THE PHYSIOLOGICAL CONTROL OF VERBAL BEHAVIOR

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The current study sought to investigate whether physiological responses, such as the electrodermographic response (EDG) and/or the frontalis muscle electrical potential (EMG) could be developed as a source of control over verbal responses. Discrimination training procedures using points exchangeable for money were employed to condition verbal responses occasioned by minute interoceptive events with 2 adult human subjects. Specific verbal responses were reinforced in the presence of changes in EDG with S1 and EDG and EMG with S2. Stimulus control over differentiated verbal responses was demonstrated with both subjects. The results suggest that minute interoceptive events can enter into controlling relations with verbal responses and that this control is partially a function of the size or range of physiological responses as well as conditioning history.

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INTRODUCTION

Behaviorism is often characterized as denying the existence of feelings and thoughts. A more accurate characterization of current behaviorist interpretation is that "feeling" and "thinking" label empirical events that occur inside the skin and enter into behavioral relations. Not all behaviorists, however, have approached events inside the skin as phenomena amenable to empirical investigation. For the methodological behaviorist, private events may be taking place within the organism, but are beyond the purview of scientific investigation. As Boring (1945) said, "Science does not consider private data" (p. 245). On the other hand, the radical behaviorist "may in some cases consider private events (inferentially, perhaps, but nonetheless meaningfully)" (Skinner, 1945, p. 276).

In lay usage there is a tendency to attribute great importance to feelings as <u>causes</u> of behavior. Similarly, for cognitivists, feelings or emotions are often hypothetical or psychic constructs. Cognitive accounts of behavior, being organism-based, explain behavior in terms of hypothesized intraorganismic variables (Hineline, 1990).

In a behavior analytic account, behavior is a function of the environment; and included among environmental events are those physical events that (1) occur within a behaving organism's skin and (2) can provide stimulation for that organism (Skinner, 1974). Schnaitter (1978), following Skinner, defined private events as "phenomena of psychological interest taking place 'inside the skin,' at a covert level, observable beyond the first person by indirect means, if at all" (p. 1). For Schnaitter (1978, 1987), like Skinner, private events can function as either responses or stimuli in behavioral relations and should be dealt with no differently than public events. Behavior analysts contend that private events are essentially physical events occurring inside the skin but they have yet to adequately investigate and describe how those events relate to behavior. An important issue in behavior analysis, then, involves the stimulus or response functions of intraorganismic events in a complete account of behavior. The role of such private events is considered of importance conceptually (e.g., Michael, 1985; Moore, 1984) and empirically (e.g., Greenspoon, 1976, Lubinski & Thompson, 1987).

Some of the events that can function as either stimuli or responses in a behavioral account may be physiochemical events. Such events are often identified in everyday usage as emotions. To say that emotions are essentially physiochemical events is fine, but how do such emotional responses relate to overt behavior? If physiological responses enter into controlling relations with overt behavior, behavior analysts can examine those relations providing they can measure those physiological events. The study of the development of functional relations between such variables and overt behavior in the laboratory is possible if technology not available in everyday settings can be used to directly measure stimulus events occurring within the skin. The empirical investigation of behavioral relations in the laboratory can serve as an analog of behavior in everyday settings and thereby facilitate interpretation of that behavior. The current study attempts to investigate empirical events occurring within the skin in order to examine experimentally behavior analytic inferences about the relations of private events to directly observable behavior.

Because of the difficulties encountered in reliably measuring private events, their significance in functional relations can potentially be overlooked. The relevance of some physiological events in a functional analysis of behavior has been suggested by many behavior analysts. Greenspoon (1976) stated, "If you consider only the extraorganismic environment (for sources of behavioral control) you will have an incomplete picture" (p. 87). Hayes (1991) pointed out that continued investigation of the role of private events, especially emotional variables, in verbal relations was potentially both clinically and conceptually important.

Skinner (1945, 1953, & 1974) and Michael (1985) emphasized the importance of putting private events into proper perspective in a behavioral account. Of particular relevance to Skinner (cf. 1945, 1953, 1957, & 1974) was the role of private events in the control of verbal behavior. For Skinner, verbal behavior is behavior which is subject to the same processes as other behavior. Skinner gave a very plausible account of the ways the verbal community might train verbal responses under control of private stimulation (1945), but little empirical investigation has occurred. Glenn suggested that clinicians look "beyond the verbal behavior for the empirical events that account for it" (1983, p. 47) and that some events functionally related to verbal behavior may be private. According to Glenn, private events are empirical events if "potentially detectable as functionally related" (p. 47) to either responses or stimulating environments.

Although empirical investigation of physiological responses in behavioral relations is rare, it is by no means new in the experimental analysis of behavior. As dependent variables, various physiological responses have been subjected to operant conditioning procedures that examined their susceptibility to operant control. Studies have demonstrated operant control of the electromyographic response (EMG) (Hefferline, Keenan, & Harford, 1958; Laurenti-Lions, Gallego, Chambille, Vardon, & Jacquemin, 1985). In addition, several studies have attempted to demonstrate consequent control of the galvanic skin response (GSR or EDG) (Kimmel & Hill, 1960; Kimmel & Kimmel, 1963; Mandler, Preven & Kuhlman, 1962).

The role of physiological responses as interoceptive stimulus events in behavioral relations has been subject to only limited empirical investigation (Glenn, 1983). This may be due not only to the difficulty of measuring physiological responses but also to the problem of controlling those responses as independent variables. Lubinski and Thompson (1987) taught pigeons to tact internal states which varied as a function of various drugs that were administered. In that study, internal events (although not directly measured) were controlled as independent variables by manipulating which drug was administered.

