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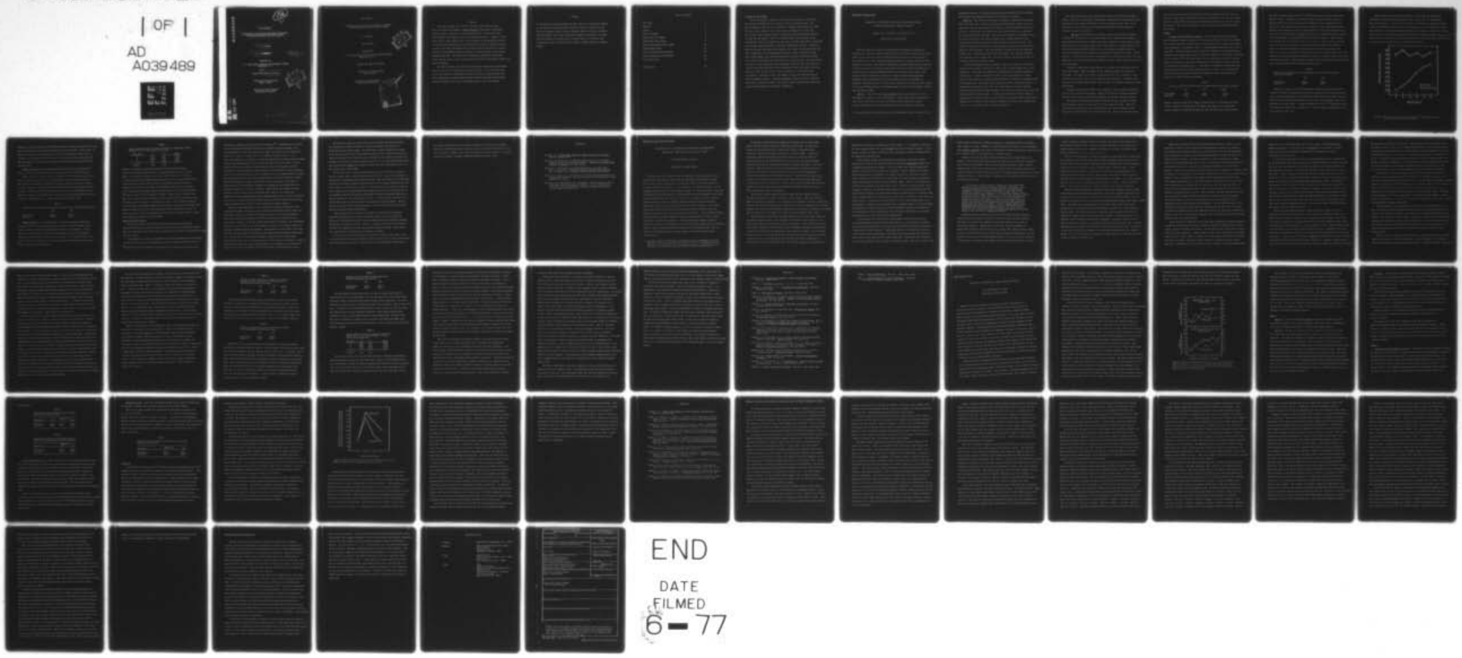

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INSTRUMENTAL AND CLASSICAL CONDITIONING TECHNIQUES FOR ESTABLISHING CHRONIC AUTONOMIC AROUSAL,

(10) H. D. Kimmel

(11) 30 June [redacted]976

(12) 60p.

Supported by

U. S. Army Medical Research and Development Command
Washington, D. C.

(15) Contract No. DAMD 17-74-C-4121

University of South Florida
Tampa, Florida

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Final Report

INSTRUMENTAL AND CLASSICAL CONDITIONING TECHNIQUES FOR ESTABLISHING CHRONIC AUTONOMIC AROUSAL

H. D. Kimmel

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Abstract

This report contains four sections. The first three are based upon data collected from two groups of *Cebus albifrons* monkeys whose electrodermal responses either postponed or were punished by shock. The main data from this study has been reported previously (Technical Report No. 1, August 1, 1975). These three sections consist of 1) a paper presented to the Psychonomic Society preliminarily reporting some of the results of the study; 2) a chapter in a book on anxiety and stress describing the theoretical basis of the work; 3) a contribution to a recent NATO symposium providing a new interpretation of the results and additional data. The fourth section summarizes collatoral research with human subjects aimed at fuller comprehension of the novel conditioning technique used with the monkeys.

The main conclusion to be drawn from this work is that the basic theoretical idea has some merit and should be investigated further. The initial work with the monkeys should be expanded and replicated and the human work should be tied more closely into the monkey effort for more effective theoretical and ultimate practical analysis of the causes of chronic emotional stress and anxiety.

Forward

In conducting the research described in this report, the investigators adhered to the "Guide for laboratory animal facilities and care," Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences, National Research Council. The research with human subjects was approved by the Human Research Committee of the University of South Florida, in accordance with requirements of the U. S. Public Health Service, National Institute of Mental Health.

Table of Contents

Statement of the Problem

The general purpose of the work summarized in this report was to develop and evaluate a new approach to the topic of chronic emotional arousal. An initial report of this work was presented in a technical report (August 1, 1975). This final report includes only a small amount of additional data from this initial work, plus a summary report of more recent studies using human subjects to study the same problem. Since the technical report presented most of the original data, these are summarized in the several sections below only in connection with certain theoretical points, rather than exhaustively repeated. In order to make the record of the project work complete, three papers are included which were direct outgrowths of the grant-supported activity. These constitute the main body of this report, plus a brief description of the more recent human research and a final section which sets forth future plans and prospects. The first section consists of a paper presented to the Psychonomic Society in 1975, the second is a version of the paper presented to the Association for the Advancement of Behavior Therapy in 1975, and the third is a paper presented at a NATO symposium on Biofeedback and Behavior in 1976. The latter two papers are both currently in press as chapters in books. As noted previously, a fourth section on recent related human research is included. This work is still in progress and none of its results have previously been reported or published.

Psychonomic Society Paper

Comparison of Instrumental and Classical Conditioning Methods for Establishing Chronic Autonomic Arousal[1]

Kimmel, H. D., McLeod, D. C. and Burns, R. A.

University of South Florida

The basic plan was to compare an instrumental conditioning paradign with a classical one. The instrumental paradigm involved two different visual discriminative stimuli (tonic stimuli), a Sidman avoidance schedule being used in the presence of one of these stimuli and a response contingent punishment schedule being used in the presence of the other. The classical conditioning paradigm analogously also contained two different tonic visual stimuli, with paired tone-shock trials being administered in the presence of one and unsignalled shock in the presence of the other. This unusual classical conditioning paradigm is a type of transswitching procedure (Asratyan, 1965), in which the visual discriminative stimuli are analogous to Asratyan's "switching agents." We have reported previously regarding the effectiveness of the transswitching design in establishing human electrodermal conditioning (Kimmel, Ray, and Iozzino, 1974).

Subjects. Four adult male *Cebus albifrons* monkeys were assigned to the two experimental conditions, two in each condition. These animals were in matched pairs (one in each condition) on the basis of unelicited skin conductance response measures obtained during a two week period prior to the beginning of the first

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[1] Paper presented at the annual meeting of the Psychonomic Society in Denver, 1975.

experimental session. The animals had previously been habituated to the handling and sitting in the experimental chairs over a period of two months.

Apparatus. The animal was restrained in specially designed Acrylite primate chair with neck, waist, and chest yokes which prevented manual contact with skin electrodes, etc. but which permitted the animal to remain confortable for at least one hour. A hole at the lower back of the chair permitted the tail to protrude for attachment of shock electrodes. The chair also contained an attachment so that the plantar surface was directly over another hole, through which the active electrodermal electrode made contact with the plantar surface of the foot. The reference electrode was attached to a shaved region on the anterior surface of the same foot, above the ankle. Both electrodermal electrodes were of the zinc-zinc sulphate type, in teflon cups filled with saline paste. The two ECG electrodes were employed to pick up heart rate. These were taped to shaved areas on the left and right sides of the animal's chest.

In the electrodermal system, the subject's skin was a resistor in a constant-voltage circuit (Venables and Christie, 1974), with an output proportional to skin conductance. This output was amplified by instrumentation operational amplifiers and recorded on a Texas Instrument Recti-Riter with a paper speed of 6 in./min. The heart rate response was amplified and recorded by a Grass Model 5 polygraph, with a 5P1 preamplifier. The primate chair containing an animal was placed inside of a sound-attenuated chamber (34 in. wide, 46 in high and 29 in. deep) so that the animal's face was oriented toward and about 14 in. away from a primate press panel capable of presenting visual stimuli. A speaker located behind the animal delivered continuous white noise at 80 dB as well as delivering the phasic auditory conditioned stimulus to the subjects in the classical condition (the latter was a 1,000 Hz pure tone, 5.0 sec. in duration with an intensity of 80 dB.)

All experimental events were programmed and delivered by a Data General Nova 2 computer except that Instrumental reinforcement contingencies were implemented by the experimenter while visually monitoring the skin conductance record. That is, the experimenter kept his finger on a microswitch and pressed the switch whenever a criterion response was observed.

Procedure. The instrumental condition involved six alternating segments of S^D AND S^Δ, consisting of red and green visual stimuli (balanced for subjects in each group) presented via the primate press panel. Durations of these segments could range from 3.0 to 5.0 minutes, with a mean of 4.0 minutes, the actual duration of any particular segment being determined by the sum of randomly determined intertrial intervals administered to the animals in the Classical condition (see below). On the average, a session was 48 minutes in total duration, not including an initial 5-10 min. period for electrode polarization and equipment checking. Sixteen sessions were run, on alternating days.

During S^D a Sidman shock-shock schedule of 40 seconds was administered for the first six sessions. This was changed for the remaining sessions to shock-shock 20 seconds. The shock was 3.0 mamps. in intensity and 0.1 sec. in duration, administered to the animal's tail via 7 mm stainless steel electrodes. A response shock interval of 40 seconds began following each criterion electrodermal response (at least .2 micromhos).

Responses which occurred within 5 secs. following a shock (elicited responses) did not result in shock postponement. During a S^Δ a response-contingent punishment schedule was run using the same shock parameters and the same criterion response.

The animals in the Classical condition received the same schedule of visual discriminative stimuli as was presented to the Instrumental animals. During S^D classical paired trials of a pure tone CS and the same electric shock as in the Instrumental condition (ISI of 4.9 seconds) were run. Inter-trial intervals ranged from 21 to 54 seconds until seven classical trials per segment were run. This the duration of each visual discriminative segment was determined by the sum of the ITI's during it. During S^{Δ} a series of unpaired shocks was administered on the same random ITI schedule. The classical animal thus received 42 paired and 42 unpaired shocks per session.

