EFFECTS OF FEEDBACK TRAINING AND KNOWLEDGE OF RESULTS ON DISCRIMINATION OF SKIN CONDUCTANCE RESPONSES

by

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Abstract

The ideomotor theory of visceral learning predicts that the ability to control a visceral response and the ability to detect its occurrence should be correlated. The experiment reported in this thesis examined the effect of training subjects to control sudomotor responding on ability to detect the occurrence of this response. While training was found to facilitate discrimination, the correlation between control and discrimination was not significantly different from zero. It was suggested that one need not abandon ideomotor theory, but realize that other influences may obscure the relationship expected. Examples of possible influences are described.

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Chapter One

Introduction

An extensive literature on biofeedback training has shown that subjects can be taught to control responses that are not usually thought of as being controlled voluntarily. Learned control has been demonstrated for responses such as heart rate (Brener and Hothersall, 1966; others); blood pressure (Shapiro, Tursky, and Schwartz, 1970); the peripheral circulation (Lynch and Shuri, 1975; Friar and Beatty, 1976); sudomotor activity measured as skin conductance, (Lacroix and Roberts, 1978) or skin potential (Crider, Shapiro, and Tursky, 1966); the electrical activity of the brain (Black, 1972); and single muscle fibers (Basmajian, 1972). We perhaps tend to think of these responses as involuntary in part because, unlike skeletal-motor acts, the activities in question do not normally exert an influence upon the external environment. In other instances this classification may be suggested by innervation of the responses by the autonomic rather than the central nervous system (Miller, 1969). The response that is of interest in this thesis, skin conductance, is one of this type.

Several procedures have been employed to demonstrate learned control of autonomic responses. One procedure that was used extensively in early studies provided one group of subjects with exteroceptive feedback contingent upon increases in the response and a second group with feedback conditional upon decreases in the response; comparison of performance between groups established whether exposure to different contingencies led to different levels of autonomic responding in each condition (for example, Crider et al., 1967; Johnson and Schwartz, 1967). Another commonly used method assesses the ability of subjects to comply with verbal instructions to increase and decrease the response before and after feedback training for changes in the visceral target. Evidence for learned control is contained in the observation that compliance with verbal instructions is superior after feedback training (for example, Brener and Hothersall, 1966). This latter procedure has the advantage of training the same subject to produce both increases and decreases in the target response. However, improved performance cannot be attributed unambiguously to the feedback contingency in the absence of a control group in which instructional compliance is tested as in the experimental group but without the intervening feedback training.

Demonstrations of visceral learning have raised the question of how control of the response is established by experience with feedback events. It seems natural that, because covert responses have been studied in these experiments, attention should be paid to the possibility that an important part of what subjects learn is how to recognize the target response. This view has been advanced by Brener (1974), who applied James' (1950) ideomotor theory of motor control to the case of visceral learning. As developed by Brener (1974) this theory asserts that repeated experience with exteroceptive feedback establishes an association between the sensory consequences of the target response and the attending verbal instruction to produce visceral change. Subsequent excitation of a memory for these sensory consequences (the "response image") by the verbal instruction is depicted as the neccesary and sufficient condition for elicitation of the visceral target specified by the image. Stated simply, this theory maintains that voluntary control of the viscera is possible only when subjects have learned to recognize and label instances of the response that have been correlated with feedback. Such learning is held to be sufficient for voluntary control as well.

This prediction has focussed attention on the relationship of performance on control tasks to performance on experimental procedures designed to assess the subject's ability to discriminate instances of target behavior. A variety of methods has been developed to assess discrimination of the response (Brener, 1977; Epstein, Cinctrapini, McCoy, and Marshall, 1977; Whitehead, Dreschler, and Blackwell, 1977; McFarland, 1975). One of the more commonly used techniques may be referred to as a contingency discrimination procedure (Brener and Jones, 1974). In this procedure, exteroceptive feedback is presented contingently upon the activity that is to be discriminated on some trials and independently of such activity on other trials. The subject's task is to identify which type of trial he has received. Another method, described by Roberts (1977) as a "response-state" discrimination procedure, asks whether subjects can tell when the same exteroceptive stimulus event (for example, a brief tone) is contingent upon high or low levels of activity in the visceral response that is to be discriminated (Baron, 1966). Ideomotor theory as developed by Brener (1974) requires a close relationship between the ability to control a response on one hand, and performance on discrimination procedures such as contingency discrimination or the response-state discrimination task, on the other.

The research to be reported in this thesis explores the relationship between control and discrimination, for the case of sudomotor responding. A summary of what is presently known about sudomotor discrimination is followed by a statement of the purposes of the present research.

A. Properties of Sudomotor Discrimination

Six published papers have examined properties of sudomotor discrimination. These will be reviewed in an approximately chonological order in this section. A response-state discrimination procedure was used in each paper.

1. Baron (1966). The first study of sudomotor discrimination appears to have been reported by Baron (1966). Subjects were told that in the first ten minutes of the experiment they would be taught to produce a "certain kind of emotional response by thinking", and that in the next ten minutes their ability to recognize this response would be tested. The response the subjects were taught to recognize was in fact a phasic change in skin conductance (i.e., a GSR). During the training period, subjects received a 1-khz, 1-sec tone for spontaneous GSRs on a 10-sec DRL schedule. All other GSRs (those following a previous GSR by less than ten seconds) were indicated by a 200-msec "blip". Subjects received $.05 for every GSR coincident with the 1-sec tone. During discrimination testing, the tones and blips were continued, but half of the tones were presented when a response had not occurred. Subjects were asked to indicate whether each tone was, or was not, coincident with a GSR. Responses were recorded by pressing either a "Yes" or a "No" key. After each trial subjects were told whether their guess had

been correct. Subjects earned $.05 for correct guesses and lost $.05 for incorrect guesses. When discrimination has been completed, the ten minute training and discrimination periods were repeated. Subjects were asked to sit still and breathe regularly throughout training and discrimination.

None of the ten subjects exposed to Baron's procedure made fewer than 50% correct guesses on the discrimination task. Four of the subjects discriminated significantly above chance, with 69%, 69%, 78%, and 81% correct discriminations. Consequently, it appears that discrimination of thought-related GSRs is possible. Baron also found that correctly and incorrectly discriminated GSRs were preceded by opposing patterns of 5 Hz EEG activity. He suggested that the EEG pattern preceding the discriminated GSRs represented a central event which both produced the sudomotor response and served as a cue for its discrimination. Baron did not, however, examine the relationship between discrimination accuracy and control of the response during the preceding DRL training procedure.

2. Stern (1972). Baron (1966) provided each of his subjects with feedback training for phasic skin conductance responses prior to discrimination testing. This was not true of Stern (1972), who studied sudomotor discrimination as a function of prior feedback training for this response. Stern also investigated whether the size of the response was a determinant of detectability on the discrimination test. Subjects were told that their ability to detect GSR's was being tested and that GSR's were produced by fearful thoughts and thoughts of other personally arousing experiences. First all subjects were instructed to attempt to

produce GSR's during a 15 minute period. Half of the subjects were given feedback for changes in skin resistance during this period. A discrimination test followed in which subjects were presented with an auditory cue approximately every 30 seconds. They were required to indicate, upon hearing the cue, whether they thought it had been preceeded by a GSR and then were told the correct answer. The experimenter attempted to present 15 of each trial type and to order trials in such a way that no obvious pattern would be available to guide subject's choices. Stern reported that the group given feedback training discriminated at above chance whereas the group not receiving feedback did not. However, it was not reported whether the performance of the two groups differed significantly from each other.

3. Lacroix (1977). Stern's study sugested that feedback training has an effect on ability to discriminate SC responses. Two of the groups in a study by Lacroix (1977) are relevant to this issue.

On two successive days subjects were tested for ability to control and discriminate skin potential. Discrimination testing preceded control training on the first day and followed it on the second so that the effect of experience in attempting to control the response could be examined. All subjects received 26 30-sec trials during each control training session. In one group continuous analog feedback for skin potential was provided during 20 of these trials whereas a second group was never provided with feedback. On half of the 26 trials subjects were instructed to increase palmar sweating, which they were told was associated with an increase in skin potential, and on half they were to inhibit it. The discrimination test consisted of an unspecified number of trials, each designated by the occurrence of a 1-sec tone. Half of the tones were given when a skin potential response occurred and half when skin potential had not changed for at least five seconds. Subjects indicated verbally after each trial which type of trial they thought they had received. They were not informed whether their decison was correct.

An effect of feedback on both control and discrimination was found in this study. Control of skin potential was evident only when feedback training had been provided. No group discriminated at above chance prior to feedback training. However, the group given feedback training performed above chance on the second discrimination test while the untrained group again performed at chance. Thus transfer of training from control to discrimination was demonstrated.

The relationship between performance on discrimination and control tasks within the group given feedback training was not reported.

4. Diekoff (1976). In the studies by Baron (1966) and Stern (1972) subjects were told after each discrimination trial whether their decision was correct whereas Lacroix (1977) did not. Diekoff (1976) studied the effect of this variable (designated herein as knowledge of results or KR) on subjects' ability to discriminate GSR's.

As in the other reports, the response state procedure was used during discrimination testing. In each session as many discrimination trials as possible were presented (this resulted in up to 110 trials). Trials were designated by the illumination of a light. Upon presentation of the light subjects pressed one of four buttons depending upon their certainty that a GSR had or had not occurred. Each session consisted of two-thirds GSR trials and one-third no-GSR trials. During tests subjects were instructed to attend to physical sensations but were not told of the events that can mediate GSR's. One group was told whether or not they were correct after each decision they made (group KR). Subjects in a second group were told whether they were correct and were also given information about the size of the sudomotor response (group KR Magnitude). In a third group subjects were given erroneous information on some occasions and correct information on others; specifically, all no-GSR trials were called GSR trials, one half of the GSR trials were called no-GSR trials and the other half of the GSR trials were called GSR trials (group KR False). Subjects in a fourth group were not given information about their decisions (group No KR). The experiment consisted of three sessions over the course of three weeks.

ROC curves were formed for each subject and the area under the curve was used as a measure of subjects' ability to detect GSR's. This measure ranged from 100% (Perfect discrimination and correct labelling of GSR and no-GSR trials) to 50% (chance performance), or, from 0% (perfect discrimination, but reversed labelling) to 50% (chance performance). Using a three factor analysis of variance, Diekoff found a significant effect of Groups but no effects attributable to Sessions or GSR magnitude. The effect of groups was examined further by t-tests that compared performance to chance. The group KR Magnitude showed significant accurate discrimination and group no-KR significant reversed discrimination, but the scores for the other groups did not differ significantly from chance. Diekoff said that these two groups did not reach significant levels because half of the members of each group labelled accurately and half reversed the labels. An interaction between Groups, Sessions and GSR magnitude was found in another similar analysis of variance. Post-hoc analyses revealed that Group no-KR improved significantly over sessions and by the third session was detecting high magnitude GSR's at levels significantly better than that of the other groups.

