*THE EFFECTS OF FEEDBACK ON
BLOOD PRESSURE DISCRIMINATION*

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Discrimination of blood pressure in the natural environment as a function of feedback was assessed. Seventeen normotensives screened for blood pressure lability were randomly assigned to two groups. These subjects were then asked to estimate their systolic and diastolic blood pressure values two times per day over a 4-week period. Feedback for accuracy of blood pressure discriminations was implemented across the two groups in a multiple baseline fashion, using a feedback withdrawal condition in Group I to assess maintenance effects over time. Results showed improvement in discrimination accuracy for subjects in both groups when feedback was used, and no decrement in performance over a 2-week period after feedback was removed for subjects in Group I. Discrimination of systolic pressures improved at a slightly faster rate than discrimination of diastolic pressures.

DESCRIPTORS: blood pressure, discrimination training, feedback, undergraduate students

The discrimination of physiological events may be important in the management of psychophysiological disorders (Epstein and Blanchard, 1977). Recent laboratory procedures have been developed to assess a subject's accuracy in detecting various levels of physiological behavior. For example, discrimination of heart rate (Brener and Jones, 1974; Epstein, Cinciripini, McCoy, and Marshall, 1977; Epstein and Stein, 1974), skeletal muscular changes (Hefferline and Perera, 1963), electrodermal activity (Stern, 1972), gastric motility (Griggs and Stunkard, 1964), and blood pressure (Luborsky, Brady,

McClintoch, Kron, Bortinchack, and Levitz, 1976; Shapiro, Redmond, McDonald, and Gaylor, 1975; Martin, Epstein, and Cinciripini, Note 1) have been reported. Discrimination of blood pressure (BP) may be particularly interesting as hypertension is considered a "silent" disease in which the immediate sensory consequences of elevated BP are not available to the individual. Thus, the development of procedures that facilitate detection of BP changes may be useful in the management of hypertension.

The application of techniques to facilitate BP discrimination should utilize procedures which are easily applied in the natural environment and not too disruptive to the subjects' daily routine. Luborsky *et al.* (1976) developed a simple training procedure for BP discrimination. Moderately hypertensive subjects were screened for BP lability over an 8-day period and were provided the range of their BPs. Subjects were then asked to estimate their systolic blood pressure (SBP) during no feedback, true feedback, or false feedback conditions. Subjects in a true feedback group showed a significant improvement in performance. However, sub-

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jects in a false feedback group also showed significant improvement with the introduction of false feedback. Maintenance of effects was observed for both groups during a feedback withdrawal phase. Subjects in the false feedback group were provided true feedback, and a subsequent improvement in discrimination accuracy was noted compared to performance during feedback withdrawal. These results suggest that subjects can discriminate SBP. However, changes in discrimination accuracy after introduction of either true or false feedback obscure identification of the important variables influencing discrimination improvement. Changes in performance during the feedback phases could have resulted from the subjects' continued contact with the range information alone.

In the present study, normotensive subjects were screened for BP lability and assigned to two groups. Both groups were asked to estimate their BP twice daily, and accuracy of discrimination scores comparing actual to estimated BPs were calculated. After baseline accuracy was established for subjects in each group, feedback for accuracy of estimation was introduced and withdrawn for subjects in Group I. After an extended baseline to assess the effects of continued exposure to range information, subjects in Group II were then provided feedback in a multiple baseline fashion. Additional statistical analyses were conducted to rule out the possibility of a systematic bias in deviations between measured and estimated pressures which could be produced by changes in BP stability.

METHOD

Subjects

Eighty-six volunteers from the university dormitories and introductory psychology classes, served, ranging in age from 18 to 22. The 76 females and 10 males of the original sample were screened for BP lability by obtaining eight successive daily BP measurements. Eight measurements appear sufficient to establish BP ranges (Clark, Schwitzer, Glock, and Vought,

1956). Subjects who demonstrated a range of 15 mm mercury (Hg) or greater in both systolic and diastolic BPs across the eight successive measurement days were chosen for the study. Blood pressure lability is an important characteristic because subjects with too little variability may show only minimal error between their estimated and true pressure by consistently guessing their mean BP value.