Results

Frequency of skin conductance response. The frequency of unelicited plantar skin conductance responses occurring in the presence of S^D and S^{Δ} in the instrumental and classical conditions, averaged per stimulus segment over the entire sixteen days of the experiment, is presented in Table 1. Two noticeable differences may be seen in these data; classical animals tended to make more responses overall and there was a tendency for the instrumental animals to make more responses in the presence of S^D than in the presence of S^{Δ}, a difference which is not present in the classical condition. Analysis of variance of these data indicated that the difference between groups was not statistically significant ($F_{1,2} = 2.30$) while the interaction between groups and discriminative stimuli was highly significant ($F_{1,2} = 72.06$). It is possible that the group affect would achieve statistical significance with a larger sample of subjects, but this is by no means certain.

TABLE 1

Frequency of SCR per stimulus segment averaged across sixteen daily sessions.

	S^D	S^{Δ}	Total
Instrumental	8.21	5.23	6.72
Classical	12.12	13.14	12.63

Response frequency during S^D was higher initially than during S^{Δ} because the first stimulus segment on each day was an S^D segment. The change in this Shock-Shock interval which was introduced following the sixth day (within the second block of four days) at first eliminated the $S^D - S^\Delta$ difference, but it recovered during subsequent sessions. Beginning in the ninth sessions, response frequency tended to increase during S^D from session to session, although it never regained the level seen in the sixth session, just prior to the reduction of the Shock-Shock interval. The basal skin conductance level was measured during the five second period prior to each shock in the Instrumental subjects and prior to each conditioned stimulus during S^D or unconditioned stimulus during S^Δ for the Classical subjects. These measures were averaged for each stimulus segment for each animal. Table 2 shows the average of the skin conductance measures in micromhos in the Instrumental and Classical animals for the two discriminative stimuli, across all segments and days of the study. As can be seen in Table 2, the Classical animals had substantially higher skin conductance levels during both discriminative stimuli, but showed no difference between discriminative stimuli. The instrumental animals tended to have higher skin conductance levels during punishment (S^Δ) than during avoidance (S^D).

TABLE 2

Average skin conductance levels (micromhos) in S^D and S^Δ in Instrumental and Classical groups

	S^D	S^Δ
Instrumental	37.90	38.60
Classical	48.49	48.51

Analysis of variance of the skin conductance measures showed that the overall difference between the Instrumental and Classical groups did not attain significance ($F_{1,2}$ =2.63), probably because of insufficient between-S *df* for precision. The interaction between Groups and Discriminative stimuli also was insignificant ($F_{1,2}$=3.30), probably for the same reason. A separate evaluation of the $S^D - S^\Delta$ difference within the Instrumental animals only, yielded an $F = 23.65$, but only a single *df* for error is available for this test.

Figure 1 shows the average skin conductance levels within the six segments (averaged for both discriminative stimuli across all days) for the Instrumental and Classical animals. As can be seen in Figure 1, the Classical animals maintained a high skin conductance level across all six segments, while the Instrumental animals' skin conductance levels increased systematically across segments. Analysis of variance showed that this interaction of Groups and Segments was highly significant ($F_{5,10} = 6.88$). This systematic increase across segments within days in the Instrumental animals however, was influenced by the alternation of discriminative stimuli.

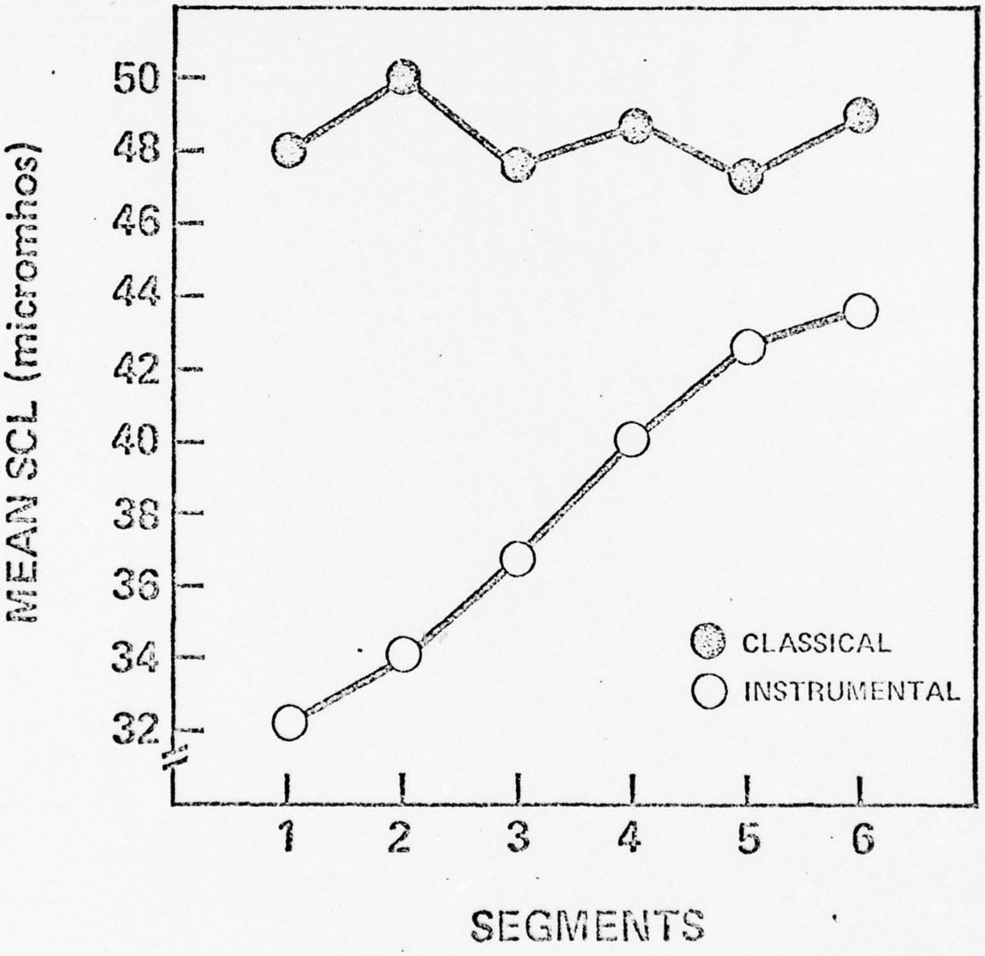

Figure 1. Skin conductance level in Instrumental and Classical groups averaged across S^D and S^Δ and days

Conductance levels during S^D were substantially higher than each preceeding S^{Δ}, but were not substantially (or even always) lower than each subsequent S^{Δ}. In other words, the within day increase in skin conductance level in the Instrumental animals had the appearance of a stepladder with the steepest rises occurring between preceeding S^{Δ}s and subsequent S^Ds and very little if any rises occurring between preceding S^DS and subsequent S^{Δ}s.

Baseline heart rate. Heart rate was measured during the five second interval prior to each phasic stimulus (CS or US) and averaged for each S^D and S^{Δ} segment.

Table 3 shows the baseline heart rate measures of the Instrumental and Classical groups in the presence of S^D and S^{Δ}, averaged across all Day blocks and Segments. The fact that the Instrumental animals' heart rates tended to be higher is evident. The table also shows that the Instrumental animals had higher heart rates during the presence of S^{Δ} than during S^D, while the reverse was true for the Classical animals. Analysis of variance revealed that this interaction between Groups and Discriminative stimuli was significant ($F_{1,2} = 31.18$), even with only 2 *df* for error.

TABLE 3

Baseline heart rate (BPM) in Instrumental and Classical groups during S^D and S^{Δ}

	S^D	S^{Δ}
Instrumental	221.5	227.5
Classical	204.4	203.0

NUMBER OF SHOCKS. It is conventional to evaluate instrumental conditioning effects in avoidance and punishment paradigm in terms of observed changes in the number of shocks actually received during the course of the experiment. Table 4 presents the average number of shocks actually administered to the Instrumental animals during S^D and S^{Δ}, in four blocks of four days. As is clear in Table 4, the number of shocks received during S^D increased across Day blocks while the number of shocks received during S^{Δ} decreased.

TABLE 4

Average number of shocks per segment received by Instrumental animals during S^D and S^{Δ} in four blocks of four days

DAY BLOCKS	S^D	S^{Δ}	TOTAL
1	2.18	9.17	11.35
2	5.08	3.92	9.00
3	5.50	5.00	10.50
4	7.54	2.83	10.37
Total $\overline{X}$	5.08	5.23	

Analysis of variance of these data showed that the interaction between Discriminative stimuli and Day blocks was highly significant ($F_{3,3} = 112.80$) while, as is apparent in Table 4, none of the other effects was. It must be recalled that shocks were administered during S^D on a 40 sec. shock-shock interval for the first six sessions and on a 20 sec. shock-shock interval thereafter. During the first block of four days, the Instrumental animals made an average of 13.27 responses per S^D segment, while making an average of 9.17 responses during a S^{Δ} segment (a total of 22.44 responses combined). During the last block of four days, on the other hand, these subjects made an average of only 6.04 responses per S^D segment and 2.83 responses per S^{Δ} segment (a total of 8.87 responses combined). While achieving this dramatic reduction in the number of responses, the average total number of shocks these animals received reduced slightly from 11.35 to 10.37, in spite of the fact that the shock-shock interval during the avoidance stimulus effectively doubled the number of possible shocks.

Discussion and Conclusion

The results indicate clearly that differences in autonomic arousal were established within the Instrumental animals in relation to the discriminative stimuli and, also, that differences between the two groups run with different conditioning paradigms also were present.

In the animals run under the instrumental conditioning paradigm, with S^D signalling periods in which unelicited skin conductance responses postponed electric shocks and S^{Δ} signalling periods in which the same responses were punished with electric shock, over 60% more responses occurred during S^D than during S^Δ. Considering the fact that the overall numbers of shocks received by these animals during the presence of the two discriminative stimuli were approximately equal, this difference in response frequency must be taken as strong evidence of conditioned stimulus control. It is clear from examination of the manner in which the distribution of shocks received changed during conditioning (Table 4), along with the fact that the overall number of shocks varied little over days while the overall number of unelicited responses declined considerably, that the animals in the Instrumental condition must have been selectively reducing and re-distributing the number of responses and, thus, substantially increasing the efficiency with which they coped electrodermally with the discriminative paradigm. The term "efficiency" is used in this context solely in reference to the manner in which unelicited skin conductance responses were employed to avoid shocks while not exposing the animals to increased punishment. Indeed unlike the findings of Greene and Sutor (1971) in their related study using human subjects, the present skin conductance response frequency data from our monkeys suggest that the basic strategy was one of reducing responding systematically during the punishment segments while holding response frequency more or less in control during the avoidance segments.

