

## OPERANT REINFORCEMENT OF AN AUTONOMIC RESPONSE: TWO STUDIES<sup>1</sup>

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Two successive studies were conducted to determine the possibility of operant reinforcement of nonspecific galvanic skin resistance responses. In the first study, with five experimental and three control subjects who served for 20 to 30 min a day for 10 days, all experimental subjects learned to emit more nonspecific galvanic skin resistance responses than their *ad hoc* matched controls. In a second study, nine experimental and nine control subjects were matched for first-day levels of reactivity and yoked for operant reinforcement schedules. Significant differences between the two groups were found on the last day of conditioning and during extinction. Six of the nine experimental subjects showed higher cumulative rate curves than their matched and yoked controls. The concomitant measures (basal resistance, heart rate, *etc.*) all supported this finding. It was suggested that operant reinforcement of autonomic response tends to maintain a certain level of responding in contrast to persistent adaptation in the control group.

As early as 1938, operant reinforcement of an autonomically controlled response (vasoconstriction) was attempted. The results were "inconclusive" (Skinner, 1938). Skinner was explicitly concerned with this distinction in the development of his system; he distinguished operants and respondents on the basis of their correlation with an observable, external stimulus and not on the more commonly accepted basis of the autonomic-skeletal division. In doing this, he left open the theoretical possibility of modifying by operant means a response which is autonomically controlled but is not correlated with any observable external stimulus.

Two major problems of experimental design exist: (1) controlling for the effect of the rein-

forcer so that an increased rate of autonomic responding cannot be attributed to the stimulating effects of the reinforcer, and, (2) controlling for, or eliminating the effect of mediating skeletal responses. If the autonomic response is produced by an intervening skeletal response, the reinforcement may be acting directly on the skeletal response and parasitically reinforcing the autonomic response.

Few studies have dealt adequately with these problems. Kimmel and Hill (1960) and Fowler and Kimmel (1962) tried operant reinforcement of drops in skin resistance in humans. They found statistically significant differences only during the first minute or two of extinction. Although their experimental and control groups were yoked for the stimulating effect of the reinforcer, they were not matched for initial levels of reactivity. Little time was allowed for subjects to adapt to the experiment and the whole operant level, reinforcement, extinction program was compressed to about 20 min. No attempt was made to control for skeletal mediators.

Lisinia (in Razran, 1961) reinforced vasodilatation in humans with shock termination. No control group was used, and neither the effect of the reinforcer nor the potential skeletal mediators were controlled. After "several experimental sessions", during which subjects were allowed to watch their own records, conditioning was observed.

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Mandler, Preven, and Kuhlman (1962) reinforced drops in skin resistance (GSR) with money and a flashing light. Nine subjects received 11 daily sessions of 30 min each. Four subjects showed significantly high responding (last 20 min of each day's run *versus* first 10 min of each day's run). They all had had significantly lower GSR rates during control periods. No control subjects were used. No effort was made to control for the stimulating effect of the reinforcer or for possible skeletal mediators.

In the two studies reported here, special efforts were made to control for the stimulating effect of the reinforcer, initial levels of reactivity, and potential skeletal mediators. Concomitant records of several other autonomic responses were used to investigate the generality of such learning. The general finding of the first study is that operant reinforcement of galvanic skin resistance deflections (nonspecific GSR's) is possible. The second study introduced some better controls and corroborated the findings of the first study.

### STUDY ONE (1961)

#### *Subjects*

Eight University of Minnesota female undergraduates, all paid volunteers, were drawn from introductory psychology classes. More experimental (five) than control subjects (three) were used because it seemed likely that each subject could serve as her own control.

#### *Apparatus*

A GSR apparatus designed by D. T. Lykken was used. A constant current of 50 microamps was passed through the subject and the voltage across the subject was read as a linear measure of her resistance. Readings were accurate to the nearest 1000 ohms. The amplified signals were recorded on a Sanborn oscillograph Model 126.

#### *Procedure*

Subjects served for 10 consecutive days. The first two were operant level days; on the third day, the reinforcer was introduced and presented randomly for 10 min. Reinforcement began on the last half of the third day's session and continued through the next four days. The last three days were extinction sessions. All sessions were 20 min long except for

the last two, which were extended to 30 min.

Control subjects followed the same procedure as experimental subjects except that they received "random", noncontingent reinforcers during the four-and-a-half days of learning. Pilot work showed that an experimental subject was likely to receive 25-30 reinforcers per 20-min session. Time of delivery of the reinforcer was obtained from random number tables. No reinforcer was administered within 15 sec of another to avoid reinforcement of a reinforcer-elicited response. Average number of reinforcers per day for the experimental group was 23; for the control group 27. An upper limit of 90 sec between reinforcers was arbitrarily given to the control group. Thus, the two groups were fairly well matched for number of reinforcers but not precisely matched for interval between reinforcers. An analysis of the results showed that time between reinforcers varied more for the experimental group.

All subjects performed a simple, randomly varied task carefully selected so that it would be similar from one day to the next, but not repeatable. These precautions were taken to avoid conditioning of GSR reactivity to the repeated elements of task. The task was also selected so that it would control, to some degree, the attention of the subject, and prevent "day-dreaming" and sub-vocal elicitation of GSR responses. A further restriction was that the task must not elicit associated implicit verbal responses. The subjects were given stacks of cards on which were printed nonsense syllables of low association value (Archer, 1960) and numbers. They were asked to read through the cards, which were shuffled each day so that order was never the same.

GSR electrodes were taped on the first and third fingers of the subject's left hand. Subjects were told that the electrodes measured changes in skin resistance, that the purpose of the experiment was a study of day-to-day changes in GSR under controlled conditions, and that a light would come on when their reactions were going well. Deflections of 2000 ohms or greater were reinforced by a flash of the light and the comment, "That's good", or "That's fine".

A wooden screen separated experimenter from subject. Subjects were asked to avoid day-dreaming and to read the cards at a steady rate. They were told they could pronounce the

nonsense syllables any way they wished and that this task was an irrelevant one, designed to give them something to do which was the same from day to day. The experimental room was sound-proofed and temperature controlled and the subjects were tested at the same time each day.

