INSTRUMENTAL CONDITIONING OF DIASTOLIC BLOOD PRESSURE IN ESSENTIAL HYPERTENSIVE PATIENTS¹

S. THOMAS ELDER AND Z. ROSALBA RUIZ

LOUISIANA STATE UNIVERSITY IN NEW ORLEANS

HERDIS L. DEABLER AND ROBERT L. DILLENKOFFER

VETERANS ADMINISTRATION HOSPITAL, NEW ORLEANS

Eighteen male essential hypertensive patients participated in an experiment designed to compare two strategies for controlling high blood pressure. Each strategy was derived from the instrumental learning literature, and the aim was to treat the blood pressure response as an operant and determine the most effective conditioning procedure for manipulating it. The results demonstrate that patients could be conditioned to lower blood pressure by 20% to 30% over a period as brief as four days by providing an external signal and verbal praise contingent upon each reduction in diastolic pressure that met a pre-set criterion.

The modification of glandular and visceral responses through operant conditioning is a recent breakthrough (Miller, 1969; Miller, Di-Cara, Solomon, Weiss, and Dworkin, 1970) that offers an opportunity for innovation in the treatment and clinical management of psychosomatic disorders. Instrumental control of blood pressure was a natural sequel (Gutman and Benson, 1971), and recent data show that it can be done.

In 1969, Shapiro, Tursky, Gershon, and Stern reported an experiment in which 10 normotensive male subjects received feedback reinforcement for raising their blood pressure, and 10 others were conditioned the same way to lower their blood pressure levels. Reinforcement was made available in the form of an external signal to the subject that he had successfully increased or decreased his systolic pressure, as the case may be. Subsequently, Shapiro, Tursky, and Schwartz (1970) showed that it was possible in a similar manner to train subjects to change their blood pressure up or

down independently or concomitantly with increases or decreases in heart rate. Thus, it became apparent that visceral response units could be shaped with a great deal of specificity, as Miller (1969) had asserted earlier, or developed as general response patterns as Shapiro, *et al.* (1969) demonstrated.

The first report that essential hypertension could be managed by operant conditioning with performance contingent feedback came from Miller's laboratory (Miller, *personal communication*). A female patient learned to lower her blood pressure, and eventually drove it down as much as 30 mm Hg. More recently, Benson, Shapiro, Tursky, and Schwartz (1971) successfully conditioned five of seven essential hypertensive patients to lower their systolic pressure as much as 16 to 34 mm Hg.

In view of these intriguing data, the present study sought: (1) to compare two different reinforcement feedback strategies in search of an optimum set of routine clinical operations, and (2) to employ a more stringent test of consequences than Shapiro *et al.* used by examining changes in diastolic as well as systolic pressures.

METHOD

Subjects

Eighteen male patients between 23 and 59 yr of age had all been diagnosed previously as

¹This study was supported in part with funds made available through the Veterans Administration Hospital, New Orleans, Louisiana, and a preliminary report of the results was presented at the American Psychological Association meetings in Honolulu, 1972. Reprints may be obtained from S. Thomas Elder, Department of Psychology, LSUNO-Lakefront, New Orleans, Louisiana 70122.

essential hypertensives; their blood pressures at the time of admission to hospital are shown in Table 1. None was receiving medication specifically for their high blood pressure, but many were on central nervous system depressants (*e.g.*, chlorthalidopoxide or diazepam), and all had received bed rest and a salt-free diet for at least three days before participating in the study.

Apparatus

The apparatus consisted of a model 1900 London pressuremeter, model 1910 alarm module, and model 2400 strip-chart recorder. Except for the addition of a small timing circuit to limit duration of the alarm module signal (red light) to 3 sec, the apparatus was standard and free of modification. With this particular system, it was possible to obtain an indirect measure of systolic and diastolic blood pressure once every

2 min over an extended interval. In addition, this could be done automatically at a distance as great as 25 ft from the subject. Sensitivity was to the nearest 5 mm Hg. As a reliability check, blood pressure was measured on an independent sample of 10 male patients using the London pressuremeter and a standard sphygmomanometer. When the two procedures were compared, the systolic pressure scores correlated 0.96 and the diastolic scores correlated 0.84 ($p < 0.001$ in both instances).

The apparatus was housed in a semi-sound-resistant air-conditioned room. Subjects were observed individually with only one experimenter in attendance.

Procedure

Patients were selected for the study with the assistance of several ward physicians, and as-

Table 1

Summary of subjects' raw blood pressures scores (mm Hg) at time of hospitalization, on-set of the experiment, and at follow-up.