Perhaps of equal significance as the finding that unelicited frequency of skin conductance responses differed during the different discriminative stimuli within the Instrumental group, but not within the Classical group, was the fact that baseline heart rates also differed during S^D and S^Δ in the Instrumental animals but not in the Classical animals. In the case of the baseline heart rate measure, the Instrumental animals' rates during S^Δ exceeded S^D, indicating a higher level of arousal during the punishment condition than during avoidance. The importance of this result lies in the fact that the skin conductance response was what determined instrumental reinforcement (i.e., postponement of shock during avoidance or administration of shock during punishment) <u>not</u> heart rate. Nevertheless the heart rate measure was sensitive to whatever arousal affects came under tonic stimulus control as a consequence of the differences between the reinforcement contingencies associated with the discriminative stimuli.

The differences that were found between the Instrumental and Classical groups (as discriminative stimulus differences) tended to complement and clarify the differential effects within groups. Skin conductance response frequently was higher in the Classical animals than the Instrumental and basal skin conductance levels also tended to be higher in the Classical group, although the latter effect interacted with segments and reduced in the latter segments each day. On the other hand, baseline heart rates were decidedly lower in the Classical animals than in the Instrumental ones, on the average by more than 30 BPM.

On the basis of the stimulus-controlled and between-group differences reported above, it appears that two major conclusions may be stated. First, the discriminative instrumental conditioning paradigm employed in this study (especially with a shock-shock interval of 40 seconds) appears to generate differences in response frequency, favoring the avoidance over the punishment condition, with this difference apparently resulting from a reduction in responding during the punishment segments more than an increase in the avoidance segments, and with this difference resulting in increased efficiency in overall adaptation to the experimental conditions. Overall response frequency greatly reduced while number of shocks received was unchanged or slightly reduced. The percentage of possible shocks avoided increased, because of the shift in the shock-shock interval introduced during the experiment.

This adaptation to the experimental situation via electrodermal responding apparently was achieved at the cost of increased arousal in terms of heart rate. Within the Instrumental group, heart rates were higher during the punishment segments than during the avoidance segments. However, a tendency for within-session increases in basal skin conductance was seen largely in the avoidance segments. These effects were either absent or negligible in the Classical condition.

In the way of a general conclusion based upon the results of this study, it may be stated that the electrodermal response system is quite capable of subtle instrumental conditioning influences, such as between the avoidance and punishment conditions of this study, and indeed, that the autonomic nervous system adjustments, including substantial within-subject heart rate differences in avoidance and punishment of the skin conductance response, are at least as finely tuned as those found in traditional research on classical autonomic conditioning (Kimmel and Burns, 1975).

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<u>Behavior Therapy Association Paper</u>

The Difference Between Conditioned Tonic Anxiety and Conditioned Phasic Fear; Implications for Behavior Therapy[1]

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University of South Florida

Emotional reactions, whether learned or unlearned, vary considerably in their duration and in the extent to which they are controlled by identifiable stimuli. At one extreme there is objectively elicited fear, such as that which accompanies a sudden, mildly painful stimulus - like a pinprick - or which anticipates a clearly impending unpleasant event - like watching a dropped vase fall to the floor. This type of emotional reaction usually has a rapid onset and a very brief duration - the entire affair occupying altogether only a few seconds. At the other extreme are aversive emotional conditions that are neither brief nor obviously stimulus-controlled. Non-specific clinical anxiety exemplifies this end of the continuum. Its duration may extend to days or even weeks, and even with intervening periods of calm, the separate episodes of acute anxiety often may last for hours. In the following analysis of these different kinds of emotional reactions, the term "phasic" refers to brief reactions to sporadic brief stimuli - such as the reactions commonly studied in laboratory research on conditioned fear, and "tonic" to those longer-lasting conditions which are either identifiably under the control of tonic stimulus events, such as constant environmental stimuli, or do not appear to be governed in any way by external events.

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1. An earlier version of this paper was prepared for the 1974 NATO Advanced Study Institute which was scheduled in Athens, Greece but was unavoidably cancelled. The present version was presented as an Invited Address to the Association for the Advancement of Behavior Therapy in San Francisco in December, 1975.

An analogous and possibly more fundamental distinction may be made between phasic and tonic stimulus conditions controlling any behavior. An instructive example of this distinction may be found in the following "transswitching" experiment reported by the Russian physiologist, Asratyan (1965). An auditory conditioned stimulus was paired with electric shock to a dog's left hind leg during experimental sessions which were run in the morning, but during sessions run in the afternoon the same auditory stimulus was paired with shock to the right hind leg. Asratyan refers to this as a simple homogeneous transswitching design, "simple" because only a single conditioned stimulus is used and "homogeneous" because both unconditioned reflexes are defensive. Needless to say the dog learns to lift its left hind leg to the auditory conditioned stimulus in the morning and its right hind leg in the afternoon. In other words, the motivational and behavioral significance of the conditioned stimulus switches according to the time of day at which the auditory stimulus is presented.

The auditory stimulus exemplifies what is meant here by a "phasic"stimulus; and the conditioned leg lifting is likewise a phasic response. The times of day at which the sessions are conducted, i.e., morning versus afternoon, represent long-lasting tonic stimuli, called "switching agents" by Asratyan. Different experimenters, different chambers, and other tonic environmental conditions have been shown to function as switching agents in this type of situation, in the same way as the different times of day.

The particular transswitching experiment described above is especially cogent for the present purpose because it also provided direct evidence of the existence of the tonic conditioned state controlled by the switching agents. After the dog was trained in the manner described, its EEG showed a focus of heightened activity in the anterior parietal region of the cortex, ipsalateral to the locus of the shock. In the morning, when shock to the left leg was being used, the left parietal area showed the elevation in EEG activation. This conditioned tonic activation was present throughout the experimental session, from the moment that the recording equipment was attached, even before the first shock was administered in that session. It is important to note that the tonic stimulus controls an ongoing *state* rather than a discrete response. In the present instance the state is defined by the long-lasting elevation in EEG activity in the appropriate cortical locus.

A more familiar example of the difference between phasic and tonic stimulus control may be found in the distinction between a Pavlovian *conditioned* stimulus and a Skinnerian discriminative stimulus. As is well known, the classical conditioned stimulus is said to be an "elicitor" of a response - a phasic response whose quantitative characteristics typically are the subject under study. The operant discriminative stimulus, the S^D or S^{Δ}, on the other hand, "sets the occasion for responding" rather than directly eliciting a response (Sidman, 1960). That is, by signalling the availability of response-contingent reinforcement it identifies an occasion for change in *rate* of responding. As was noted with respect to the tonic switching agent in the transswitching situation, the operant discriminative stimulus also is a relatively long-lasting environmental event which controls a tonic state of elevation in some particular ongoing process. Although to do so would take us too far from the main topic of this presentation, it should be noted in passing that a thorough analysis of the relationship between the tonic stimuli and states of the transswitching situation, on one hand, and the discriminative stimuli and response rates of operant conditioning, on the other, would appear to be a potentially fruitful undertaking.

In the context of this distinction between phasic and tonic stimuli and the corresponding phasic and tonic behaviors they control, it is instructive to consider the way in which American behaviorists have come to deal with the parallel concepts of "conditioned fear" and "anxiety". "Conditioned fear" is a term that came into vogue in the heyday of Hulliam psychology, principally through the research and writing of Hobart Mowrer (1939, 1940) and Neal Miller (1948,1951). "Conditioned fear" referred to the emotional component of the reaction to a painful stimulus, such as an electric shock, which could be conditioned in Pavlovian fashion to a previously indifferent stimulus, like a sound or a light. Although it conflicted with Hull's theory, the view developed that temporal contiguity alone, and not instrumental reinforcement via drive reduction, was the essential factor in the acquisition of conditioned fear.

Almost at the same time that conditioned fear was first conceptualized, a re-analysis of the traditional Freudian concept of "anxiety" in terms of the individual's past experience with painful stimuli was also suggested by Mowrer (1939). Mowrer's seminal paper on this subject proposed quite directly that "all anxiety reactions are probably learned," and he based his position on a stimulus-response translation of Freud's treatment of anxiety. Here is Mowrer's summary of his version of what Freud said about the learning of anxiety.

> "A so-called traumatic stimulus impinges upon the organism and produces a more or less violent defense reaction. Furthermore, such a stimulus-response sequence is usually preceded or accompanied by originally "indifferent" stimuli which, however, after one or more temporally contiguous associations with the traumatic stimulus, begin to be perceived as "danger signals", i.e., acquire the capacity to elicit an anxiety reaction. This reaction consists of a state of heightened tension and, because this tension is itself a form of discomfort, it adaptively motivates the organism to escape from the danger situation, thereby lessening the tension and probably decreasing the changes of encountering the traumatic stimulus. In short, anxiety (fear) is the conditioned form of the pain reaction, which has the highly useful function of motivating and reinforcing behavior that tends to avoid or prevent the recurrence of the pain-producing (unconditioned) stimulus" (Mowrer, 1939, pp. 554-555, italics in original).

Although Mowrer was explicitly aware of the fact that Freud differentiated between neurotic and objective anxiety (or fear) in terms of whether a definite fear-object or stimulus was involved, he explicitly decided to treat them as essentially synonymous. Behavioristic writers have opted for synonymity of anxiety and conditioned fear ever since (e.g., Brown, 1961; Dollard & Miller, 1950), in spite of the fact that there are good reasons to question this decision. The most obvious of these is the fact that conditioned fear, as far as it has been studied in the laboratory, extinguishes very rapidly when the unconditioned stimulus is removed

- indeed, sometimes even when the subject is simply told that no more shocks will be used (Mandel & Bridger, 1973). Whatever, "anxiety" actually is, it is surely not so easily dispelled, nor does its repeated elicitation in the absence of painful stimulation typically result in its rapid extinction.

Even if it were possible to overcome the problem of rapid extinction of conditioned fear responses, there are two other types of data and argument which lead to the conclusion that the classical fear conditioning model is inappropriate for the acquisition of anxiety or for some of its commonly described clinical characteristics. First, peripheral autonomic indices of conditioned fear reactions are *not persistent* even with continued reinforcement (Kimmel & Burns, 1973). And, second, ordinary clinical characterizations of anxiety appear to require longer term changes - i.e., tonic changes - than are seen typically in laboratory conditioned fear reactions - these are usually phasic, lasting only a few seconds. These two issues may be analyzed separately.

