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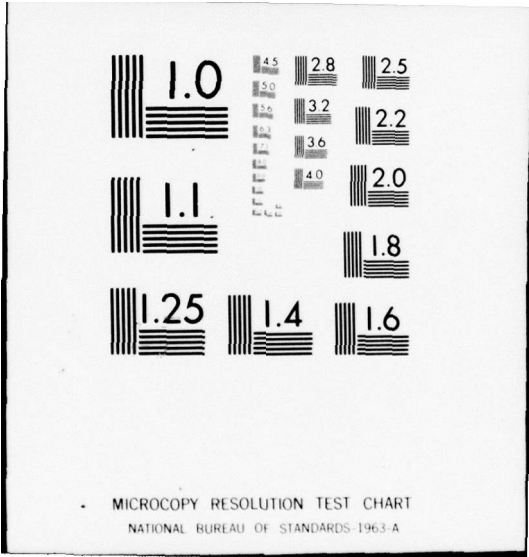
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Technical Report No. 2

An Instrumental Autonomic Conditioning Method
for Establishing Chronic Arousal
(Annual Report)

H. D. Kimmel, F. Brennan, D. McLeod, M. Raich
and L. Schonfeld

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April 15, 1977

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Abstract

The two groups of Cebus albifrons monkeys (n=8 in each), matched in preliminary frequency of unelicited skin conductance responses, received 24 daily sessions (twice per week) of either instrumental or classical autonomic conditioning. In the instrumental group visual discriminative stimuli marked occasions of either Sidman avoidance or punishment, with the skin conductance response determining reinforcement. Periods of time out from the visual stimuli were interpolated between adjacent visual segments. In the classical group the same discriminative stimuli marked occasions of pairings of tone and shock or tone alone. Heart rate and plantar skin conductance were recorded throughout and processed by a Nova II Data General computer. The computer also implemented the reinforcement contingencies.

The instrumental animals made significantly more skin conductance responses during avoidance than punishment and received significantly fewer shocks during avoidance. Unelicited skin conductance responses measured in preliminary contingency-free periods showed substantial increase in the instrumental group (and reduction in the classical group), but did not differentiate between the visual stimuli. Skin conductance responses elicited by the onset of the visual stimuli changed in a similar fashion, but differentiated between the visual stimuli only weakly. Substantial elevations in heart rates were observed in both groups, slightly more in the instrumental group, but again these increases were not associated differentially with the visual stimuli in the instrumental group.

It was concluded that the unelicited skin conductance response was brought under the control of the instrumental reinforcement contingencies, and that the animals became more aroused autonomically, but that no clear evidence of an instrumentally developed increase in chronic arousal occurred. Further work on some of the unexplained findings was suggested.

Foreword

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal, Resources, National Academy of Sciences-National Research Council.

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Statement of the problem

The research described in this report was designed to investigate in detail the differences in chronic autonomic arousal generated by a discriminative instrumental autonomic conditioning technique as compared with a classical conditioning method which is matched in stimulus patterning to the instrumental procedure but which involves classical reinforcement contingencies rather than response-contingent instrumental ones. The approach that was taken is an outgrowth of an operant autonomic conditioning model of tonic peripheral autonomic activation recently proposed by the principal investigator (Kimmel, 1975). Based upon this model, preliminary work with a small group of subhuman primates (Kimmel and Burns, 1977) indicates that chronically elevated levels of heart rate are produced under conditions in which another autonomic response, the unelicited plantar skin conductance response, is arranged to determine avoidance and punishment reinforcement contingencies. In addition to the observed differences in heart rates between animals which received the instrumental procedure, differences in heart rates were observed within animals in the instrumental procedure, between the avoidance and punishment conditions (favoring punishment). Two different possible interpretations of these preliminary findings appeared feasible. The first was that the animals adapted to the avoidance and punishment conditions by adjusting their electrodermal responding (mainly reducing it), but that this adjustment was achieved at the expense of sharply increased chronic heart rates. This is essentially a compensatory interpretation. The other interpretation was that fortuitous reinforcement of brief heart rate changes that are associated with concomitant unelicited vasomotor reactions may have led to the observed heart rate differences. This associative interpretation received some support from an examination of changes in stimulus-controlled heart rate differences immediately following

shifts from the avoidance to the punishment stimulus and vice versa.

Given the suggestive nature of the results of this preliminary study, it was desirable to obtain an enlarged, comprehensive view of the results of these experimental conditions, using a greater number of animals and a longer systematic conditioning history. It was hoped that the highly suggestive results of the preliminary study would become more stable and lend themselves to clearer interpretation. For these reasons, sixteen monkeys were run over a period of twelve weeks, with eight monkeys receiving a mixed avoidance-punishment instrumental conditioning program and the other eight receiving the classical procedure. The results to be reported below are based upon the skin conductance and heart rate data obtained from these two groups. Although the findings obtained to date will be presented in the fashion of a completed experiment, the experimental procedures are actually to be continued and changes in procedure introduced during the three month period remaining in the current grant year, and possibly beyond that.

