

AD 663160

Cross-Modal Generalization in Human Skeletal
And Autonomic Classical Conditioning

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Technical Report No. 22
Contract Nonr 908-15
December 1967
Roger W. Russell, Project Director

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Acknowledgements

The data reported in this paper were gathered from two experiments run concurrently in different laboratories at Indiana University in order to test essentially similar ideas about cross-modal generalization. I appreciated the opportunity to discuss these ideas and how they should be tested with Dr. Isidore Gormezano. Moreover, without his generous cooperation, the eyelid data gathered for Experiment I could not have been obtained. I gratefully acknowledge, therefore, not only his spending time to teach me how to run an eyelid conditioning experiment, but also for financial support, through his NSF Grant GB-2843, for both equipment and for the paying of subjects. In the actual modifications of the equipment in the eyelid laboratory, I was aided by Denny Fernald, who also stepped in most generously with Tom Lawson when I needed help in the running of subjects.

In gathering the data for the autonomic conditioning study described in Experiment II, I made full use of the help of members of the O.N.R. project. In particular, I am grateful to: Eric Helmer for designing, constructing, and educating me about the necessary equipment; Eric Helmer and Norman Worrall for discussing and educating me about problems concerning the characteristics and measurement of the plethysmograph, heart-rate, and respiration, indices with which I was completely unfamiliar before my arrival to Indiana; Sam Boyd for assistance in running subjects.

For the reading of records obtained from Experiment II, and for the reduction of the data of both experiments for computer analysis, I am most grateful to the following members of the O.N.R. project: Nancy Garrett, John Stevens, Sam Boyd, Steve Mackey, and Jim Terhune.

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Abstract

The extent of cross-modal generalization (CMG) was examined under identical and non-identical reinforcement schedules for tone and light as the two CSs. In Exp. I, the skeletal eyelid response of 128 Ss was conditioned with a 500-msec. CS-UCS interval, where an infra-orbital shock served as UCS. Exp. II employed a 1-sec. CS-UCS interval for 128 Ss with a forearm shock as UCS, and GSR, digital volume pulse change (VPC), heart rate, and respiration as the autonomic responses. Both experiments included groups of 64 Ss run as controls for conditioning, and this was reliably obtained in Exp. I. In addition, CMG in the eyelid CR was a reliable function of the reinforcement-schedule manipulation, as well as of within- and between-Ss manipulations of UCS intensity. In Exp. II, only the GSR and the VPC responses indicated reliable conditioning, but even with these responses the other factors shown to be effective in Exp. I did not produce reliable differences.

Among the many explanations of primary stimulus generalization is the "failure-to-discriminate" interpretation, which asserts that the stimuli must be confused by the organism for there to be any generalization between them. Kimble (1961, p. 353) has noted that experiments exhibiting any appreciable amount of cross-modal generalization (CMG) weaken this hypothesis, since it is unlikely that confusion would occur across modalities. Razran (1949) has described Russian experiments in which conditioned responses (CRs) generalized across modalities by as much as 38%, while American investigators have reported cases of CMGs as high as 60% (Marlatt, Lilie, Selvidge, Sipes, & Gormezano, 1966). The confusion hypothesis was even more conclusively refuted, however, by a case of total or 100% CMG, a situation where, at least for the conditioned GSR, it was as if the two modally different conditioned stimuli (CSs) of tone and light were the same (Furedy, 1965, p. 206). More recently it has been

suggested that this lack of CR differentiation between two clearly discriminable CSs was due to the fact that the training or reinforcement schedules for the CSs were identical, both stimuli being paired with the unconditioned stimulus (UCS) at the same rate (Furedy, 1966). The same report outlined methods for testing whether generalization was total (no differentiation) or partial between any two CSs. The purpose of the two experiments to be reported was to apply these methods to study the extent of CMG or, its converse, CMD (cross-modal differentiation), as a function of whether or not the reinforcement schedules were the same for the CSs, and whether or not the UCSs paired with the CSs differed in intensity.