At the conclusion of the experiment, subjects were asked to predict the occurrence of the light, and to specify what determined the appearance of the reinforcer and what the purpose of the experiment had been.

The methodology used here was very close to that used by Mandler *et al.* (1962), with some important differences. A control, non-contingent reinforcement group was used, and a distracting, continuous task controlled for attention and ideation. Results were scored in terms of daily rate of nonspecifics, excluding the first 2 min, which seemed to represent an elevated reaction to onset of the experiment. No nonspecifics occurring within 15 sec of the reinforcer were included in the final counts of nonspecifics.

### Results

Experimental and control groups differed significantly in production of nonspecific GSR deflections on three of the four days of conditioning and on the last day of extinction (if a score is estimated for one missing subject). Mann-Whitney U tests (Siegal, 1956) show that these differences were significant at the .05 level or better.

There were no significant differences between the two groups on the first two days of adaptation or during the introduction of the reinforcer on day three.

These group differences reflect the differences seen in the individual learning curves of Fig. 1. Cumulative curves for control subjects are shown on the same set of coordinates as learning curves for experimental subjects who had approximately the same initial (day 1) rate of responding. (Note, however, that they were not matched for the experiment.) In all cases the experimental subjects showed a steeper and more uniform rate of responding than their *ad hoc* matched controls. The control subjects showed a negative acceleration or bending of their curves, which probably reflects their gradually increasing adaptation to the experimental situation and the reinforcer. The individual cumulative curves of the ex-

perimental subjects seemed to vary around a relatively constant, individually determined slope.

A slight increase in rate at the onset of the first full trial of extinction may be seen in two of the three control subjects (BA and VJ) and in two of the five experimental subjects (WC and DB). This effect is probably obscured by the already high rate of responding of two other experimental subjects (AP and BB).

Responses to the reinforcers were counted to see if the differences found could be accounted for by different reactivity to the reinforcer. The daily record of each subject was inspected for obvious responses to the light and the latency of those clear responses was used as a criterion to evaluate other questionable reinforcer-elicited responses. There were no significant differences in percent of light-elicited responses for the two groups on any of the five days on which the reinforcer was presented. All but one experimental subject (AP) and one control subject (SJ) showed a decreasing rate of reinforcer-elicited GSR responses as conditioning progressed from day 3 to day 7. This finding, replicated in the next study where very similar curves were obtained, is important because it shows that GSR "respondents" of this type followed a different course than GSR "operants" or nonspecifics. Furthermore, it suggests that the differences in rate of nonspecifics cannot be explained by simple differences in responses elicited by the reinforcer.

Nonspecific responses during the 15-sec interval after each reinforcer were counted. Since these responses were not reinforced for either group, no obvious differences could be seen, as was expected. These data are based on very small time samples and may not be reliable. They suggest, however, that the experimental group may have been learning the very subtle discrimination of responding only after 15 sec had lapsed after reinforcement, during which no responses were reinforced.

Some initially low experimental subjects (for example, RL) showed an increase in absolute rate of nonspecifics, from day 1 to day 10, while some initially high experimentals (AP and DB) showed a decline in absolute rate of responding but not as much as initially high control subjects (see Fig. 1). This suggests that Mandler *et al.* (1962) were not able to de-