Approach to the problem

Subjects. Sixteen adult male Cebus albifrons monkeys¹ were assigned at random to the two experimental conditions in pairs matched as well as possible on the basis of unelicited skin conductance response frequency during a four week preliminary period. The animals had previously been habituated over a period of two months to handling and sitting in the experimental chairs.

Apparatus. The animal was restrained in a specially designed plexiglass primate chair with neck, waist, and chest yokes which prevented manual contact with skin electrodes but which permitted the animal to remain comfortable for at least one hour. A hole at the back of the chair permitted the

1. Four of these monkeys were previously used in the preliminary study and remain in their original experimental conditions.

tail to protrude for attachment of shock electrodes. The chair also contained attachments for restraining the animal's feet and attachment of the skin conductance electrodes to the plantar surface of each foot. The electrodes were of the zinc-zinc sulphate type, in teflon cups filled with saline electrode paste. Two needle ECG electrodes were attached subdermally to the right and left sides of the chest and taped in place after examination of the signal indicated proper electrode placement.

In the electrodermal system the subject's skin was a bi-polar 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 fed into a voltage-to-frequency converter. The square-wave output of the V-F converter was processed by a Data General Nova 2 digital computer. The computer was programmed to maintain a continuous search for unelicited (or elicited in classical animals and at stimulus onsets) skin conductance responses, utilizing successive time bins of 0.33 sec. and a response criterion of two successive conductance increases of 0.13 micro-mhos per 0.33 sec. All responses that met or exceeded this criterion were counted and their amplitude scored by the computer program. The cardiac signal was amplified by a Grass Model 5 polygraph and fed into the coil of a relay whose contacts delivered a DC pulse into the computer coincident with each heart beat. The computer was programmed to count heart beats during pre-determined time periods and to record interbeat intervals during occasions when the form of the heart rate change was desired. The computer also administered all experimental events. Back-up polygraphic records of skin conductance and heart rate were obtained for subsequent evaluation of the effectiveness of the computer program² and for occasions of computer or

2. To the best of our knowledge, the skin conductance computer program is the first for on-line detection and scoring of SCRs and it will be more fully described and evaluated in a separate, later report.

teletype failure.

The primate chair containing the monkey was placed inside of a sound-attenuated chamber (34 in. wide, 29 in. deep, 34 in. high) so that the animal's face was oriented towards 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 presenting the phasic conditioned stimulus in the classical condition (1,000 Hz pure tone, 5 sec. in duration, 80 dB intensity).

Procedure. The instrumental condition involved a random sequence of four positive and four negative visual discriminative stimuli (red and green, via the primate press panel) with interpolated 30 sec. periods of time out (no visual stimulus). The program permitted a maximum of two consecutive positive or negative visual segments, except when three were needed to achieve four of each type of segment. The visual discriminative stimuli varied randomly in duration between 3.33 and 5.33 min., with a mean of 4.33 min. On the average, session length was 40 min., not including an initial 5 - 10 min. period for electrode polarization and equipment checking. Twenty-four sessions were run, two sessions per week for twelve weeks.³

During the positive discriminative stimulus a 40 sec. Sidman shock-shock schedule was administered. The shock was 3.0 mamps. in intensity and had a duration of 0.2 sec. It was administered to the animal's tail via 7 mm. stainless steel electrodes. Each criterion skin conductance response began a response-shock interval of 40 sec. Responses occurring within 5 sec. of shock (elicited responses) did not result in shock postponement. No shock was administered during the first 40 sec. following the transition from time

3. a preliminary training day was administered to all subjects (making an actual total of 25 days) without data being recorded. Thus, the "first" day reported below is actually the second day of conditioning.

out to the positive discriminative stimulus.

During the negative discriminative stimulus a response-contingent punishment schedule was run, using the same shock parameters as during avoidance. An initial shock-free 40 sec. period was maintained during punishment segments as was done during avoidance, and responses within 5 sec. of previous shocks were not punished.