In an earlier study with human subjects, Hefferline and Perera (1963) demonstrated the development of a minute muscle twitch already occurring within the subjects as a source of control over an overt nonverbal response. They demonstrated that faint proprioceptive feedback from a small muscle twitch in the abductor muscle could be conditioned as a discriminative stimulus for an overt response, a key press. The muscle twitch was measured by observing 1- to 3-microvolt (μv) changes in muscle electrical potential using an EMG. After obtaining a baseline rate of occurrence of muscle twitches followed and not followed by key presses, Hefferline and Perera then operantly conditioned key pressing in the presence of a tone. The tone was only presented immediately following a thumb twitch. If the subject then pressed the key, points exchangeable for money were presented. In the following phase, key presses following muscle twitches were shaped by presenting the tone only when the electrical potential (i.e., electrical activity correlated with muscle tension) in the finger used for pressing increased following an abductor muscle twitch. Finally, the tone was gradually faded out, and key presses following muscle twitches resulted in point presentation.

In the Hefferline and Perera study, interoceptive events, already occurring in the subjects, were measured using physiograph equipment, giving the experimenters access to physical events within the skin of the subject. One provocative finding was that after the tone was faded out, subjects continued to press the key and in addition, reported still hearing the tone. This research clearly demonstrated that under specified circumstances interoceptive events do function as controlling stimuli for other directly observable behavior.

In view of the potential importance of intraorganismic events in an empirically based behavioral account, a reasonable question arises from the Lubinski and Thompson

(1987) and Hefferline and Perera (1963) research studies: Can minute physiological responses enter into controlling relations with human verbal responses? In attempting to answer that question, the present research investigates whether minute changes in the electrodermographic response (EDG) or both EDG and the frontalis muscle EMG could be developed as differential sources of control over two different verbal responses. The current research follows from the tradition established by Hefferline and Perera (1963), in that a physiograph is used to gain access to interoceptive events without directly controlling those events. The current study uses positive reinforcement procedures similar to those demonstrated to be effective in developing exteroceptive stimuli as sources of control over overt responses in countless studies.

The inclusion of the EDG as a physiological variable for the present study was considered important. Malott and Whaley defined emotion as "a temporary physiological change due to stimulus change in the creature's world" (1976, p. 459). The EDG was specifically selected because it is regulated by the autonomic nervous system and is thought to be correlated with what is commonly referred to as emotional responses (Peffer, 1979).

The purpose of the current research is (1) to develop and present an experimental preparation for systematic investigation of private events within a behavior analytic framework, (2) to experimentally demonstrate the similarity between the function of interoceptive and exteroceptive events in stimulus control relations and (3) to examine the relation of physical events occurring within the skin to verbal behavior under stimulus control of these events. It focuses on developing experimental procedures to take advantage of technological advances that allow reliable measurement of internal events.

METHOD

Apparatus

A J&J I-330 Computerized Physiological Monitoring System®, was used to monitor and record physiological responses. An EMG Module provided signals in the 0 to 100 microvolt (μv) range at 100 to 200 Hertz. Skin conductance was measured with an electrodermograph (EDG) module using 0.166 VDC across electrodes in the 0 to 50 microampere (μa) range. Both EMG and EDG signals were monitored using silver/silver chloride skin contact electrodes. EMG electrodes were attached to the subject's forehead across the frontalis muscle, 1 inch above the eyebrows. EDG electrodes were attached to the middle pads of the subject's index and middle fingers.

Two IBM compatible 80386 computers with VGA monitors were used for subject stimulus presentations and physiograph control. Programs for the subject screen computer, data recording and data analysis were written specifically for these experiments in Borland Turbo Pascal®.

Subjects and Setting

Subjects were recruited through advertisements in the campus newspaper. The criterion for continued participation in the experiment was demonstration of an adequate range of physiological responding (i.e., EDG range greater than 2 µa/session and/or mean EMG range greater than 2 µv/session) for at least three sessions. Of the four subjects recruited, two female undergraduates (ages 19 and 21) from the University of North Texas met the criteria and were continued in the experiment.

The research was conducted in a 3 m x 5 m laboratory in the Center for Behavior Analysis at the University of North Texas. Subjects sat in front of a small table containing only the subject computer monitor (subject screen). All other equipment (e.g., the subject screen computer, its keyboard and the physiograph computer) were located on a large table behind and to the right of the subject. Two experimenters sat facing the physiograph computer monitor which was out of the subject's line of sight. The first experimenter ran the computer controlling the subject stimulus presentation screen, while the second experimenter ran the physiograph computer and took reliability data.

Stimuli

The subject screen was used for the presentation of antecedent and consequent stimuli. The cumulative point screen was displayed whenever no other stimuli were being presented upon the screen. A blue background occupied the top half of the screen with total cumulative points displayed in a small black square in the center of the blue area.

To set the occasion for subject verbal responses, a 5 cm x 8 cm green box appeared in either the lower left, lower center, or lower right of the subject's computer screen. Box presentations were accompanied by a 1/2 s tone rapidly oscillating around 440 Hz.

The consequent stimuli used in the current study were points presented on the subject's monitor. Prior to point presentation the screen was blanked. A correct verbal response following either a left or right box was consequated with a sliding scale tone (from 100 to 2000 Hz) and a blue box that expanded to fill the upper portion with 5 points added to the cumulative total in the center. A correct verbal response following a center box presentation resulted in a different sliding scale tone (1 to 4000 Hz) and a tan box which expanded to fill the complete screen with 'PLUS 10 POINTS' presented in the center.

If a subject's physiological response levels gradually declined across a session, a brief verbal interaction with the experimenter was introduced. Subjects were asked to count from 0 to 50 or 50 to 0 as fast as they could. Occasionally, two or three digit addition or multiplication problems were presented for the subject to solve. The counting and math tasks appeared to evoke EDG responding only occasionally for both subjects. Number and timing of verbal interactions with the subjects were monitored so as to control for the possibility of the interactions developing discriminative control over verbal responses.

Procedures

The procedures for both subjects included prompted and unprompted discrimination training of verbal responses under differential control of physiological events measured by the physiograph. Each session lasted 26 minutes and included a baseline period and training phase.