In Exp. I a skeletal response, the eyelid, was the dependent variable. This response was used for two reasons: (a) its conditionability is relatively well established; (b) its short latency allows measurement of conditioning on training (CS-UCS) trials even with interstimulus intervals (ISIs) as short as 500 msec., a feature which in turn permits the use of the extinction generalization test (Furedy, 1966, p. 6). In addition, it was thought that differentiation in such a skeletal system may be superior to that in the autonomic responses used in Exp. II, where the following indices were examined: (a) galvanic skin response (GSR), (b) the plethysmographic digital blood volume pulse change, (c) heart-rate, and (d) respiration.*

Information additional to that concerning the extent of CMG or CMD was sought from both experiments. First, there was the question of whether the response system involved demonstrated reliable conditioning, a question which was rhetorical only in the case of the eyelid response. Secondly, there were

*Respiration is not a "pure" autonomic response in that striate muscle systems are clearly involved. However, for the present purposes, this response will be treated as autonomic to distinguish it from the clearly skeletal eyelid response.

other questions concerning such aspects of conditioning as the effects of within- and between-Ss variations of UCS intensity.

Experiment I: Skeletal CMD

The most commonly used UCS for eyelid conditioning has been the corneal puff. However, the fact that the conditioned response (CR) can modify the noxious effect of the air-puff UCS introduces the problem of "voluntary" responders (Gormezano, 1965). On the other hand, the noxious effects of an infra-orbital shock UCS is less likely to be modifiable by the CR, and such a UCS has recently been used to demonstrate relatively unequivocal eyelid conditioning (Fernald, Gormezano, and Smith, 1966). In the present experiment, therefore, the infraorbital shock technique, as developed by Gormezano and his associates, was employed to condition the skeletal eyelid response.

Method.

Experimental design.--Stimulus orders were developed for the purpose of measuring the extent of CMD by the use of two tests: training differentiation (TD) and extinction differentiation (ED). Except for the label change from "generalization" to "differentiation", both the two tests and their rationales have been described in detail in the previous report (Furedy, 1966). The TD test, briefly, compares conditioning performance to two sets of extinction or non-reinforced (N) trials: N(S,d) and N(s,D). Any trial in the N(S,d) set has been preceded by more training or reinforced (R) trials with the same (s) CS as that being tested than R trials with the different (d) CS. For any trial in the N(s,D) set, on the other hand, the s value for previous R trials is exceeded by the d value for previous R trials. Provided that the two sets of N trials are equal in all other respects (such as the mean sum of the s and d values for previous R trials), the outcomes of $N(S,d) = N(s,D)$ and $N(S,d) > N(s,D)$ indicate,

respectively, the absence and presence of training differentiation between the two CSs. Similarly, the ED test compares conditioning performance on two sets of R trials: (s,D)R and (S,d)R. For any trial in the (s,D)R set, the s value for previous extinction or non-reinforced (N) trials is exceeded by the d value for previous N trials, while this s : d relationship is reversed for all R trials in the (S,d)R set. Then, provided that the two sets of R trials are equal in all other respects (such as the mean sum of the s and d values for previous N trials), the absence and presence of extinction differentiation is indicated, respectively, by outcomes of (s,D)R = (S,d)R and (s,D)R > (S,d)R.

Table 1 shows the four basic 41-trial orders in which the two CSs (x-type and y-type) are paired under partial (67%) reinforcement schedules. The schedules are identical for the two CSs throughout training, with the maximal variation (MV) at any point between s and d values being unity (MV1). For the TD test, the orders provide an N test trial for all unequal pairs of s and d values for previously presented R trials; for the ED test, the s and d values for previously presented N trials are given only for those R trials which were used in the test. Within the limits set by having to provide the conditions for the differentiation tests, the stimulus orders are relatively unsystematic with respect both to R-N (training vs test trials) and to x-y (type of CS) sequences along the 41-trial series. The most regular R-N pattern occurs early in the series: in Orders 1 and 2, trials 2-13, there is an NRR pattern repeated four times. The most regular x-y pattern is a simple triplet (xxx) occurring in Order 4, trials 14-16.

