transfer			
1	70.90	74.80	72.20
2	71.20	76.00	70.40
3	70.00	74.40	70.10
4	70.10	76.90	68.90

	Groups		
	Informed No Feedback	Informed Feedback	Uninformed Feedback
Session 2			
Trials			
Acquisition			
1	75.50	78.80	69.60
2	77.10	77.90	69.30
3	76.50	79.20	69.10
4	73.80	75.50	69.10
5	74.90	78.30	70.70
6	74.90	77.40	68.00
7	74.50	78.00	70.00
8	75.00	76.10	68.30
Transfer			
1	75.70	75.60	69.40
2	73.30	75.10	68.40
3	74.40	74.60	67.50
4	73.20	76.20	66.30



APPROVAL SHEET

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

Date

4/19/79

Director's Signature

Alan S. De Wolfe