Subject 1. For the first session, the subject was escorted into the experimental room and seated in front of the subject screen. The experimenter indicated the physiograph and stated, "This is a standard bio-feedback system. It is for passive recording only, and does not stimulate or shock in any way." After attachment of physiograph electrodes, the following instructions were read to the subject:

When the session begins, please watch the computer screen. On the screen the points you earn will be presented. When you earn points it looks and sounds like this (Experimenter demonstrated 5 point presentation). The total number of points you have earned in the session will remain on the screen.

I want you to practice saying each of these words, out loud, three times. (Experimenter handed subject a page with printed 'MEC' and 'PAV'). The way you earn points is by saying one of these words when you see a green box appear at the bottom of the screen.

During sessions, if I ask you to answer a question or describe something, just do the best you can. If a green box appears on the screen, stop what you are doing and say one of the words. Do not return to answering the question you were working on.

Please remain as still as possible during the session. It is important that you not move your hands, so find a comfortable position for them now.

The experimenter then explained that she would receive half of her daily earnings at the end of each session. As an inducement for attendance she was told that the balance would be payable upon completion of the experiment.

Baseline. Each session began with a 3-minute baseline period for observing current EDG range and variability. At the beginning of baseline, the cumulative point screen was presented. No other stimuli were presented during baseline.

The physiological response selected for subject 1 was the electrodermal-response as measured by an electrodermograph (EDG). The EDG provides a measure of skin conductivity as regulated by the autonomic nervous system (Peffer, 1979).

During baseline of each session, the experimenters determined the levels above and below which the physiological response would be designated High or Low. In order to differentiate these conditions, a window rather than a single threshold was specified for the EDG. The window was defined with an upper limit threshold at approximately the mean of baseline responding, and lower limit threshold at 90% of the upper limit.

Prompted Discrimination Training. After baseline each day, the training session began. For sessions 1 and 4, both 'MEC' and 'PAV' were trained. During training, the prompts (left or right box presentations) occurred at random intervals varying from 3 seconds to 2 minutes. At those intervals, when the subject's EDG was above threshold, a left box was presented. When the subject's EDG was below threshold, a right box was presented at random intervals. If the subject said 'MEC' in the presence of High EDG and the left box, points were delivered. If the subject said 'PAV' in the presence of Low EDG and the right box, points were also delivered. Responses in the presence of experimenter designated 'incorrect' stimulus events were not followed by points (extinction procedure). Training started with the prompted discrimination procedure in an attempt to give the subject a history of 'correct' verbal responding in the presence of the appropriate physiological response.

Only the High EDG - left box - 'MEC' relation was trained for sessions 2, 3, and 5 through 9. During those sessions, right boxes were not presented in the presence of Low EDG.

<u>Screen Exposure</u>. By the end of session 9, the subject had not acquired the left box - 'MEC' and right box - 'PAV' discriminations. An alternative training procedure, the screen exposure, was implemented. For session 10, the subject was exposed to the experimenters' physiograph screen. Because the subject's verbal responding was not totally controlled by the left and right box exteroceptive prompts, the screen exposure procedure was implemented to provide alternative exteroceptive prompts. The subject was

seated with the experimenters in front of the physiograph screen and instructed as follows:

> The purple line is from the sensors on your hand. When the purple line is above the light blue line, and you hear the sound that comes with the box, say 'MEC'. When the purple line is below the dark blue line, and you hear the sound, say 'PAV'.

Training continued as in session 1 and 4 with both 'MEC' and 'PAV' training.

Unprompted Discrimination Training. Immediately following the Screen Exposure session, session 11 was conducted with S1 returned to her position in front of the subject screen. This was the only day that two sessions occurred in one day. From session 11 through the end of the experiment the discrimination training did not involve exteroceptive prompts differentially associated with high and low EDG responding. In the unprompted discrimination training phase the green box was always presented in the lower center portion of the subject screen. A demonstration of discriminated responding under the control of changes in physiological responding required the removal of differentially associated exteroceptive prompts. In unprompted discrimination training trials, all box presentations were in the center and the only differentially associated antecedent events were interoceptive.

Following center-box presentation when EDG was above threshold window, if the subject said 'MEC', points were presented, if she said 'PAV' there was no change in the subject screen display. Following center box presentations, when EDG was below threshold, a 'PAV' response resulted in a 10 point presentation and a 'MEC' response did not. The discrimination training procedures continued in all remaining sessions for S1.

Subject 2.

Procedures for S2 were similar but with several important differences. A combination of physiological responses was specified for development as controlling stimuli. High EMG/Low EDG was defined as occurring when the frontalis EMG was above its threshold and EDG was below its threshold. Low EMG/High EDG was defined as occurring when the frontalis EMG was below threshold and EDG was above threshold. The verbal response 'MEC' was reinforceable in the presence of High EMG/Low EDG and 'PAV' in the presence of Low EMG/High EDG.

Baseline. Threshold windows were established for S2 during session 1. As EDG and frontalis EMG varied around a mean value of 3 (3 μv EMG, 3 μa EDG), an upper window limit of 3 and lower window limit of 2.7 were established for both EMG and EDG. The threshold windows for both EDG and frontalis EMG remained constant throughout the course of the experiment.

Subject 2 was given the same instructions as those for S1 except the following was substituted for the underlined section of S1's instructions.

> I want you to practice saying this word three times. (Experimenter handed subject page with printed 'MEC'). The way you earn points is by saying that word when you see a green box appear at the bottom of the screen.

In addition, 'say the word' was substituted for 'say one of the words.'

<u>Prompted Discrimination Training</u>. Only the High EMG/ Low EDG - 'MEC' relation was trained for the first two sessions. Training consisted of always presenting the box in the lower left of the screen. Points would be presented when the subject responded 'MEC' to the box presentation.

<u>Unprompted Discrimination Training</u>. Prior to Session 3, the following instructions were read to the subject:

> When we start, remain as still as possible. Today there is something new: When bar is on the right side - say 'PAV'. (Instructor placed a page with printed 'MEC' and 'PAV' on table next to subject screen. Page remained on table for all of session #3.)