The classical condition involved the same visual discriminative stimuli as were used for the instrumental animals, with four positive and negative segments having a range of durations from 3.33 to 5.33 min., with a mean of 4.33 min. The actual duration of each segment was determined for the classical animals by the random intertrial intervals which occurred within each segment. Thirty sec. time out periods separated these segments. During each positive segment, the classical animals received five paired trials of a 5 sec. pure tone and shock, with intertrial intervals ranging from 33 to 53 sec., with a mean of 43 sec. During each negative segment five tone-only trials were administered, with the same schedule of intertrial intervals. Each positive and negative segment began with a trial-free period at least 43 sec. long and each of these segments terminated with an intertrial interval prior to the beginning of time out. The classical animals thus received 20 paired and 20 unpaired conditioning trials per session for 24 sessions administered two sessions per week.

Results

Although data from a total of 24 experimental sessions were available for analysis, only the first and last six daily sessions will be described in this report. The reason for this exclusion is that sufficient information is available to show both early and terminal behavioral levels by using only the first and last six sessions. In addition, equipment failures during some of the intermediate sessions caused losses of data for some of the animals.

Since four of the subjects in this study had already served in a preliminary investigation of the same problem and experienced quite similar experimental procedures, it was decided that information regarding these animals would be presented both separately and in combination with the twelve new animals. The separate presentations are intended to provide information both regarding the stability of some of the effects to be reported (since data were available for comparison from both the preliminary and larger studies) and, in certain cases, regarding possible differences between the old and new animals which either enhanced or tended to obscure some of the effects.

Instrumental responses. During the preliminary investigation, two monkeys received sixteen daily sessions in which a Sidman avoidance schedule prevailed during the presence of one of the visual discriminative stimuli and a response-contingent punishment schedule was applied during the other visual stimulus. Under these conditions these two animals made an average of 8.21 unelicited skin conductance responses per avoidance segment and 5.23 responses per punishment segment. The comparable measures from the same two animals during the present study were 8.81 during avoidance and 5.12 during punishment. In other words, even with an additional 24 training sessions the avoidance-punishment skin conductance response effect seen in the first study remained almost unchanged. This testifies to the remarkable consistency of this effect.

The eight instrumental animals in the present study (i.e., including the two old subjects) made an average of 15.31 unelicited skin conductance responses per avoidance segment and 8.59 responses per punishment segment. This difference was highly statistically significant, $F(1, 7) = 12.70, p < .01$. The significance of the avoidance-punishment difference of the preliminary study could not be evaluated because of the small number of subjects. Even when the six new monkeys are considered separately, the avoidance-punishment effect

in the unelicited skin conductance response data was still significant, $F(1, 5) = 10.64, p < .025$.

Because of the availability of skin conductance response frequency data during 40 sec. preliminary periods in each visual segment when neither contingencies nor stimuli were administered (next section), it was unnecessary to obtain these measures throughout the visual segments for the classical animals. Because the classical animals received paired tone-shock trials during these visual segments, it was felt that the 40 sec. periods would provide less contaminated instances of evidence of control over tonic electrodermal responding by the visual discriminative stimuli.

Frequency of skin conductance responses at beginning of visual segments.

The frequency of unelicited skin conductance responses was measured during 30 sec. periods beginning 10 sec. after the onset of each visual discriminative stimulus (i.e., before the introduction of any contingencies or stimuli within that segment and without any responses elicited by onset of the segment). Table 1 shows these data for both discriminative stimulus segments combined, for the classical and instrumental animals. As can be seen in Table 1, the classical subjects tended to make more responses in these preliminary periods than the instrumental subjects early in training, but this was clearly reversed later in training.

Table 1. Average number of unelicited skin conductance responses made by classical and instrumental animals early and late in training (discriminative stimuli combined)

| | Early Sessions | | | | | |
|--------------|----------------|------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Classical | 3.56 | 3.33 | 1.95 | 1.83 | 3.09 | 3.67 |
| Instrumental | 2.17 | 3.06 | 2.64 | 1.34 | 1.86 | 1.44 |
| | Later sessions | | | | | |
| | 19 | 20 | 21 | 22 | 23 | 24 |
| Classical | 2.38 | 2.70 | 3.05 | 2.88 | 1.12 | 0.03 |
| Instrumental | 3.84 | 2.69 | 3.50 | 3.30 | 3.38 | 3.47 |

