

ROLE OF FEEDBACK IN VOLUNTARY CONTROL OF HEART RATE

STEPHEN B. MANUCK
University of Virginia

ROBERT W. LEVENSON
Indiana University

JAMES J. HINRICHSEN AND STEVEN L. GRYLL
Vanderbilt University

Summary.—The relative effectiveness of biofeedback techniques on the voluntary control of heart rate was examined by randomly assigning 32 Ss to one of four feedback conditions in a bi-directional heart-rate control task: (1) no feedback, (2) binary feedback—S was signaled when an interbeat interval had changed in the correct direction, (3) "real-time," proportional feedback—S was provided information about the relative duration of successive interbeat intervals, and (4) numerical, proportional feedback—each interbeat interval was represented as a numeral indicating its relationship to pre-trial mean by direction and magnitude. Significant over-all heart-rate changes were evidenced for both increase and decrease directions, but no differences were found between the feedback conditions. While these data suggest that feedback may be a relatively insignificant factor in voluntary heart-rate control, it was recommended that further investigation examine the role of feedback within the context of other training, mediating and motivational variables.

The accumulating literature relating to the ability of human Ss to attain voluntary control of heart rate attributes much of the obtained cardiac control to the employment of heart-rate feedback techniques. These feedback procedures, which signal S when he is changing his heart rate in the instructed direction, have been utilized in studies of heart-rate increases (Bergman & Johnson, 1972; Blanchard, Young, Scott, & Haynes, 1974; Engel & Chism, 1967) and decreases (Engel & Hansen, 1966), as well as investigations of bi-directional changes (Blanchard & Young, 1972; Blanchard, Young, & McLeod, 1972; Brener & Hothersall, 1966, 1967; Brener, Kleinman, & Goesling, 1969; Headrick, Feather, & Wells, 1971; Lang & Twentyman, 1974; Levene, Engel, & Pearson, 1968; Levenson & Strupp, 1972; Levenson, 1974; Ray, 1974; Ray & Lamb, 1974; Stephens, Harris, & Brady, 1972). In general, these investigators have found that with appropriate response contingent feedback, human Ss can readily attain some degree of control over their heart rates. A theoretical extension of this conclusion within an information-theory framework would predict that Ss will attain a greater magnitude of heart-rate change when greater amounts of relevant information (feedback) are provided (Brener, *et al.*, 1969). For example, Lang and Twentyman (1974) have reported that an analog or proportional feedback procedure is superior to simple binary feedback in the production of heart-rate increases.

However, as Bergman and Johnson (1971) point out, experimenters have generally assumed that any obtained heart-rate changes can be attributed to the feedback manipulations, thus ignoring the possibility that Ss could produce suc-

cessful heart-rate control without feedback. Furthermore, these authors demonstrated significant increases and decreases when Ss were merely instructed to alter heart rate, suggesting that instructional sets, alone, can account for heart-rate changes. In a subsequent study, Bergman and Johnson (1972) found that heart-rate increases were no greater for Ss receiving feedback than for "no-feedback" controls. On the other hand, Blanchard and his associates (Blanchard & Young, 1972; Blanchard, *et al.*, 1974) and Ray (1974) have reported results indicating that feedback may facilitate heart-rate control, especially heart-rate increases, and in an investigation of bi-directional control, Brener, *et al.* (1969) concluded that increasing amounts of feedback produced greater heart-rate changes. Levenson and Strupp (1972), providing Ss with three levels of feedback (no feedback, heart-rate feedback, heart-rate plus respiration-rate feedback), found successful over-all heart-rate control but no significant differences between the three feedback conditions, implying that feedback had no significant effect on heart-rate control. This last result has recently been replicated under more protracted training conditions (Levenson, 1974). Thus, it appears that the current literature is ambiguous concerning the extent to which heart-rate changes in control tasks employing heart-rate contingent feedback can be attributed to the feedback procedures. Moreover, the diversity of feedback techniques, both in terms of modality, *i.e.*, visual or auditory, and level of information, *i.e.*, binary or proportional, further obscures the comparison of relevant studies.

The purpose of the present experiment was to investigate the role of feedback in voluntary heart-rate control by manipulating the level of information that Ss received as feedback. Accordingly, there were four feedback conditions: (1) no feedback, (2) binary feedback—S was signaled when an interbeat interval had changed in the instructed direction, (3) "real time," proportional feedback—S was provided information about the relative duration of successive interbeat intervals, and (4) numerical, proportional feedback—each interbeat interval was represented as a numeral indicating its relationship to pre-trial mean by direction and magnitude. Following Lang and Twentyman (1974), it was predicted that the "proportional" feedback procedures, which provide the greatest amount of information concerning heart-rate control, would yield larger heart-rate changes than the binary feedback condition. Likewise, it was predicted that the no-feedback condition would yield the smallest magnitude of heart-rate changes.

METHOD

Subjects

Ss (16 male, 16 female) were students in introductory psychology courses at Vanderbilt University. They received course credit for their participation.