	Age	Time of Hospitalization		Basal Pressure (Session 1)		Follow-up (Session 9)	
		Systolic	Diastolic	Systolic	Diastolic	Systolic	Diastolic
Group I (Control)							
1	39	250	115	155	103	144	99
2	45	162	110	169	97	—	—
3	47	200	136	130	87	—	—
4	48	184	120	149	108	—	—
5	52	172	110	150	89	140	88
6	57	170	110	147	85	—	—
Group II (Strategy 1)							
1	28	190	120	155	130	143	94
2	42	170	120	177	116	160	114
3	48	184	120	141	108	—	—
4	49	230	130	148	105	146	108
5	49	200	140	145	95	153	94
6	54	190	102	124	91	—	—
Group III (Strategy 2)							
1	23	170	120	137	101	138	89
2	44	220	126	176	123	123	77
3	47	200	120	151	105	147	102
4	53	170	120	144	88	124	72
5	58	170	95	164	94	121	76
6	59	160	105	150	112	—	—

signed to one of three groups in random order. The experimental conditions represented by the three groups were: (I) control (no feedback), (II) strategy 1 in which a signal (3-sec red light) was given to the patient contingent on a reduction in his diastolic pressure, and (III) strategy 2 in which verbal approval was paired with the signal employed in strategy 1.

On the morning of Day 1, each patient arrived at the laboratory on schedule, and was immediately directed to urinate. After that, he was asked to have a seat outside the experimental room, and wait until called. Ten to 20 min later, he was invited into the laboratory and seated in an upholstered straight-back chair facing the signal panel of the apparatus, but away from the pressuremeter. Then the cuff was secured to his upper left arm, which rested on the arm of the chair, taking care to position the microphone directly over the brachial artery. Next, his blood pressure was measured automatically every 2 min for a total of 20 successive determinations. No experimental manipulations were made during this session and the mean of these readings was taken as the patient's *basal* systolic and diastolic blood pressures.

That afternoon the subject returned for Session 2, and at that point designated experimental treatments began and were continued at the rate of one training session each morning and afternoon for the next three days. Treatments were discontinued after training session 8, and the patient was not seen again until the follow-up examination (Session 9) one week later.

Positive stimulus feedback such as that employed in strategies 1 and 2 is illustrated in Table 2. On Trial 1 (T1), the subject's basal

diastolic pressure occurred so that no feedback was given. When pressure was found to be 5 mm lower on T3, the feedback signal was presented. The same events occurred on T4 and T5. On T6, the feedback signal was withheld even though the pressure was 105, since the objective was to shape the patient's behavior further. Note that withdrawal of feedback reinforcement on T6 was followed by further reduction in blood pressure which resulted in response-contingent feedback on T7 through T10. On T11, feedback was withheld once more by way of requiring the subject to lower his pressure still more. The utilization of response shaping was considered essential to the success of this experiment. In strategy 2, verbal reinforcement consisted of saying "good" if diastolic pressure was at the criterion, "very good" if it was five units below the criterion, and "wonderful" if blood pressure fell 10 mm Hg below the criterion value.

At no point was the training procedure explained to the patient except to instruct him to lower his blood pressure any way he could. He was advised to hold his gaze on the signal module, and told that whenever the red light appeared it meant that he had succeeded in reducing his pressure by at least a small amount. Patients in the control group were given the same instructions except that no mention was made of the light signal. Then he was told to relax, to avoid thinking about personal problems, and to focus his attention on lowering his blood pressure.

Following Session 8, each patient was asked to return in exactly one week for a follow-up examination. Nine remained in the hospital for

Table 2
Illustration of Training Procedure

T-1	T-2	T-3	T-4
110 (no signal)	110 (no signal)	105 (red light)	105 (red light)
T-5	T-6	T-7	T-8
105 (red light)	105 (no signal)	100 (red light)	95 (red light)
T-9	T-10	T-11	
95 (red light)	95 (red light)	95 (no signal) . . .	

more than an additional week and eight appeared voluntarily for follow-up. Nine were discharged before follow-up and three returned for the final session. The Session 9 procedure was identical to that employed in Session 1. The 20 systolic and diastolic scores obtained from each session were averaged and taken as the follow-up score (see Table 1).

RESULTS

To determine whether or not differences in basal blood pressure existed among the three groups before experimental treatments were initiated, systolic and diastolic scores were subjected to one-way analyses of variance. In the former, $F = 0.20$ was obtained, and in the latter $F = 1.71$ was found (with $df = 2/15$, $F = 3.68$ required for significance at the 0.05 level). Then, each patient's raw systolic and diastolic blood pressure scores determined over Sessions 2 to 8 and at follow-up (Session 9) were con-

verted to per cent of basal pressure and subjected to two-way analyses of variance. Raw scores were expressed as per cent of basal pressure in order to bring the distribution characteristics of the data set in line with the assumptions of analysis of variance.