Analysis of variance of the frequency of unelicited skin conductance responses during initial 30 sec. periods just prior to the introduction of contingencies in the visual discriminative stimulus segments showed that the early-late reversal between the groups was highly significant, $F(1, 14) = 15.70$, $p < .005$. In addition, this early-late reversal interacted highly significantly with days within the early and late blocks of sessions, $F(5, 70) = 6.11$, $p < .001$. Because of the latter interaction, a separate analysis was done using only the last six days (the later sessions of Table 1). This analysis revealed a highly significant interaction of days and groups, $F(5, 70) = 4.02$, $p < .005$. In other words, the early-late tendency for the classical animals to reduce in frequency of unelicited skin conductance responses continued within the last six days, while the instrumental animals increased from early to late and remained high during the last six days. These effects were also shown in an analysis of the 12 new animals separately, where the early-late reversal was highly significant, $F(1, 11) = 17.24$, $p < .005$, and the early-late \times days \times groups interaction was also highly significant, $F(5, 50) = 3.52$, $p < .01$. Further analysis of the days \times groups last six days interaction in the 12 new animals showed that in these animals this effect also interacted with discriminative stimuli. During the last six days the six new classical animals actually increased in response frequency across segments within each day during the positive discriminative stimulus but not during the negative discriminative stimulus, while the six new instrumental animals tended to increase in response frequency across visual segments within each day during both discriminative stimuli. This interaction was also statistically significant, $F(3, 30) = 3.00$, $p < .05$. Since these measures were obtained at the beginning of visual discriminative stimulus segments, prior to the administration of either

instrumental contingencies or classical trials, it is quite clear that the different conditioning paradigms generated patterns of unelicited electrodermal response frequency which changed in different ways for the different groups and that the net outcome was a high and increasing level of unelicited response frequency in the presence of both discriminative stimuli in the instrumental subjects but a within-session increase only in the presence of the discriminative stimulus during which shocks were administered in the classical animals. It is also clear that the instrumental conditioning procedure employed resulted in a terminal level of unelicited response frequency that was substantially higher in the instrumental animals than in the classical ones. Even though the unelicited skin conductance response was instrumentalized in half of the animals in this experiment, the manner in which response frequency was measured at the beginning of visual stimulus segments and the fact that the measure did not differentiate between the discriminative stimuli in the instrumental animals indicates that its terminal levels are probably best thought of as indicating chronic autonomic arousal rather than simply as instrumental responding.

Skin conductance response elicited by onset of discriminative stimuli.

Table 2 shows the average magnitude of the skin conductance response elicited by the onset of the visual discriminative stimuli in the classical and instrumental animals. As was true of the unelicited response frequency data, the data in Table 2 show a reversal from early to late in the experiment between the two groups of subjects. The strength of the segment-elicited skin conductance response decreased in the classical animals, while the instrumental animals responses increased. Analysis of variance of these measures indicated that the early-late x groups interaction was significant, $F(1, 14) = 5.83, p < .05$. This interaction was even more noticeable in the 12 new animals, where the effect was highly significant, $F(1, 10) = 9.45, p < .025$. Separate analysis of the last six days showed some tendency for the change over days to interact with groups and discriminative stimuli (mainly a decline in the negative discriminative

stimulus in the classical animals and in the avoidance segments in the instrumental animals), but this effect did not attain statistical significance.

Table 2. Average magnitude (micromhos) of skin conductance responses elicited by onsets of visual stimuli in classical and instrumental animals early and late in training

| | Early | Late |
|--------------|-------|------|
| Classical | 0.22 | 0.18 |
| Instrumental | 0.12 | 0.18 |

Skin conductance levels during initial 40 sec. periods of discriminative stimulus segments. Skin conductance levels were measured immediately before the end of the initial 40 sec. periods of presentation of the visual segments, just prior to introducing contingencies or classical trials. Although the classical animals' conductance levels tended to be higher than those of the instrumental animals, as was observed in the preliminary study, the difference between the two groups was not significant and did not interact significantly with discriminative stimuli. We have noted (Kimmel and Ray, in press) that these measures tend to change too slowly following the introduction of tonic stimulus events to reflect differences between types of events, and for this reason our present inclination is not to place great emphasis upon the tonic skin conductance level during initial periods of the discriminative stimuli.

Number of shocks received by instrumental animals. Further evidence of the instrumental monkeys' adjustment to the avoidance-punishment electrodermal conditioning schedule can be seen in the average number of shocks they received during the avoidance and punishment segments. During avoidance the animals received an average of 1.86 shocks per segment and during punishment they received an average of 8.54 shocks per segment. This difference was highly significant, $F(1, 7) = 15.47, p < .01$, as it was separately in the six new instrumental animals, $F(1, 5) = 17.80, p < .01$. However, considering that the average length of a segment was 4.33 min., this adjustment can hardly be

considered adaptive. If the animal made no responses at all it would have received an average of 6.82 shocks per avoidance segment (shock-shock interval equalled 40 sec.) and no shocks whatsoever during the punishment segments. Thus, by responding during the avoidance segments the animals succeeded in reducing the number of avoidance shocks from 6.82 to 1.86, a reduction of almost five shocks per segment. But the price paid for this reduction in shock during avoidance may have been a great increase in shocks during punishment, assuming that responding during avoidance fostered responding during punishment. The net loss to the animal was about 3.5 extra shocks per segment pair, or a total of about 14 extra shocks per session.