In session 3, discrimination training was begun. The session was conducted as prior sessions with two changes. In addition to Left-box when subject's EDG was above threshold window and frontalis EMG was below window, Right-box was presented when EDG was below threshold window and frontalis EMG was above threshold window. The session continued in this manner until the final 6 minutes of session, at which point, center box presentations were faded in by interspersing them with right and left box presentations. The fading in of the unprompted discrimination training began when the subject had responded appropriately (i.e., responded correctly on 100% of the prompted discrimination trials) to the exteroceptive prompts for 17 minutes. Center, right, and left box presentations were continued in sessions 4 and 5. Sessions 6 through 13 contained only center box presentations.

RESULTS

Response Measures

Reliability data were taken on 90% of all sessions. Agreement between experimenters on both verbal response scoring and occurrence of physiological responses was above 98%. The two major response measures were the range of physiological values during a session and the relative frequency of correct switches when the center box was presented.

The range of physiological values refers to the difference between minimum and maximum value of a physiological response across an entire session. When the range is large, the S's physiological response is farther above or below the threshold. As the range narrows the discrepancy between the above and below threshold values becomes smaller and smaller.

The relative frequency of correct switches was the dependent variable measure of physiological response control of verbal responses. The opportunity for a correct switch occurred only when the physiological response(s) changed from high to low or low to high. A correct switch required the subject to change her verbal response when the physiological response values changed from above to below or below to above threshold(s). For example, if the previous appropriate verbal response was 'MEC' and the subject responded with 'MEC' and if the next appropriate response was 'PAV' and the subject responded with 'PAV', the sequence constituted a correct switch. For S1, a correct switch consisted of emitting 'MEC' when the EDG was above threshold followed by emitting 'PAV' when the EDG fell below threshold. The reverse of the sequence also constituted a correct switch. For S2, a correct switch consisted of emitting 'MEC' when the EMG was above threshold and the EDG was below followed by emitting 'PAV' as the next response when the EDG was above threshold and the EMG was below. The reverse of this was also scored a correct switch. If a subject's physiological response remained above or below threshold across an entire session, there were no switch opportunities.

Subject 1

S1's within-session EDG values were usually variable throughout each session. There were usually numerous opportunities for both above and below threshold box presentations. Figure 1 in the Appendix presents the EDG values for session 19, which were generally characteristic of S1's EDG responding.

The data for S1's verbal responses are presented in Figure 2 in the Appendix. The open data circles represent the relative frequency of correct verbal responses following a presentation of either a left or right box. The open triangles indicate the relative frequency of correct switches following a center box presentation.

The data for the first 9 sessions indicate a gradual acquisition of the initial left-right discrimination. During the screen exposure session, the subject made no errors. The data appear to indicate that exposure to the physiograph screen with the explanation of the contingencies under which points are delivered did not result in acquisition of discriminative control of the verbal responses by the physiological responses since there were no correct switches in the session immediately following exposure to the physiograph screen.

The absence of a data point in Figure 2, for session 20 indicates the lack of switch opportunities. During that session her EDG trended upward across the entire session. The relative frequency of correct switches increased significantly after session 16. An upward trend from session 11 through 23 suggests a gradual acquisition of the discrimination. Maintenance of the discrimination seems to be indicated by sessions 23, 24, 26, and 27. The relative frequency of correct switches in Session 25 appears to be rather deviant from all of the data points after Session 16. This particular session was conducted late on a Friday afternoon.

The relative frequency of correct switches and the range for S1's EDG are presented in Figure 3 in the Appendix. The range of S1's EDG responses is fairly consistent across sessions at about 6 μa, a rather large range in skin resistance for the laboratory setting.

Subject 2

The physiological responses of interest for S2 were EDG and frontalis EMG. Across-sessions, S2's EMG tended to stabilize around 1.8 μv with occasional excursions to approximately 3.75 µv. S2's EMG responding remained fairly constant across all sessions. S2's EDG responding tended to vary fairly consistently within sessions. However, across sessions the range of her EDG responses tended to decrease. Figure 4 in the Appendix illustrates her physiological responses for a fairly typical session prior to the declining trend in her EDG range.

During complex discrimination training, the relative frequency of correct switches for S2 (see Appendix, Figure 5) increases steadily until session 10. Beginning with session 10 the frequency of correct switches shows a steady decline. Paralleling the decline in the correct switches is the decline in the EDG range. When S2 had an EDG range of 6 µa, she also showed a high relative frequency of correct switches. As S2's EDG range declined, ultimately to a range of about 2 µa, so did her frequency of correct switches. The lack of a data point for correct switches in session 16 indicates a lack of switch opportunities.

By session 14, the subject's EDG response range had decreased to 2.6 µa and the experimenter presented a center box when her EDG was just at the upper limit of the threshold window and her EMG was at the lower limit of the window. The subject responded with 'PEC'. Presentations near threshold limits were repeated seven times in session 15 and the subject responded 'PEC' to two of those presentations. She responded 'MEC' to two and 'PAV' to three of the near threshold presentations. This response did not occur in any other sessions. The emission of the novel response 'PEC' seems to be a serendipitous instance of a novel verbal response under multiple control (Skinner, 1957, pp. 293-294).

Observations

Following some reinforcer presentations, an immediate and rapid increment in EDG was observed with both subjects. In earlier sessions, point presentations tended to elicit a 1 to 3 μa increase. Across and within sessions the size and frequency of EDG elicitation tended to decrease. Spontaneous recovery was also noted within and across sessions. Both subjects presented sessions with little or no point-elicited responding and sessions where elicited responding occurred. Mandler, Preven and Kuhlman (1962) reported that some subjects showed appreciable increases in GSR (i.e., EDG) following reinforcer delivery and indicated there may be two types of subjects (i.e., those that show increases and those who do not). Our observations of these and similar occurrences with pilot subjects suggest an alternative explanation. For each subject, across time, point presentations will elicit EDG responses on some occasions and not on others.