Research on the acquisition of conditioned fear almost invariably is built around a Pavlovian (classical) conditioning procedure. One of the principal reasons for this is the persistent, albeit false, belief that autonomically mediated behavior cannot be modified in any other way (e.g., by instrumental conditioning) (Kimble, 1961; Skinner, 1938, 1953). Basically, the classical method for fear conditioning involves the paired presentation of an initially innocuous stimulus with a painful or at least unpleasant electric shock. The conditioned stimulus typically comes on shortly before the unconditioned stimulus, and both stimuli terminate together. With human subjects, this procedure rapidly transforms the initially indifferent conditioned stimulus into one which is capable of eliciting strong sympathetically mediated reactions, such as digital vasoconstriction, decreased skin resistance, increased blood pressure, etc. In addition to these more or less direct measures of the autonomic concomitants of fear, indirect measures of interference with or augmentation of other behaviors are also sometimes used in the description of learned fear.

Rather than continuing to build up and protractedly maintain a tendency for the conditioned stimulus to evoke strong conditioned autonomic reactions, the classical fear conditioning procedure provides only a brief opportunity for the impending danger of the unconditioned stimulus to be anticipated emotionally via rapid acquisition of a conditioned fear response. But almost as quickly as fear is acquired, the subject adjusts to the uncontrollability of the shock - even though it is perfectly predictable - or perhaps because it is - and now stops reacting autonomically to the conditioned stimulus. That is, the subject shows learned management of the learned fear (Kimmel, 1963). In addition, even the vigor of the autonomic unconditioned reaction to the shock begins to diminish. This is certainly not the metaphor for the "expectation of trauma" that Freud (1936) thought anxiety is - by means of which a person may "act as if the trauma were already present as long as there is still time to avert it" (pp. 149-150). In classical fear conditioning there may be time to avert the shock but the subject is without the behavioral means to do so. With no response available with which the shock can be controlled, rather a different condition from anxiety comes into existence - the subject appears to accept his or her fate and does a reasonably good job of managing the fear or even casting it off completely. The very characteristics of the classical conditioning situation that make the acquisition of fear easy - the highly predictable relationship between the conditioned stimulus and shock and the uncontrollability of the shock, also make fear management easy - and classical conditioning itself hardly a basis for learning anxiety.

As has already been mentioned, before they either extinguish or otherwise disappear, classically conditioned fear reactions, indexed by peripheral autonomic nervous system changes, tend to last only a few seconds - far too short a time to be suitable as candidates for anxiety conditions. Indeed, anxiety is much better conceptualized as a state rather than as a phasic reaction, and this is the other main problem with the classical fear model of anxiety. Obviously, what is needed is a conditioning model in which anxiety is conceptualized as an elevation in a tonic condition, as in the transswitching experiment, or as an increase in the rate of some response, as in discriminative operant conditioning. If the model uses an autonomic index of anxiety, the trans-switching and operant discriminative conditioning conceptualizations become essentially one and the same.

It was noted briefly above that one of the main reasons why only a classical but not an instrumental conditioning approach to the autonomic analysis of anxiety has been taken until now was the pervasive belief that autonomic nervous system processes are only modifiable classically. This view has been with us almost continuously from the late 1920s. However, beginning in 1958 and joined by several others soon thereafter, we and others began to demonstrate that humans' autonomic nervous system processes are capable of modification by instrumental conditioning (Kimmel, 1967). Using mainly free-operant reward training of the GSR, vasomotor reflex, heart rate, blood pressure, etc., we have shown that chronic elevations and reductions in ongoing levels of these autonomic processes can be achieved and maintained, with either informational feedback plus extrinsic reinforcement or simply with augmented feedback. On the basis of these studies it is no longer necessary to assume that only classical conditioning methods can be used to modify autonomic processes - thus we are no longer stuck with classical fear conditioning as a model for anxiety.

Consider the following alternative. Suppose a person is exposed to not too infrequent unsignalled aversive events - such as happens to laboratory animals in a Sidman avoidance schedule. Whether or not the person has some effective skeletal way to postpone or prevent these aversive events (as in the Sidman schedule), there will be an elevation in autonomic activity - e.g., increased heart rate, elevated blood pressure, skin conductance, etc., and brief burst of increase in these. Ordinarily, these manifestations of sympathetic activity are not deliberately made instrumental by some cosmic experimenter, indeed, they are almost never naturally instrumental in the sense of really postponing or preventing any external events. However, in a natural setting involving frequent aversive events, brief sympathetic bursts,such as might occur following occasional protracted periods without the occurrence of the aversive event, are usually followed by nothing aversive at all, i.e., by "apparent" postponement, a kind of "adventitious" reinforcement, which might better be called "magical" because it obviously has no real relationship to whether or not an aversive event occurs soon after it. Sometimes, of course, a sympathetic burst may accidentally occur just before an aversive event, producing an occasion of punishment. It is likely that many more sympathetic bursts will be followed by periods of no aversive stimulation than by an aversive event. What will be the autonomic effect of this hypothetical magical reinforcement schedule?

If instrumental conditioning results, there will be an increase in the rate of occurrence of these sympathetic bursts of activity - the reinforcement being due to the magical "postponement" of the aversive events. As these bursts of sympathetic activity increase in frequency and temporal density, it is likely that there will be a concomitant increase in the frequency of adventitious response-contingent punishment, i.e., a sympathetic burst being followed closely in the time by an aversive event. The effect of this probably will be one of potentiation - augmentation of the frequency of these bursts. Augmentation is the most likely consequence of punishment of any behavior which is maintained by avoidance reinforcement.

The word magical is chosen quite deliberately, but not only because there is no more of a causal connection between the autonomic fluctuation and the avoidance of the aversive event than there is between the mumbling of some magical incantation and prevention of some desired or feared outcome. Behaviorists have shown little reluctance to accepting the unproved idea that superstitious behavior of the verbal incantation type may result from adventitious intermittent reinforcement -- and magical maintenance of unelicited sympathetic bursts require not much more in the way of faith, at least not for openers.

Another reason for using the word "magical" is to draw attention to the relationship between anxiety as a kind of modern magic - a way of "warding off" of aversive events which probably weren't going to happen anyway but which did sometimes in the past -

and the magic of more primitive human beings. Of course, Freud had something to say about magic as well as about anxiety - indeed, he dealt with the two of them at once in his very early demonstration of the similarities in thinking and verbalizing among primitive humans, normal human children, and neurotic human adults. Primitive humans and children commonly display magical thought processes both in the form of animism and "action at a distance", i.e., sticking pins into effigies of their enemies, etc. - but modern adult humans have become too sophisticated and knowledgable about the natural world to engage in such primitive superstitious practices. So instead of protecting oneself from danger by incantations, gods' eyes, or magic beans, we have been reduced in the 20th century to the magic of the autonomic nervous system - we protect ourselves from danger by being anxious. What a hell of a note that is!

During the past several months we have been conducting laboratory research using monkeys as subjects, in an effort to evaluate some of the foregoing ideas. Although we are a long way from a definitive theory of instrumental anxiety as a substitute for the inadequate classical theory, the results we have obtained to date are promising and suggestive. We borrowed the basic plan of our monkey experiments from a study done by Greene and Sutor, (1971),using human subjects and the unelicited GSR. In the Greene and Sutor study, visual discriminative stimuli, horizontally or vertically arrayed dots, identified periods of Sidman avoidance of unpleasant interruptions of music (½ sec. on and ½ sec. off), from periods of response-contingent punishment, using the same aversive stimulus. Thus the subject could prevent or postpone the aversive interruptions during the presence of one of the visual discriminative stimuli, by making GRSs (i.e., having an elevated level of response rate), but was punished for the same thing when the other visual stimulus was present. Differentiation between the two visual stimulus periods was obtained in this study, with a higher level of GSR response rate occurring during avoidance than during punishment, and with this difference increasing during the ten days of training. The increase did not result from reduction of response level during punishment as much as from increase during avoidance.

We used the same strategy with our monkeys as Greene and Sutor had used with their human subjects - avoidance during one visual discriminative stimulus and punishment during the other with the instrumental response being a brief increase in skin conductance (Kimmel, McLeod and Burns, 1975). Our aversive stimulus was a shock to the monkey's tail. We had six periods of 3, 4, or 5 minutes of each visual stimulus during an experimental session, and sixteen sessions were run altogether on alternating days. In addition to the monkeys run in this mixed avoidance-punishment condition, we ran other animals in a classical transswitching procedure that was calculated to be roughly similar to the instrumental one. The same visual discriminative stimuli, or switching agents, were run, and during one of these, classical pairing of tone and shock was administered, while during the other, unsignalled shock was given. In the classical condition, a total of 42 paired and 42 unpaired shocks was given each day for the sixteen sessions. It should be clear that in the classical procedure the visual stimulus is tonic and the classical tone is phasic.

There were two different ways to examine the effect of using unelicited bursts of increased skin conductance as the instrumental avoidance and punishment response - we could look at the tonic frequency of skin conductance responses during each tonic discriminative stimulus, and we could look at the tonic skin conductance levels. Although the classical animals made somewhat more skin conductance responses, the instrumental animals differentiated between the two discriminative stimuli - making about 60% more skin conductance responses during avoidance than during punishment. This is a replication of the Greene and Sutor finding. No difference in skin conductance response frequency between the discriminative stimuli was found in the classical animals. In the instrumental animals, response frequency increased systematically during avoidance during the last eight experimental sessions. These results are summarized in Table 1.

TABLE 1

Frequency of skin conductance responses per stimulus segment averaged across sixteen daily sessions in Instrumental and Classical groups

	S^D	S^{Δ}	TOTAL
Instrumental	8.21	5.23	6.72
Classical	12.12	13.14	12.63

The instrumental and classical groups also differed in tonic levels of skin conductance, measured in five second periods prior to the phasic stimuli, with the classical animals having a somewhat higher level of skin conductance. There was a difference associated with the visual discriminative stimuli only within the instrumental group, with conductance higher during punishment - i.e., higher during a time when fewer nonspecific responses were occurring. This result is shown in Table 2.

TABLE 2

Average skin conductance levels (micromhos) in S^D and S^{Δ} in Instrumental and Classical groups

	S^D	S^{Δ}
Instrumental	37.90	38.60
Classical	48.49	48.51

Tonic heart rate was measured during five second periods prior to the phasic stimuli during both discriminative stimuli. The instrumental animals' heart rates tended to be about 25 bpm higher than the classical animals' heart rates. In addition, heart rates were higher during punishment than during avoidance in the instrumental animals - there was no difference between the discriminative stimulus conditions in the classical group. This within-subject heart rate difference favoring the punishment periods over avoidance, summarized in Table 3, is certainly significant when one considers that heart rate was not the instrumental response but was merely being measured during periods of CSR avoidance and punishment - periods in which in general the monkeys received more or less the same numbers of shocks.