5. Diekoff (1977). Diekoff (1977) extended his previous study to examine the effects of GSR magnitude and phase of respiration on discrimination. The procedure used previously was duplicated with the exception that only groups KR and KR Magnitude were run in this study. He found that subjects were no better at discriminating large magnitude GSR's than low magnitude GSR's. However, an effect of phase of respiration was observed. Subjects were better able to discriminate GSR's that occurred during inhalation than those that occurred during exhalation. Diekoff attributed this effect to enhanced interoceptive acuity during inspiration; however, his results are also consistent with the view that subjects are using respiration as a cue to solve the discrimination problem. The results obtained could occur if GSR's are more likely to occur during inhalation than during exhalation and subjects assume that inhalation mediates GSR's.

It is instructive at this point to consider one respect in which Diekoff's (1976, 1977) findings differ from those of previous investigators. Earlier work by Baron (1966), Stern (1972) and Lacroix (1977) suggested that subjects could not discriminate skin conductance responses prior to feedback training. Since little afferentation arises from sudomotor activation (Kuno, 1956) this result is expected; only with feedback would subjects be able to identify what variations in skin conductivity are like. However, Diekoff's results contradict this view. He found above chance discrimination in all groups even though none received prior feedback training. Two possible explanations of this discrepancy are as follows.

First it is possible that subjects are not capable of discriminating conductance responses prior to feedback training. However, they may have learned to do so over the course of discrimination testing, owing to contiguous pairings of exteroceptive feedback (discrimination probes) and behavior that are implicit in discrimination procedures (Roberts, 1977). In particular, a fixed production of the trial cues (usually one-half) is given on occasions on which the subject emits a response. These temporal conjunctions between exteroceptive stimulus events and behavior may be sufficient to establish an awareness of activities related to the proportion of GSR's, particularly if the number of such trials is large. In this respect it should be noted that Diekoff appears to have given his subjects a larger number of discrimination trials than did previous investigators (up to a total of 110 trials per session or conceivably a "response" trial for every GSR that occurred). Subjects may have learned to discriminate GSR's from this experience. Performance was not, however, enhanced by provision of knowledge of results as would have been expected had this learning process been involved. This explanation could be assessed further by examining discrimination scores within the first discrimination session for evidence of acquisition. However, this was not done.

The second explanation is also difficult to evaluate but deserved mention because it calls attention to possible sources of error in the measurement of discrimination ability. The possibility of error arises because the delivery of "respond" and "non-respond" trials is necssarily dependent upon the subject's behavior. A "respond" trial cannot be given unless a response has occurred; neither can a "non-response" trial be given during episodes in which the effector is spontaneously and continuously active. Consequently the ability of the experimenter to determine trial parameters (sequence and intertrial interval) is limited. Such limitations are inherent in all response discrimination procedures, although the nature of the difficulties presented depends in part upon how discrimination testing is carried out.

In the case of response-state procedures, the possible sources of error can be divided into two groups. First, it is possible that subjects may base their decisions regarding trial type upon an appreciation of consistencies in the manner in which the experimenter allocates discrimination trials. For example, the subject may learn that trials given after a long intertrial interval are "respond" trials, or that trial type changes after a fixed number of trials of the other type has occurred. It should be noted that such learning could occur in the absence of the ability to discriminate only if (i) non-response cues are embedded within the discrimination procedure and (ii) knowledge of results is given so that such cues can be discovered. Consequently errors arising from this source do not appear adequate to explain Diekhoff's findings. In his study discrimination was obtained even when subjects were tested without knowledge of results.

A second source of possible error, however, is more difficult to discount. In this case the experimenter may inadvertently administer discrimination trials on the basis of an appreciation of consistencies in the subject's choice behavior. Several types of consistency are possible. For example, subjects may tend to avoid selecting the same alternative ("response" or "no-response") several times in succession. Or, if knowledge of results is given, subjects may tend to repeat choices that were correct (reinforced) on the previous trial. Any tendency on the part of the experimenter to take advantage of these and other consistencies will spuriously inflate accuracy on the discrimination test. The minimum step required to prevent this is a set of rules determining how trials are to be administered. Diekoff and Stern did not follow a prearranged random sequence but an attempt was made to avoid a pattern of trial administration. Lacroix does not report the method used in ordering trials. In view of this apparent lack of detail it is difficult to establish whether biases arising from this source affected discrimination performance in previous work. However, while there is no particular reason to expect that this was a problem in the case of Stern (1972), Baron (1966), or Lacroix (1977), the ability of subjects to discriminate without prior feedback training and in the absence of knowledge of results as reported by Diekoff (1976 & 1977) raises uncertainties in this regard.

6. Lacroix and Gowen (in press). The last of a total of six studies on sudomotor discrimination was reported by Lacroix and Gowen (in press). This is the only study that examined between-subject correlations for control and discrimination performance. Subjects attended nine experimental sessions. On days 1,3,4,6,7 and 8 subjects were given 16 feedback trials. On half of these trials they were to produce increases in skin potential and on half decreases in this response. No specific response strategies were suggested or prohibited. In addition, on each of these days subjects were provided with a four-minute period in which feedback was available and they were encouraged to "play with the response" to learn how to control it. On days 2,5, and 9 subjects were given 6 "refresher" control trials and then their ability to discriminate was tested. Some subjects received feedback during these referesher trials and some did not but this variable had no effect on discrimination performance. On each discrimination day subjects received a series of 5 tests with each test consisting of 24 trials. On three of the tests subjects were required to perform a particular task which was thought to be a potential source of interference with discrimination. Tasks consisted of counting backwards by threes, or maintaining either regular respiration or an increased level of muscle activity in the forearms. During discrimination tests subjects were instructed to refrain from attempts to control skin potential.

Lacroix and Gowen reported significant discrimination on all sessions and significant control on all sessions except the first. Discrimination performance was not adversely affected by the requirements imposed by counting backwards or maintaining respiration or muscle tension. The main findings, however, concerned the relationship between control and discrimination. Although an effect of feedback training on discrimination was seen in the first session, control and discrimination were not correlated during this session or in sessions prior to the end of training. For control on session 1 and discrimination on session 2 r = .19; for control on session 4 and discrimination on session 5 r = .08. Not until late in the experiment did a significant correlation occur, with r = .70 on control session 7 & 8 and discrimination session 9.

7. <u>Summary</u>. It appears possible to summarize the results of these six experiments in the following way. There is evidence that subjects can discriminate phasic sudomotor activity measured as SC or SP. All studies which have examined the question (Baron, 1966; Stern, 1972; Lacroix, 1977; Lacroix and Gowen, in press) agree that this ability is facilitated by feedback training. There is also evidence which indicates that the response that is discriminated is correlated with concurrent changes in other aspects of the subjects' behavior. In Baron (1966) an EEG correlate was found whereas respiratory concommitants were noted by Diekoff (1976).

On the other hand, there are some surprising results. Only one study examined the effects of KR (Diekoff, 1976) and this study found no effect. Diekoff also reported discrimination prior to feedback training whereas others had consistently not found such evidence. Whether the reason for this resides in the high trial densities or in error in the measurement of discrimination cannot be established on the basis of available data. Diekoff also reported improvements in discrimination ability with extended testing, but only without KR. Why this should be so is perplexing.

Finally, only one experiment has provided information on the problem of principal interest in this thesis, namely, the relationship between control and discrimination of the response. In this experiment (Lacroix and Gowen in press) discrimination and control were observed in early sessions, but a significant relationship did not materialize between these phenomena until after extended training. This outcome is not predicted by ideomotor theory, which maintains that subjects who have learned to control a visceral response as a consequence of prior feedback training should display a similar ability to recognize instances of their response on a subsequent discrimination test (Brener, 1974). Possible explanations of this result will be deferred until the present research has been described.

B. Purposes of the Present Research

Evidence reviewed in the previous section made clear that data relating discrimination and control for the case of sudomotor responding are lacking. Only one experiment has addressed the question and in this instance the outcome was unfavourable to ideomotor theory. The review also reported disagreements concerning whether discrimination was possible prior to feedback training and on whether KR facilitated discrimination performance.

The research to be reported in this thesis was undertaken to provide further information on each of these questions. The specific objectives were:

(1) To replicate previous studies which observed facilitation of sudomotor discrimination by prior feedback training for this response;

(2) To examine between-subject correlations relating control and discrimination;

(3) To determine whether discrimination performance and/or between-subject correlations relating discrimination to control were improved when knowledge of results was given on the discrimination task; and

(4) To assess discrimination under circumstances in which the sensitivity of subject to non-response cues could be assessed and under which the possibility of entrainment of the experimenter to consistencies in the subject's choice behavior during discrimination was minimized.

It was felt that information concerning these questions would provide a basis upon which one might begin to better understand the nature of control and discrimination and the relationship between performance on these two tasks.

Briefly, the experimental procedure was as follows. Two groups of subjects received two days of discrimination testing after one day of feedback training to control skin conductance. One group received knowledge of results on the discrimination task (Group F+KR) whereas the other did not (Group F+noKR). A third group of subjects received three days of discrimination testing with knowledge of results, but feedback training was omitted (Group noF+KR). A comparison of the discrimination performance of the latter group with those given feedback training established whether discrimination was facilitated by this procedure. A comparison of Group F+KR and F+noKR, on the other hand, established whether knowledge of results facilitate discrimination. Relationships between control and discrimination were also calculable within these groups, since subjects received prior feedback training. Trial sequence was established prior to discrimination testing in all experimental conditions to ensure that the ordering of discrimination trials was not influenced by visceral performance or consistencies in the subject's choice behavior.

Chapter 2

Method

A. Subjects

Fourty-one male high school and college students participated in this experiment. Of these, 8 were excluded owing to equipment failure (n=3) or because of artifact or inactivity in the skin conductance (SC) measure (n=5). The remaining subjects were assigned, prior to their arrival in the laboratory, to three groups of 11 subjects each.

Two of the groups received two days of discrimination testing after feedback training (F) to control skin conductance (SC). One group received knowledge of results (KR) for correct choices on discrimination trials (Group F+KR) whereas the other did not (Group F+noKR). A third group received three days of discrimination testing with KR, but feedback training was omitted (Group noF+KR). Thus each subject participated for three sessions, with sessions occurring on successive days.

B. Apparatus

Feedback training and discrimination testing were carried out in an electrically shielded and sound-deadened room. A carpeted enclosure measuring 2 x 3 m was fashioned by suspending curtains from the ceiling of the room. A padded chair, fixed in a non-reclining position, was placed in the center of this enclosure. Control equipment was located in an adjoining room.

Trial cues and feedback were displayed on a Sony Model 110 videomonitor (18 x 23 cm) situated 1.2 m in front of the subject at eye level. Trial cues, consisting of the word increase or decrease, were projected in the upper right hand corner of the screen. The feedback display consisted of a fixed horizontal line, situated slightly below the center of the screen, and a vertical line which moved continuously in the vertical plane. An example of this display is shown in Figure 1. Movements of the line toward the top of the screen corresponded to increases in skin conductance and movements of the line towards the bottom of the screen corresponded to decreases in skin conductance. The extent of the line's excursion was proportional to the difference between the current level of skin conductivity and the last value recorded in the pretrial period. The sensitivity of the feedback display was set before the onset of the first training trial. It was usually 1 micromho/cm although display sensitivity was increased for subjects whose skin conductivity fluctuations were small. The feedback display was updated every 125 msec.