DISCUSSION

Despite the different procedures and physiological response measures used, the results from these two subjects are very similar in many respects. A striking similarity is the apparent control demonstrated by the physiological responses when the range of response values was relatively large. Both S1 and S2 evidenced a high relative frequency of correct switches when their EDG range was around 6 µa. The decline in correct switches for S2 when the range of her EDG responding declined illustrates the importance of the range. This suggests that if the range becomes too narrow, discriminative responding may fail to occur.

The results suggest that there may be some minimal range of a physiological response that is necessary for a discrimination to develop and be maintained. The failure of the discriminative responding is certainly consistent with research involving discriminated behavior under control of exteroceptive stimuli. There is an abundance of research in psychophysics demonstrating that discriminated responding requires some minimum difference along some physical dimension (Guilford, 1954; Johnston & Pennypacker, 1980; Stevens, Morgan, & Volkmann, 1941). It may be reasonable to suggest the same situation may prevail with respect to discriminated responding under control of interoceptive stimulation. As the range in S2's EDG values narrowed, the basis for differential verbal responding may have become increasingly difficult, if not impossible. This has procedural and theoretical implications for future research. Procedures must be developed that will allow reliable elicitation of physiological responses of sufficient magnitude to enter into behavioral relations.

S1 was exposed to the physiograph screen during session 10. In addition, the contingencies under which points were delivered were explained to her. Session 11 was conducted 5 minutes after session 10. That the relative frequency of correct switches during session 11 was 0 indicates that the subject was unable to discriminate between high and low EDG levels, even with a description of the contingencies under which points were delivered. That, in light of the apparent gradual acquisition of the discrimination, appears to suggest the subject had no prior history of discriminative control by that particular type of stimulation. This is to be expected because without special equipment, the verbal community would have no way to train such discriminative responding. This is consistent with Skinner's (cf. 1945, 1953, 1957) explanation of how difficult it is for the verbal community to bring verbal behavior under discriminative control of private events. These findings appear to lend support to Lubinski and Thompson's contention that "one might expect large individual differences in ability to report internal feelings depending on the adequacy of their discriminative learning histories with respect to interoceptive events, often acquired under the tutelage of parent (or in some instances later in life, e.g., via counseling or psychotherapy" (1987, p. 12).

The results from both subjects appear to indicate that physiological responses can indeed enter into controlling relations with verbal responses. For the current study, that control was developed following Skinner's specification of a tact as "a verbal operant in which a response of a given form is evoked (or at least strengthened) by a particular object or event or property of an object or event" (1957, pp. 81-82) following a history of generalized reinforcement contingent on such responding. This required the experimenters to function as a highly specialized verbal community using specialized equipment to access the interoceptive events. The question arises of how, if at all, interoceptive events could enter into controlling relations with behavior (verbal or nonverbal) in natural environments.

The current study relied solely on positive reinforcement of <u>verbal</u> responses in the presence of physiological changes at minute levels. Discriminative relations between physiological responding and overt behavior need not entail tact training, however. Stimulus control may develop in the natural environments in which verbal or non-verbal escape or avoidance is reinforced in the presence of high levels of physiological stimulation. The development of control may be adventitious (i.e., not specifically arranged by a verbal community). For example, for an employee who has been aversively stimulated by his boss every time he is called in to see him, an upcoming appointment to see his boss may result in increases in blood pressure, heart rate, and skin conductance as well as an increased likelihood of leaving the work place. The employee may actually state that he does not want to talk to the boss, which initially cues avoidance of the meeting with the boss. If this happens enough times, the physiological responses may acquire some degree of control over the verbal response. If similar physiological responses occur in an entirely different situation, there may be an increased probability of occurrence of a verbal response similar to "I'm going home." Further research is needed to investigate whether these kind of behavioral relations are indeed probable or even possible. The current experimental preparation can be used in experiments where aversive contingencies are manipulated to stimulate greater physiological responding and develop control over verbal responses.

As noted in the results, one serendipitous finding was that delivery of points often produced rapid increases in the EDG. Donahoe's 'Unified Principle of Reinforcement' (Donahoe, 1977; Donahoe, Crowley, Millard, & Stickney,

1982) appears relevant to the current analysis. Donahoe (1977, 1991) and Donahoe et al. (1982) proposed that respondent elicitation is a part of any operant selection process. Donahoe et al. (1982) and Donahoe (1991) referred to any primary or conditioned reinforcing stimulus as an eliciting stimulus if it has the property that it reliably elicits a measurable response. For example, if food placed in the mouth elicits salivation, the food in mouth is an eliciting stimulus. He suggested that a quantitative analysis of the interaction of the elicitation process and prior responses will predict the probability of operant response selection.

Generalized conditioned reinforcers, such as points used in the current study, as stimulus events in an elicitation process do not appear to have been directly addressed in Donahoe's analysis. A generalized reinforcer is one that has been paired with or is exchangeable for many other conditioned or primary reinforcers. Much human responding seems to be maintained by these generalized reinforcers (e.g., money, points, tokens and praise). If the 'Unified Principle of Reinforcement' is to prove valid in an analysis of human behavior, it must account for behavior acquired and maintained by these stimulus events. In other words, these stimulus events would need to be shown to be elements of an elicitation process.

The basic point delivery and physiograph monitoring used in the current study appears well suited for an examination of Donahoe's analysis. Measures of point-elicited responding (e.g., EDG, heart rate, EMG, etc.) across multiple discrimination tasks could be correlated with data on discriminative responding on each task to determine if there is a relation between size of elicited responses and probability of discriminated response selection or reinforcer effectiveness. Discovery of a relation between magnitude of elicited responses and momentary effectiveness of a reinforcer could prove extremely valuable in molecular analyses of behavior/environment interactions.