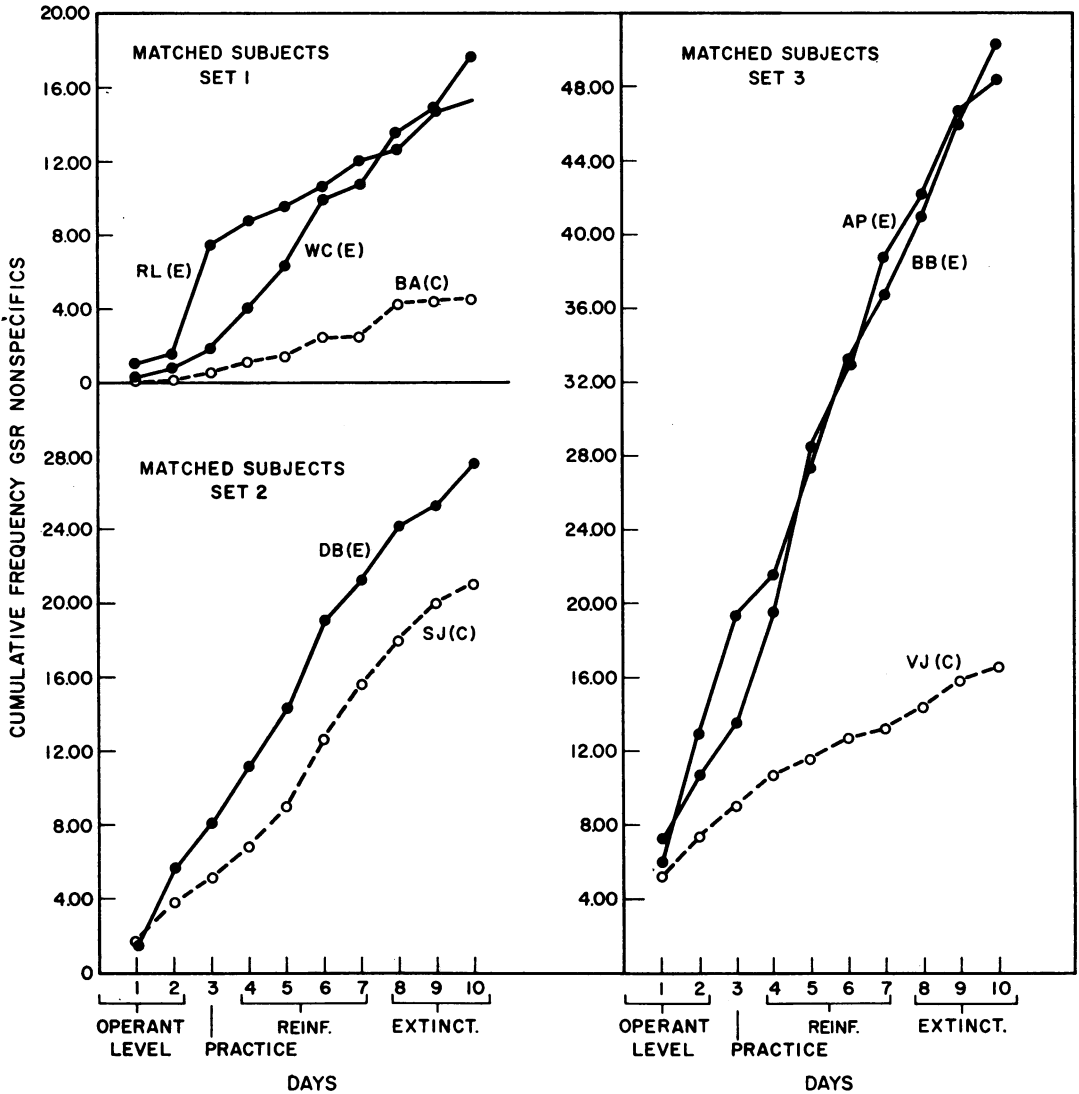


Fig. 1. Study 1: Cumulative GSR nonspecifics for *ad hoc* matched pairs.

tect differences in their high responders because of their decision not to use a noncontingent control group. An examination of the first 10 min *versus* the last 10 of each day's run (Table 1) shows a very consistent trend for diminished responding over the time within a session for both control and experimental groups. Thus Mandler *et al.* (1962), using the first 10 min of each day's run as a basal level, would further favor initially low responders because they showed less decrease (less adaptation) over time than did initially high responders.

Size of both nonspecifics and responses to the light was evaluated. No difference was found

in size of responses to the light. Amplitude of nonspecifics tended to be larger for the experimental group throughout conditioning, but these differences reached statistical significance only on day 5. Further research is needed to assess the reliability of this finding.

Basal levels of skin resistance tended to increase over the 10-day period for all subjects; they increased more for the control than for the experimental subjects.

Only one subject showed any ability to predict the reinforcer at the end of the experiment. None surmised the purpose of the experiment nor had any idea of the relation between GSR deflections and the reinforcer.

Finally, of two pilot subjects, one seemed to cough and drop her cards during extinction. This was also observed in one of the experimental subjects. This raised the question of whether or not such accidental responses represent unconscious (skeletal) attempts to elicit GSR deflections.

In broad outline, these data support the hypothesis that the output of GSR nonspecific deflections can be modified by operant reinforcement techniques. The lack of control over variability of time between reinforcers may have exaggerated experimental-control differences; this was controlled in the later study. It appears that the use of a distracting task and the long duration of the study may have contributed importantly to the validity and reliability of the findings.

The use of a control group is essential to this kind of study; otherwise a decreased tendency to adapt in initially high responders will not be observed.

It appears that operant modification of an autonomic response results in a different form of learning than operant reinforcement of a skeletal response. Control curves seemed to show a negatively accelerated cumulative adaptation curve; while experimental curves were more constant in slope. The nonspecific GSR response did not always show an absolute increase in rate but often appeared to be maintained at some level higher than that of the control group. This may be construed as preventing adaptation. Some heightened reaction to the onset of extinction may be seen; this is also seen in skeletal, operant-reinforcement learning curves.

## STUDY TWO (1964)

### *Subjects*

Eighteen college-age girls, all paid volunteers, were drawn from the student employment bureau. The girls were carefully screened for diseases, especially of the heart and metabolic disorders; no girl under medication of any kind or with allergies was used. All served between menstrual periods. Two control subjects who became dizzy and ill during the experiment were excluded from the data analyses.<sup>3</sup>

<sup>3</sup>Dr. F. Kottke of the University of Minnesota, has suggested that this fainting was a result of the extreme

### *Apparatus*

A standard Wenger GSR apparatus (Sanborn model 350-12/E5838) and the accompanying palmar electrodes (zinc) and zinc sulfate paste were used. Deflections of 400 ohms or greater were counted.

A small photoelectric plethysmograph that clipped onto the finger (Kenelco Corp.) measured finger volume; heart rate was read from the plethysmograph record.

A belt-type pneumatometer recorded respiration. All responses were amplified and read out on a Sanborn multichannel recorder. The room was maintained at a constant temperature and was soundproofed.

### *Procedure*

The most important innovation was that subjects were matched on the basis of their nonspecific GSR rate on the first day of the experiment. These matched pairs were then yoked for schedule of reinforcement. Again, GSR deflections occurring within 15 sec after the reinforcer were not counted.

The superimposed, "distracting" task was made more uniform. The nonsense syllables were spelled aloud once every 5 sec over a tape recorder; subjects were asked to respond as soon as they heard them. This had the added advantage of controlling rate of respiration as well as subvocal ideation. Subjects were instructed to sit as quietly as possible. Moderate restrictions were placed on their diet, sleep, exercise, and smoking during the experiment. All subjects sat quietly for 25 min before the experiment began.

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immobility of the subjects in this experiment. Ordinarily small muscle contractions serve to compress the veins of the lower extremities and force blood to return towards the heart (the muscle pump action). Kottke says: "If a person sits perfectly still without any muscular contraction in the feet or legs, blood eventually accumulates in the capillaries and veins in the dependent extremities. The vessels must be distended before any blood gets back to the heart where it can be pumped into the arterial circulation again. The stasis of blood in the feet and legs leaves too small a blood volume returning to the heart to maintain arterial pressure and, consequently, the subject faints. It requires very little movement to prevent this, but in a situation such as yours (study two) where you advised the subject to be quiet, such stasis can occur." (Personal communication.) It is interesting to note that this suggests that skeletal responses were quite well controlled in the experiment.

