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ROLE OF FEEDBACK IN VOLUNTARY CONTROL OF HEART RATE

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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 successful heart-rate control without feedback. Furthermore, these authors demonstrated significant increases and decreases when *S*s 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 *S*s 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 *S*s 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 *S*s 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

*S*s (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 polygraph in conjunction with a Hewlett-Packard 2114A laboratory computer. In addition, the computer operated the three feedback displays: (1) For binary feedback, a signal light was illuminated whenever an interbeat interval deviated from pre-trial baseline mean by at least 30 msec. (2) For "real-time," proportional feedback, the first light of a string of 16 lights was illuminated 350 msec. after the onset of the first R-wave of a given trial. An additional light was illuminated every 60 msec. thereafter until the occurrence of the next R-wave, at which point the display blanked and the procedure started anew. In this manner the number of lights illuminated before blanking was proportional to the length of the interbeat interval. This system was previously utilized by Ray (1974). (3) For numerical, proportional feedback, a display of numerals "2" through "8" was operated such that "5" was equated with an interbeat interval within 30 msec. of the pre-trial baseline mean. Additional increases of 60 msec. in the interbeat interval were associated with successively lower numerals, while similar decreases caused successively higher numerals to light. Feedback of this nature (reported by Levenson & Strupp, 1972) provides *S* with information as to the directional and magnitudinal relationship between each interbeat interval and the baseline mean.

Procedure

Each *S* was scheduled for a 1-hr. session and was randomly assigned to one of the four conditions: (1) no feedback, (2) binary feedback, (3) "real-time," proportional feedback, and (4) numerical, proportional feedback. Following a ten-min. adaptation period, tape-recorded instructions were played corresponding to *S*'s feedback condition. Specifically, *Ss* were told that they were to attempt to increase or decrease their heart rates, as indicated by the instruction light on the feedback-display panel, on successive trials. Between trials, they were simply to relax quietly. *Ss* were instructed to use "mental" means only in changing their heart rates, and cautioned against changing their respiration or muscle tension. There were 12 heart-rate control trials which each lasted for 100 interbeat intervals (six increase and six decrease trials in randomized order). During the control trials, *Ss* received feedback or no feedback consistent with their assigned conditions. Baselines of 40 interbeat intervals were taken preceding each heart-rate control trial.

RESULTS

Mean interbeat intervals were calculated for all baseline and heart-rate control periods for each *S*. These data were subjected to a $4 \times 2 \times 6 \times 2$ (Feedback Condition $\times$ Direction $\times$ Trials $\times$ Periods, i.e., baseline or control) analysis of variance.

The Direction $\times$ Periods interaction ($F_{1,28} = 47.67$, $p < .001$) indicated that *Ss* were able to produce significant heart-rate changes across feedback conditions and trials. Planned comparisons between baseline and control period means showed that the heart-rate changes were significant in both the increase [$t_{28} = 3.03$, $p < .005$; $M\Delta = -25$ msec. ($+2.6$ bpm)] and decrease [$t_{28} = 3.15$, $p < .005$; $M\Delta = +27$ msec. (-2.6 bpm)] directions. However, the Feedback Condition $\times$ Direction $\times$ Periods interaction was not significant ($F < 1.00$), indicating that the magnitude of the obtained heart-rate changes did not vary as a function of the type of feedback *S*s received. Further, the lack of a significant Feedback Condition $\times$ Direction $\times$ Trials $\times$ Periods interaction indicated that *S*s in no group produced heart-rate changes of increasing magnitude as the experimental session progressed.

In order to investigate the consistency with which heart-rate changes were produced, the number of "correct" interbeat intervals (defined as a change, in the instructed direction, of at least 30 msec.) per trial were subjected to a $4 \times 2 \times 6$ (Feedback Condition $\times$ Direction $\times$ Trials) analysis of variance. No significant main effects or interactions were obtained, indicating that neither type of feedback nor length of training had an effect on the consistency with which *S*s produced heart-rate changes.

Although *S*s were not balanced by sex across feedback conditions, a separate analysis showed no over-all sex-related differences in the magnitude of heart-rate control in either the increase or decrease direction.

Discussion

The present findings, while demonstrating significant bi-directional heart-rate changes, do not support the hypothesis that feedback facilitates voluntary heart-rate control. Neither the predicted rank order of feedback conditions nor the general hypothesis that feedback groups would produce greater heart-rate control than *S*s receiving no feedback, received support from this investigation.[1] Thus, it may be speculated that the case for feedback assisted heart-rate control has been somewhat overstated in the recent literature. The interpretation and generalizability of these results, however, must be tempered by a number of methodological considerations.

Sample Size

With a between-*S*s design, as in the present study, a considerably larger sample size may be necessary to detect small differences in magnitude between feedback and no-feedback conditions. Of course, if very large numbers of *S*s are required to demonstrate a minimal effect of feedback, this too would tend to indicate the relative weakness of manipulations.

[1]It might be argued that *S*s in the no-feedback condition did receive some feedback of a covert nature via heart palpitations or pulsations in some part of the body. As feedback, however, this type of information would prove rather insensitive since *S*s would need to discriminate very small differences between successive interbeat intervals. In addition, *S*s in the present study did not report the presence or use of such "covert" feedback, although this possibility remains an unexplored hypothesis.

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 *S*s. With respect to the present investigation, highly motivated *S*s, e.g., those receiving performance-contingent monetary rewards, might have made greater use of the feedback than our *S*s, 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 *S*s.

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