Although the current study did not specifically investigate the type of controlling relations the physiological events apparently entered into, the possibilities warrant further discussion. If interoceptive events can enter into behavioral relations there appears to be no reason why they could not assume any of the functions that have been demonstrated with exteroceptive events. As antecedent controlling stimuli, physiological responses could function as either conditional or discriminative stimuli. Cumming and Berryman (1965) stated that conditional stimuli may function as selectors of discriminations rather than of individual responses. Sidman (1986) stated that conditional stimuli determine the control which other stimuli exert over responses. As conditional stimuli, physiological responses could influence what verbal responses are strengthened at a given time in the presence of particular audience or individual.

The results of this study have clinical implications as well. Greenspoon (1976) emphasized the importance of investigating intraorganismic sources of control in problem behavior. He proposed that if development of control of verbal behavior by physiological events is a function of the history of an individual, "it is entirely possible that an individual may emit verbal behaviors in environmental settings that are considered inappropriate" (p. 82). He further stated that with technical advances it should be easier to make observations of "the control of the environment over physiological reactions and of physiological reactions over behavioral acts" (p. 82) and understand the apparently bizarre behaviors frequently observed in behavior disordered patients. Greenspoon concluded that an inclusion of intraorganismic sources of control may obviate the use of "psychic constructs to account for abnormal behavior" (p.87).

In summary, the results of the current investigation suggest that minute interoceptive events can enter into controlling relations with verbal responses and that this control is partially a function of the size or range of the physiological responses as well as the conditioning history. This demonstration, far from being reductionistic, demonstrates that interoceptive events enter into controlling relations with other behavior as a result of interaction with exteroceptive events. Further investigations of the role of interoceptive events are suggested using the experimental preparation developed for this study.

APPENDIX

Figure 1. Session 19 EDG values for S1. Each datapoint indicates the average EDG value in microamperes (μa) for each 2-second interval across the session. The dashed lines represent upper and lower threshold window settings.

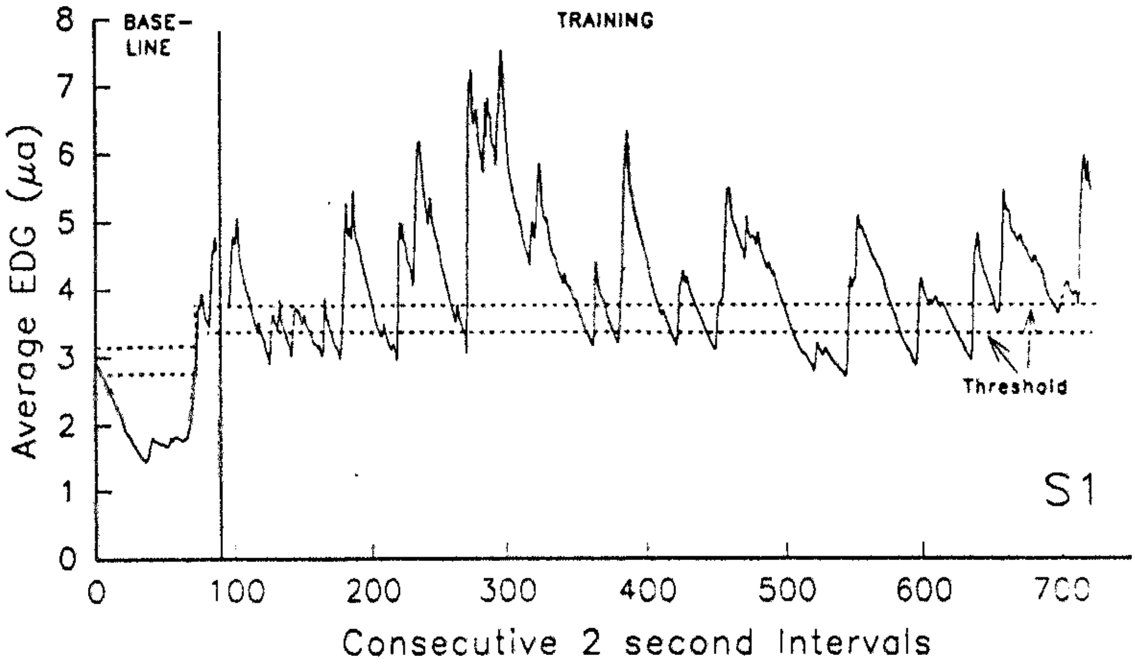
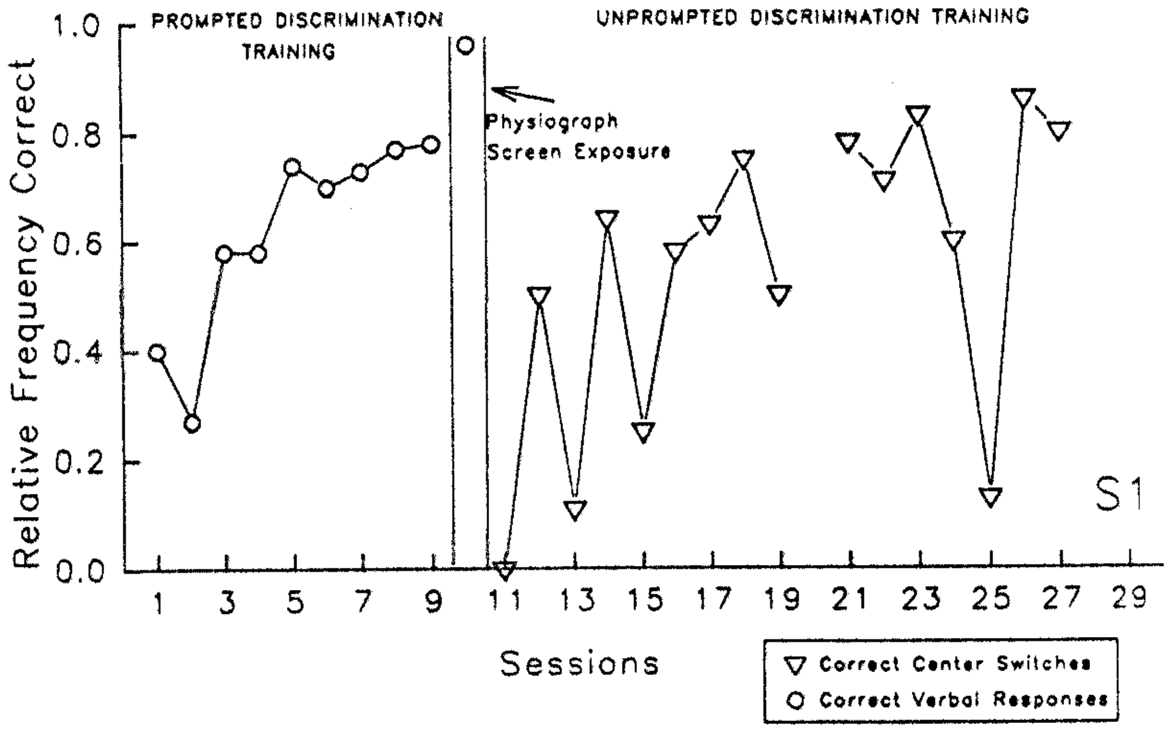