Table 1  
Study One. 1961. Adaptation of Nonspecifics within Daily Sessions (First 10 min)  
Second 10 min

Subject	Conditioning Days				
	3	4	5	6	7
A.P.(E)	7.27	2.44	8.27	8.12	4.17
	5.92	2.02	4.20	4.58	3.35
B.B.(E)	4.72	6.58	11.15	7.22	7.30
	No data	5.17	7.93	2.52	4.80
D.B.(E)	3.92	3.72	4.01	3.96	2.90
	1.70	3.02	2.27	1.68	1.07
W.C.(E)	3.80	3.50	1.45	1.93	2.23
	8.75	.59	.91	.37	1.16
V.J.(C)	3.18	1.42	.75	1.00	.81
	.68	.46	1.02	1.25	.54
S.J.(C)	2.32	2.52	3.47	4.82	No
	.60	1.37	1.72	2.65	Data
R.L.(E)	2.00	3.44	3.20	3.44	1.42
	.68	1.72	1.52	3.35	.97
B.A.(C)	.53	1.13	.00	1.39	.17
	.28	.17	.46	.97	.17

Increasing Initial Rates ↑

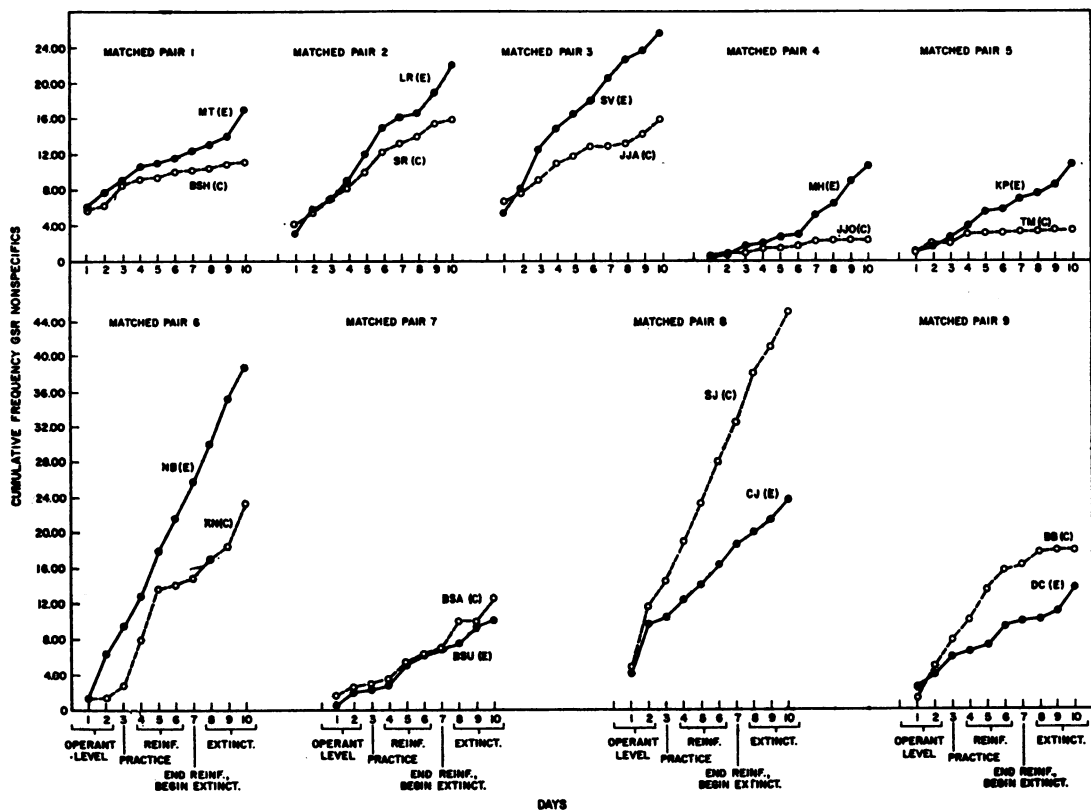


Fig. 2. Study 2: Cumulative GSR nonspecifics for matched-yoked pairs.

Introduction to the reinforcer was limited to 5 min, rather than 10, on day 3 and extinction was begun half way through day 7. Subjects were told that the experiment was a study of day-to-day changes in various autonomic responses. At the end of the experiment they were questioned about their subjective reactions, and the experiment was explained to them.

Results

Cumulative rate curves (see Fig. 2) compare favorably with the *ad hoc* matched pairs of study one (Fig. 1). Six of the nine subjects of the present study clearly showed a cumulative gain over their matched control.<sup>4</sup> The other three subjects did not. It is possible that one pair of subjects was not well matched (CJ and SJ). Table 3 shows that initial heart rate was almost 16 beats per min faster for CJ. For all of the other pairs, initial heart rate difference varied from 0.2 to 8.6. It should be remembered that in this study an arbitrary time limit was imposed on the opportunity to learn; these three subjects might have shown learning if given an extended series of reinforcement trials. It is also true that extinction trials were arbitrarily limited; a longer series of extinction trials may have been more sensitive to learning effects.

As in study one, the cumulative curves for

the experimental subjects roughly approximate a straight line, with an individually determined slope. With the exception of NB, none of the experimental subjects maintained their first (day 1) level of GSR activity. Initially high experimental subjects showed an overall decline in rate but did not decline as much as their matched controls. Initially low subjects showed an overall increase in rate. The conditioning is, clearly, superimposed upon a trend to adapt to the experimental situation. Absolute rates are shown in Fig. 3.

The cumulative GSR curves for the control subjects tend to approximate a negatively accelerated curve. This reflects the general trend for an overall decrease in their absolute rate from beginning to end of the experiment. (Control subjects showed a statistically significant decline in rate of GSR nonspecifics from even their lowest operant level day (day 2) to the last day of conditioning (day 7). Experimental subjects did not.) This in turn probably mirrors their increasing adaptation to the experimental situation, the task, and the reinforcer.

<sup>4</sup>Group differences between experimentals and controls in rate of GSR nonspecifics were significant on the last day of conditioning, and the second day of extinction (day nine). (Wilcoxon Matched Pairs,  $P > .05$  or better.)