TABLE 3

Baseline heart rate (BPM) in Instrumental and Classical groups during S^D and S^Δ

	S^D	S^Δ
Instrumental	221.5	227.5
Classical	204.4	203.0

The total number of shocks received by the animals remained pretty much the same throughout the entire experiment, the only real change being that shocks during punishment reduced considerably while shocks during avoidance increased - all of this taking place while the number of responses actually reduced greatly. Table 4 shows these data. It appeared that the instrumental animals' coping strategy was one of reducing and redistributing the skin conductance responses, so that fewer occurred during punishment periods and fewer punishment-shocks were administered. But while making 60% more skin conductance responses during avoidance, the monkeys had higher basal skin conductances and heart rates during punishment - this is when they were maximally aroused - anxious.

TABLE 4

Average number of shocks per segment received by Instrumental animals during S^D and S^Δ in four blocks of four days each

Day Blocks	S^D	S^Δ	Total
1	2.18	9.17	11.35
2	5.08	3.92	9.00
3	5.50	5.00	10.50
4	7.54	2.83	10.37
Total $\overline{X}$	5.08	5.23	

On the basis of this initial study of discriminative avoidance and punishment, using an autonomic response, the skin conductance response, it would appear that we are in a position to expand our empirical approach and slightly revise our theoretical one. We did not expect heart rate to be a better index of tonic autonomic arousal than the response that actually was instrumentalized, the skin conductance response.

But that was because we did not give adequate consideration of what might be required of the monkeys in the mixed avoidance and punishment procedure into which we thrust them. We tended to think in terms of how a monkey would achieve avoidance - but our monkeys apparently found more latitude to adjust autonomically in the punishment periods - that is, it was easier for them to reduce the rate of electrodermal responding during punishment than it was to increase it during avoidance - given that both contingencies existed and had to be dealt with in the same experimental situation. In this respect our monkeys differed from Greene and Sutor's human subjects - they did better during avoidance. But, their aversive stimulus was hardly comparable in aversiveness to the shock to the monkey's tail - and this may be why the human and monkey data differed somewhat. In any case, while managing to reduce responding and thus the number of shocks received during punishment, the monkeys achieved this at the cost of increased heart rates and basal skin conductances - i.e., increased arousal or anxiety especially during punishment. Naturally, we are now more intrigued with the possibility that further experimentation along these lines may actually provide empirical support for the theoretical speculation outlined above. At a minimum it may be concluded that differences in tonic autonomic measures resulted from different experimental procedures and stimuli in this study.

What are the implications for behavior therapy of the possibility that anxiety is best construed as a tonic conditioned state, established and maintained by avoidance reinforcement and potentiated by occasional contingent punishment. Well, for one thing, consideration must be given to the possibility that the aversive events originally responsible for the development of heightened arousal via avoidance reinforcement may still be functioning in the objective environment. They may or may not be associated with a tonic discriminative stimulus, although to some extent all of the unchanging stimuli in a person's environment can come to control tonic states at least for certain periods of time. Obviously, if the events which led to the original acquisition are still active in the environment, some way will have to be developed to remove either them or the individual from the environment.

Assuming that the environment is at present no more hostile than it is for any ordinary person, we can now attempt to deal with the problem of trying to get rid of an instrumentally conditioned elevation in arousal - anxiety - that reinforces itself magically simply by existing. Probably the best approach would be to make it possible for the person to obtain the same or more reinforcement for not being anxious. The problem here is that the person receives much more discernible feedback from heightened arousal than from a more normal autonomic condition. What might be needed is some kind of miniaturized biofeedback device which would make it possible for the person to be informed when normal limits of autonomic functioning begin to be approached. It is possible that this could be achieved by providing the person with augmented feedback of only a single tonic autonomic measure, such as heart rate or basal skin conductance, so that when it begins to approach a level high enough to be considered incipient anxiety, a signal could be transmitted to the person and some pre-arranged method for relaxation could be employed to lower arousal to a more acceptable level. That is, the person would first receive thorough training in achieving <u>temporary</u> relaxation. Then autonomic measures would be studied to determine which were most likely to antedate aversive elevations in autonomic arousal (i.e., anxiety) for this individual. The assumption is that different measures or patterns of measures might be appropriate for different individuals. Then the problem becomes merely one of instrumentation. It is possible that the feedback device would not be used at all times, since certain normal daily activities might be expected to lead to elevated autonomic indices which are normally reactive and only temporary. The assumption is that systematic desensitization could not be employed because of the inability to establish any kind of stimulus hierarchy (Wolpe, 1958).

One obvious implication of the current approach is that one would surely not use punishment to try to suppress anxiety - the likelihood is that the anxiety would be potentiated in this way. Since the model assumes that there has already been an interplay of avoidance and punishment which has contributed to the elevated level of autonomic arousal in the first place, additional punishment would be just about the last thing in the world one would want to do. It is gratifying to realize that common practice and the present theory are in agreement in this instance (Sandler & Davidson,1973).

Other kinds of practical implications came to mind, pertaining to prophylaxis - prevention, more than to treatment. Aversive stimulation in and of itself - i.e., punishment or pain suffered via ordinary accidents during childhood - should not be expected to lead to the develoment of anxiety in the manner outlined above, because ordinarily this kind of aversive stimulation is more or less systematically associated with regular stimuli. That is, punishment *does* tend ordinarily to be applied consistently-the cookie jar *does* usually result in punishment, and the hand on the stove of course *does* lead to pain. It takes an unsystematic interplay of punishment and avoidance - it takes an inconsistent regimen, for the kind of situation I have described to come into existence. It is interesting that Dr. Spock came to the same position from so different a starting point (Spock, 1970). In any case, it would not simply be recommended that punishment be avoided entirely - as some Skinnerians recommend. Rather, that whatever punishment *is* used, be used in a systematic consistent fashion rather than wantonly administered. When children are punished non-contingently - when the punishment is correlated with how the parent feels from day to day rather than keyed consistently by the child's behavior, that's when anxiety is likely to develop in the child. Consistent punishment may lead to rigidity or anger - but not to chronic anxiety.

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NATO Symposium Paper

Inter-Effector Influences In Operant Autonomic Control

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Almost from the very beginning of research on operant reinforcement of autonomically mediated responses, the possibility has been considered that contingencies explicitly introduced in relation to a particular autonomic response might influence other autonomically mediated behaviors. For example, Shapiro, Crider, and Tursky (1964) examined skin potential levels and heart rates in conjunction with the administration of positive reinforcement contingent upon the frequency of skin potential responses. They concluded that their observed operant conditioning effect on skin potential response frequency was independent of changes in the other autonomic measures. Subsequently, Crider, Shapiro, and Tursky (1966) obtained quite similar results in a replication of their first study. In both of these studies, basal skin potential levels and heart rates actually declined during training in both experimental and control groups and skin potential levels tended to be slightly higher and heart rates slightly lower (the latter increasingly so) in the group reinforced for emitting spontaneous skin potential responses than in the control group. But these consistent differences were not statistically significant.

Similarly, Miller and Banuazizi (1968) reported that curarized rats reinforced with intracranial shock for either increases or decreases in heart rate or intestinal contractions showed appropriate operant conditioning effects in the reinforced response independent of changes in the other. Again, however, a consistently higher heart rate was found in animals reinforced for intestinal contractions than in those reinforced for intestinal relaxation. The statistical significance of this heart rate difference was not reported, probably because the effect did not change appreciably across conditioning trials. Likewise, Hamano and Miyake (1972) operantly conditioned human skin resistance responses with no apparent changes in heart rate, and Schwartz (1972) conditioned increased blood pressure levels and decreased heart rates conjointly and separately. In general, the conclusion of all of these authors has been that specific changes may be brought about in a particular autonomic effector by operant reinforcement without concomitant changes occurring in other ones.

In conflict with this general conclusion, other studies have reported intereffector influences in operant autonomic conditioning. Schell and Grings (1971) reinforced skin resistance responses using a signaled avoidance paradigm and found significantly higher heart rates in their yoked controls than in the avoidance group, in addition to the explicitly hypothesized electrodermal differences. Gavalas (1967) presented positive reinforcement contingent upon emitted skin resistance responses during ten daily sessions and found higher heart rates in her yoked controls than in the reinforced group on eight of the ten days. The significance of this effect was not reported. In a study procedurally resembling the Miller and Banuazizi (1968) experiment on intestinal contractions and heart rate, Kimmel and Kimmel (1967)reinforced emitted skin resistance responses in one group of subjects and digital vasoconstrictions in another, in addition to measuring both responses and running noncontingent controls. They found that the concomitant reinforcement effect on one autonomic response significantly depended upon which of the two responses was explicitly reinforced. When the vasomotor response was reinforced, the frequencey of both it and the skin resistance response were higher in the experimental group than in the controls. But when the skin resistance response was explicitly reinforced, its frequency was higher in the experimentals than in the controls, but the frequency of emitted vasoconstrictions was unchanged in the experimental group and increased in the controls. Kimmel and Kimmel attributed this complex outcome to the fact that the initial operant rate of the skin resistance response was almost twice that of the vasomotor response, resulting in adventitious intermittent reinforcement of the former when the latter was explicitly reinforced and reinforcement for omission of vasomotor responses when the skin resistance response was reinforced. Because of the relevance of the vasomotor data obtained by Kimmel and Kimmel to the results and arguments presented below, they are reproduced in Figure 1.