On the other hand, the fact that the animals received so many fewer shocks during avoidance than during punishment indicates that the difference in instrumental responding favoring avoidance over punishment cannot simply be attributed to responses being indirectly elicited by shock frequency, since the animals made more responses during avoidance where they received fewer shocks and fewer responses during punishment where they received more shocks. Thus, the combined shock frequency and instrumental response frequency data provide further support for the conclusion that the instrumental animals' behavior was modified in accordance with the instrumental reinforcement contingencies functioning in the experiment.

Baseline heart rate. Heart rate was measured during the initial 40 sec. periods following the onset of each visual discriminative stimulus, prior to introduction of stimuli or contingencies during the particular segment. The average interbeat interval over the last fifty consecutive heart beats at the end of these 40 sec. periods was converted to beats/min. for this purpose. It should be noted that the current baseline heart rate measures are much less contaminated by events occurring during the visual discriminative segments than was the case in the preliminary investigation. However, for the purposes

of comparison, it was instructive to examine the analogous data from the four monkeys of the preliminary study along with these monkeys' baseline heart rates in the present study. Table 3 presents these data from both studies.

Table 3. Baseline heart rates of two classical and two instrumental monkeys in preliminary and present studies

| | Preliminary study | | Present study | |
|--------------|-------------------|----------------|----------------|----------------|
| | S ^D | S ^A | S ^D | S ^A |
| Classical | 204.4 | 203.0 | 207.3 | 207.2 |
| Instrumental | 221.5 | 227.5 | 241.5 | 237.6 |

As in the case of the preliminary study, there was a substantial difference in baseline heart rates between the two classical and two instrumental animals, although with only 2 df for error the $F(1, 2) = 5.76$ was not statistically significant. Unlike in the preliminary study, the present data show an increase in heart rates with training, especially in the classical monkeys. It is clear, in any case, that the large classical-instrumental difference remains present through both studies and that the lack of overall difference between the discriminative stimuli persists as well.

Table 4 presents the baseline heart rate data for all sixteen animals in the present study, segregated to permit interpretation of the statistically significant interaction between early vs. late sessions, segments within sessions, discriminative stimuli, and groups. Analysis of variance of these data showed that the 4-way interaction in question was highly significant, $F(3, 42) = 3.51, p < .025$. This interaction results from the fact that the classical and instrumental animals both showed a within-session increase in baseline heart rates in both types of visual discriminative stimulus segments in the first six sessions of the experiment, but this increase was present

during the last six sessions only in positive visual segments in the classical animals and only in punishment segments in the instrumental animals.

Table 4. Baseline heart rate in classical and instrumental animals during first and last six daily sessions, averaged within visual stimulus segments.

| | | Stimulus segments | | | | |
|-------|----------------|-------------------|-------|-------|-------|--------------|
| | | 1 | 2 | 3 | 4 | |
| Early | S ^D | 211.7 | 221.4 | 227.8 | 223.5 | Classical |
| | S [△] | 211.2 | 221.7 | 223.9 | 225.9 | |
| Late | S ^D | 236.0 | 235.5 | 238.1 | 243.8 | |
| | S [△] | 240.1 | 227.0 | 234.0 | 238.3 | |
| Early | S ^D | 237.4 | 243.4 | 237.4 | 244.0 | Instrumental |
| | S [△] | 238.3 | 240.9 | 238.8 | 245.0 | |
| Late | S ^D | 245.2 | 240.7 | 247.1 | 245.2 | |
| | S [△] | 238.2 | 241.2 | 242.4 | 245.9 | |

The segments x discriminative stimuli x groups interaction during the last six days separately was also highly significant, $F(3, 42) = 5.61, p < .005$, indicating that it was mainly during these last six days that the negative discriminative stimulus in the classical subjects and the avoidance stimulus in the instrumental subjects ceased to show a systematic increase in heart rate across segments within daily sessions. These stimuli, of course, were associated with either no shocks (classical) or few shocks (instrumental). It should be noted, however, that the monkeys' heart rates during these visual stimulus segments were already quite a bit higher even in the first segment during the last six days than they were in the last segment during the first six days, indicating substantial chronic elevation of cardiovascular arousal near the end of the experiment. In general the animals baseline heart rates were some 60 - 70 beats/min. higher than their initial resting heart rates at the end of the experiment. Even during the last few seconds of the interpolated periods of time out from either visual discriminative stimulus, just before the onset of a visual stimulus, the classical animals' heart rates averaged about 235 beats/min. and the instrumental animals' rates averaged about 240 beats/min. during the last

few days of the experiment. These heart rates are somewhat lower than were present during the presence of the visual stimuli (just seconds later), but were much higher than initial resting heart rates.