The feedback training procedure was carried out by a PDP-8/L computer while discrimination testing was controlled manually. A Beckman Type R polygraph operating at a paper speed of 1 mm/sec during feedback training and 2.5 mm/sec during discrimination testing was used to record data. Also, during feedback training, electrophysiological data was digitized and transferred to floppy disk for subsequent analysis on an LSI 11 system computer.

C. Electrophysiological Recording

Skin conductance was measured through Beckman Ag/AgCl skin conductance electrodes placed upon the thenar eminence of each hand. Reference sites on the ventral surface of each wrist were abraded lightly with sandpaper to reduce epidermal resistance. Active and reference electrodes were coated with a paste consisting of 1 part

Figure 1: Example of feedback display and instruction word presented to subjects.

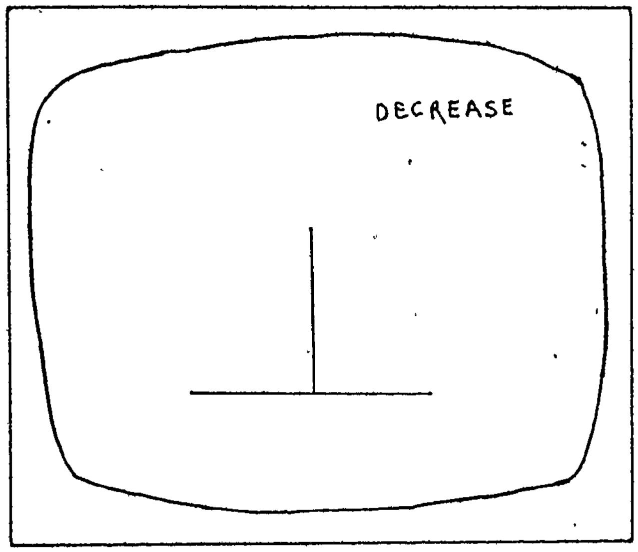


Figure 1: Feedback display. The horizontal line remained fixed in place and depicted the level of the response at the beginning of the trial. The line moved in a vertical plane and depicted the current value of the response. Trial type was designated by the word (Increase or Decrease) displayed in the upper right-hand corner of the screen.

Unibase mixed with 3 parts .1M NaCl by volume. Contact with the skin was through an opening 10 mm in diameter. The electrodermal signal was generated by a 500 mv DC source applied through a series resistance of 2 K-ohms. Recordings were taken through a Beckman AC/DC coupler (9806a) set in the DC mode. A calibrated zero-suppression circuit was used to suppress and retain the tonic level. The preamplifier output was subject to post-amplication (X5) and stored by the computer together with the suppressed tonic level. This provided a continuous measure of sudomotor function for use in subsequent data analysis. In addition, the postamplified output was used by the computer to drive the feedback display.

Cardiac activity was measured by Beckman Ag/AgCl electrodes placed over the sternum and lower rib cage. Beckman electrode paste was used as the electrode medium. The raw electrocardiogram was recorded with a Beckman AC/DC coupler and fed to a BRS digital circuit which discriminated the R-wave from occasional muscle artifact. The circuit diagram for this filter is in Appendix A. The output of this circuit triggered a cardiotachometer (Beckman 9857b) producing a continuous analog output.

Other electrophysiological recordings were taken. Respiration was recorded by means of a mercury strain gauge which encircled the subject's upper torso. Electromyographic activity was recorded from both forearms through Ag/AgCl electrodes placed as described by Lippold (1967). Gross body movement was measured by attaching a pressure transducer to an inflatable cushion which was concealed within the subject's chair. Thermistor probes were also taped to each palm and one pair of EEG electrodes was affixed to the forehead. The EEG electrodes were attached to achieve the standard electrode configuration employed in this laboratory and recordings were not taken from them. Subjects were not told the purpose of any transducer other than those used to measure skin conductivity. Answers to occasional questions concerning electrode function were deferred until the end of the experiment. Further details on the recording of these responses are given in Wilton (1977).

D. Procedure

Subjects were greeted by the experimenter and given a brief explanation of the purpose of the experiment. Subjects scheduled to receive feedback training were told:

> "We are going to test your ability to detect the occurrence of a physiological response; since the response is novel we are going to train you to control the response today. Then we will test your ability to detect the response on the following two days".

Subjects not receiving feedback training, on the other hand, were told:

> "We are going to test your ability to detect the occurrence of a physiological response. Since the response is novel we will test you for three days since there might be some improvement in subsequent sessions."

A medical history, which is reprinted in Wilton (1977), was then completed to screen subjects for those who ought not participate owing to cardiovascular disorder or previous biofeedback training.

Next, recording electrodes were applied as detailed by Wilton (1977). The subject was then taken into the experimental chamber where a test for artifact in recordings was performed. In this test subjects were told:

> "We want to ensure that the electrodes are firmly attached. Please make fists with your hands and shake your arms a bit. Fine. Now close your eyes and shake your head back and forth."

Electrodes that did not provide satisfactory records were reapplied at this point.

Once recordings were patent, tape-recorded instructions were presented. For all subjects these began as follows:

> "The purpose of this experiment is to find out whether you can detect the occurrence of a particular physiological response. The response we want you to detect is a change in the conductivity of the skin, which is measured by electrodes we have attached to your palm and wrist. Normally we are not aware of changes in skin conductivity, but there is reason to believe that subjects can detect these responses under some circumstances."

The remaining instructions differed depending upon whether subjects were given discrimination testing or were to receive feedback training first. Instructions were reproduced in full in Appendix B.

The procedure for feedback training was as follows. Subjects received 30-second training trials during which analog feedback for skin conductivity was continuously available. On half of these trials the subject was instructed to increase skin conductance whereas on the remainder a decrease in the response was required. This was accomplished by presenting either the word "increase" or "decrease" in the upper right hand corner of the video monitor together with the feedback display (illustrated previously in Figure 1). Increase and decrease trials were ordered irregularly with no more than two of one type occurring in succession. Subjects were told that the feedback display presented with the instruction word showed changes in "skin conductivity" and thus indicated their success in producing the required change. They were not given specific information about how they might control skin conductance but were told they could try any method they wished as long as they did not touch the electrodes or get up from the chair.

The ability to control skin conductance when feedback was not available was also tested both before and after training. On what will be called "transfer trials", subjects were presented with an instruction word but were not provided with feedback. Subjects received a block consisting of 2 increase and 2 decrease transfer trials in an irregular order before and after feedback training. A "blank trial" consisting of an extended intertrial interval preceded and followed each transfer block.

In the second session four "refresher" training trials and two transfer trials were presented to the feedback groups. The structure of feedback trials for the two days is described in Appendix C.

The procedure for discrimination was as follows. A total of 24 discrimination trials was given. Each trial was designated by a 830 Hz, 70 dB(A) tone coming from a speaker at the front of the experimental chamber. Twelve of the trials were given on occasions on which a phasic skin conductance response had occurred ("Response" trial) whereas twelve were given when skin conductance had not changed ("Non response" trial). Subjects were required to decide following each tone which type of trial they had received. They indicated their decision by pressing one of two buttons above which were affixed the labels "Response" or "No response". Subjects in the groups that received knowledge of results (F+KR and noF+KR) had the correct choice indicated to them after their decision by the brief illumination of a light above the button they should have pushed. The buttons and lights were situated in a console (13cm X 13cm) that was attached conveniently to the right arm of the subject's chair. A similar console without lights was used for subjects in Group F+noKR. Subjects in all groups were told that correct decisions earned $.05 whereas incorrect decisions lost $.05.

Discrimination trials were presented in one of four sequences, which were randomly generated with the constraint that no more than three of one type occur in succession. The sequences are as follows:

1). $\overline{R}RRR\overline{R}RR\overline{R}R\overline{RR}R\overline{R}R\overline{RR}RR\overline{R}RRR\overline{RR}$

2). $\overline{R}RR\overline{R}RRR\overline{R}R\overline{R}R\overline{RR}RR\overline{RR}R\overline{RRR}R\overline{R}R$

3). $R\overline{R}RR\overline{RRR}R\overline{RRR}RRR\overline{R}RR\overline{R}RRR\overline{RRR}$

4). $RR\overline{RR}RRR\overline{RR}RR\overline{RR}R\overline{RRR}RR\overline{R}RR\overline{R}R$

Trials were allocated by the experimenter as he watched on-line data being recorded on the polygraph. Response trials were presented during the rising portion of a skin conductance response while non-response trials were presented if no increase in skin conductivity had occurred for at least 10 seconds. The experimenter attempted to present trials so that the difference in conductance change for the two trial types was maximized. Intertrial interval was not strictly controlled although an attempt was made to equate the intertrial intervals of the two types of trials.

All subjects were encouraged to "actively produce various sensations or behaviors" during the discrimination test. They were further told "that only if they did this would they be able to solve the discrimination task". The complete instructions presented to subjects prior to the discrimination tests are reprinted in Appendix B.

E. <u>Analysis of Physiological Data</u>

Heart rate, electrodermal responding, temperature, EMG, body movement and respiration signals were sampled by the computer throughout the 30-sec trial period. These measures were also recorded throughout a pretrial period of equal duration. Heart rate and respiration were sampled eight times per second and the others four times per second. EMG and body movement, signals that changed rapidly, were integrated over sampling periods. These data were then used to compute 5-sec averages for all variables throughout the trial and pretrial periods. The effect of trial presentation on each variable was estimated by subtracting the mean of the pretrial values from the mean of measurements taken during the trial period.

Chapter Three

Results

Analysis of the data is presented in three sections. The first two sections describe subjects' ability to control skin conductance and discriminate its occurrence. Then the relationship between performance on these two tasks is examined.

A. Control of Skin Conductance

Performance of groups F+KR and F+noKR during feedback and transfer trials on day 1, and on refresher and transfer trials on day 2, is depicted in Figure 2. The change in skin conductance from the pretrial baseline is shown. Inspection of these data reveals that subjects evidenced large differences in skin conductance between trials on which instructions to increase and decrease the response were given.

The extent of control on feedback trials of day 1 was tested. A repeated-measures analysis of variance with Trial Type (Increase and Decrease) and Trial Number (1 to 10) as variates was applied to each group separately. Change scores were greater on increase trials for both groups as indicated by a main effect of Trial Type [$F(1,10)=13.21$, $p<.01$ for group F+noKR; $F(1,10)=8.55$, $p<.025$ for group F+KR]. In addition, there was a significant main effect attributable to Trial Number in both groups [$F(9,90)=6.02$, $p<.01$ for group F+noKR and $F(9,90)=3.75$, $p<.01$ for group F+KR). Inspection of Figure 2 shows that this was attributable primarily to larger increases in skin conductance on both increase and decrease trials early in feedback training. Significant interactions between Trial Type and Trial Number, however,

Figure 2. Mean skin conductance on feedback (F) and transfer (T) trials for days 1 and 2. Groups F+KR and F+noKR are shown separately.