Systolic pressure. The analysis of the data generated over Sessions 2 to 8 failed to yield any significant differences. There was, however, a consistent tendency for the Group III means to decrease over trials, as shown in Figure 1. Similarly, analysis of the follow-up scores failed to yield significant differences, but these, too, have been included in Figure 1 because the apparent decrease developed in Group III over Sessions 2 to 8 tended to persist throughout follow-up.

Diastolic pressure. Analysis of the diastolic data obtained over Sessions 2 to 8 yielded a significant Groups main effect ($F = 3.99$; $df = 2/15$; $p < 0.05$) and a significant Groups X Session interaction ($F = 2.42$; $df = 12/90$;

Fig. 1. Mean per cent of basal systolic pressure as a function of sessions.

$p < 0.01$). The means contributing to the latter effect have been plotted in Figure 2. Tukey's (a) procedure (Tukey, 1949) was used to evaluate the differences between any set of session means, and this yielded a value of 9.80 at the 0.05 level. Thus, the means of Group III were reliably different from those of Groups I and II over Sessions 3 to 8. In addition, the mean of Group II was different from the Group I mean over Sessions 7 to 8. That is to say, strategy 1 began to have a significant decremental effect by Sessions 7 to 8 as compared with strategy 2, which produced a significant and persistent decrement as early as Session 3.

Only 11 of the 18 subjects returned for follow-up examination, rendering analysis of the following-up data difficult. Even so, means of the available data have been included in Figure 2.

DISCUSSION

These data suggest that diastolic pressure is a more suitable dependent variable than systolic blood pressure. Although in essential hypertension both systolic and diastolic pressure are raised, it is a common belief among cardiologists that diastolic pressure is more significant in the development of heart disease. Since systolic and diastolic pressures are not uncorrelated variables, it may be expected that modification of one should be accompanied somewhat by correlated changes in the other, but to what extent instrumental control of one modulates changes in the other must await the collation of additional data.

Another interesting feature of this experiment was the follow-up results. Any routine application of instrumental conditioning to the clinical management of essential hypertension must be

Fig. 2. Mean per cent of basal diastolic pressure as a function of sessions.

predicated on data that demonstrate some persistence of conditioned pressure reduction over time. The data assembled here, coupled with results of an animal experiment by DiCara and Miller (1968), provide a basis for encouragement, but many more data are needed before a firm conclusion regarding clinical use can be drawn.

The present study confirmed the earlier results of Miller (1969) and Shapiro, Tursky, Gershon, and Stern (1969). In addition, it has been shown that diastolic blood pressure can be lowered by as much as 25% over a period of four days, and that this conditioned reduction tends to persist for at least a week after training. Moreover, the most effective strategy for controlling systolic and/or diastolic blood pressure seems to consist of substantial and immediate positive stimulus feedback indicating correct and error responses. Some additional experiments are required to evaluate other strategies, to carry out follow-up evaluations over longer intervals, and to improve the measurement procedures; but the present results bring the management of essential hypertension through operant conditioning one step nearer.

REFERENCES

- Benson, H., Shapiro, D., Tursky, B., and Schwartz, G. Decreased systolic blood pressure through operant conditioning techniques in patients with essential hypertension. *Science*, 1971, **173**, 740-742.
- DiCara, L. V. and Miller, N. E. Long term retention of instrumentally learned heart-rate changes in curarized rats. *Communication Behavioral Biology*, Part A, 1968, **2**, 19-23.
- Gutmann, M. C. and Benson, H. Interaction of environmental factors and systematic arterial blood pressure: a review. *Medicine*, 1971, **50**, 543-553.
- Miller, N. E. Learning visceral and glandular responses. *Science*, 1969, **163**, 434-445.
- Miller, N. E. Personal communication, 1970.
- Miller, N. E., DiCara, L. V., Solomon, H., Weiss, J. M., and Dworkin, B. Learned modifications of autonomic functions: a review and some new data. *Supplement 1 to Circulation Research*, 26 and 27, 1970.
- Shapiro, D., Tursky, B., Gershon, E., and Stern, M. Effects of feedback and reinforcement on the control of human systolic blood pressure. *Science*, 1969, **163**, 558-590.
- Shapiro, D., Tursky, B., and Schwartz, G. Differentiation of heart rate and systolic blood pressure in man by operant conditioning. *Psychosomatic Medicine*, 1970, **32**, 417-423.
- Tukey, J. W. Comparing individual means in the analysis of variance. *Biometrics*, 1949, **4**, 6.

Received 15 May 1972.

(Revision requested 7 August 1972.)

(Revision requested 24 November 1972.)

(Final acceptance 9 April 1973.)