Eighteen subjects met the 15 mm Hg criterion for BP lability. The average range value (highest to lowest) for the experimental subjects was 21 mm Hg for systolic and 17 mm Hg for diastolic, compared to an average range of 18 mm Hg for systolic and 13 mm Hg for diastolic in the original sample. The difference in ranges between the total population of subjects and the experimental subjects was significant for both systolic [$t(84) = 2.30, p < .005$] and diastolic [$t(84) = 3.3, p < .005$] blood pressure. While the range of systolic and diastolic BPs was different for the two populations, the average BP was not ($p > .05$), averaging 101/54 mm Hg for the population and 98/55 mm Hg for the experimental subjects.

Nine subjects were randomly assigned to Group I (6 females and 3 males) and nine to Group II (6 females and 3 males). Blood pressure ranges were not significantly different for the two groups [$t(16) < 1.00, p > .05$]. All subjects in psychology classes received credit at the end of the study, to be applied toward their final grade, for participating in screening and/or the subsequent experimental sessions. All experimental subjects were of normal height and weight for their age and body structure. Subjects were all in good health and had no personal history of cardiovascular dysfunction. One female subject in Group II withdrew from the study during baseline, leaving 17 subjects in the study.

Settings, Apparatus, and Measurement

The study was conducted at Auburn University in the lobby of a girls' dormitory which was centrally located on campus. Separate tables

were arranged for each experimenter to obtain measurements in the morning and afternoon at approximately the same times each day.

Procedure

General instructions regarding blood pressure measurement, the origin of Korotkoff sounds, and the use of a sphygmomanometer were given prior to the study. Detection and interpretation of systolic and diastolic BP were also explained.

Blood pressure measurement was conducted using a Barry-Martin mercury sphygmomanometer and a Py-Mah oversized cuff and bladder (15.0 by 38 cm). Although BP values obtained with the large cuff and bladder can be expected to be much lower than those values obtained by the standard 12- by 23-cm cuff (Geddes and Whistler, 1978; King, 1967), values obtained with the oversized cuff are less variable and more likely to correspond to direct cannula BP estimates than measures obtained with a standard cuff (Alexander, Cohen, and Steinfield, 1977; King, 1967).

Blood pressure values were obtained every morning and afternoon for 20 consecutive weekdays. On each measurement occasion two BP measurements were taken within a 30–60 second interval and averaged to yield a mean BP value for that measurement session. Cuff pressure was varied above systolic BP to avoid systematic peripheral feedback generated by the time duration prior to sensing the brachial artery pulse.

Five trained undergraduates served as experimenters during screening. Three of the five were used as experimenters in the remainder of the study. Each subject was assigned to a specific experimenter during screening and the experimenter proper, with the number of subjects in each group balanced for each experimenter.

Experimenter training and interobserver agreement. Practice trials, training trials, and interobserver agreement assessments were accomplished using a dual stethoscope which permitted the senior experimenter and the under-

graduate experimenters to listen to the Korotkoff sounds of the same subject (Martin and Epstein, 1977). During the 50 practice trials, undergraduate experimenters were supervised by the senior experimenter in the mechanics of BP measurement. Then, during training the pressure values determined by the two observers using the dual stethoscope method were compared, which provided direct feedback on interobserver agreement.

Reliability assessments were begun following the practice trials. Each primary observer/experimenter obtained 10 BP values per day on five different volunteer subjects, without feedback by the secondary observer/senior experimenter, making a total of up to 50 comparisons per training session. The BP values obtained by the primary and secondary observers were recorded separately. An agreement between the senior experimenter and trainee was defined as no more than ± 4 mm Hg variation in both the systolic and diastolic BP. Alexander *et al.* (1977) have shown that the expected error between sphygmomanometer and cannula measurement using the appropriate sized cuff width and length (*e.g.*, 15 by 38 cm) may be ± 3 mm Hg. Criterion reliability was set at 80% (agreements/trials) agreement over 10 trials for three consecutive 10 trial blocks. Screening began following achievement of criterion reliability for all five experimenters.

Reliability was assessed at the beginning of each of the four weeks following screening using the measurements obtained from the subjects assigned to each experimenter. Criterion for reliability was set at 80% over one block of 10 trials for each of the subsequent weeks.