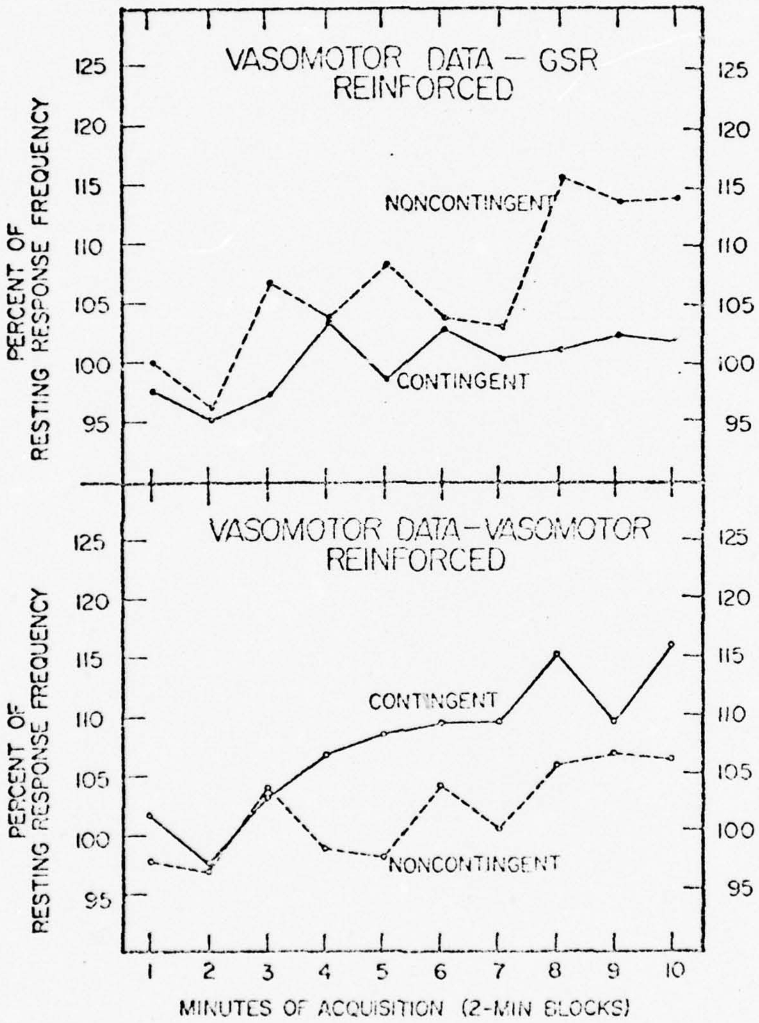

Figure 1. Frequency of digital vasoconstriction responses in subjects receiving reinforcement contingent upon the presence or absence of skin conductance responses (upper panel) and vasomotor responses (lower panel). From Kimmel and Kimmel, 1967.

More recently, we have been examining inter-effector autonomic operant conditioning effects in monkeys. Our basic plan was to compare an instrumental conditioning paradigm with a classical one. The instrumental paradigm involved two different visual discriminative stimuli (tonic stimuli), a Sidman avoidance schedule being used in the presence of one of these stimuli and response contingent punishment schedule being used in the presence of the other. The classical conditioning paradigm analogously also contained two different tonic visual stimuli, with paired tone-shock trials being administered in the presence of one and unsignaled shock in the presence of the other. This unusual classical conditioning paradigm is a type of trans-switching procedure (Asratyan, 1965), in which the visual discriminative stimuli are analogous to Asratyan's "switching agents."

Method

Subjects. Four adult male Cebus albifrons monkeys were assigned to the two experimental conditions, two in each condition. These animals were in matched pairs on the basis of initial unelicited skin conductance response measures.

Apparatus. The animal was restrained in a primate chair with a hole at the lower back of the chair permitting the tail to protrude for attachment of shock electrodes. The chair also contained an attachment so that the active electrodermal electrode made contact with the plantar surface of the foot. The electrodermal electrodes were of the zinc-zinc sulphate type, in teflon cups filled with saline paste. Two electrocardiographic electrodes were employed to measure heart rate. These were taped to shaved areas on the left and right sides of the animal's chest. The primate chair was placed inside of a sound-attenuated chamber with the animal facing a panel which presented visual stimuli. A speaker located behind the animal delivered continuous white noise at 80 db as well as delivering the phasic auditory conditioned stimulus to the subjects in the classical condition (the latter was a 1,000 Hz pure tone, 5.0 sec. in duration with an intensity of 80 db).

Procedure. The instrumental condition involved alternating segments of S^D and S^{Δ}, consisting of red and green visual stimuli. Durations of these segments could range from 3.0 to 5.0 minutes, with a mean of 4.0 minutes. Sessions averaged 48 minutes in duration, not including an initial period for electrode polarization. Sixteen sessions were run, on alternating days.

During S^D a Sidman shock-shock schedule of 40 seconds was administered for the first six sessions. This was changed for the remaining sessions to shock-shock 20 seconds. The shock was 3.0 mamps in intensity and 0.1 sec. in duration, administered to the animal's tail. A response-shock interval of 40 seconds began following each criterion electrodermal response (at least 2 micromhos).

Responses within 5 secs. following shock did not result in shock postponement. During S^{Δ} a response-contingent punishment schedule was run using the same criterion response.

The animals in the Classical condition received the same schedule of visual discriminative stimuli as was presented to the Instrumental animals. During S^D classical paired trials of a pure tone CS and shock (ISI of 4.9 seconds) were run. Inter-trial intervals ranged from 21 to 54 seconds with seven classical trials per S^D segment. During the seven S^{Δ} segments unpaired shocks were administered on the same random ITI schedule.

Results

Frequency of Skin Conductance Response. The frequency of skin conductance responses in the presence of S^D and S^{Δ} in the instrumental and classical conditions, averaged over the sixteen sessions, is shown in Table 1. Two noticeable differences may be seen; classical animals tended to make more responses overall and there was a tendency for the instrumental animals to make more responses in the presence of S^D than in the presence of S^{Δ}. The difference between groups was not significant (F(1,2)=2.30) but the interaction between groups and discriminative stimuli was highly significant

(F(1,2)=72.06).

TABLE 1

Frequency of SCR per Stimulus Segment Averaged Across Sixteen Daily Sessions

	Conditions		
Treatments	S^D	S^{Δ}	Total
Instrumental	8.21	5.23	6.72
Classical	12.12	13.14	12.63

TABLE 2

Average Skin Conductance Levels (micromhos) in S^D and S^{Δ} in Instrumental and Classical Groups

	Conditions	
Treatments	S^D	S^{Δ}
Instrumental	37.90	38.60
Classical	48.49	48.51

Basal Skin Conductance. The basal skin conductance level was measured during the five second period prior to each shock in the Instrumental subjects and prior to each conditioned stimulus during S^D or unconditioned stimulus during S^{Δ} for the Classical subjects. Table 2 shows the average of the skin conductance measures in micromhos in the Instrumental and Classical animals for the two discriminative stimuli, across all sessions. The Classical animals had substantially higher skin conductance levels but showed no difference between discriminative stimuli. The Instrumental animals tended to have higher skin conductance levels during punishment (S^{Δ}) than during avoidance (S^D).

Neither the overall difference between the Instrumental and Classical groups (F(1,2)=2.63), nor the interaction between Groups and Discriminative stimuli (F(1,2)=3.30), were significant. A separate evaluation of the S^D - S^{Δ} difference within the Instrumental animals only, yielded an F=23.65, but only a single df for error is available for this test.

Baseline Heartrate. Heart rate was measured during the five second interval prior to each phasic stimulus (CS or US) and averaged for each S^D and S^Δ segment.

Table 3 shows these measures for the Instrumental and Classical groups in the presence of S^D and S^Δ, a [illegible]. The fact that the Instrumental animals' heart rates tended to be higher is evident. In addition, the Instrumental animals had higher heart rates during the presence of S^Δ than during S^D, while the reverse was true for the Classical animals. Analysis of variance revealed that this interaction between Groups and Discriminative stimuli was significant (F(1,2)=31.18), even with only 2 df for error.

TABLE 3

Baseline Heart Rate (BPM) in Instrumental and Classical Groups During S^D and S^Δ

Treatments	Conditions S^D	S^Δ
Instrumental	221.5	227.5
Classical	204.4	203.0

Discussion

In the Instrumental animals, with S^D signaling available shock-postponement and S^Δ signaling punishment, some 60% more responses occurred during S^D than during S^Δ. Since the overall number of shocks received during the presence of the two discriminative stimuli were approximately equal, this difference in response frequency must be taken as persuasive evidence of operantly conditioned stimulus control of the skin conductance response. The animals in the Instrumental condition selectively reduced and redistributed the number of skin conductance responses and substantially increased the efficiency with which they coped electroderm[illegible]y with the discriminative paradigm. Unlike the findings of Greene and Sutor (1971) in a related study using human subjects, the monkeys' basic strategy was one of reducing responding systematically during punishment while holding response frequency steady during avoidance.

Of particular interest in the present context was the fact that heart rates also differed during S^D and S^{Δ} in the Instrumental animals but not in the Classical animals. In the case of the heart rate measure, the Instrumental animals' rates during S^{Δ} exceeded S^D. The importance of this result lies in the fact that the skin conductance response was what explicitly determined instrumental reinforcement, not heart rate. Nevertheless heart rate came under tonic stimulus control as a consequence of the differences between the electrodermal reinforcement contingencies associated with the discriminative stimuli.

The basis for this heart rate difference is not immediately apparent. Our initial assumption was that the Instrumental monkeys' adaptation to the experimental situation via electrodermal responding might have been achieved at the cost of increased arousal in terms of heart rate, especially during the punishment periods when an environmental demand for reduced electrodermal behavior existed and when the animals did in fact reduce responding to some 20% of their initial levels. But the heart rate effect may also have itself been adventitiously instrumentally conditioned rather than being merely compensatory. To examine this possibility more closely, we looked at the monkeys' heart rates during periods immediately following shifts from the avoidance to the punishment discriminative stimulus and vice versa, at times before any shocks occurred. Figure 2 shows these data averaged in blocks of four sessions.

As is shown in Figure 2, heart rates increased during the initial sessions and subsequently declined more rapidly immediately following transitions to avoidance than transitions to punishment. The avoidance-punishment difference was significant, $t=3.19$, but the interaction of this and blocks of sessions was not. The stimulus-controlled differentiation of heart rates seems to fit an associative hypotheses more parsimoniously than a non-associative, compensation explanation. We are inclined towards this view, analyzing its possible mechanism as follows.