Table 2 shows the four basic orders for the non-identical reinforcement schedules, where the maximal variation (MV) between s and d values for previously presented R trials is five (MV5). It will be noted that the N trials, which are required for the test of TD, appear in the same position in the MV5 orders

Table 1. Basic four orders for identical reinforcement schedules (MVI orders)

Trials	Orders			
	1	2	3	4
1	Rx	Ry	Rx	Ry
2	Nx(1,0)	Nx(0,1)	Ny(0,1)	Ny(1,0)
3	(0,1)Ry	(1,0)Rx	(1,0)Ry	(0,1)Rx
4	(1,0)Rx	(0,1)Ry	(0,1)Rx	(1,0)Ry
5	Ny(1,2)	Ny(2,1)	Nx(2,1)	Nx(1,2)
6	Ry	Rx	Ry	Rx
7	Rx	Ry	Rx	Ry
8	Nx(3,2)	Nx(2,3)	Ny(2,3)	Ny(3,2)
9	(1,2)Ry	(2,1)Rx	(2,1)Ry	(1,2)Rx
10	(2,1)Rx	(1,2)Ry	(1,2)Rx	(2,1)Ry
11	Ny(3,4)	Ny(4,3)	Nx(4,3)	Nx(3,4)
12	Ry	Rx	Ry	Rx
13	Rx	Ry	Rx	Ry
14	Ny(4,5)	Ny(5,4)	Ry	Rx
15	Nx(5,4)	Nx(4,5)	Ry	Rx
16	Ry	Rx	Nx(5,6)	Nx(6,5)
17	Ry	Ry	Ny(6,5)	Ny(5,6)
18	Rx	Rx	Rx	Ry
19	Ry	Rx	Ry	Rx
20	Ny(7,6)	Ny(6,7)	Nx(6,7)	Nx(7,6)
21	(3,4)Rx	(4,3)Ry	(4,3)Rx	(3,4)Ry
22	(4,3)Ry	(3,4)Rx	(3,4)Ry	(4,3)Rx
23	Nx(7,8)	Nx(8,7)	Ny(8,7)	Ny(7,8)
24	Rx	Ry	Rx	Ry
25	Ry	Rx	Ry	Rx
26	Rx	Ry	Ny(9,8)	Ny(8,9)
27	Rx	Ry	Nx(8,9)	Nx(9,8)
28	Nx(10,9)	Nx(9,10)	Rx	Ry
29	Ny(9,10)	Ny(10,9)	Ry	Ry
30	Ry	Rx	Rx	Rx
31	Rx	Rx	Ry	Ry
32	Ny(10,11)	Nx(11,10)	Ny(11,10)	Nx(10,11)
33	(6,5)Ry	(5,6)Ry	(5,6)Rx	(6,5)Rx
34	(5,6)Rx	(6,5)Rx	(6,5)Ry	(5,6)Ry
35	Nx(12,11)	Ny(11,12)	Nx(11,12)	Ny(12,11)
36	Ry	Ry	Rx	Rx
37	Rx	Rx	Ry	Ry
38	Ny(12,13)	Rx(13,12)	Ny(13,12)	Nx(12,13)
39	Ry	Ry	Rx	Rx
40	Rx	Rx	Ry	Ry
41	Nx(14,13)	Ry(13,14)	Nx(13,14)	Ny(14,13)

Note that: N(s,d) denotes a non-reinforced trial preceded by s reinforced trials with the same CS as that being presented and by d reinforced trials with the different CS from that being presented; (s,d)R denotes a reinforced trial preceded by s non-reinforced trials with the same CS as that being presented and by d non-reinforced trials with the different CS from that being presented; for both non-reinforced (N) and reinforced (R) trials, the x-y variable specifies the nature of the CS on the trial being presented.