Two experimental conditions were used throughout the study. They are described as follows:

Baseline. During baseline subjects came to the experimental room twice daily and were asked to record a numerical estimate of their systolic and diastolic BP 10 seconds prior to measurement. Subjects recorded their estimates by circling two values on a graphic representa-

tion of the mercury column of the sphygmomanometer. The estimates were concealed from the experimenters until after all BP measurements had been taken. The range of BPs during screening for each subject had been previously noted on the sheet by drawing a colored line through the lowest and highest systolic and diastolic BP values. Subjects were instructed to use the range information only as a guideline in making their judgment and to feel free to circle any values along the column. Subjects received no feedback and could not see the mercury column of the sphygmomanometer during BP measurement.

Feedback. Procedures for estimation and measurement were the same as in the baseline. Following the second BP measurement, the subject was told his average BP and the absolute deviation between his estimation and his true BP. Subjects were told that the object of the feedback phase was to differentiate BP values on the basis of their associated body sensations.

After screening, baseline measurement was begun for subjects in both groups during week I. Feedback for discrimination was then implemented for subjects in Group I during week 2, while baseline was extended for subjects in Group II. During week 3, feedback was removed for subjects in Group I, with continuation of baseline for subjects in Group II. Feedback was implemented in a multiple baseline fashion for subjects in Group II during week 4. The phases of the design are presented in Table I.

The design represents a slight departure from

typical multiple baseline designs (Hersen and Barlow, 1976), in which treatment would have remained in effect for Group I while it was concurrently being implemented for Group II. The initial plan for the experimental analysis of the feedback procedure involved withdrawal of feedback for Group I during week 3. However, this planned withdrawal was not associated with decrement in discrimination accuracy. Consequently, feedback effects could not be assessed in a withdrawal design. The absence of changes in discrimination for Group I during week 3 suggested the effects of treatment were being maintained. Feedback for subjects in Group II could then be implemented sequentially across groups in week 4 in a multiple baseline fashion without difficulty in interpreting the effects of feedback.

RESULTS

Interobserver Agreement

The interobserver agreement for simultaneous BP measurements obtained by the senior and junior experimenters ranged between 80% and 100% agreement. Prescreening criterion agreement was set at 80% over three consecutive blocks of 10 trials. All experimenters achieved prescreening criterion within seven blocks of 10 trials, and all experimenters achieved 80% or greater agreement with the secondary observer on each of the subsequent weekly reliability checks. Prescreening and weekly agreement averaged 86% and 91%, respectively, across all experimenters.

Table 1
Overall Experimental Design

		Duration			
		Week 1:	Week 2:	Week 3:	Week 4:
	Screening: 8 sessions 8 days	10 sessions 5 days	10 sessions 5 days	10 sessions 5 days	10 sessions 5 days
GROUP I (N = 9)	Measurement of systolic and diastolic BP	Baseline	Feedback	Baseline	Baseline
GROUP II (N = 8)	Measurement of systolic and diastolic BP	Baseline	Baseline	Baseline	Feedback

Discrimination Accuracy

An index of discrimination accuracy was computed from the absolute deviation in mm Hg between the subject's estimate and his/her true blood pressure. Large deviations represent poor discrimination, while small deviations indicate good performance. The deviation scores were averaged across the morning and afternoon sessions to yield separate mean daily deviation scores for systolic and diastolic measurement. A three-factor ANOVA with repeated measures on two factors was used to analyze the mean daily deviation scores for both systolic and diastolic deviations with Groups as the between factor and Days and Weeks as the within factors.

Post hoc analyses were conducted using Duncan's Multiple Range Tests and *F*-tests for simple effects.

Systolic. Systolic deviation scores for each group are presented in the left-hand part of Figure 1. The results for Group I showed a mean systolic daily deviation of 9.6 during the initial baseline week. Group I's deviation scores steadily declined with the introduction of feedback on week 2, reaching a mean level of 5.9. The effects of feedback were generally maintained during the no feedback conditions of weeks 3 and 4, although a slight rise in the deviation scores was noted. The performance of subjects in Group II remained stable across the first three weeks of baseline with an average deviation of 9.0. With the introduction of feedback during week 4, the deviation of Group II rapidly declined to a level of 3.6, thus replicating the feedback effect observed in Group I. Statistical analysis of the systolic deviation scores confirmed visual inspection of Figure 1.

