EFFICACY OF PATTERN FEEDBACK FOR THE DISSOCIATION OF HEART RATE AND RESPIRATION RATE *

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The present study assessed the efficacy of pattern feedback for producing integrative and dissociative patterns of heart rate (HR) and respiration rate (RR). 60 uninformed subjects were assigned to six groups in which beat-by-beat feedback was contingent upon production of a specific pattern of increased (↑), decreased (↓), or unchanged (=) HR and RR during 11 feedback trials. Concomitant changes in respiratory volume and general activity (GA) were also recorded. Groups given feedback for HR and RR changes in the same directions (HR↑RR↑ and HR↓RR↓) and for changes in opposite directions (HR↑RR↓ and HR↓RR↑) were generally unable to produce the respective patterns, indicating that pattern feedback does not enable subjects to produce a wide range of HR–RR patterns. However, evidence of dissociation of HR and RR was obtained in the HR↑RR= and HR↓RR= groups in which HR changed significantly in the appropriate directions without significant changes in RR. These results are not consistent with the view that RR changes are necessary for HR control, although significant concomitant changes in respiratory volume and GA indicated that HR control was non-specific relative to these variables.

1. Introduction

The ability of subjects to alter heart rate (HR) with instructions and/or augmented sensory feedback has been amply demonstrated (Blanchard and Young, 1973). However, fundamental questions concerning central nervous system 'mediation' of HR control (summarized by Katkin and Murray, 1968) remain largely unresolved. HR control studies in which respiratory and somatic events were monitored but not experimentally manipulated have provided conflicting evidence concerning the role of somatic activity during HR control (McCanne and Sandman, 1976). However, research conducted in this laboratory has generally found consistent changes in respiration rate (RR), tidal volume (TV), and general somatic activity (GA) during directional HR control; these changes have taken the form of RR,

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TV and GA increases during HR increase trials and RR and GA decreases during HR decrease trials (Levenson, 1976; 1977).

Strategies for minimizing somatic concomitance during HR control have had limited success. These strategies have included instructional control of RR (e.g. Levenson, 1977), pacing RR[1] to an external timing stimulus (Brener and Hothersall, 1967), independent RR feedback (Levenson, 1976), and passively respiring subjects (VanDercar, Feldstein and Solomon, 1977). Thus, evidence supporting the viability of directly controlling respiratory changes during HR control has not been overly convincing.

An alternative approach to 'uncoupling' HR and respiratory activity can be derived from Schwartz's (1972) 'integration–differentiation' pattern feedback model. Schwartz found that subjects who were given feedback contingent upon patterns of systolic blood pressure (BP) and HR change showed some evidence of independent BP and HR control. Although the pattern feedback approach has been applied to other physiological responses (Schwartz, 1974; 1976), it has not been used to manipulate HR and respiratory relationships.

The purpose of the present experiment was to test the hypothesis that subjects could voluntarily dissociate HR and RR. Following Schwartz (1972), two groups of subjects were given pattern feedback contingent upon HR and RR changes in the same direction, and two groups received feedback for dissociative patterns involving HR and RR changes in opposite directions. In addition, two groups were given feedback contingent upon HR changes which were unaccompanied by changes in RR. Again following Schwartz (1972), subjects were not informed of the feedback contingencies. In this context, successful dissociation of HR and RR can be viewed as evidence against RR as a necessary concomitant of HR control. Conversely, failure to dissociate HR and RR would be consistent both with the view that RR changes are necessary for HR control and with the proposed relationship between cardiac and somatic events in relatively nonstressful experimental situations (Obrist, Howard, Lawler and Galosy, 1975).

2. Method

2.1. Subjects

30 male and 30 female undergraduate students participated in the experiment in partial fulfillment of introductory psychology course requirements.

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[1] Wells (1973) and Obrist, Howard, Lawler and Galosy (1975) have presented evidence of respiratory alternations during HR control despite the pacing procedure.

2.2. Apparatus

EKG was recorded on a Grass Model 7 Polygraph using Beckman surface electrodes in bipolar configuration. Respiratory data were obtained with a calibrated Grass PT5 Volumetric Transducer attached to a Bennet Type A facemask (with the nose securely clamped to insure mouth-breathing). The output of the pressure transducer was integrated with a Grass 7P10 Integrator to provide the respiratory volume measures. GA was measured using an electromagnetic coil attached to the subject chair to register slight bodily movements and amplified with a Grass 7P5 A–C Preamplifier.