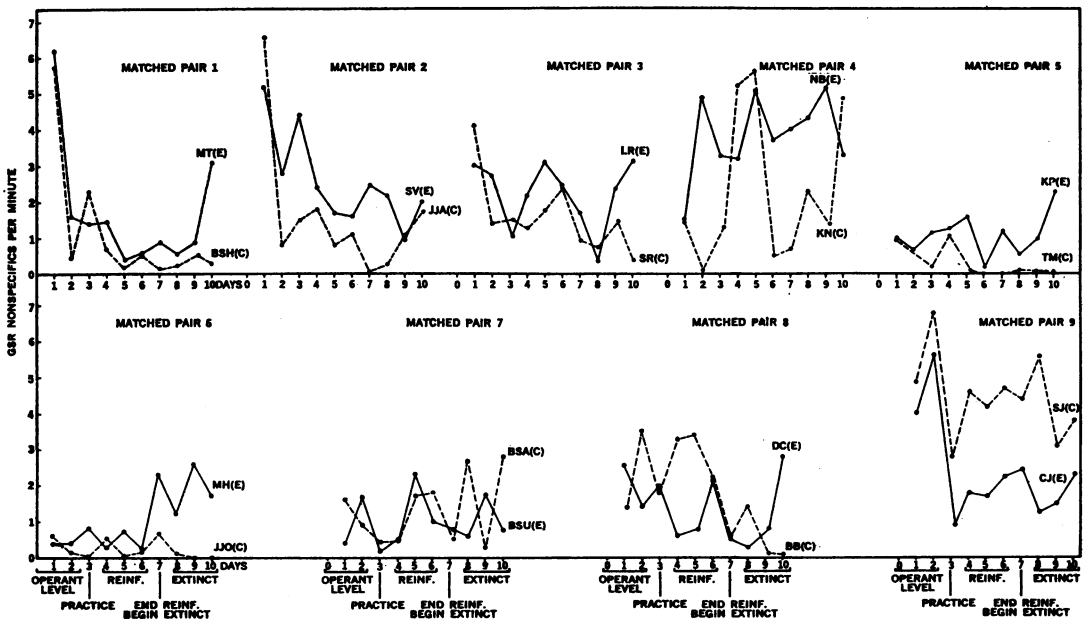


Fig. 3. Study 2: Absolute rates of GSR nonspecifics.

The absolute level of responding tended to be slightly lower in this study than in study one for both experimental and control subjects, perhaps because the distracting task was a more monotonous one or because larger (more discriminable) nonspecific GSRs were reinforced in study one. It is interesting to note that one experimental subject and one control subject showed an almost constant rate of responding throughout the experiment.

The overall course of the autonomic learning may be most easily seen in a graph of experimental-control differences, which shows the relative gain of each experimental subject over her expected adaptation curve *i.e.*, the curve of her matched and yoked control (Fig. 4).

Figure 4 shows medians and ranges of experimental-control differences, over the 10 days (the mismatched pair, CJ-SJ, are excluded). There is an overall increase in the whole distribution of eight scores; this increase is most marked on day 6 and the gain is maintained through day 7. On day 8, the first full day of extinction, significant experimental-control differences did not occur: the absolute rate increased in six of the eight control subjects and decreased for seven of the eight experimentals. On day 9, significant experimental-control differences again occurred. The large range of day 10 scores suggests that extinction had begun to have its effect (extinction began on the last half of day 7).

Note that both the medians and the range of scores show that there were no important

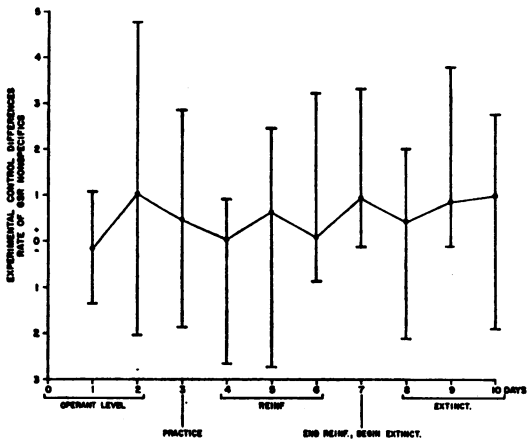


Fig. 4. Study 2: Experimental-control differences in GSR nonspecifics.

experimental-control differences before learning. Indeed, the results of the first days of learning (day 3 to day 4) suggest that controls were favored over experimentals.

GSR deflections elicited by the reinforcer declined over the four-and-one-half days of conditioning for both experimental and control subjects. The two groups did not differ significantly in the rate of these reinforcer-elicited respondents and the curves resemble those found in study one.

Basal resistance, estimated from the 10th and 11th min of each subject's daily session, increased over the 10 days for each group. As in study one, resistance readings for control subjects tended to reach a higher level from beginning to end of the experiment, than those for experimental subjects.

Because so few studies of this type have been done, tables presenting absolute scores for all subjects are given. GSR nonspecifics, heart rate, and plethysmograph data are shown in Tables 2, 3, and 4, respectively.

Group rather than individual curves of heart rate are presented because heart rate was only a concomitant measure and because

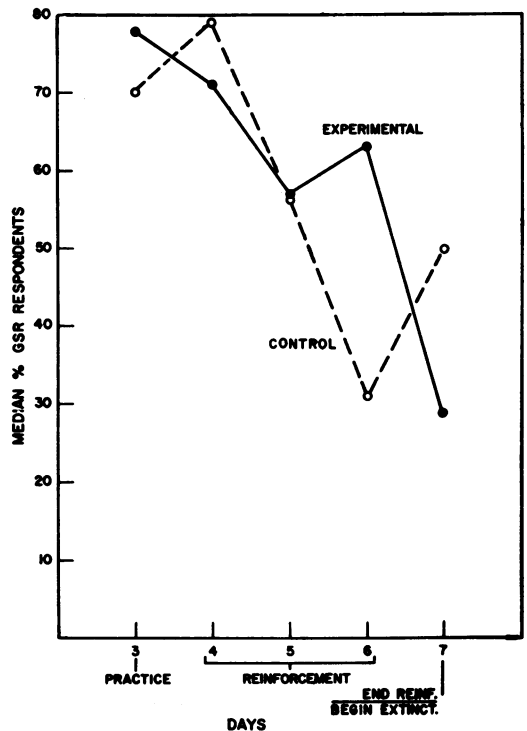


Fig. 5. Study 2: Percent reinforcer-elicited GSR respondents.