Fig. 1. Deviations in discrimination of systolic and diastolic blood pressures for subjects in both groups across baseline and feedback phases.

Significant effects ($p < .01$) for Weeks, $F(3,45) = 10.99$, Group $\times$ Weeks, $F(3,45) = 8.50$, and Weeks $\times$ Days interaction, $F(12,180) = 11.9$, were found.

The Groups $\times$ Weeks interaction indicates differential performance of the groups during the weeks in which feedback was introduced. Duncan's Multiple Range Test on all pairwise comparisons of the weekly means of Group I revealed a significant improvement in performance from the baseline conditions of week 1 to the feedback conditions of week 2, with subsequent maintenance of performance during weeks 3 and 4. Duncan's tests on weekly means of Group II showed stability of performance during weeks 1 through 3, with subsequent significant improvements during the feedback of week 4.

The Weeks $\times$ Days interaction reflects changes in stability of daily and weekly data and does not add much to the information of the effects of experimental procedures beyond that contributed by Groups $\times$ Weeks interaction. The changes in stability of daily data evaluated by Duncan's Multiple Range Test showed that all days of week 1, during no feedback conditions for both Groups, were significantly higher than all days of week 4, when feedback in Group II and maintenance of effects in Group I were in effect. All days of week 2 and 3 (collapsed across groups) were not significantly different.

Diastolic. Diastolic deviation scores are presented for each group in the right-hand portion of Figure 1. The results of the diastolic deviation scores are similar to the systolic results. As noted in Figure 1, diastolic deviation scores for Group I averaged 9.5. A decline in deviation scores was noted during the feedback condition of week 2, reaching a mean of 6.2. Diastolic error was slower to be changed during feedback but was reduced finally to a level of 4.3 over the last three days of the feedback condition. No change in performance was observed during the no feedback condition in weeks 3 and 4. Deviation for Group II during the first three

weeks of baseline averaged 9.0. A slight improvement in performance was noted during week 2, in the absence of feedback but performance deteriorated and returned to higher deviation levels during week 3. Significant improvements in performance were noted with the introduction of feedback during week 4, reaching an average error of 4.5.

Statistical analysis of the diastolic mean deviation scores also confirmed visual inspection of Figure 1. A significant effect ($p < .01$) was noted for Weeks, $F(3,45) = 17.01$, Days, $F(4,60) = 4.35$; Weeks $\times$ Days, $F(12,180) = 2.42$; Group $\times$ Weeks, $F(3,45) = 9.35$; Groups $\times$ Weeks $\times$ Days, $F(12,180) = 2.13$.

As noted in Figure 1, the Groups $\times$ Weeks $\times$ Days interaction indicates similar performance of the two groups during the initial baseline week, and during week 4 in which Group II received feedback and Group I maintained its feedback effect. Group I's performance improved during the feedback of week 2 and continued to improve during weeks 3 and 4. Group II's performance became more variable during weeks 3 and 4 and improved during feedback of week 4.

The Groups $\times$ Weeks $\times$ Days interaction was analyzed for stability using F -tests for simple effects. Pairwise comparisons of the daily data within each group were then made to assess the effects of feedback on daily changes in performance.

As shown in Figure 1, the performance of both groups is stable within all baseline weeks. Significant decreasing trends were found only during week 2 for Group I, $F(4,180) = 10.66$; and week 4 for Group II, $F(4,180) = 2.6$, corresponding to the initial exposure to feedback in the respective groups and indicating daily improvement in performance.

Pairwise comparison of the daily means of Group I was made using Duncan's Test for Multiple Ranges. The effects of feedback were assessed by comparing the *lowest* daily mean measurement during the baseline conditions of week 1 to each of the *daily* means during the

feedback condition of week 2. This is the most conservative method to assess feedback effects within the groups, given the three-way interaction. The difference between the lowest daily baseline point and daily feedback means becomes significant on day 3 of week 2, and continues to be significantly different on days 4 and 5 of week 2 and throughout all days of weeks 3 and 4.

The same type of comparison was also made for Group II. The lowest baseline point of week 3 was compared to the daily feedback means of week 4. The difference between baseline and feedback conditions also becomes significant on day 3 and remains different on days 4 and 5. The results of this analysis indicate that both the rate and magnitude of feedback effects on diastolic estimation observed for Group I are replicated in Group II.