HR, respiration and GA analog signals were routed from the polygraph to analog conversion channels on a PDP–11 minicomputer which processed and stored all dependent physiological measures on-line and controlled feedback of HR–RR patterns.

2.3. Feedback

Beat-by-beat pattern feedback was both auditory and visual. Feedback trials began when a 0 appeared on an illuminated digital display placed 5 ft in front of the subject at eye level. When the 'target response' (HR–RR pattern) occurred, a 1 appeared on the feedback display and a 600 Hz tone was sounded in the subject chamber. The number and the tone were presented only following beats on which both the inter-beat-interval (IBI) and the most recent inter-cycle-interval (ICI) met criteria, and the display returned to 0 when the criteria were not met. If the ICI criterion was met and the IBI exceeded criterion in the appropriate direction by more than 30 msec, a 2 appeared on the feedback display and the tone was sounded.

Feedback criteria were based upon traveling HR and RR means in order to track changes in baseline physiological activity while avoiding extreme criterion values based upon short baselines. For each trial, the feedback criteria consisted of the unweighted mean IBI and ICI of the five preceding trials. In addition, separate inspiration-to-inspiration and expiration-to-expiration ICI data were processed so that respiratory feedback could be updated at each inspiration and expiration. This reduced the delay between RR changes and pattern feedback update by 50% without basing feedback on less than a complete respiratory cycle.

2.4. Procedure

After electrodes were attached, subjects were given written instructions that their 'thoughts, feelings, and internal state' could activate the feedback display and produce a tone. They were informed that whenever a 0 appeared on the feedback display, they should try to make 1s and 2s appear and the tone come on. They were told that 2s indicated greater success than 1s but not to be discouraged

if they did not receive many 2s. In order to increase motivations, they were instructed that they would receive points for making the numbers come on.

Following the instructions, there was a 5-min adaptation period while subjects breathed through the facemask before the first baseline trial began. Subjects were then randomly assigned to six pattern feedback groups with the following contingencies: (1) HR↑RR↑, feedback contingent on both IBI and ICI shorter than respective traveling means; (2) HR↓RR↓, both IBI and ICI longer than traveling means; (3) HR↑RR↓, IBI shorter than mean and ICI longer; (4) HR↓RR↑, IBI longer than mean and ICI shorter; (5) HR↑RR=, IBI shorter than mean and ICI within 350 msec of mean; (6) HR↓RR=, IBI longer than mean and ICI 5 male and 5 female subjects were assigned to each group.

The experiment consisted of a series of baseline 'rest' (no feedback) trials of 40 heart-beat duration and pattern feedback trials of 80-beat length. Eight initial baseline trials were followed by an alternating series of 11 baseline and 11 pattern feedback trials such that a 40-beat baseline preceded each 80-beat feedback trial. After each feedback trial, points earned appeared on the feedback display for 15 sec.

2.5. Data analysis

Trial means for the following dependent measures were obtained: IBI (duration in msec between successive R-waves); ICI (duration in msec between successive points of maximum inspiratory flow); TV (average sum of inspiratory and expiratory volume per breath in litres of air); MV (minute volume—total respiratory volume during a trial divided by length of trial in minutes); and GA.

IBI and ICI data were analysed by multivariate analysis of variance (MANOVA). This analysis required averaging across the 11 repetitions of baseline and feedback trials, leaving a $6 \times 2 \times 2$ (group × sex × feedback or baseline trial) MANOVA. Groups were partitioned into pairs (HR↑RR↑ and HR↓RR↓; HR↑RR↓ and HR↓RR↑; and HR↑RR= and HR↓RR=) for planned comparisons.

All physiological dependent measures were submitted to separate analyses of variance (ANOVA). Data from the nine initial baseline trials were analyzed with 6×9 (group × trials) ANOVAs in order to check for baseline differences between groups prior to the first feedback trial. Analyses of the pre-trial baseline and feedback trial data were performed using $6 \times 2 \times 2 \times 11$ (group × sex of subject × feedback or baseline trial × trials) repeated-measures ANOVAs. Planned one-tailed *t*-test comparisons (Kirk, 1968) were performed in order to test hypotheses concerning physiological changes from baseline during feedback trials in each group. Unless otherwise indicated, the 0.05 level of significance was adopted for all statistical tests reported.

3. Results

3.1. Basal physiological activity

There were no significant baseline differences between groups of subjects for any of the dependent measures on the nine initial baseline trials. The absence of significant trials effects for these initial baselines indicates that subjects were fully adapted to the experimental environment prior to the first feedback trial. Males and females differed in basal levels of IBI, TV, MV and GA. Since there were no significant interactions with experimental variables involving the sex-of-subject factor on these measures, sex differences will not be reported further.