Table 2  
Study Two. 1964. Individual Scores by Days: GSR Nonspecifics

Matched Pairs	Day 1		Day 2		Day 3		Day 4		Day 5	
	E	C	E	C	E	C	E	C	E	C
MT-BS	6.19	5.76	1.58	0.44	1.39	2.28	1.45	0.73	0.44	0.18
SV-JJA	5.21	6.56	2.76	0.83	4.40	1.52	2.38	1.87	1.67	0.93
CJ-SJ	4.02	4.85	5.64	6.86	0.89	2.77	1.77	4.61	1.70	4.18
LR-SR	3.03	4.07	2.74	1.40	1.05	1.49	2.16	1.24	3.09	1.74
DC-BB	2.56	1.42	1.40	3.51	1.98	1.92	0.60	3.26	0.67	3.39
NB-KN	1.48	1.41	4.89	0.10	3.28	1.27	3.23	5.24	5.10	5.65
KP-TM	0.99	0.96	0.66	??	1.15	0.17	1.25	1.03	1.60	0.11
MH-JJO	0.37	0.61	0.38	0.15	0.93	0.06	0.27	0.53	0.74	0.06
BSU-BSA	0.41	1.64	1.67	0.93	0.18	0.46	0.47	0.46	2.36	1.76
Means	2.77	3.05	2.41	1.78	1.70	1.33	1.51	2.11	1.93	2.00
Medians	2.56	1.64	1.67	0.88	1.15	1.49	1.45	1.24	1.65	1.74

Matched Pairs	Day 6		Day 7		Day 8		Day 9		Day 10	
	E	C	E	C	E	C	E	C	E	C
MT-BS	0.57	0.54	0.89	0.16	0.63	0.26	0.88	0.57	3.09	0.31
SV-JJA	1.59	1.11	2.45	0.00	2.17	0.25	0.94	1.04	2.01	1.70
CJ-SJ	2.26	4.71	2.45	4.42	1.23	5.62	1.51	3.11	2.32	3.83
LR-SR	2.45	2.34	1.69	0.94	0.36	0.76	2.39	1.49	3.15	0.43
DC-BB	2.14	2.26	0.51	0.61	0.26	1.41	0.92	0.10	2.79	0.05
NB-KN	3.72	0.48	4.05	0.70	4.34	2.33	5.17	1.36	3.31	4.87
KP-TM	0.21	0.00	1.21	0.05	0.56	0.10	1.00	0.10	2.29	0.05
MH-JJO	0.22	0.16	2.28	0.64	1.23	0.11	2.61	0.00	1.72	0.00
BSU-BSA	1.06	1.94	0.78	0.56	0.58	2.69	1.76	0.30	0.90	2.80
Means	1.58	1.40	1.81	0.90	1.26	1.50	1.91	0.90	2.40	1.56
Medians	1.59	1.04	1.69	0.56	0.63	0.76	1.51	0.57	2.32	0.43

Table 3  
Study Two. 1964. Individual Scores by Days: Heart Rate

Matched Pairs	Day 1		Day 2		Day 3		Day 4		Day 5	
	E	C	E	C	E	C	E	C	E	C
MT-BS	104.7	98.7	101.2	90.9	100.3	93.2	102.4	89.7	101.6	92.2
MH-JJO	89.8	82.6	105.0	73.7	91.4	63.3	95.7	67.5	90.8	62.2
LR-SR	85.1	89.1	74.4	65.5	74.0	82.4	73.0	80.5	74.8	67.7
DC-BB	83.5	88.5	76.8	89.8	76.0	82.4	71.4	86.4	74.3	80.3
SV-JJA	83.0	87.6	77.9	79.6	79.6	82.6	82.9	77.1	82.3	86.4
KP-TM	74.8	74.6	66.7	75.7	65.4	84.5	74.7	71.4	75.9	85.1
BSU-BSA	67.5	76.1	69.0	80.4	70.9	76.2	77.8	74.2	73.0	79.5
NB-KN	67.4	73.6	68.8	67.0	68.5	59.5	65.7	63.9	78.8	66.3
CJ-SJ	61.8	78.5	61.5	79.6	69.0	77.5	69.1	73.2	75.7	82.6
Means	80.6	84.9	80.3	77.8	76.8	78.8	78.9	75.6	81.3	76.2
Medians	12.8	7.9	13.3	9.1	11.5	11.3	12.2	8.4	10.4	10.4

Matched Pairs	Day 6		Day 7		Day 8		Day 9		Day 10	
	E	C	E	C	E	C	E	C	E	C
MT-BS	95.9	83.0	101.7	95.3	99.7	92.0	97.7	97.5	104.7	97.8
MH-JJO	84.2	65.6	99.4	70.0	96.3	70.3	98.9	73.0	94.5	71.0
LR-SR	67.7	65.9	70.9	65.6	73.9	65.5	75.2	73.6	83.8	76.6
DC-BB	85.2	86.4	68.8	82.5	72.5	91.2	73.3	89.2	74.0	86.7
SV-JJA	79.9	75.6	80.2	87.8	78.5	86.8	80.7	78.8	79.0	81.5
KP-TM	75.7	79.2	73.8	76.0	75.7	72.5	72.0	76.0	86.9	88.6
BSU-BSA	67.5	76.1	69.0	80.4	70.9	76.2	77.8	74.2	73.0	79.5
NB-KN	66.5	68.2	70.3	63.9	61.6	63.8	61.3	67.1	63.7	68.1
CJ-SJ	61.8	78.5	61.5	79.6	79.0	77.5	69.1	73.2	75.7	82.6
Means	76.0	75.4	77.3	77.9	77.6	77.3	78.4	78.1	81.7	81.2
Medians	11.5	6.8	13.8	10.4	12.6	10.3	12.5	9.1	9.0	9.7