Table 2. Basic four orders for non-identical reinforcement schedules (MV5 orders)

Trials	Orders			
	1	2	3	4
1	Rx	Ry	Rx	Ry
2	Nx(1,0)	Nx(0,1)	Ny(0,1)	Ny(1,0)
3	Rx	Ry	Rx	Ry
4	Rx	Ry	Rx	Ry
5	Ny(0,3)	Ny(3,0)	Nx(3,0)	Nx(0,3)
6	Rx	Ry	Rx	Ry
7	Rx	Ry	Rx	Ry
8	Nx(5,0)	Nx(0,5)	Ny(0,5)	Ny(5,0)
9	Ry	Rx	Ry	Rx
10	Rx	Ry	Rx	Ry
11	Ny(1,6)	Ny(6,1)	Nx(6,1)	Nx(1,6)
12	Ry	Rx	Ry	Rx
13	Ry	Rx	Ry	Rx
14	Ny(3,6)	Ny(6,3)	Ry	Rx
15	Nx(6,3)	Nx(3,6)	Ry	Rx
16	Ry	Rx	Nx(6,5)	Nx(5,6)
17	Ry	Rx	Ry(5,6)	Ry(6,5)
18	Ry	Rx	Ry	Rx
19	Ry	Rx	Ry	Rx
20	Ny(7,6)	Ny(6,7)	Nx(6,7)	Nx(7,6)
21	Rx	Ry	Ry	Ry
22	Ry	Rx	Ry	Ry
23	Nx(7,8)	Nx(8,7)	Ny(9,6)	Ny(6,9)
24	Ry	Rx	Ry	Rx
25	Ry	Rx	Ry	Rx
26	Ry	Rx	Ny(11,6)	Ny(6,11)
27	Ry	Rx	Nx(6,11)	Nx(11,6)
28	Nx(7,12)	Nx(12,7)	Rx	Ry
29	Ny(12,7)	Ny(7,12)	Rx	Ry
30	Rx	Ry	Rx	Ry
31	Rx	Ry	Rx	Ry
32	Nx(9,12)	Nx(12,9)	Ny(11,10)	Ny(10,11)
33	Rx	Ry	Rx	Rx
34	Rx	Ry	Ry	Ry
35	Ny(12,11)	Ny(11,12)	Nx(11,12)	Nx(12,11)
36	Ry	Rx	Rx	Ry
37	Rx	Ry	Rx	Ry
38	Nx(12,13)	Nx(13,12)	Ny(12,13)	Ny(13,12)
39	Rx	Ry	Rx	Ry
40	Rx	Ry	Rx	Ry
41	Ny(13,14)	Ny(14,13)	Nx(15,12)	Nx(12,15)

Note: See note for Table 1.

as in the MV1 orders, which allows comparisons of TD as a function of the degree of identity of reinforcement schedules. On the other hand, ED was not assessed with the MV5 orders, since there are very few suitable R trials available for such a test, there being too many places where the same CS is repeatedly presented on successive R trials.

The Ss for whom the CS and UCS were paired (experimental group) were run under one of 128 different conditions which were generated as follows. Introducing the reinforcement-schedule (MV) factor (MV1-MV5) doubled the original 4 stimulus orders or conditions. The 8 conditions were again doubled by the factor of UCS variation (UV): whether the UCS paired with the two CSs for a given S was constant (CON) or varied (VAR) in intensity. The 16 conditions were further doubled by the UCS intensity (UI) factor. For CSs paired with the constant intensity UCS (CON), the UI factor was varied between Ss in terms of whether both the x- and y-type CSs were paired with the weak (WEA) or the strong (STR) UCS; for CSs paired with UCSs of varied intensities (VAR), UI was varied within Ss in terms of whether the x- and y-type CSs were paired, respectively, with the STR and WEA, or WEA and STR, UCSs. The 32 conditions resulting from the variation of the UI factor were further doubled through varying the factor of the nature of the CS (NC): whether the CS was a tone (T) or a light (L). For half the conditions, x and y were specified as T and L, respectively; while the converse specification held for the remaining conditions. Finally, the 64 conditions were doubled by introducing sex as a factor. The experimental group (paired CS and UCS), consisted of one replication of each of the 128 conditions. The control group, for whom the CS and UCS was unpaired, consisted of one replication for each of the 64 conditions derived from all factors except that of sex; the sex factor was randomly assigned over the 64 conditions with the restriction that half of the control Ss be male. The unpairing of CS and UCS for

control Ss was achieved by separating the CS and UCS elements of the R trials of Tables 1 and 2 above, the randomising the order of CS and UCS for these separations with the restriction that no sequences of more than 3 adjacent CS trials were allowed. Thus the control group received 68 trials as compared to the 41 trials received by the experimental group, but both groups were presented with the CS on 41 trials.