Analysis of Blood Pressure Changes

Blood pressure discrimination may be affected in several ways by systematic and substantial BP changes or changes in stability. Blood pressure values may be systematically higher or lower across groups, weeks, or measurement time, and these BP differences may spuriously improve discrimination performance. To analyze these possible differences, BP values were collapsed across days and within measurement sessions to yield weekly means for morning and afternoon measurement. The data were analyzed using a three-factor ANOVA with repeated measures on two factors with Groups as the between factor and Weeks and Measurement Time as the within factors.

The ANOVA results for systolic BPs show no significant main effects due to Groups, Weeks, or Measurement Time, or any of the interactions. It would appear that differences in systolic deviation scores are attributable to the experimental procedures and not to systematic BP changes.

Results for the diastolic ANOVA show no significant effects or interactions except the main effect due to Measurement Time. Morning diastolic measurements ($\bar{X} = 56$ mm Hg)

were significantly higher than afternoon ($\bar{X} = 54.5$ mm Hg) $F(1,15) = 8.65$, $MS_e = 9.44$ measurements. One would expect that discrimination based only on temporal changes would affect both groups equally and obscure group differences due to experimental manipulations. Given the small differences in BP values and the large magnitude of feedback effects, it is unlikely that temporal variation influenced diastolic BP discrimination.

Blood pressure variability also was analyzed. Decreasing BP variability could decrease the range of possible BP values and hence spuriously increase the probability of a correct estimation. The subject with little BP variability could show a low deviation score by simply guessing his mean BP. Weekly standard deviations were computed on both systolic and diastolic measures by combining all morning and afternoon BP values for that week. A two-factor ANOVA, with repeated measures on one factor, was used to analyze the standard deviations with Groups as the between factor and Weeks as the within factor. The results of the ANOVA on the systolic and diastolic standard deviations revealed no significant differences on the Groups, Weeks, or Groups $\times$ Weeks dimensions. Variability in BP did not appear to change in the course of the experiment and thus could not have systematically influenced the results.

DISCUSSION

The results of the present study showed that differences between estimated and measured systolic and diastolic BP were comparable for both groups during initial baseline, but the performance of both groups significantly improved after the sequential implementation of feedback. Improved discrimination of Group I was also maintained during the no feedback phase. This finding suggests that the improvement observed by Luborsky *et al.* (1976) was not simply a function of repeated exposure to range information. The range information was continuously available to the subjects in Group

II throughout the extended baseline but did not appreciably influence discrimination. However, consistent changes in discrimination performance were observed after the introduction of feedback. Feedback effects were consistent in both groups and did not appear to be affected by changes in BP stability or measurement error. Analysis of the subjects' BP revealed no systematic change in the range of measured pressure values generated by the subject. Hence, the subject was presented with the same range of BP stimuli throughout the experiment.

The results of the present study are consistent with previous research in which physiological cues are established as discriminative stimuli (*e.g.*, Brener and Jones, 1974; Epstein and Stein, 1974; Epstein, Cinciripini, McCoy, and Marshall, 1977). An interesting finding was the maintenance of feedback effects in Group I for two weeks following feedback withdrawal. The maintenance of high levels of discrimination accuracy in the absence of feedback may be due to the specific properties of the feedback itself. The numerical feedback provided in the present study (Luborsky *et al.*, 1976) reflected the exact value of the measured BP and the difference between that value and the subject's estimate. The subject may be able to correlate the different levels of physiological activity with the various numerical or quantitative feedback systems. The numbers may allow the subject to anchor his estimates to the sensory consequences of BP changes experienced during the feedback with an analogue external referent (Brener, 1974). Once this calibration takes place, only minimal reexposure to feedback may be needed to maintain accurate discrimination.

The discrimination training procedures used in this study have an advantage of providing relatively continuous estimates of levels of a physiological response. Other techniques for monitoring BP, such as sphygmomanometric measures, would not provide continuous sampling of BP and may be disruptive to a person's ongoing activities. However, it is probable that continued checking of the reliability of discrim-

ination accuracy using sphygmomanometric procedures would be important to the long-term maintenance of BP discrimination.

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