Table 4  
Study Two, 1964. Individual Scores by Days: Plethysmograph Amplitudes

Matched Pairs	Day 1		Day 2		Day 3		Day 4		Day 5	
	E	C	E	C	E	C	E	C	E	C
MT-BS	11.3	7.2	13.5	6.8	14.0	5.8	14.2	9.9	12.5	8.5
CJ-SJ	7.0	5.0	14.5	2.9	8.4	9.9	17.0	6.7	8.2	6.9
DC-BB	8.3	11.4	7.7	7.7	12.2	13.9	9.4	17.0	11.5	18.9
BSU-BSA	9.9	7.8	10.1	7.2	4.7	7.7	6.3	6.6	8.3	8.0
NB-KN	11.7	7.2	20.3	5.1	19.8	6.7	8.0	12.8	20.4	12.1
LR-SR	16.9	5.7	14.5	13.2	17.7	13.4	28.1	12.0	7.6	13.0
KP-TM	5.8	6.2	6.0	6.2	5.3	17.0	9.9	10.9	8.9	14.3
MH-JJO	12.1	11.2	10.9	8.6	15.1	13.1	12.8	16.2	15.2	15.7
SV-JJA	16.3	14.0	17.3	10.9	14.6	15.2	18.2	14.8	18.2	18.6
Means	12.1	8.4	12.8	7.6	12.4	11.4	13.9	11.5	12.3	12.9
Medians	11.3	7.4	13.5	7.2	14.0	13.1	14.2	12.0	11.5	14.3

Matched Pairs	Day 6		Day 7		Day 8		Day 9		Day 10	
	E	C	E	C	E	C	E	C	E	C
MT-BS	15.4	8.2	15.1	9.0	9.2	11.1	17.1	13.6	5.2	12.4
CJ-SJ	11.6	4.6	10.5	3.1	8.8	8.1	13.8	8.6	8.2	15.8
DC-BB	21.7	7.4	11.6	5.7	11.5	9.0	14.3	9.3	15.1	
BSU-BSA	14.6	10.6	4.8	6.4	3.6	9.3	7.0	9.6	6.1	8.8
NB-KN	16.1	3.4	18.0	7.3	14.4	10.7	18.5	15.7	21.0	13.4
LR-SR	16.3	14.4	30.0	15.8	16.6	11.4	24.1	12.0	21.2	16.3
KP-TM	5.1	12.4	8.7	9.5	9.6	7.4	10.3	10.3	8.2	
MH-JJO	17.5	8.7	9.3	12.2	11.8	13.6	12.0	10.5	9.0	
SV-JJA	9.6	12.1	15.3	11.8	15.2	14.6	13.3			
Means	14.2	9.1	13.7	9.1	11.2	10.6	14.5	10.5	11.5	11.2
Medians	15.4	8.7	11.6	9.0	11.8	10.7	13.8	10.5	8.5	14.6

experimental and control subjects were not specifically matched for day 1 levels on this variable. The nine control subjects had an initially higher heart rate than their matched experimental subjects (a mean rate of 84.9 *versus* 80.6). Nevertheless, by the end of the experiment the experimental group had reached approximately the same level as the control group (81.7 and 81.6). As in the case of the GSR nonspecifics, the control subjects showed significant adaptation in heart rate over the 10 days; experimental subjects did not.

A scattergram of group means across the 10 days (Fig. 7) suggests that there was a low to moderate intra-individual correlation between heart rate and rate of nonspecific GSRs. This would seem to support the work of Lazarus, Speisman, and Mordkoff (1963) which stressed the importance of this kind of correlational approach to autonomic responses. The N of this study was too small to permit a precise correlation estimate.

Concomitant changes in plethysmograph amplitude are shown in Fig. 8. The control group had a substantially lower initial ampli-

tude, which probably reflects the initial difference in heart rate between the two samples. There may have been a general trend in the control group for a relative increase in amplitude from day 1 to day 10 (increasing vasodilatation), whereas the experimental group tended to remain at about the same overall level, or to decrease slightly. This, again, may reflect progressive adaptation or relaxation in the control group.

The two groups maintained approximately the same respiration rate throughout the experiment. This reflects the controlling effect of the task.

Respiration records were evaluated for gross irregularities and, although the experimental group tended to have slightly more irregularities, the differences were not significant. No analysis of reflex-elicited changes in heart rate or respiration-elicited nonspecific GSRs was made.

None of the subjects reported any knowledge of the purpose of the experiment or believed that they could predict or control the occurrence of the reinforcer.

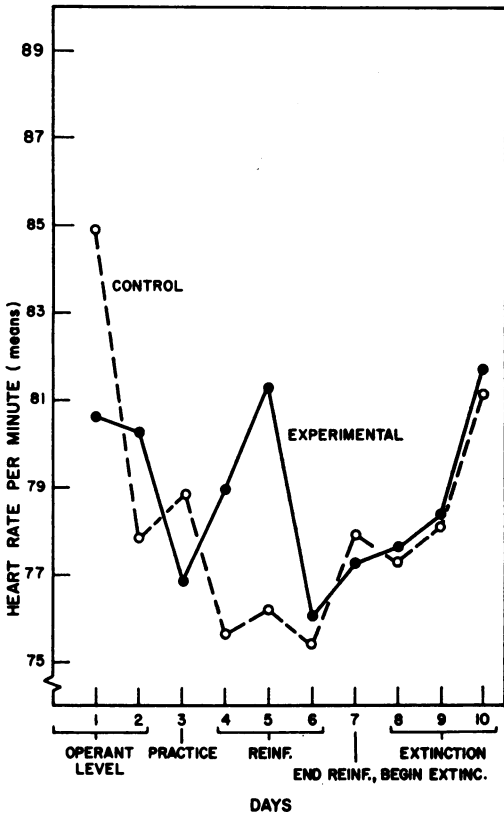


Fig. 6. Study 2: Day-to-day changes in heart rate.