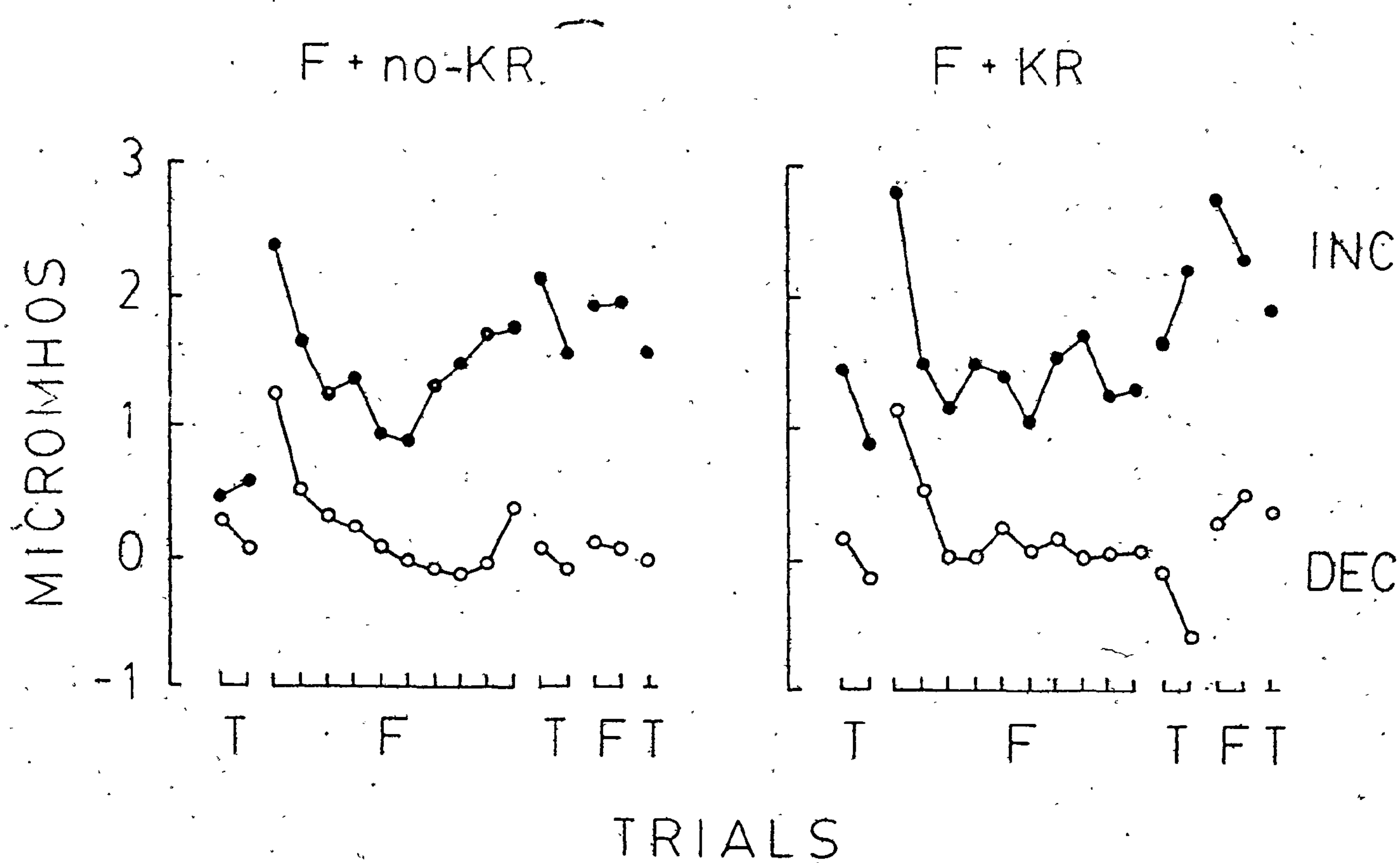


Figure 2

were not found. It will be noted that the outcome of these analyses was the same in each training group. This was to be expected since up to this point the two groups had been treated identically.

Statistical analyses were also applied to performance on transfer trials on day 1. These revealed that performance on increase and decrease trials differed significantly on the first transfer block, before subjects had received feedback training [$t(10)=2.12$, $p<.05$ for F+KR, one-tailed; $t(10)=1.96$, $p<.05$ for F+noKR, one-tailed]. Consequently modest control of the response was evident prior to feedback training. An analysis of variance employing Trial Type (increase/decrease), Transfer Block (pre/post) and Group (F+KR/F+noKR) was subsequently applied to the transfer data. This analysis revealed a significant effect attributable to Trial Type, $F(1,20)=10.11$, $p<.05$, and also a significant interaction between Trial Type and Transfer Block, $F(1,20)=4.61$, $p<.05$. The latter result indicates that control of the response was significantly greater after feedback training than before training began. No factor involving Groups reached significance, indicating comparable performance when the groups were exposed to the same training procedure.

Figure 3 shows how skin conductance changed within trials during the second transfer block (post-training block, day 1). Data from increase, decrease and blank (extended inter-trial intervals) trials are given with data from groups F+KR and F+noKR combined. A three-factor analysis of variance employing Trial Type (increase, decrease or blank), Periods (5-second intervals during the trial) and Groups (F+KR and F+noKR) was applied to these data. A significant effect of Trial

Figure 3. Mean skin conductance for each 5 second period within trials on the second transfer block on day 1. Performance on blank, increase and decrease trials is shown separately.

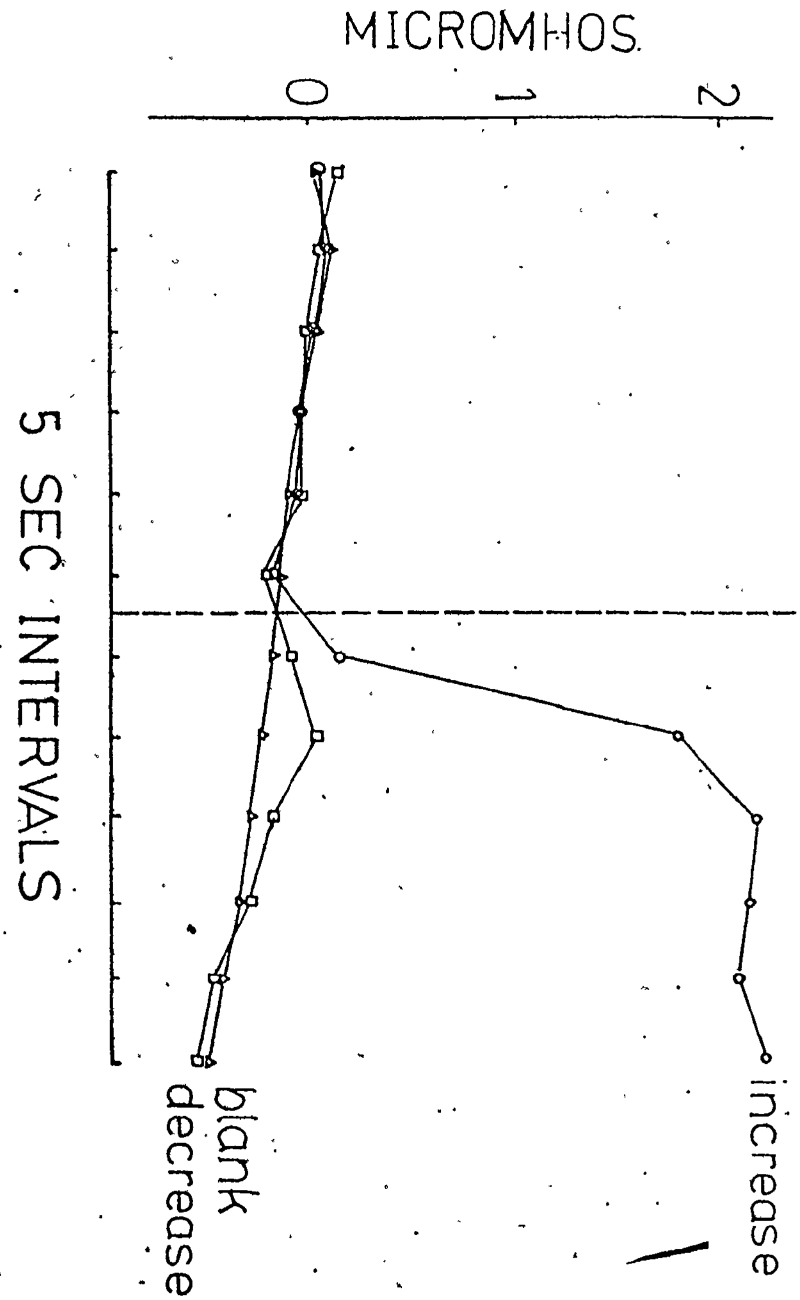


Figure 3

Type was found, F(2,40) = 10.3, p<.01. Inspection of Figure 3 shows that skin conductance differed from the pre-trial period only on increase trials. There was no statistical indication of a difference in skin conductance between blank and decrease trials.

Between-subject corelations were computed to examine the reliability of individual differences in control of target responding. The results are presented in Table 1, in which the two feedback groups have been combined. Inspection of these data shows that between-subject variability on the final transfer block (Transfer, Day 2) was predictable from variability in this measure on Day 1 and from control on feedback trials on both days of training. Transfer performance at the end of Day 1 was also predictable from feedback trials given on this day. However, control on feedback trials was not significantly correlated across days 1 and 2 in either discrimination group. These results indicate that reliable individual differences in control performance were present, and that these tended to be more evident on transfer trials where feedback was removed. Nevertheless it should be noted that a substantial portion of the between subject-variance (up to 66%) could not be predicted from earlier performance, even on transfer trials.

B. <u>Discrimination of Skin Conductance Responses</u>

The performance of each group on the discrimination task is depicted in Figure 4. Since it was evident that there were no differences between days of discrimination testing within groups, the results for each subject were averaged over days. Discrimination, as measured by percent of trials on which the subject's decision about

Table 1

Product mean correlations between measures of control on feedback and transfer trials on days 1 and 2. On Day 1, the second transfer block is shown.