Apparatus

Heart-rate data were recorded and analyzed on-line using a Grass Model 7

Length of Training

Effects of feedback may not become manifest in the initial stages of training, but require more extended practice, as suggested by Headrick, *et al.* (1971): Even though the extent of feedback-training in the present study was sufficient to show significant heart-rate changes, the typical single session design may simply be too short to provide an adequate test of the effects of feedback. This conclusion is supported by the fact that significant effects of feedback have usually been reported only in studies involving more than one experimental session (Blanchard & Young, 1972; Blanchard, *et al.*, 1974; Brener, *et al.*, 1969).

Concomitant Somatic Responses

While the question of respiratory or skeletal mediation of heart-rate control remains unresolved in the literature (Blanchard & Young, 1973), a consideration of this issue suggests a possible interaction between the effects of feedback and mediators, such that muscular and respiratory changes may be prepotent over feedback contingencies when somatic variables are not controlled. Reciprocally, feedback may contribute significantly to heart-rate changes only when the potential effects of the mediators have been minimized or eliminated.

Motivational Variables

A seldom studied factor within the heart-rate control paradigm involves motivational constraints and incentives operating on Ss. With respect to the present investigation, highly motivated Ss, e.g., those receiving performance-contingent monetary rewards, might have made greater use of the feedback than our Ss, who received course credit for their participation.

In summary, the foregoing results indicate the heart-rate-contingent feedback is not a necessary condition for voluntary heart-rate control. While these data also suggest that feedback may not facilitate heart-rate changes, either, it was argued that some effects of feedback might be demonstrated under conditions of increased sample size, protracted training, effective somatic restraint, or heightened motivation of Ss.

REFERENCES

- BERGMAN, J. S., & JOHNSON, H. J. The effects of instructional set and autonomic perception on cardiac control. *Psychophysiology*, 1971, 8, 180-190.
- BERGMAN, J. S., & JOHNSON, H. J. Sources of information which affect training and raising of heart rate. *Psychophysiology*, 1972, 9, 30-39.
- BLANCHARD, E. B., & YOUNG, L. D. Relative efficiency of visual and auditory feedback for self-control of heart rate. *Journal of General Psychology*, 1972, 87, 195-202.
- BLANCHARD, E. B., & YOUNG, L. D. Self-control of cardiac functioning: a promise as yet unfulfilled. *Psychological Bulletin*, 1973, 79, 145-163.
- BLANCHARD, E. B., YOUNG, L. D., & MCLEOD, P. G. Awareness of heart activity and self-control of heart rate. *Psychophysiology*, 1972, 9, 63-68.
- BLANCHARD, E. B., YOUNG, L. D., SCOTT, R. W., & HAYNES, M. R. Differential effects of feedback and reinforcement in voluntary acceleration of human heart rate. *Perceptual and Motor Skills*, 1974, 38, 683-691.

- BRENER, J., & HOTHERSALL, D. Heart rate control under conditions of augmented sensory feedback. *Psychophysiology*, 1966, 3, 23-28.
- BRENER, J., & HOTHERSALL, D. Paced respiration and heart rate control. *Psychophysiology*, 1967, 4, 1-6.
- BRENER, J., KLEINMAN, R. A., & GOESLING, W. J. The effects of different exposures to augmented sensory feedback on the control of heart rate. *Psychophysiology*, 1969, 5, 510-516.
- ENGEL, B. T., & CHISM, R. A. Operant conditioning of heart rate speeding. *Psychophysiology*, 1967, 4, 418-426.
- ENGEL, B. T., & HANSEN, S. P. Operant conditioning of heart rate slowing. *Psychophysiology*, 1966, 3, 176-187.
- HEADRICK, M. W., FEATHER, B. W., & WELLS, D. T. Unidirectional and large magnitude heart-rate changes with augmented sensory feedback. *Psychophysiology*, 1971, 8, 132-142.
- LANG, P. J., & TWENTYMAN, C. T. Learning to control heart rate; binary vs analog feedback. *Psychophysiology*, 1974, 11, 616-629.
- LEVENE, H. I., ENGEL, B. T., & PEARSON, J. A. Differential operant conditioning of heart rate. *Psychosomatic Medicine*, 1968, 30, 837-845.
- LEVENSON, R. W. Simultaneous heart rate and respiration rate feedback and the relationship of tidal volume to heart rate control. Unpublished doctoral dissertation, Vanderbilt Univer., 1974.
- LEVENSON, R. W., & STRUPP, H. H. Simultaneous feedback and control of heart rate and respiration rate. Presented at the Twelfth Annual Meeting of the Society for Psychophysiological Research, November, 1972.
- RAY, W. J. The relationship of locus of control, self-report measures, and feedback to the voluntary control of heart rate. *Psychophysiology*, 1974, 11, 527-534.
- RAY, W. J., & LAMB, S. B. Locus of control and the voluntary control of heart rate. *Psychosomatic Medicine*, 1974, 36, 180-182.
- STEPHENS, J. H., HARRIS, A. H., & BRADY, J. V. Large magnitude heart rate changes in subjects instructed to change their heart rate and given exteroceptive feedback. *Psychophysiology*, 1972, 9, 283-285.

Accepted February 10, 1975.