Heart rate changes elicited by onset of visual discriminative stimuli.

These measures were obtained by converting the average interbeat interval for the last ten successive heart beats immediately preceding the onset of the visual discriminative stimulus into beats/min., converting the average interbeat interval for the first ten heart beats immediately following the onset of the stimulus into beats/min., and subtracting the second of these converted measures from the first to obtain a measure of the change in heart rate occasioned by stimulus onset. Table 5 presents the averages of these measures for both discriminative stimulus segments for the classical and instrumental animals. As can be seen in Table 5, the instrumental animals tended to make small accelerative changes in heart rate while the classical animals changed slightly in the direction of deceleration. The overall group difference was just short of statistical significance, $F(1, 14) = 3.59, p < .10$, and the interaction of groups and stimuli failed to approach significance. There was a highly significant interaction of days and stimuli, $F(5, 70) = 4.00, p < .005$. This interaction stemmed mainly from the tendency in the instrumental animals' heart rate changes during punishment segments to become increasingly accelerative over the last several daily sessions; no other systematic tendencies across daily segments were present in either the instrumental group's avoidance segments or the classical group's positive or negative segments. This effect was also significant in the 12 new animals.

Table 5. Average heart rate changes elicited by the onset of visual discriminative segments in the classical and instrumental animals

| | s^D | s^Δ |
|--------------|-------|------------|
| Classical | -0.75 | -0.23 |
| Instrumental | +0.47 | +1.61 |

Classically conditioned responses. The skin conductance and heart rate responses elicited by the tone in the classical animals were measured during the time interval between tone onset and offset, prior to the administration of shock. By using data from only the first classical trial in each discriminative stimulus segment, it was possible to examine the extent to which the visual discriminative stimuli exercised control over responding to the classical tone, prior to the animals' receiving either paired or unpaired stimuli during each visual segment. Table 6 presents the average magnitude of the skin conductance response elicited by the first tone per visual segment, separately for the first and last six daily sessions of the experiment. During the first six sessions there was a slight difference in the size of these elicited first-trial skin conductance responses, favoring the negative segments. This small difference reversed in the last six daily sessions as a result of the fact that responses to the tone increased in magnitude during the positive segments and reduced during the negative ones. Analysis of variance showed, however, that the interaction depicted in Table 6 was not quite statistically significant, $F(1,7) = 4.23, p < .10$. This effect also approached significance in a separate analysis of the six new classical animals.

Table 6. Average magnitude of first-trial classical skin conductance responses during positive and negative visual discrimination segments in the first and last six daily sessions (micromhos)

| | Discriminative stimulus | |
|-------|-------------------------|----------|
| | Positive | Negative |
| Early | 0.25 | 0.27 |
| Late | 0.28 | 0.21 |

Table 7 shows the average heart rate change elicited by the first tone per visual segment, separately for the first and last six daily sessions. Unlike the electrodermal responses, the heart rate changes elicited by the tone tended to become even more accelerative during negative segments than positive ones.

later in the experiment. The interaction shown in Table 7, did not approach significance. This effect was somewhat more pronounced in the six new animals separately, but again did not approach significance. A separate analysis of elicited heart rate responses on the first trial of the first positive and negative segments of each daily session revealed a significant difference in amount of acceleration, favoring the positive segments, $t(15) = 2.89$, $p < .02$. Apparently, classical heart rate differentiation between positive and negative segments was present at the beginning of each daily session but then dissipated during the remaining segments during these sessions. There was a significant interaction between discriminative stimuli and segments, $F(3, 15) = 4.11$, $p < .05$, which is in accord with this observation.

Table 7. Average first-trial classical heart rate response during positive and negative visual discriminative segments in the first and last six daily sessions (beats/min.)

| | Discriminative Stimulus | |
|-------|-------------------------|----------|
| | Positive | Negative |
| Early | 2.53 | 2.69 |
| Late | 2.65 | 4.35 |

Discussion

The purpose of the present investigation was to examine in detail the differences in chronic autonomic arousal generated by a discriminative instrumental autonomic conditioning technique as compared with a classical conditioning method which is matched to the instrumental procedure in stimulus patterning but which involves classical rather than instrumental reinforcement contingencies. Although the instrumental avoidance and punishment contingencies related to the unelicited skin conductance response, elicited skin conductance responses and heart rate measures were essential components of this evaluation.