	Transfer Day 1	Feedback Day 2	Feedback Day 1
Transfer Day 2	.67*	.77*	.67*
Transfer Day 1		.59*	.67*
Feedback Day 2			.30

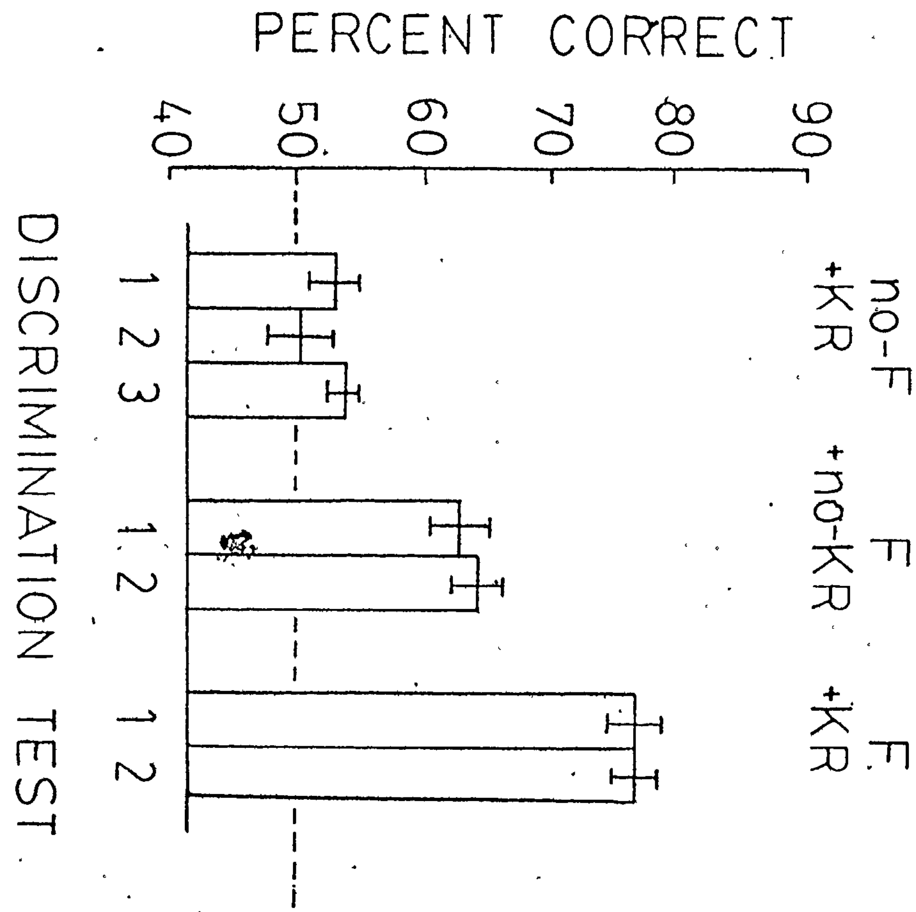
$* \ p < .05$

trial type was correct (%C), was 76.8 for group F+KR, 63.6 for group F+noKR and 52.6 for group noF+KR. Both groups that received feedback training achieved above chance discrimination [t(10)=3.40, p<.01 for F+noKR, one-tailed; t(10=7.69, p<.01 for F+KR, one-tailed]. However, the group that did not receive feedback training (noF+KR) did not discriminate above chance [t(10) = .98, p >.05]. Inspection of individual performances suggested that subjects were equally accurate on response and non-response trials.

A one-way analysis of variance was used to investigate the effect of feedback and knowledge of results on discrimination performance. A significant difference between groups [F(2,30)=12.65, p<.01] reflected significant differences between all experimental comparisons except F+noKR and noF+KR (Tukey, p<.05). Further analyses by t-test provided evidence for a difference between these groups as well [t(20)=2.50, p<.05, one-tailed].

Several analyses examined the extent to which information from non-response cues contributed to discrimination performance. Specifically, the use of information derived from the intertrial interval and trial sequence was considered. The possibility that information about trial type was obtainable from the intertrial interval was examined by computing Kolmogorov-Smirnov D statistics for each subject. These examined whether distributions of intertrial intervals for response and non-response trials were similar. Only for two subjects (both of whom were in group F+KR) was there a significant difference in the distribution of intertrial intervals for response and non-response trials. These subjects were both in group F+KR and were

Figure 4. Percentage of correct choices on discrimination tests for Groups noF+KR, F+noKR and F+KR. Scores for each test day are shown separately. The bars are SE_m.



PERCENT CORRECT
40
50
60
70
80
90
no-F
+KR
1 2 3
+no-KR
F
1 2
+KR
F
1 2
DISCRIMINATION TEST

Figure 4

the 3rd and 10th best performers of the 11 subjects in this group. It therefore appears that possible use of intertrial interval as a cue contributed little to performance on the current discrimination task.

To minimize the possibility that subjects would be able to discriminate trial type on the basis of the sequence of trials that had just occurred the experimenter followed a preset sequence in allocating trials. The trial sequences used in discrimination testing were random with the exception that no more than three of any one trial type occurred in succession. A test was made to see if subjects were sensitive to this aspect of trial sequence. Figure 5 shows the relation between the subject's choice and preceding trial sequence (1,2, or 3 of the same type). Choice behavior on trials which followed a sequence of two or three was compared for each group. For none of the groups was performance significantly different on these two types of trials (t max = 1.50, this for group F+KR on Discrimination Test 2). Also, trials following a sequence of three were compared with trials following a sequence of one. Only for group F+KR was a significant effect found, in this case involving performance on trials following a sequence of three on the second discrimination test [$t(10)=2.9$, $p<.01$]. This suggests that subjects in Group F+KR may have become sensitive to trial sequence by the second day of training.

Although some subjects may have been sensitive to regularity in trial sequence, further analyses showed that group differences in discrimination performance did not appear to depend upon differential use of this source of information. Evidence for this conclusion comes

Figure 5. Probability that the subject chooses the response other than that which was correct for the previous sequence of one, two or three trials of the same type.

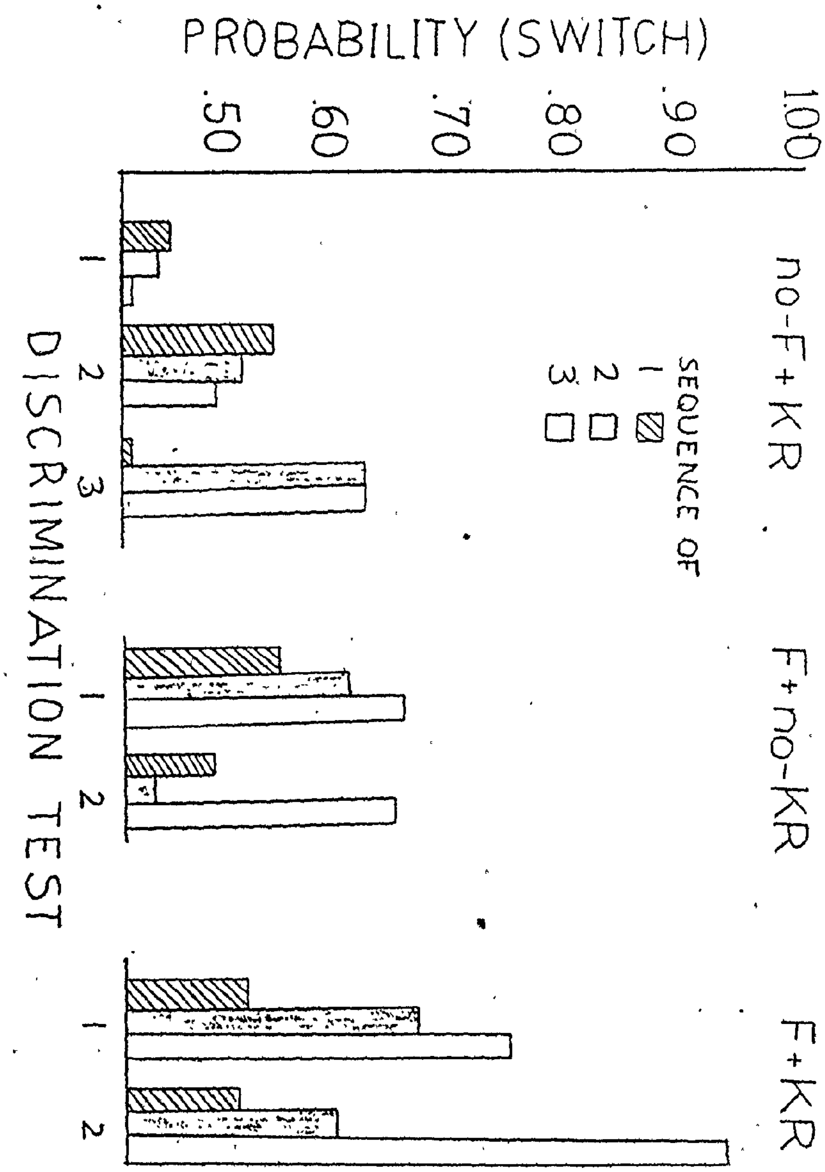

PROBABILITY (SWITCH)
100
.90
.80
.70
.60
.50
no-F+KR
F+no-KR
F+KR
SEQUENCE OF
1
2
3
1
2
3
1
2
1
2
DISCRIMINATION TEST

Figure 5

from analyses of discrimination performance based only upon trials that did not occur in runs (specifically, choice behavior following a trial sequence of one). Discrimination performance on these trials is shown in Figure 6, which may be compared with discrimination performance on all of the trials as given previously in Figure 4. When performance on trials following a sequence of one was compared with chance it was still found that the scores of groups F+KR and F+noKR were significant [$t(10)=5.67$ and 3.43, $p<.01$, respectively] whereas those of group noF+KR were not [$t(10)=1.50$, $p>.05$). Discrimination was found to differ significantly between the groups. The results for groups F+KR versus noF+KR and groups F+noKR versus noF+KR were $t(20)=4.34$ and 2.28, respectively [$p<.05$, two-tailed); for group F+KR versus F+noKR, $t(20)$ was 1.78 ($p<.05$, one-tailed]. Thus it is apparent that the group differences evident in Figure 4 were preserved when any possible effect of trial sequence on discrimination accuracy was removed from the data.

C. <u>The Relationship Between Control and Discrimination</u>

Correlations depicting the relationship between control and discrimination in the two groups that were given feedback training (F+KR and F+noKR) are reported in Table 2. Correlations were computed first for each group separately on each day of discrimination testing (first four columns, Table 2). They were then recalculated when accuracy was averaged over days of discrimination testing and when the data from the two training conditions were combined (Column 5, Table 2). Control during feedback trials and transfer trials was assessed in micromhos as well as by t-statistics computed for individual subjects in each group.

Figure 6. Percentage of correct choices on discrimination tests when trials following a sequence of two or three in a row have been excluded for Groups noF+KR, F+noKR and F+KR. Scores for each test day are shown separately. The bars are SE_m.

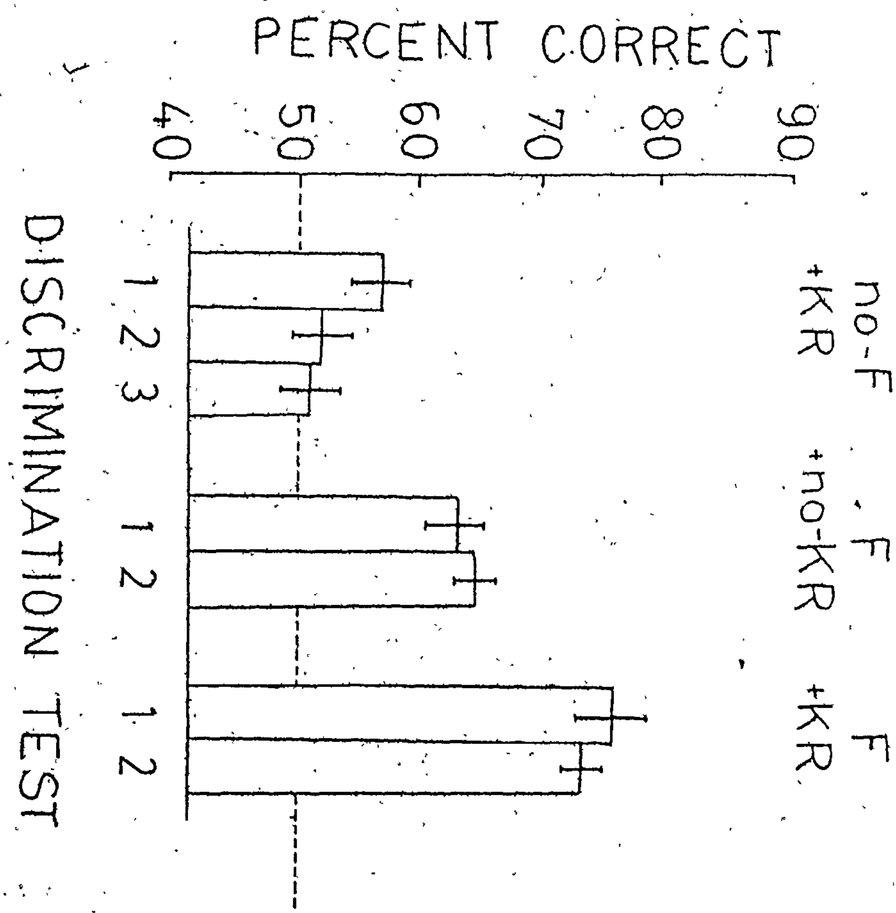

PERCENT CORRECT
40
50
60
70
80
90
no-F +KR
F +no-KR
F +KR
1 2 3
1 2
1 2
DISCRIMINATION TEST

Figure 6

Table 2

Product moment correlations between control measures and discrimination scores.