Figure 2. The relative frequency of correct responses. The relative frequency of correct verbal responses following a left or right box presentation are indicated by open circles. The relative frequency of correct switches following a center box presentation are indicated by open triangles. In session 20 there were no opportunities for switches.



<u>Figure 3</u>. Illustrates relation of relative frequency of correct switches to range of EDG in microamperes (μa). The open triangles indicate the relative frequency of correct switches per session. The solid squares indicate the absolute range of EDG (i.e., maximum EDG value - minimum EDG value) per session. The curves are 3rd order regression lines of best fir for the two sets of data for S1.

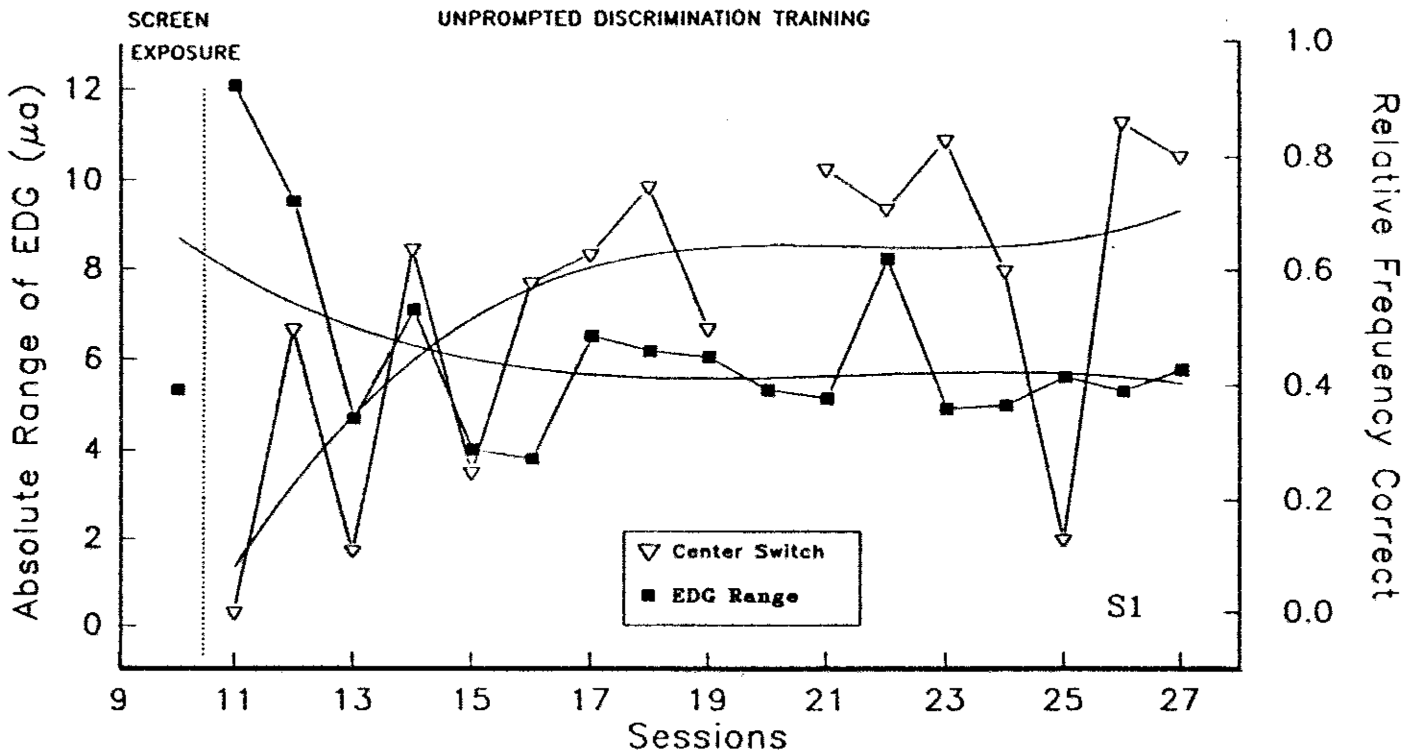
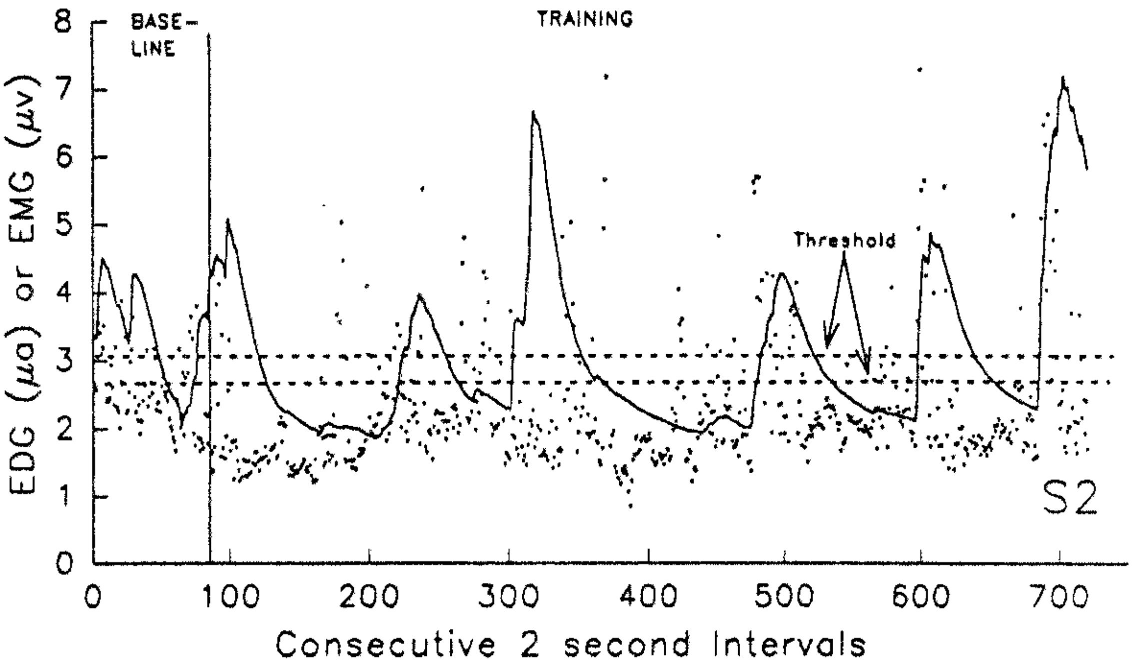