Apparatus.--Separate from E and the main apparatus, S sat on a hard-backed chair with chin rests (approximately 100 Ss) or, later, in a dentist chair which allowed positioning of the head without a chin rest (the remaining Ss). The S's room, well-illuminated and sound-treated, contained a 4' x 4' white board with a 10-cm. milk glass disc at its center, which was approximately 4 ft. in front of S. An abrupt change in hue (to reddish-orange) and an increase of illumination (from .19 to .26 m_L.) of the disc served as the light CS. The tone CS was a 1000-cps, 70-db SPL tone presented over a continuous 50 db white noise through Grason-Stadler D30 headphones which also permitted E to communicate with S. The duration of both CSs was set on a Hunter timer at 500 msec. The UCS was a 120-v. (weak) or 260-v. (strong) dc shock of approximately 1-msec. duration delivered simultaneously with CS offset by the discharge of a .01-MFD capacitor. Silver electrodes, 9 mm. dia., were impeded in a 22 mm. Plexiglass disc filled with Offner electrode paste, and were placed 2 cm. below the temporal end of the right lower eyelid (negative electrode) and at the right external canthus (indifferent electrode). The pickup and recording apparatus was identical to that described by Moore and Gormesano (1961). A Western Union tape transmitter controlled the intertrial intervals and partly determined the nature of the stimuli on each trial. The latter aspect was further determined by 16 tapes which, in conjunction with a system of switches, delivered the 128 types of stimulus orders.

Subjects.--For the experiment proper, the Ss were 96 men and 96 women from introductory psychology classes at Indiana University who were free to choose between receiving \$1.50 or satisfying a course requirement. In addition, there were 40 male Ss from the same source who were used in the two pilot studies to be described below.

Procedure.--In connection with the tests of training generalization, an inspection of the orders in Tables 1 and 2 indicates that the first place at which the variation between s and d values differs most between the identical (MV1) and the non-identical (IV5) reinforcement schedules is at trials 8 and 11. However, it was noted previously that a desirable condition for using the N(S,d) : N(s,D) test TD is that performance be an increasing function of previous number of R (training) trials (Furedy, 1966, p. 8). This condition, moreover, may fail to hold not only through performance becoming asymptotic, but also through it not having started to improve for some Ss. Because the eyelid can be relatively slow to condition (Prokasy, 1965, p. 215), a pilot study was run with 20 Ss to estimate what percentage of Ss would be likely to be giving at least some CRs by the stage of the series bounded by trials 8 and 11. The study was also used to gain some idea of the sensitivity of the TD test to a situation where some differentiation (only partial generalization) was expected. Hence, only the non-identical (MV5) reinforcement schedule series was employed with both CSs paired at a 500-msec. interstimulus interval with the strong UCS. The response measures were frequency and magnitude, as described more precisely at the beginning of the Results section below. Examination of CR magnitudes on trials 8 and 11 indicated only an insignificant tendency for performance on N(S,d) trials (in this case, N(5,0) and N(6,1)) to be superior to performance on N(s,D) trials (in this case, N(0,5) and N(1,6)). However, since 65% and 70% of the Ss did not respond at all on trials 8 and 11, respectively, it was

clear that the desirable condition of performance being an increasing function of previous number of R trials had not been generally met.