Control Measure	Discrimination Test 1 F+KR	1 F+noKR	2 F+KR	2 F+noKR	1&2 F+KR & F+noKR
Feedback Day 1	.51	.09	.16	-.15	.15
Transfer (Post) Day 1	.18	.45	.37	.06	.28
Transfer (Post-Pre) Day 1	-.07	.31	.08	.00	.01
Feedback Day 1 (t)	.60*	.08	-.07	-.26	.14
Transfer (Post) Day 1 (t)	.18	-.03	-.10	.11	.03
Feedback Day 2	-.14	-.07	.01	-.06	.08
Transfer Day 2	.18	-.07	.14	-.03	.29
Feedback Day 2 (t)	.15	.59*	.18	.32	.40*

*$p < .05$

The latter step was taken to investigate the possibility that relationships with discrimination might be more substantial if control was assessed by a measure that took the consistency as well as magnitude of skin control into account.

Clear evidence of a relationship between discrimination and control failed to emerge from these analyses. Inspection of Table 2 shows that only three correlations of the total of 40 that were calculated were found to be statistically significant. Furthermore, correlations that were significant showed little consistency across groups, discrimination sessions, or measure of control performance. The correlations reported in Table 2 were also recomputed when discrimination performance was based upon response choice following trial sequences of one. The purpose was to remove any distorting influence of non-response cues in Group F+KR. These results are included as Table 3. It can be seen that the picture depicted in Table 2 was not changed.

It is of interest to examine further the nature of the relationship between discrimination and control revealed by these data. For this purpose the relationship ($r=.40$, $p<.05$) between mean discrimination performance and control on feedback trials immediately prior to the discrimination test (measured as $\underline{t}$) is depicted graphically in Figure 7. Inspection of this figure reveals several instances in which significant control of the response was evident without significant discrimination and vice-versa. Apparently the relationship between discrimination and control was reduced by dissociation of the phenomena rather than simply by inconsistencies in the magnitude of control and discrimination evidenced by the subjects.

The extent of dissociations between discrimination and control is documented further in Table 4. To form this table subjects in Groups F+KR and F+noKR were classified according to whether they gave evidence of control, or whether they failed to control the response altogether. Decisions were based upon t-statistics computed individually for (i) feedback trials on Day 1, (ii) transfer trials after feedback training on Day 1, and (iii) feedback trials on Day 2. Subjects were then divided again, according to whether their discrimination performance exceeded chance over two days of discrimination testing. Table 4 reports the percentage of subjects falling into each of the four cells produced by these classifications. The results for each control measure were similar and revealed little evidence of a relationship between performance on feedback and discrimination problems. Inspection of the last column of Table 4 reveals that the percentage of instances showing dissociation between the tasks (31/64 or 48.4%) was approximately the same as the percentage of instances showing consistency on the measures (33/64 or 51.6%).

Table 3

Product moment correlations between control measures and discrimination when trials following sequences of two or three have been excluded.

Control Measure	Discrimination Test 1 + 2 F+KR and F+noKR combined
Feedback Day 1	.17
Transfer (Post) Day 1	.30
Transfer (Post-Pre) Day 1	.07
Feedback Day 1 (t)	.08
Transfer (Post) Day 1 (t)	.00
Feedback Day 2	-.01
Transfer Day 2	.08
Feedback Day 2 (t)	.00

Figure 7. Scatter plot of control and discrimination performance for subjects in the two groups given feedback training. The control measure is taken from feedback trials on day 2, expressed as a t-statistic. The discrimination measure is the average percentage of correct choices on both test days. The vertical dashed line indicates significant skin conductivity control [$\underline{t}(2)_{.05}$=2.92] and the horizontal line indicates significant discrimination performance (64% = $\underline{p}$<.05).

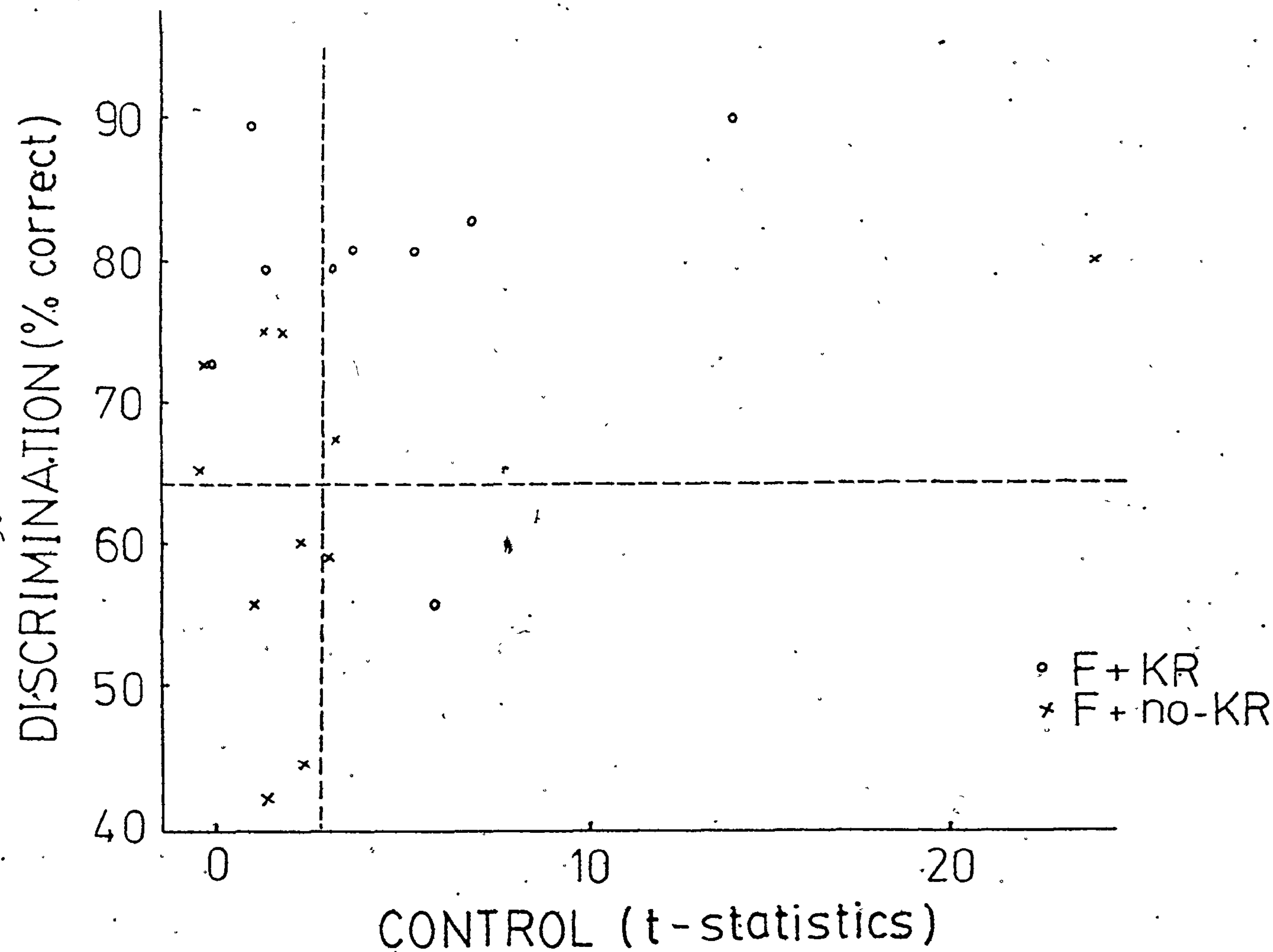

DISCRIMINATION (% correct)
40
50
60
70
80
90
0
10
20
CONTROL (t-statistics)
F + KR
F + no-KR

Figure 7

Table 4

Number and percentage of subjects showing dissociation of control and discrimination.

	No control	Control	Dissociation	Consistency
(i) Feedback trials, Day 1				
Discrimination	5(23%)	10(45%)	10/22	12/22
No discrimination	2(9%)	5(23%)	(45.5%)	(54.5%)
(ii) Transfer trials (post-feedback), Day 1				
Discrimination	9(41%)	6(27%)	12/22	10/22
No discrimination	4(18%)	3(14%)	(54.5%)	(45.5%)
(iii) Feedback trials, Day 2				
Discrimination	7(35%)	7(35%)	9/20	11/20
No discrimination	4(20%)	2(10%)	(45%)	(55%)
			31/64 (48.4%)	33/64 (51.6%)

Chapter Four

Discussion

The present experiment replicated previous reports that feedback training for changes in skin conductance facilitates performance on sudomotor discrimination tasks (Lacroix, 1977; Lacroix and Gowen, in press; Stern, 1972). Only groups given prior feedback training successfully distinguished between the presence and absence of phasic skin conductance responses in the discrimination test. Knowledge of results facilitated discrimination but was not necessary for success on this task. Knowledge of results also appears to have sensitized subjects in group F+KR to the use of trial sequence as a decision cue, but superior discrimination was retained under this condition when the effect of this bias was removed from the data.

The main findings of the experiment, however, concerned the relationship found between discrimination and control. While facilitation of discrimination by feedback training indicates that information was transferred between the two tasks, the relationship between discrimination and control was poor and did not in most instances differ significantly from zero. There were in the present data many instances (approximately 15% of the total sample) in which successful control of the response during feedback training did not eventuate in successful discrimination. Apparently the information provided about the response by exposure to the feedback training procedure did not assure accuracy on the discrimination task. There were also instances (approximately 33% of the total sample) in which discrimination was observed without prior success at control. The discrimination performance of these subjects suggests that they knew something about the response, but the extent or form of their knowledge was insufficient for production of the response during control testing. Overall, the percentage of subjects showing dissociation of discrimination and control (48%, Table 4) was approximately the same as the percentage showing consistency on the two tasks (51%).