3.2. HR and RR

MANOVA revealed significant group × feedback or baseline trial interactions for the HR↑RR↑ and HR↓RR↓ comparison (Wilks $\lambda = 0.88$; $F(2, 47) = 3.30$, $p < 0.05$), and for the HR↑RR= and HR↓RR= comparison (Wilks $\lambda = 0.88$, $F(2, 47) = 3.27$, $p < 0.05$), indicating that overall changes from baseline in the manipulated variables were significant in these groups. The HR↑RR↓ and HR↓RR↑ comparison was not significant.

IBI trial means and IBI changes from pretrial baselines to feedback trials for each group are presented in table 1. A significant $[F(5, 48) = 3.4, p < 0.01]$ group × feedback or baseline trial interaction was obtained, indicating that HR change from baseline was affected by the group feedback contingencies. IBI changes from

Table 1
Mean feedback trial (FB) values and changes from baseline (BL)

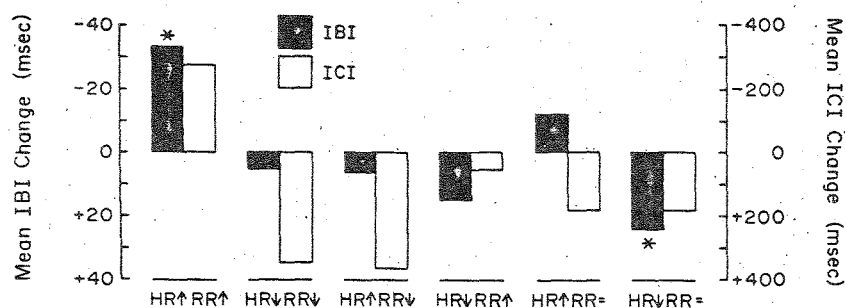| Group		IBI (msec)	ICI (msec)	TV (liters)	MV (liters)	GA
HR ↑ RR ↑	FB	792	3504	0.79	14.0	42
	FB−BL	−33 a)	−274	+0.04	+1.6	+14 a)
HR ↓ RR ↓	FB	828	4862	1.19	15.0	21
	FB−BL	+6	+347	+0.11	+0.1	−8 a)
HR ↑ RR ↓	FB	792	4612	0.98	13.0	21
	FB−BL	+7	+368	+0.01	−0.9	−4
HR ↓ RR ↑	FB	805	4095	1.03	15.0	22
	FB−BL	+15	+54	+0.07	+0.5	−12 a)
HR ↑ RR =	FB	761	4482	1.11	15.0	21
	FB−BL	−12	+184	+0.21 a)	+2.6	−5
HR ↓ RR =	FB	798	4324	0.98	14.0	19
	FB−BL	+24 a)	+179	−0.02	−0.9	−13 a)

a) $P < 0.05$.

Fig. 1. Mean IBI and ICI change from intermediate baselines across feedback trials (N = 10 per group; $p < 0.05$).

baseline for each group are depicted in fig. 1. Planned t-test comparisons revealed that HR increased significantly [$t(48) = 2.4$, $p < 0.01$] from baseline in the HR↑RR↑ group and decreased significantly [$t(48) = 1.8, p < 0.05$] in the HR↓RR= group. HR changes in the remaining four groups were not significant (see fig. 1).

Also presented in table 1 and fig. 1 are mean ICI changes from pretrial baselines across feedback trials for each group. There was no overall group feedback effect upon RR change as indicated by a non-significant [$F(5, 48) = 1.2$] group × feedback or baseline trial interaction. Confirming this result, t-test comparisons revealed no significant RR changes from baseline for any group.

3.3. Trials analysis of HR and RR data

Additional analyses were performed on HR and RR trial means in order to examine evidence of successful HR–RR integration and dissociation on individual trials. Pair-wise comparisons of feedback trials with the respective pre-trial baselines were made with the least significant difference (LSD) test (Kirk, 1968) to determine critical differences significant at the 0.05 level.

In terms of successful HR–RR integration, subjects in the HR↑RR↑ group significantly increased both HR and RR during four feedback trials. There was also one trial in which the HR↓RR↓ group was successful in decreasing both HR and RR on the same trial.

In terms of HR–RR dissociation, neither the HR↑RR↓ nor HR↓RR↑ groups were able to effect significant HR and RR changes in their target directions on any of the 11 feedback trials. There were six trials during which the HR↑RR↑ group actually increased HR significantly without significantly increasing RR. The HR↑RR= group successfully increased HR without significant RR change on five feedback trials. Finally, there were five trials in which the HR↓RR= group significantly decreased HR without significantly changing RR.