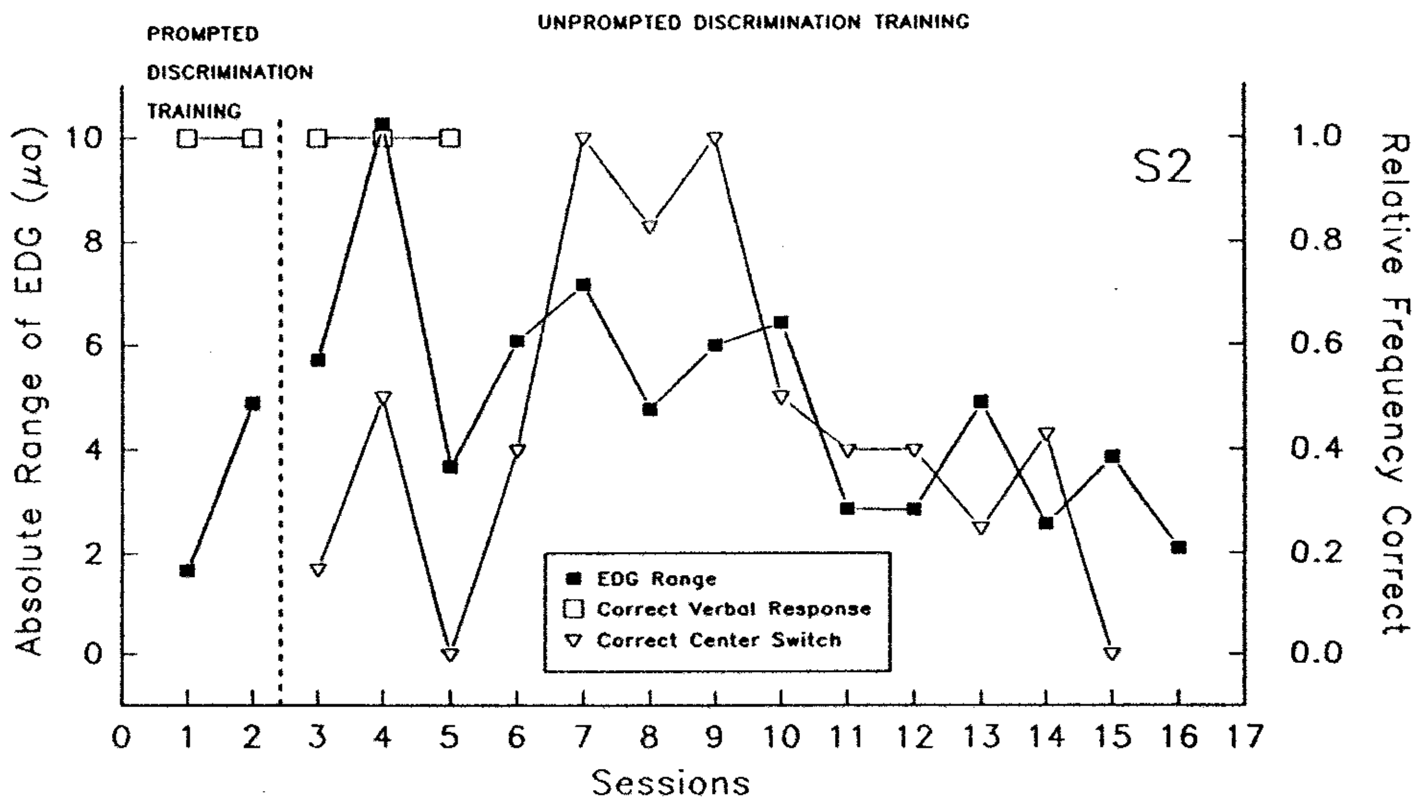


Figure 4. Session 7 physiological response values for S2. Scatterplot indicates average EMG in microvolts (μv) per 2-second interval. solid line indicates 2-second averages for EDG in microamperes (μa). The upper and lower limits of threshold window for both EMG and EDG are indicated by dashed lines.



<u>Figure 5</u>. Illustrates relation of relative frequency of correct switches to range of EDG in microamperes (μa). The open triangles indicate the relative frequency of correct switches per session. The solid squares indicate the absolute range of EDG (i.e., maximum EDG value - minimum EDG value) per session. The open squares in sessions 1 through 5 indicate the relative frequency of correct verbal responses following left or right box presentations.



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