DISCUSSION

These studies support the hypothesis that autonomic responses not correlated with an observable, external stimulus can be modified by operant reinforcement techniques. It sug-

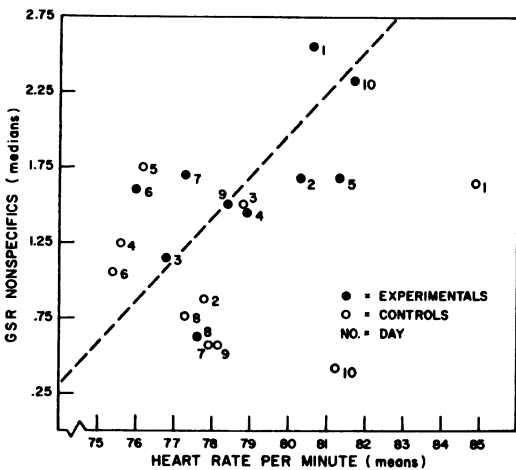


Fig. 7. Study 2: Scattergram of heart rate and GSR nonspecifics over days.

gests that there is overlap between autonomic and skeletal responses, and that they are not as different in kind as generally believed. Correlation with an eliciting stimulus may be a more useful distinction for both theorizing and for research purposes than categorizing responses as autonomic or skeletal.

Reliable differences between experimental and matched control subjects in rate of non-specific GSR deflections were observed in both studies. It is noteworthy that when the experiment was better controlled and better designed, the difference became more predictable; that is, it would be expected that the last day of conditioning and the extinction trials would be most sensitive to differences if a cumulative learning process had in fact taken place. This was precisely where the differences were found in study two.

The modification of autonomic responses may be described as the prevention of adaptation. Overall increases in absolute frequency

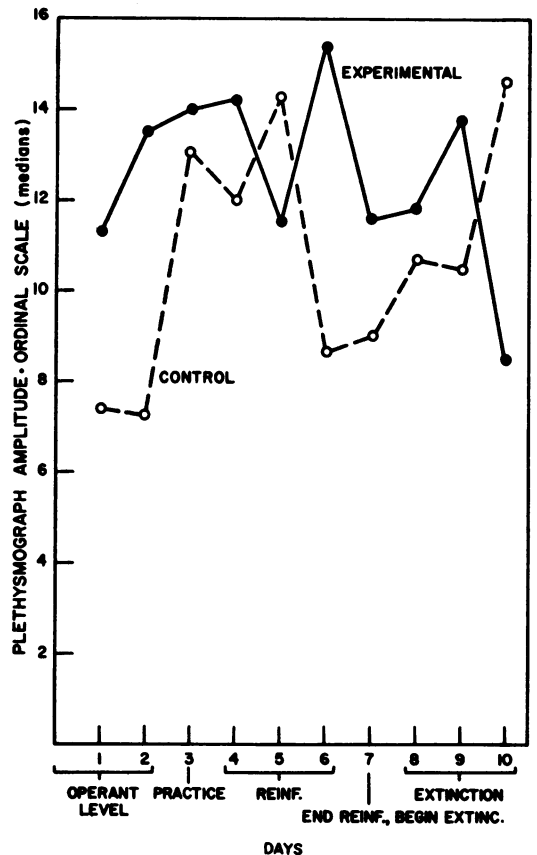


Fig. 8. Study 2: Day-to-day changes in amplitude of plethysmograph readings.

of responses of the kind usually seen in skeletal learning curves are not found. Instead, the experimental group appears to maintain a level of responding higher than that of a matched control group. The control group, under the conditions of these experiments, shows decreasing reactivity from beginning to end.

The heart rate and plethysmograph findings tend to complement the general findings of increasing basal resistance and decreasing number of nonspecifics in the control group. These all seem to describe a progressive state of adaptation or relaxation in that group.

It is important to note that these studies were all conducted under conditions of very mild reinforcement and motivating instructions, and that the subjects were not aware of the relation between their responses and the appearance of the reinforcer. Learning would be expected to be even greater under more highly motivating conditions.

In these studies, an artificial time limit was imposed on learning. It is possible that the conditioning may have occurred in all subjects if the experiment were indefinitely extended. Even classical conditioning does not always succeed with all animals when the number of trials is arbitrarily limited.

This research raises, but does not answer the question of whether all individuals may be conditioned under ideal conditions. It will probably be impossible to demonstrate conditioning in individuals with initially high rates who show no adaptation to the experimental situation.

In addition, the response was unquestionably difficult to discriminate and the design of the experiment forced a fixed-interval schedule of reinforcement. Furthermore, the decision not to reinforce responses within 15 sec of the reinforcer established an upper limit of about four reinforceable responses per minute.

In future experiments, it may be possible to generate hypothetical adaptation curves from data on individual subjects, and thereby eliminate the need for matched and yoked controls.

This series of studies brings closer a reliable and predictable technique for studying changes in autonomic reactivity over long time-spans. It has also lent support to the idea that some autonomic responses can be modified by operant reinforcement techniques, and that

the form of this modification is different in some ways from traditional skeletal-response learning.<sup>5</sup>

Along with contemporary studies of arousal and habituation, this kind of study demonstrates that it is no longer necessary to view autonomic responses within the rigid framework of classical, Pavlovian conditioning. Autonomic responses exhibit reliable and predictable variability over time, within individuals. As such, they may be studied as an important variable in traditional operant learning studies; as response systems with important individual characteristics and individual differences; and, finally, as response systems in their own right, subject to at least some forms of non-Pavlovian modification.

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<sup>5</sup>Since this study was first submitted for publication, two studies have been published which support these findings. Miller, Trowill, DiCara, Carmona, and Banuazizi (1966), have reported success in operant conditioning of heart rate and vasodilatation in rats under curare. Crider, Shapiro, and Tursky (1966) have reported success in reinforcement of spontaneous GSRs over a short learning span when the same subjects are compared for contingent and non-contingent reinforcement.

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