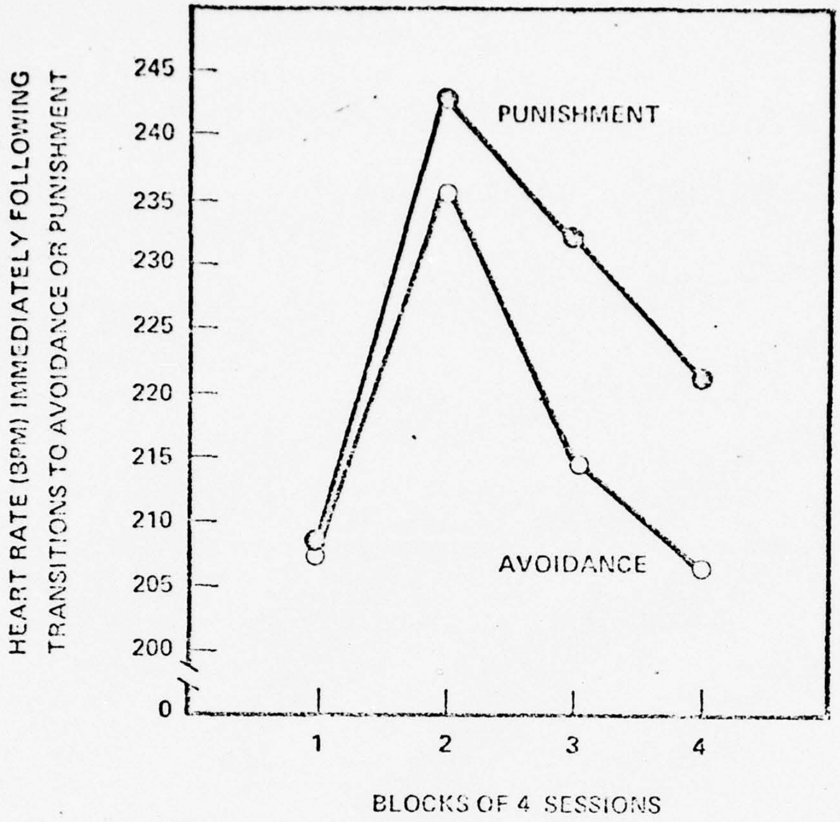

Figure 2. Heart rates in Instrumental monkeys following shifts to avoidance or punishment, averaged in blocks of four sessions.

Kimmel and Kimmel (1967) found that the frequency of digital vasoconstricitive responses increases when human subjects are given positive reinforcements at times when skin conductance responses are not occurring, but does not increase when reinforcements are given at times of nonoccurrence of vasoconstrictions. These results were depicted in the noncontingent curves in the upper and lower sections of Figure 1. Synder and Noble (1966) have shown that brief episodes of cardiac deceleration accompany digital vasoconstrictions. Indeed, they instrumentally conditioned the frequency of occurrence of vasoconstrictions and simultaneously found an increase in the degree of these concomitant decelerations. To the extent that our monkeys may have emitted some vasoconstrictive responses in conjunction with skin conductance responses and others independent of skin conductance responses (some 16% of Kimmel and Kimmel's humans'operant-level skin conductance responses were accompanied by vasoconstrictions and 30% of their vasoconstrictions were accompanied by skin conductance responses), the animals may have been receiving both adventitious intermittant avoidance and punishment training of the vasoconstriction response. Specifically, the initial increase in heart rate shown in Figure 2 may have resulted from an initial tendency for vasoconstrictive responses (i.e., cardiac decelerations) to be punished by shock during both avoidance and punishment periods, reducing their initial frequency of occurrence and consequently increasing heart rate. As the monkey learned to reduce the frequency of skin conductance responses during punishment, however, vasoconstrictions were less often punished. This would account for the slight reduction of heart rate following the second block of four sessions. During the avoidance periods, however, the shock-shock interval was reduced from 40 to 20 seconds following the sixth session, but the number of shocks actually received remained essentially unchanged. The animals, as noted above, were actually avoiding more efficiently. Since some 30% of emitted vasoconstrictions initially may have been accompanied by skin conductance responses (based on Kimmel and Kimmel's data), the vasoconstriction response may have increasingly benefitted from intermittent avoidance reinforcement during the avoidance periods and more rapidly begun to increase in frequency. This would account for the more rapid and steeper decline in heart rate during the avoidance than in the punishment periods in the last two blocks of four sessions. The tortuousness of this logic to the contrary notwithstanding, we think it makes sufficient sense to justify its empirical evaluation in follow-up study of monkeys' skin conductance and heart rate behavior. In every published instance of inter-effector influence mentioned previously, in which cardiovascular changes were found to be associated with reinforcement of some other autonomic response, the nature or direction of these changes is predictable from the foregoing logic and data, although present space limitations preclude a detailed review of these cases.

In conclusion, there is reason to believe that the current belief that reinforcement-feedback contingent upon the occurrence or nonoccurrence of autonomically mediated responses influences only the explicitly determining response may be incorrect. Other autonomic responses may be concomitantly influenced to the extent that the reinforcing events adventitiously occur in significant temporal relation to their presence or absence. In particular, responses of the cardiovascular system, such as vasoconstrictions or brief episodes of cardiac acceleration or deceleration, themselves being quite susceptible of instrumental reinforcement, are likely to be modified in various degrees and fashions when other autonomic responses with which they have some partial direct or reciprocal correlation are used to determine the occurrence of the reinforcing events. That this may be the case should not be at all surprising, given the extent to which the autonomic nervous system functions as a complex, integrated regulator of the entire internal environment.

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Summary of Recent Human Research on Conditioned Tonic and Phasic Emotional Responses

In conjunction with the research on monkeys' emotional responses, a series of five experiments have now been done using human subjects to clarify the differences between tonic (long lasting) and phasic (brief) emotional changes that can be brought under the control of experimental stimuli. The series of studies will be reviewed in this section somewhat cursorily, but their major findings will be included. The last of these five experiments involved the greatest degree of effort to measure several phasic and tonic behaviors, and the results of this study will be described in greatest detail.

The design used in these studies is a variant of the transswitching procedure first employed by Russian and other Eastern European investigators. This design involves two types of experimental stimuli, tonic stimuli of relatively long duration and phasic ones that are substantially briefer. In our studies, the tonic stimuli identify occasions during which the phasic stimuli will or will not be associated with an aversive event, electric shock. The tonic stimuli, therefore, play somewhat the same role as discriminative stimuli in an operant conditioning paradigm, identifying periods of reinforcement and nonreinforcement; in the present studies, however, the reinforcement is classical pairing rather than response-contingent. The general expectation, based upon the Eastern European findings, is that the tonic stimuli will come to control the nature of responding to the phasic ones. But, in the present research an effort was made to measure tonic changes as well as phasic response differences, unlike the bulk of the earlier studies, since our interest was primarily in long-lasting differences in emotional activation.

In the first study, two different geometrical shapes served as tonic stimuli. The shapes were presented for 4, 5, or 6 minutes in an alternating sequence. During the presence of the positive tonic visual stimulus, a 5 sec., 1,000 Hz. tone of 40 dB was paired with a 4 mamps. shock of 0.1 sec. duration, with an ISI of 4.9 sec. Paired trials were run with a mean ITI of 40 sec. During the negative tonic visual stimulus, tone-only trials were run on the same ITI schedule. There were 1 min. periods at the beginning of each tonic stimulus segment during which no phasic tone-shock or tone-only trials were run. Tonic measures were obtained during these periods.

A control group was run which received the same program of tonic visual stimuli as above but which had half of its tone-shock trials administered during the "positive" segments and half during the "negative" segments. In other words, both experimental and control subjects received the same numbers of paired and unpaired phasic trials; however, for the experimental subjects the paired trials occurred only during one of the tonic stimuli and never during the other, while for the controls the probability of a paired or unpaired trial was the same in both tonic segments.

The phasic response measured was the skin conductance response (palmar) to the phasic tone stimulus. These were averaged for all of the phasic trials within each tonic stimulus segment. The tonic measures obtained during the 1 min. periods of no phasic trials at the beginning of tonic segments was the frequency/min. of unelicited skin conductance responses. Examination of the phasic responses indicated that they were significantly larger in magnitude during the presence of the positive tonic stimulus than during the presence of the negative tonic stimulus, but only in the experimental subjects. The control subjects showed no difference in phasic responding between their different tonic stimulus segments. Thus, the interaction of groups and tonic stimuli was also significant. The interaction between groups and tonic stimuli was also significant for the unelicited skin conductance responses (i.e., the tonic measures). However, in this case, the difference favoring the positive tonic stimulus over the negative in the experimental group was not separately significant. In the control group the difference was in the reverse direction (negative positive), which may account for the significant interaction. In the experimental subjects, the tonic response difference was largest in the comparison between the last positive and negative stimulus segments, indicating that the phasic difference was observable earlier during conditioning than the tonic difference.

Because of the fact that the tonic stimulus segments differed for the experimental subjects with respect to whether or not paired tone-shock trials were run, they also differed regarding whether or not shock was present at all (i.e., regardless of its pairing with the tone). The fact that the tonic stimuli appeared to control phasic responding to the tone, therefore, may have been due to their direct association with shock rather than to tone-shock pairing. In order to evaluate this possibility, a second experiment was conducted in which the positive tonic stimulus set the occasion for tone-shock pairing while the negative positive stimulus marked periods in which tones and shocks were presented unpaired. The procedural details of this experiment were otherwise identical with those of the first one. Likewise, the same phasic and tonic dependent measures were obtained.

The size of the phasic responses to the tone during positive tonic segments was significantly greater than during negative tonic stimulus segments. This indicated that the tonic control of phasic responding in both studies was dependent upon tone-shock pairing during the positive tonic stimulus and nonpairing (with or without unpaired shocks) during the negative tonic stimulus. However, the slight difference in tonic frequency of unelicited skin conductance responses which had been observed in the first experiment, especially in the last positive and negative segments, was absent entirely in the second experiment. This suggests that tonic control of tonic emotional activity may be independent of tonic control of phasic conditioned emotional responses, or, at least, that the phasic difference does not require an observable tonic difference. The third and fourth experiments were run in an effort to clarify this issue.

In the third experiment the tonic stimuli were pure tones delivered via earphones and differing in frequency. The phasic stimulus was visual. Its duration and the timing parameters in the conditioning procedure were as in the first two studies, except that the initial period, with no phasic trials, was reduced to 45 sec. The decision to reverse the auditory and visual stimuli from tonic to phasic and vice versa was based upon our suspicion that auditory tonic stimuli might prove to be more noticeable than visual ones (e.g., the subject couldn't turn his head and accidentally miss a change from one to the other). Also, the number of tonic segments was increased to six for both the positive and negative tonic stimuli, on the assumption that better tonic differentiation might be achieved with a greater number of alternations from one tonic stimulus to the other. The positive tonic stimulus contained light-shock trials and the negative one contained light-only trials. In this study, basal skin conductance levels during the initial trial-free periods provided an additional tonic measure.

As in the first two studies, the size of the phasic skin conductance response was significantly greater during the positive tonic segments than during the negative. Neither the tonic skin conductance levels nor the tonic frequency of unelicited skin conductance responses during the initial 45 sec. periods significantly differentiated between the two tonic stimuli, although there was some divergence in the latter measures from the early to the later segments. Because the method of delivery of the tone (earphones) may have made it difficult for the subject to notice the change in frequency which marked tonic stimulus shifts, it was decided that a fourth experiment would be conducted using a wall loudspeaker to deliver them.