Of primary importance was the finding that monkeys receiving discriminative avoidance and punishment conditioning made almost twice as many unelicited skin

conductance responses during signalled periods of avoidance than during periods of response-contingent punishment. This difference was highly statistically significant and was associated with a significant difference in the number of shocks the instrumental animals received during avoidance and punishment, favoring punishment. As has already been noted, this difference in response frequency cannot be attributed to shock frequency itself, via some kind of short-term arousal mechanism, since the visual discriminative stimulus that was associated with the larger number of shocks marked occasions when fewer responses occurred. The visual discriminative stimulus that was associated with a smaller number of shocks, likewise, marked occasions when more responses occurred.

The possibility that something other than "instrumental" conditioning may have been responsible for the observed difference in response frequency between avoidance and punishment, however, cannot be dismissed without more detailed consideration of the experimental procedures. During both avoidance and punishment periods, shocks were automatically followed by 5 sec. intervals of time out from both the instrumental contingencies and from having responses counted. Since approximately 8.5 shocks were administered per punishment segment and only about 2 shocks were administered per avoidance segment, on the average, the avoidance segments "benefitted" from about 30 extra seconds during which responses could occur and be counted. Since the average number of responses made during avoidance segments was about fifteen, these responses were occurring about sixteen seconds apart (with an average segment duration of 4.33 min.). In other words, only approximately two additional responses per punishment segment would have been expected to occur during the 30 sec. "lost" as a result of these 5 sec. periods of time out. It does not seem likely that this factor was responsible for the difference in response frequency that was observed. Furthermore, during punishment periods, shocks were administered about 0.66 sec. following the onset of a criterion response. In other words, during punishment,

these 5 sec. periods of time out following shocks occurred at times of relatively low response probability. On the other hand, during avoidance shocks were administered only when 40 sec. elapsed without a response having occurred. It may be assumed that the post-shock 5 sec. periods came at times of higher response probability during avoidance. These considerations also do not seem to support the possibility that something other than "instrumental" conditioning was the reason for the observed difference in response frequency between avoidance and punishment. On the basis of these considerations, it appears likely that a genuine instrumental reinforcement process underlay the observed avoidance-punishment effect. However, follow-up on this issue should probably employ the yoked-control technique, so that other unidentified non-conditioning alternatives may also be ruled out. Even without this recommended follow-up, however, it seems reasonable to conclude that skin conductance responses of monkeys are as responsive to instrumental reinforcement contingencies as those of humans, and in this respect the present study adds an important piece of information to the instrumental autonomic conditioning literature.

Since it appears reasonable to conclude that the unelicited skin conductance response was modified by the avoidance and punishment contingencies applied in the instrumental subjects, based upon the foregoing data and arguments, a question must be raised regarding the fact that the unelicited skin conductance responses measured during 30 sec. intervals beginning 10 sec. after the onset of the discriminative stimuli did not differentiate between these stimuli in the instrumental animals. It should be noted that the average response frequency during these 30 sec. periods was about 5.5 responses/min. in both avoidance and punishment segments. This translates to approximately 24 responses per segment, a response frequency that is substantially higher than even that attained in the avoidance segments after the contingencies were introduced (i.e., immediately following these 30 sec. periods). One possible explanation of the lack of difference in these measures between the avoidance and punishment segments is

that the onset of the visual stimulus, itself, may have evoked a short-term arousal reaction in both types of segments, bringing response frequencies close to their ceiling. It may be that longer initial periods prior to the introduction of contingencies would be needed for this short-term arousal to subside sufficiently for differences in response frequency between the avoidance and punishment segments to become observable.

The initial unelicited skin conductance response frequency data did, however, reveal some interesting differences between the early and late experimental sessions in the instrumental animals (substantially higher later) and between the instrumental and classical animals. The latter difference consisted mainly in the fact that response frequency declined consistently and, in the last six sessions, dramatically in the classical animals, while it increased in the instrumental animals and then remained at a high level (equivalent to about 30 responses per segment) during the last six days. This decline was most noticeable in the negative discriminative segments in the classical animals.

It may be that the unelicited skin conductance response frequency data reflect genuine differences between the classical and instrumental subjects in chronic arousal and, because of the large increase during training in the instrumental animals, an increase in chronic arousal within this group. This interpretation is in accord with some of the other findings to be discussed below.

The magnitude of the skin conductance responses elicited by the onset of the visual discriminative stimuli fit the same pattern. These responses increased in size during training in the instrumental animals and decreased in the classical ones. As was the case in connection with the frequency of unelicited skin conductance responses prior to the introduction of contingencies within each segment, there was some tendency for a decline in the size of the response elicited by the negative discriminative stimulus in the classical group during the later sessions. But this may have been mainly due to absence of

shock during this stimulus, since a similar tendency was present during the avoidance stimulus in the instrumental subjects. Although these latter changes were not statistically significant, they suggest that the skin conductance response elicited by the onset of the visual discriminative stimuli may have been due to classical association of these stimuli and shocks.