3.4. Tidal and minute volume

Differences between feedback and baseline means for TV and MV are presented in table 1. Nonsignificant group × feedback or baseline trial interactions for TV [$F(5, 48) = 1.0$] and MV [$F(5, 48) = 1.6$] indicated that there were no overall effects of the group feedback contingencies on these variables. Higher TV during feedback than baseline trials produced a significant [$F(1, 48) = 4.1, p < 0.05$] main effect for the feedback or baseline trial factor. Planned t-test comparisons revealed significant increases in TV [$t(48) = 2.4$, $p < 0.01$] and MV [$t(48) = 2.5, p < 0.01$] for the HR↑RR= group and a significant MV increase [$t(48) = 1.7, p < 0.05$] for the HR↑RR↑ group (see table 1).

3.5. General somatic activity

The group feedback contingencies had no overall effect upon GA, as indicated by a non-significant [$F(1, 48) = 1.10$] group × feedback or baseline trial interaction. Referring to table 1, GA significantly increased [$t(48) = 3.6, p < 0.001$] during feedback trials in HR↑RR↑ group, and decreased significantly in the HR↓RR↓ [$t(49) = -17, p < 0.05$], HR↓RR↑ [$t(48) = -2.8, p < 0.01$] and HR↓RR= [$t(48 = -3.0, p < 0.01$] groups.

4. Discussion

The results do not consistently support the hypothesis that subjects can voluntarily dissociate HR and RR with pattern feedback, although some confirming evidence was obtained. The two groups with feedback contingent upon HR change unaccompanied by changes in RR exhibited small magnitude HR changes in the target directions with non-significant RR decreases in both groups. Additional evidence of HR–RR dissociation was obtained in the HR↑RR↑ group which increased HR across feedback trials but (contrary to feedback contingency) failed to significantly change RR. The results for these groups indicate some degree of specificity of HR change relative to RR, and are not consistent with the necessity of RR change for successful HR control. These results also represent greater freedom from RR concomitance during HR control than data from previous research conducted in this laboratory (e.g. Levenson, 1976).

In contrast, subjects in the HR↑RR↓ and HR↓RR↑ groups were unable to consistently change HR and RR in opposite directions either across trials or on individual trials. Poor performance for these groups may be interpreted as reflecting constraints on the malleability of HR–RR relationships, and lends support to the model of cardiac-somatic interaction proposed by Obrist, Webb, Sutterer and Howard (1970).

Taken as a whole, the results do not support the efficacy of pattern feedback for

enabling subjects to generate a wide range of HR–RR patterns. The 'integration' (HR↑RR↑ and HR↓RR↓) and 'differentiation' (HR↑RR↓ and HR↓RR↑) groups analogous to Schwartz's (1972) groups were generally unsuccessful in producing the physiological patterns specified by the respective feedback contingencies. However, indications of successful performance were found with feedback contingencies involving change in one response without parallel changes in the other (the HR↑RR= and HR↓RR= groups), contingencies which were not employed in previous pattern feedback studies (see Schwartz, 1974; 1976). These successes are encouraging but must be viewed in the context of the other physiological variables which were measured.

Results for the additional respiratory and somatic measures indicate lack of specificity of HR control. This is consistent with previous reports of concomitant variation in nonmanipulated measures during HR control (Blanchard and Young, 1973; McCanne and Sandman, 1976). Every example of HR–RR dissociation in the present study was associated with significant changes in respiratory volume or GA.

Issues raised by the present research concerning length of training and knowledge of contingency require some comment. The single session, multiple trial design for training used here was modelled after Schwartz (1972). It is possible that greater control of HR-RR patterns and/or greater specificity of HR control could be achieved with extended training. Similarly, the efficacy of informing subjects of the pattern feedback contingencies needs to be tested to determine whether knowledge can enhance performance with pattern feedback. However, it must be noted that Schwartz (1972) found HR–BP dissociation in a single session with uninformed subjects.

The present study demonstrated that pattern feedback shows promise for reducing parallel RR changes during HR control when feedback is contingent upon HR change unaccompanied by changes in RR. Some evidence of HR–RR dissociation was obtained, indicating that RR change is not a necessary condition for voluntary HR control. However, there was no evidence of dramatic HR–RR dissociation — that is, HR and RR changes in opposite directions across trials. It is anticipated that further research with pattern feedback may yield additional information concerning the malleability of cardiac–somatic relationships.

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