The relationship of control and discrimination did not appear to be a function of several variables that were examined in this work. Discrimination was superior when knowledge of results was provided, but substantial relationships nevertheless failed to eventuate under this condition. The relationship did not appear to depend importantly upon whether control was assessed with feedback present or feedback absent, or upon whether original response units or t-statistics were employed to assess performance on the control task. Neither did substantial relationships materialize when efforts were undertaken to remove any infuence of non-response cues on choice behavior. This was true even though superior performance in group F+KR was retained under this condition. Finally, it does not appear that possible relationships were masked by individual differences in effector lability on the control problem. Subjects giving evidence of significant control irrespective of magnitude (as indicated by significant _t_ statistics during feedback training) were no better at discrimination than were subjects who failed to control the response altogether (Table 4).

The interpretation that should be given to this result is open to question. At first inspection these findings appear incompatible with ideomotor theory which maintains that identification of activities related to the response (formation of a "response image") is necessary for control of a response following feedback training. Several of the subjects tested in the present work controlled the response but gave no evidence on the discrimination task that a response image had been formed. The further prediction of this theory that the presence of a response image is sufficient for control is also unsupported by the data. Several subjects succeeded at discrimination but gave no evidence that they controlled the response during previous feedback training. Dissociations of these types, and other evidence showing independence of discrimination and control, have been interpreted by Black et al. (1977) and Whitehead et al. (1977) as weighing against the proposition (implicit in ideomotor theory) that learning to recognize instances of the response is an important component of the process of visceral learning.

This conclusion can be questioned, however. One problem with it is that it overlooks evidence of transfer-of-training from feedback to discrimination tasks. Discrimination and control apparently drew to some extent upon common or correlated processes in the present work, since exposure to the feedback training procedure facilitated performance on the discrimination problem. Similar transfer-of-training effects have been reported for the case of skin potential discrimination by Lacroix (1977) (also see Brener, 1977, for suggestive data on heart rate). The presence of these transfer-of-training effects raises the possibility that discrimination and control may have the intimate relationships suggested for them by ideomotor theory (Brener, 1974) and more recent analyses of the learning process (Roberts and Marlin, 1979). Dissociation of the phenomena may imply merely that discrimination and control are affected as well by factors that are to some extent specific to each task.

One approach to identification of these factors divides them into two broad categories. The first category concerns inferences that were drawn about the structure of the control and discrimination problems by the process of understanding task instructions. The second category considers what the subjects may have learned about the response and about the learning problem as a consequence of exposure to the feedback training procedure. Several examples are given to define each category in the discussion that follows.

A. Task Structure

One inference about task structure that may have affected the relationship between discrimination and control concerns assumptions that may have been made about activities that were permissable on the control problem. For example, subjects exposed to the feedback training procedure may have correctly noticed that gross body movements or deep breaths were related to variation in the feedback display. However, verbal instructions given prior to feedback training emphasized that they would be taught to control "a response that is not usually thought of as being controlled voluntarily". Consequently, a few subjects may have concluded that these activities were not those they were supposed to control. As a result, they may have failed to produce changes in sudomotor activation during feedback trials. Nevertheless the knowledge they acquired about somatomotor and respiratory concomitants may have been adequate to serve as a basis for response choice on the discrimination task, particularly in Group F+KR where knowledge of results may have informed subjects that respiratory-related GSRs were being tested on the discrimination problem. A process of this sort could have generated instances in which discrimination was observed without prior evidence of control during feedback training.

The opposite result of instances in which control was achieved but subjects did not discriminate might have occurred by a similar process. Verbal instructions given immediately prior to the discrimination test informed subjects that they would be tested for their "ability to detect changes in the response" they learned to control during feedback training. Description of the discrimination task as a detection or perceptual problem may have led subjects to adopt a passive response strategy in which attention was focussed upon identification of sensations that might have served as a basis for choice behavior on discrimination trials. As a result of this passive strategy, activities that were important to control of sudomotor activity and that were learned about during feedback training may not have been emitted during discrimination testing. Consequently subjects failed at discrimination because the events associated with the response during discrimination testing were not the same as those they learned about during prior feedback training.

The previous examples concerned inferences that may have been drawn regarding which of several activities was permissable or desirable on feedback and discrimination problems. Another inference about task structure that may have been important concerns the subject's definition of task objective during feedback training. At the outset of the experiment subjects in the feedback conditions were told that the eventual purpose of the experiment was to see whether they could "detect changes in skin conductivity". However, it was further explained that feedback training would be given first, so that they could tell "what variations in skin conductivity are like". These instructions may have led to a problem specification in which emphasis was placed upon learning about activities related to variations in skin conductance rather than upon control or production of the response. Consequently, exposure to feedback may have provided information that facilitated discrimination, but performance on the control task was inconsistent and did not reflect the extent of the subject's knowledge or his control abilities.

In each of these three examples, it was assumed that an inference concerning task structure was drawn during the course of understanding verbal instructions. In the first two examples the inference concerned the nature of activities that were permissible or desirable during feedback training and discrimination whereas in the remaining example the inference concerned what subjects were supposed to do on the feedback task. The extent to which these inferences may have obscured the relationship between discrimination and control in the present work is difficult to assess. It should be noted, however, that in some instances steps were taken to discourage certain of these factors from working. For example, although discrimination was described as a detection or perceptual problem, the verbal instructions for this task also emphasized the necessity of attempting to produce changes in the response from time to time over the course of the discrimination procedure. Whether subjects remembered and complied with this request is difficult to say.

The factors discussed in this section may have masked a relationship between discrimination and control by obstructing the application of knowledge acquired about the response to feedback and discrimination performance. A second group of factors that may have affected this relationship concerns what was learned as a consequence of exposure to the feedback problem.

B. What is learned

The effects of a feedback training procedure upon what is learned appear to be of two general types. First, subjects may acquire information about activities or other events which are related to variation in the feedback display. Progressive improvements in performance over the course of training are presumably dependent upon the accumulation of such knowledge. Second, subjects may acquire information about the structure of the learning problem itself. The apparent structure of the problem and subsequent performance may be changed when this happens. Examples of such effects that may occur in the present work are as follows.

Consider first what subjects may have learned about effective response state as a consequence of feedback training. It will be recalled that the behavioral goal during control training was defined by verbal instructions to increase and decrease a response as well as by a feedback contingency that identified instances of the response that was to be produced. Concepts of the behavioral goal established by this procedure may therefore have derived from the instruction to increase and decrease responding as well as from experience with feedback itself. Verbal instructions appear to have had an impact on the subjects' concept of the behavioral goal, since instructed control of skin conductance was observed on transfer trials given to both feedback groups (F+KR and F+noKR) at the outset of feedback training. However, although control of the response appears to have been augmented by experience with feedback, one cannot be certain that subjects developed an appreciation of which of several activities was related to target responding over the course of feedback training. Instead, feedback may have served merely to confirm that diffuse attempts to increase and decrease responding were adequate to accomplish the control problem. In this circumstance control of the response may have eventuated on feedback and transfer trials, but the form of the subject's knowledge may have been insufficiently precise for success at discrimination. As a consequence, control without discrimination was observed.

A further source of difficulty may concern the breadth of the subject's knowledge of activities related to variations in skin conductance. The sudomotor control system appears to be completely organized at the central level (Roberts, 1974). Inputs to the effector apparatus appear to arise from movement control mechanisms (Edelberg and Culp, 1966; Roberts et al., 1979), from non-specific processes which are independent of these mechanisms (Lacroix and Comper, 1979; Roberts and Young, 1971), and from sensory afferents in smooth muscle and skin (although not all of these may be mediated centrally). Thermoregulatory processes may also be a factor under some circumstances (Wilcott, 1963). It is plausible to suggest that subjects may learn about some of these neural inputs to the sudomotor apparatus during feedback training, but not about others. One would normally expect discrimination accuracy to be reduced by this state of affairs, since the source of a response is not easily ascertainable and is therefore not usually a factor in the allocation of discrimination trials. In this connection it should be noted that the importance of a given source may depend upon procedural details of feedback training and the subsequent discrimination test. Any procedural manipulation that alters the composition of sudomotor activation between control and discrimination tests is likely to favor dissociation of performance on these two tasks insofar as the response states encountered on each are different.

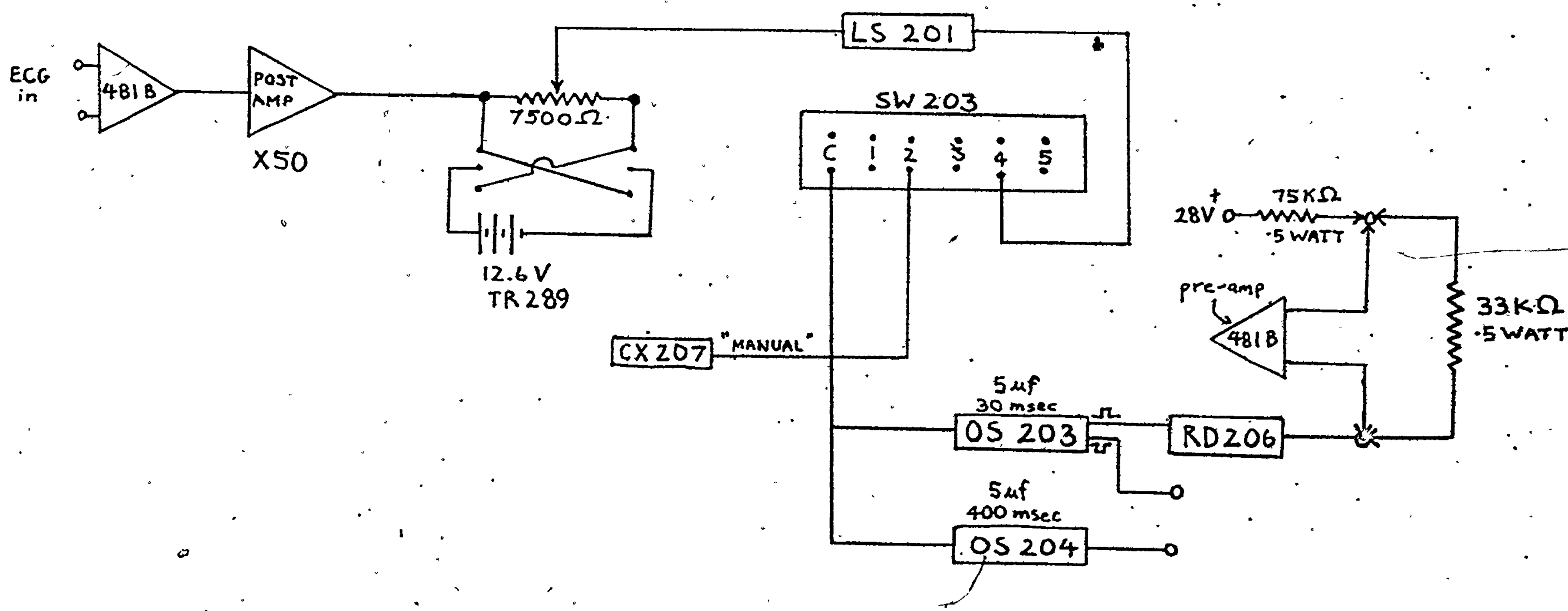
A second class of effects that may have influenced performance on both control and discrimination tasks concerns what subjects learned about properties of the task during feedback and discrimination training. An example which may serve to illustrate this point concerns whether subjects believed they were capable of solving the learning problem. Since the response that was to be detected was described as a novel one, subjects may have doubted their ability to perform successfully. Consequently, it is possible that the feedback training procedure facilitated discrimination in part by altering the subject's view of control and discrimination as soluble tasks. In turn, subjects with an expectation of success may have been more likely to undertake activities or actions that were conducive to control and discrimination (Bandura, 1978). Facilitation of discrimination by knowledge of results may also have originated from this source. Subjects given knowledge of results were in a position to recognize their success aand may therefore have expended greater effort on the task than subjects in Group F+noKR who may have been less confident about their choices on the discrimination problem. However, whether this factor influenced the relationship between control and discrimination is difficult to say. It perhaps seems unlikely to have been a factor since it is reasonable to suppose that subjects who succeeded during feedback training worked harder at discrimination than did subjects who failed on the feedback problem.