The baseline heart rate data also support the hypothesis that the classical and instrumental conditioning procedures generated differences in chronic arousal, and that the discriminative stimuli that were associated with shock (or greater shock) tended to reflect this effect more consistently than discriminative stimuli that were associated with no shock (or less shock). The instrumental subjects' heart rates tended to be quite high even during the initial daily discriminative segments near the end of the experiment. It is especially interesting that this was true even in the avoidance segments, where very few shocks were being administered to these animals. Even at the very beginning of the late daily sessions, when the animals had been in their home cages for two or more days since their last session, baseline heart rates were some 55 - 65 beats/min. higher than resting heart rates at the beginning of the experiment.

Although we have previously speculated regarding the basis of these changes in heart rate, examining the possibility that they may have been due either to some kind of compensation for regulated electrodermal responding or to adventitious avoidance and punishment reinforcement of brief decelerations or accelerations, the present data do not seem to support either of these conjectures. Rather, the most parsimonious interpretation of the baseline heart rate results is that repeated exposure to shock stress induces a chronic elevation in heart rate, eventually even at times before shocks have been administered, and that this effect is a function of shock frequency. Because of the relatively unsophisticated manner in which the heart rate was picked up (i.e., needle electrodes), it may be that judgment should be reserved regarding

the basis for the observed changes until improved heart rate pick-up techniques are employed.

The same general comments are appropriate regarding the elicited heart rate responses at the onset of the discriminative visual stimuli. There was some tendency for the instrumental animals heart rate responses to be accelerative and the classical animals to be negligibly decelerative, but this difference between groups was just short of significance. Since the instrumental animals' avoidance stimulus was associated with very few shocks, however, there seems to be no simple explanation regarding why it should produce an accelerative response while the positive stimulus in the classical animals produced a decelerative one. Many more shocks were presented in the latter case than in the former. Better analysis of the heart rate data, using plots of interbeat intervals over 20 - 30 heart beats following stimulus onset, is needed before firm conclusions can be made regarding this measure.

Within the classical group it was found that the skin conductance response elicited by the first tone in each positive segment became somewhat larger in size during training than the equivalent response in each negative discriminative segment. However, this effect was not quite statistically significant. The heart rate change elicited by these tones tended to become increasingly more accelerative in the negative segments towards the end of training, but was significantly more accelerative in the positive segment very early in training. Since it is known that the classically conditioned skin conductance and heart rate responses tend to reduce in strength after protracted training with relatively long interstimulus intervals, it is likely that strong evidence of differentiation between the discriminative stimuli would only be found in an analysis of all of the responses in the first one or two training sessions. Since these analyses are more or less irrelevant to the main purposes of this investigation, they are not reported at present.

The classical procedure, however, did tend to generate substantial arousal in terms of increased baseline heart rates in the last six sessions of the study. This was particularly the case in the presence of the positive discriminative stimulus. Fairly good differentiation of unelicited skin conductance responding and baseline heart rates in the positive and negative segments were seen in the classical group during the last six sessions. On the other hand, in the instrumental group, more chronic arousal appeared to be present late in the experiment, but this did not differentiate reliably between the discriminative stimuli. This may have been due to the use of only a brief period at the beginning of each segment for obtaining these measures, a matter which should be investigated further in follow-up research.

A somewhat guarded general conclusion appears justified. This is that the discriminative avoidance-punishment autonomic conditioning procedure results in some differentiation in unelicited skin conductance response frequency during periods in which the responses are indeed instrumental (i.e., when the contingencies are operating), but that these stimulus controlled differences in responding were not present in initial periods prior to the introduction of the contingencies. There was, however, a substantial increase in unelicited electrodermal responding and an elevated level of heart rate under these conditions. The heart rate elevation seems to be present almost as much during periods of time out from the visual stimuli as when they are present. In the classical procedure, the arousal was confined mainly to periods when the positive visual stimulus was present, suggesting its close association with the administration of shocks. The present findings do not support the conclusion that the proposed instrumental autonomic conditioning model of the development of chronic arousal is or is not correct. This is, although it may be concluded that the skin conductance response was modified differently in the instrumental as compared to the classical animals, and that differentiation occurred within

the instrumental animals in this response, the nondifferential changes in heart rate and the lack of differentiation in the skin conductance responses of the initial periods within each segment are not in clear accord with the model. Although it was initially thought that a yoked control condition would not be necessary in an experiment of the present type, it now appears that it would be desirable for such a control to be run in future work on this problem. Only if differentiation can be found between a group receiving the present instrumental procedure and a group of yoked controls who receive the same patterns of shocks can it be concluded that the instrumental contingencies play a critical role in the development of the kinds of autonomic changes observed in this study.

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