In addition to the use of a speaker instead of earphones to deliver the tonic auditory stimuli, the fourth experiment introduced two additional changes in method. Instead of alternating positive and negative stimulus segments, in the fourth study we decided to introduce a period of time out from any auditory stimulus (1 min. in duration) between adjacent tonic segments, with the probability of positive and negative stimuli following a time out being equal. In this way, the subjects would be unable to anticipate the next tonic stimulus and, accordingly, more likely to begin reacting to it following its onset. In addition, the first tonic stimulus segment was with the negative tonic stimulus (i.e., containing light-only trials), instead of with the positive tonic stimulus as in the previous experiments. This was also expected to facilitate tonic differentiation. The actual sequence of tonic segments used was: negative - time out - positive - time out - negative - time out - negative - time out - positive - time out - positive - time out - negative. Positive and negative had the same meaning as in the third study.

The results of the fourth study replicated the consistent significant difference in phasic response magnitude during the positive and negative tonic segments. The frequency of unelicited skin conductance responses in the periods following segments onsets did not differentiate between the positive and negative segments, other than to show "following" effects, i.e., higher following a recent period of shocks than following a period of no shocks. Likewise, skin conductance levels did not differ following the onsets of the positive and negative segments. An analysis of the course of skin conductance levels during the time out periods following positive and negative tonic segments (in 10 sec. stages) was undertaken, indicating no significant differences. There was some tendency for skin conductance levels to decline more during time out periods which followed the negative tonic stimulus than in those after the positive stimulus, but this difference was not significant. One additional measure was examined, the size of the skin conductance response elicited by segment onset (this could not be employed in the previous studies because segment onsets were also segment offsets, whereas in this study segment onsets followed time outs). There was no apparent difference in responses elicited by the onsets of positive and negative tonic segments.

It was decided that the time out methodology made it possible to return to using visual tonic stimuli. The fifth experiment, thus, employed a white square and white circle as tonic stimuli. The phasic stimulus was a 5 sec. change in the color of the tonic stimulus; this was achieved simply by leaving the tonic shape on and having the multiple stimulus projector add a red color it it. During the positive tonic stimulus, the red phasic stimulus was followed by 0.1 sec. shock. During the negative tonic stimulus, the phasic stimulus was presented without shock. Time outs separated adjacent tonic segments as in the previous study. In order to increase the amount of training and possible differentiation, each subject was run twice, on two successive days. Day one consisted of the following tonic sequence: negative - time out - positive - time out - negative - time out - negative - time out - positive; on day two it was: positive - time out - negative - time out - positive - time out - positive - time out - negative. Six phasic trials were run during each tonic segment. Time out was 20 sec. in duration and there were 30 sec. periods with no phasic trials at the beginning of all tonic segments. In addition to the skin conductance measures previously employed, heart rate and respiration data were also collected in this study.

Analyses of phasic response differences were conducted at several different stages of the experiment. Comparison of the phasic skin conductance magnitudes on the first three phasic trials during the first positive tonic segment and the first three phasic trials during the negative tonic segment immediately afterward (i.e., the second negative segment) showed that there was a significant interaction between tonic stimuli and trials, with phasic response magnitudes increasing during the positive tonic stimulus (acquisition) and decreasing during the negative tonic stimulus (extinction). This interaction established that there was a phasic conditioning-extinction difference between the first two relevant tonic stimulus segments. This phasic difference was also significantly present when the responses during the last positive and negative tonic segments of the first day were compared. Similarly, a comparison of all of the phasic responses during the positive and negative tonic stimuli of the second day also was significant. The degree to which these phasic response differences were "purely" under the control of the tonic stimuli during the latter part of the first day and thereafter is best illustrated by comparing the average magnitude of the phasic response on the last phasic trial during the last negative tonic segment of the first day with the average magnitude of the phasic response on the first phasic trial during the immediately subsequent positive tonic segment (i.e., nothing but time out and the onset of the positive tonic stimulus had intervened - no shocks have yet occurred during the positive tonic segment). The response to the phasic stimulus was significantly larger during the last positive tonic segment than during the immediately preceding negative one, even though the subjects had not received any shocks in the interim. This establishes without any doubt that the tonic stimuli gained discriminative control over responding to the phasic stimulus which occurred when one or the other tonic stimulus was present.

Of course, our principal interest was in the manner in which the tonic stimuli gain this control over phasic responding, particularly in whether any underlying tonic behavioral differences exist during the presence of the different tonic stimuli. On the first day, shocks were not paired with the phasic stimulus until the positive tonic stimulus was first introduced. Prior to this, during the initial negative tonic segment, the phasic stimulus had merely been presented six times without shock. During the first positive segment, six paired trials occurred. This was followed by two successive segments with the negative tonic stimulus, each containing six nonshocked phasic trials, (with appropriate time outs between adjacent tonic segments), and, finally, a second positive segment with six more paired trials. In other words, no opportunity existed for a tonic difference to be observed until the final positive segment of the first day began. Comparing the initial periods (without any phasic events yet introduced) of the last two tonic segments of the first day, the following observations were made: frequency of unelicited skin conductance responses (no difference between positive and negative segments was found), skin conductance levels (no difference was found), heart rate during the period preceding the first phasic stimulus (no difference was found), respiration rate preceding the first phasic stimulus (significantly higher during the positive segment than the negative), skin conductance response elicited by onset of tonic stimulus (no difference was found), heart rate response elicited by onset of tonic stimulus (significantly greater and longer lasting acceleration following the onset of the positive than the negative tonic stimulus). In other words, at the earliest possible opportunity for tonic differences to be found, some were found. And, at these same points in the experiment, tonically controlled phasic differences also were seen.

On the second day, the frequency of unelicited skin conductance responses during the initial periods of the positive tonic segments was significantly higher than during corresponding periods in the negative segments, the skin conductance levels during these periods were significantly higher in the positive segments than in the negative, and the magnitudes of the skin conductance responses elicited by segment onset were significantly greater for positive than for negative segments. Indeed, these electrodermal indices of tonic stimulus control were noticeable immediately at the beginning of the second session. The heart rate and respiration tonic differences that were seen at the end of the first day were not significantly present during the second day.

Rank correlations were determined between tonic and phasic differences that separately had been significant during the first or second day. Only one of these correlations was significant, the correlation between the degree to which a subject showed a difference between his skin conductance responses elicited by positive and negative segment onsets and the degree to which he showed a corresponding difference between skin conductance responses elicited by the first phasic stimulus presented during the positive and negative segments. What this correlation means is that those individuals whose reactions to the onsets of the tonic stimuli differentiated most between them also made reactions to the first phasic stimulus that reflected differentiation between the positive and negative tonic segments. Thus, tonic and phasic differentiation appeared to occur at about the same time during the experiment and they occurred to similar degrees in different subjects.

Although no grant-paid personnel have worked on the transswitching experiments involving human subjects, we now feel that there is enough evidence from these studies supporting the conclusion that long-lasting shifts in emotional arousal may be produced and brought under stimulus control by transswitching that a closer articulation between the human and monkey work is justified. Regarding the theoretical issue of which type of change, phasic or tonic, occurs earlier in the transswitching conditioning process, it now appears that the standard paradigm really does not permit such a differentiation to be made. Both tonic and phasic differences become noticeable at about the same time in the experiment, and the logic of the experimental plan permits no more precise distinction to be made. It is possible that a modified transswitching design, with single phasic trials during each tonic segment, might reveal the development of tonic changes prior to clear phasic differentiation. This would be important because of its relationship to the tonic control achieved in the discriminative avoidance-punishment experiment. It seems quite possible that a classical transswitching process enables a tonic emotional change to come under the control of the discriminative stimulus, which change then serves as a background for appropriate operant responding or nonresponding.

General Discussion and Prospectus

The main purpose of the research done under this contract was to develop a suitable experimental preparation for establishing elevated levels of emotional activation which could be controlled by environmental stimuli and utilized subsequently to evaluate predictions regarding the etiology of opiate addiction. Because of the 1975 congressional action which removed research on drug abuse from the Department of Defense appropriation, the drug-abuse aims of the project could not be achieved. Thus, this discussion must be confined to the question of establishing chronic, stimulus-controlled emotional arousal. Even this topic can only be addressed in a preliminary way because of the premature termination of the contract.

On the basis of the one completed study involving four Cebus monkeys, the results of which are summarized above, the most that can be said is that a promising start was made. The fact that heart rate differences were established using an instrumental reinforcement paradigm keyed by electrodermal responses may be a significant indication that the original theoretical idea was not totally misguided. That is, it may be that instrumental avoidance-reinforcement (whether by means of explicit skin conductance response reinforcement or fortuitously via reinforcement of heart rate changes) is the basis for the development of chronic arousal and achieving stimulus control of it. Since only four animals were used in the study, and because the results were far from unequivocal, it must be acknowledged that we are still at a very early stage in the development of the chronic emotional preparation we were seeking. Nevertheless, justification for continuing the effort is considerable.

In relation to this question, the results of a larger study of the same technique, using 16 monkeys, should provide more definitive answers. Since this larger study is now underway, there is presently no way to know how much more we will learn about this process from it. If its results replicate and extend those of the initial, smaller study, it may be that more direct concentration on cardiac behavior would be appropriate for future work on the problem. But, the related results in the human transswitching studies do not compel such a change in approach, since the tonic control over autonomic responding shown by the tonic stimuli on the second day was primarily control of electrodermal behavior. The heart rate tonic effect seen at the end of the first day was not present on the second day. Obviously, nothing definitive can be made of these findings. When the larger monkey study has been completed and fully analyzed, it is possible that a more definitive evaluation of the original theoretical idea may be made and a sounder statement of future prospects given. In the light of the rather short period of time that was available for this project, and considering how much of that time had to be devoted to the creation of a laboratory and research technology, it is not extravagent to say that considerable success was achieved. But this is "success" only within the limited time-frame context, not "success" with respect to the project's real longer-range goals.

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5. TYPE OF REPORT & PERIOD COVERED
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6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
H.D. Kimmel

8. CONTRACT OR GRANT NUMBER(s)
DAMD 17-74-C-4121 ✓

9. PERFORMING ORGANIZATION NAME AND ADDRESS
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10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
SGRD-EDE

11. CONTROLLING OFFICE NAME AND ADDRESS
Biomedical Stress Research Division
U.S. Army Medical R & D Command
Washington, D.C. 20314

12. REPORT DATE
June 30, 1976

13. NUMBER OF PAGES
59

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
University of South Florida
Tampa, Florida 33620

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A model for the development of chronic emotional arousal was studied in 4 monkeys in an avoidance-punishment skin conductance response procedure. Some evidence supporting the model was obtained in the conductance and heart rate results. Collatoral data in humans were also obtained which were supportive of the approach taken.