C. Conclusion

The present findings indicate that the statement of ideomotor theory that control and discrimination will be correlated is untenable for the case of sudomotor responding. However, it does not follow that learning about the response is unimportant in visceral control. Rather, it has been suggested here that the relationship implied by ideomotor theory can be obscured by complicating influences. Examples of these influences were given.

A question can be raised concerning how these possible influences of task structure and what is learned should be conceptualized. Up to this point they have been described as inferences concerning task structure and what is learned. However, this terminology implies a role for consciousness that may be inappropriate. A more neutral characterization depicts these influences as representations or constructions within which learning proceeds (Simon, 1979). The extent to which such representations were established by the current procedures, and the extent to which they were important determinants of performance on control and discrimination tasks, is not clear. Further work might examine the effect of such representations by manipulating descriptions of the task which subjects are given.

List of Appendices



Cardiac Filter
Appendix A

Appendix B

Instructions for Discrimination Experiments

Subjects Given Feedback Training

Day 1

The purpose of this experiment is to find out whether you can detect the occurrence of a particular physiological response. The response we want you to detect is a change in the conductivity of the skin, which is measured by electrodes we have attached to your palm and wrist. Normally we are not aware of changes in skin conductivity, but there is reason to believe that subjects can detect these responses under some circumstances.

Since the response we want you to detect is novel, it may help if we begin by first training you to produce increases and decreases in skin conductivity using a biofeedback procedure. The advantage of doing this is that such training will give you an idea of what variations in skin conductivity are like. The purpose of today's session is to teach you to control the response. Tomorrow we will begin discrimination testing.

We are going to teach you to control the response in the following way. At designated times during the course of today's session, we will ask you to increase skin conductivity by displaying the word "INCREASE" on the video monitor in front of you. At other times we will ask you to decrease the response by displaying the word "DECREASE" on the video monitor. During times when there is no instruction word on the monitor, you should sit quietly and wait for the next trial.

To help you perform this task, we will give you feedback on some trials, to show you how well you are doing. Here is an example of what the feedback display will look like (Present Display). The horizontal line represents your level of skin conductivity at the start of the trial. The vertical line, on the other hand, shows changes in the response. Movements of the vertical line toward the top of the screen correspond to increases in conductivity. Movements of the vertical ine toward the bottom of the screen correspond to decreases in conductivity. Your task is to move the vertical line as far above the horizontal line as possible on Increase trials, and to move it as far below the horizontal line as possible on Decrease trials.

There will be some trials on which no feedback will be given but you will still be instructed to increase or decrease the response. On these trials we want you to control skin conductivity as best you can, without feedback.

Feel free to use any method you wish to control the response, but please do not touch the electrodes we have attached to your body. This will create visible artifact in our recordings. If you need to talk to us during the experiment you can do so simply by speaking out loud. We will hear you over the intercom and will reply, if we think a reply is necessary.

To provide extra incentive, we are going to pay you bonus money for responding correctly. You could earn as much as one dollar extra for today's session of the experiment, were you to respond correctly all of the time. You will be told how much bonus money you have earned at the end of the session.

If you would like to have these instructions repeated, please tell us now. Otherwise, the experiment will begin in two or three minutes. Good luck.

Instructions for Discrimination Experiment

Subjects Given Feedback Training

Day 2

Part A

Today we are going to test your ability to detect instances of the response you learned to control last time. However, we are going to start by giving you a few "refresher" trials on which you are to again control the response, as you did in the last session. We will give you three increase and three decrease trials. Some of these trials will be with feedback; others will be without. We will pay you bonus money for performing correctly, as before. Here we go.

Part B

That was fine. We are coming into the room now, to prepare you for the next part of the experiment.

Part C

We will now test your ability to detect changes in the response you have learned to control. Specifically, we are going to test your ability to detect increases in skin conductivity. We are going to do this in the following way.

From time to time, you will hear a tone coming from a loudspeaker placed at the front of the room. The tone will sound like this. (Give sample tone). On some occasions, the tone will be presented when an increase in conductivity has just occurred; on other occasions, the tone will be presented when conductivity has not changed. Your task is to indicate whether the tone was, or was not, associated with a conductivity response. You can indicate your decision by pressing one of the two buttons placed in front of you. If you think a response has occurred, press the button on the left; if you think a response has not occurred, press the button on the right. You must make a decision every time the tone is sounded. However, this is not a test of how quickly you can press the button, but of how accurate you can be.

We are going to pay you bonus money for doing well. For every correct decision you will receive 5¢ but for every incorrect decision you will lose 5¢. You should note that whatever the outcome of the task, you will still receive your base pay. In other words, we will not ask you to pay us should you get more wrong than right. You could earn as much as $1.20 in bonus money, should you perform well. We will tell you how much bonus money you have earned at the end of the session.

(To help you perform correctly, we are going to tell you whether your decision was correct after each tone-trial. We will do this by turning on a light above the button that was correct, as soon as you have made your choice. This information may help you discriminate between trials on which an increase in conductivity occurred, and trials on which conductivity did not change.)[1]

We cannot tell you exactly how to go about making your decision on each trial. However, we can tell you that you are more likely to succeed if you try to actively produce sensations or behaviors that you think are related to changes in skin conductivity, over the course of testing. Only if you do this can you ascertain whether tone-trials are consistently related to some aspect of your experience. Consequently, you should try to manipulate your behavior and experience in an effort to solve the task.

If you wish to talk to us during the experiment, you may do so simply by speaking out loud. We will hear you over the intercom and will reply if we think a reply is necessary. If you would like to have these instructions repeated, please say so now. Otherwise, the discrimination test will begin in two or three minutes. Good luck.

[1] Section in parentheses omitted for group F+noKR

Instructions for Discrimination Experiment

Subjects Given Feedback Training

Day 3

Today we will again test your ability to detect increases in skin conductivity. The procedure will be the same as in the last session, except there will be no "refresher" feedback trials.

Remember, your task is to decide whether each tone was, or was not, associated with a conductivity response. If you think a response has occurred, press the button on the left. If you think a response has not occurred, press the button on the right. You must make a decision every time the tone is sounded. We will (indicate whether your decision was correct and will)[1] pay bonus money for correct choices, as before. Also remember that you are more likely to succeed if you try to actively produce sensations or behaviors that you think are related to changes in skin conductivity, over the course of testing.

If you would like to have these instructions repeated, please tell us now. Otherwise the experiment will begin in two or three minutes. Good luck.

[1] Section in parentheses omitted for Group F+noKR.

Instructions for Discrimination Feedback

Subjects Not Given Feedback Training

Day 1

The purpose of this experiment is to find out whether you can detect the occurrence of a particular physiological response. The response we want you to detect is an increase in the conductivity of the skin, which is measured by electrodes we have attached to your palm and wrist. Normally we are not aware of increases in skin conductivity but there is reason to believe that subjects can detect such responses under some circumstances.

We are going to measure your ability to detect this response in the following way. From time to time, you will hear a tone coming from a loudspeaker placed at the front of the room. The tone will sound like this. (Present sample tone.) On some occasions the tone will be presented when an increase in conductivity has not changed. Your task is to indicate whether the tone was, or was not, associated with a conductivity response. You can indicate your decision by pressing one of the two buttons placed in front of you. If you think a response has occurred, press the button on the left; if you think a response has not occurred, press the button on the right. You must make a decision every time the tone is sounded. However, this is not a test of how quickly you can press the button, but of how accurate you can be.

We are going to pay you bonus money for doing well. For every correct decision you will receive 5¢ but for every incorrect decision you will lose 5¢. You should note that whatever the outcome of the task, you will still receive your base pay. In other words, we will not ask you to pay us should you get more wrong than right. You can earn as much as $1.20 in bonus money should you perform well. We will tell you how much bonus money you have earned at the end of the session.

To help you perform correctly, we are going to tell you whether your decision was correct after each tone-trial. We will do this by turning on a light above the button that was correct, as soon as you have made your choice. This information may help you discriminate between trials on which an increase in conductivity occurred, and trials on which conductivity did not change.

At this point you are probably wondering how you can possibly discriminate between the presence and absence of conductivity responses, if you do not know what the response is like. We cannot tell you what the response is like, because we do not know ourselves. However, we can tell you that you are more likely to succeed if you try to actively produce various sensations or behaviors that you think are related to changes in skin conductivity, over the course of testing. Only if you do this can you ascertain whether tone-trials are consistently related to some aspect of your experience. Consequently, you should try to manipulate your behavior and experience in an effort to solve the task.

If you wish to talk to us during the experiment, you may do so simply by speaking out loud. We will hear you over the intercom and will reply if we think a reply is necessary. Also, we ask that you not touch the electrodes we have attached to your body. This will create visible artifact in our recordings. If you would like to have these instructions repeated, please say so now. Otherwise, the discrimination test will begin in two or three minutes. Good luck.

Instructions for Discrimination Experiment

Subjects Not Given Feedback Training

Days 2 and 3

Today we will again test your ability to detect increases in skin conductivity. The procedure will be the same as in the last session.

Remember, your task is to decide whether each tone was, or was not, associated with a conductivity response. If you think a response has occurred, press the button on the left. If you think a response has not occurred, press the button on the right. You must make a decision every time the tone is sounded. We will indicate whether your decision was correct and will pay bonus money for correct choices, as before. Also remember that you are more likely to succeed if you try to actively produce sensations or behaviors that you think are related to changes in skin conductivity, over the course of testing.

If you would like to have these instructions repeated, please tell us now. Otherwise the experiment will begin in two or three minutes. Good luck.

Appendix C

Structure of Feedback Training Trials

Trial #	Type of Trial	Instruction Word	Feedback
		Day 1	
1	Blank	absent	absent
2-5	Transfer	Two increase (I) and two decrease (D) in one of the following sequences: IDID, DIDI, DIID, IDDI, IIDD, DDII	absent
6	Blank	absent	absent
7-26	Feedback	Ten increase and ten decrease in one of the following sequences: IIDIDDIIDIIDDIIDDIDD IDIIDIDIIDDIDDIIDIDD DDIDIIDDIDDIIDDIIDII DIDDIDIDDIIDIIDDIDII	present
27	Blank	absent	absent
28-31	Transfer	as in trials 2-5	absent
32	Blank	absent	absent
		Day 2	
1-4	Feedback	Two increase and two decrease in one of the following sequences; IDDI DIID	present
5-6	Transfer	One increase and one decrease in either order	absent

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