In the second pilot study, therefore, the alternative was tried of initially training all Ss to a low criterion of performance (Furedy, 1966, p. 8) before administering one of the MV5 test series. The training consisted of 36 CS-UCS trials with the two CSs being continuously reinforced (all R trials). Training was terminated either at the end of the training series, or when S had reached a criterion which is specified in more detail below. Each of 20 Ss was then presented with the first 11 trials of one of the four MV5 orders, as in the first pilot study. This time only 35% of the Ss failed to give a CR on both trials 8 and 11. Moreover, when these trials were used for the TD test, a sign test based on differences in CR magnitudes on the N(S,d) and N(s,D) trials for each S yielded a significant, $p < .05$, difference in favor of the N(S,d) trials.

Since the method of training to criterion appeared to yield a sufficiently sensitive index of TD, this technique was used in the main experiment. After attaching the recording apparatus and the shock electrodes to S, and describing the type of stimuli (tone, light, and shock) to be presented, E left S's room and read the following instructions through S's earphones.

Please listen carefully to the following instructions. Remain seated comfortably and keep looking at the gray disc in front of you. Do not touch anything on your head at any time during the experimental session. The stimuli will consist of a tone, a light from the disc, and a mild electrical stimulus to your cheek. Be careful not to control voluntarily your natural reactions to the stimuli. Keep as detached an attitude as possible and simply let your reactions take care of themselves. You can communicate with me at any time by speaking in a normal voice. Are these instructions perfectly clear to you?

Following instructions, all Ss were presented with a continuous series of R trials in which the x- and y-type CSs were unsystematically presented with the restriction that the number presented of each type be equal after

trials 2, 4, 8, 12, 14, 16, 18, 20, 22, 24, 26, 28, and 32. The intertrial interval (ITI) was randomly varied between 25, 30 (mean) and 35 sec. The specification of x and y, and the intensity of the two UCSs were the same as that employed in the following 41-trial (experimental group) or 68-trial (control group) test series. The training series was terminated either after the 36th trial, or as soon as S had given CRs on two consecutive trials and had also satisfied one of the following conditions: (a) at least one CR to each CS before the 12th trial; (b) at least two CRs to each CS before the 25th trial; (c) at least three CRs to each CS before the 36th trial.

In the test series, the 40 ITIs for the experimental group (paired CS-UCS) was varied unsystematically between 30, 40, and 50 sec. intervals of which there were, respectively, 13, 14, and 13. The test series for the control group (unpaired CS and UCS) had 67 unsystematically varied 20, 25, and 30 sec. intervals of which there were, respectively, 30, 20, and 17. These ITI distributions approximately equated the duration of the test series for the two groups. The Ss were randomly allocated to groups and conditions until all 192 cells specified in the Experimental design section above had been filled.

Results.

Response definition and measures of conditioning.--On both R (CS-UCS) and N (CS-alone) trials, pen deflections of at least 1 mm. initiated between 151 and 500 msec. following CS onset were counted as CRs. The amplitude of any such CR was measured to the nearest mm., and was defined as the difference between response initiation and the maximal point of deflection up to 500 msec. following CS onset.

The various aspects of conditioning were measured in three ways: (a) percentage frequency of CRs over blocks of 10 trials; (b) CR magnitude in mm. deflection, where the absence of a CR was defined as a zero score; (c) trials

to criterion during the training trial series, where failure to reach criterion before the 36th trial was scored as 36.

Conditioning and sex.--Fig. 1* shows mean percentage CRs to the CS (tone or light) for the first 40 of the 41 times that it was presented during the test series. The variables shown are those of conditioning (experimental-control), sex (male-female), and trial-blocks (1 ... 4). It will be noted that CS and UCS were paired for all control as well as experimental Ss during the immediately preceding training trial series. A three-factor analysis of variance for unequal groups, using an unweighted-means solution (Winer, 1962, 337-340), and applied to the arcsine transforms of the individual percentage CRs, showed that the divergence between experimentals and controls over trial-blocks was significant, as indicated by the conditioning x blocks interaction, $F(3, 572) = 54.939$, $p < .001$. Other significant effects were: (a) superior overall performance of experimentals relative to controls, $F(1, 188) = 31.491$, $p < .001$; (b) a non-monotonic increase over blocks, $F(3, 572) = 3.543$, $p < .05$, with mean (arcsine) performance decreasing from the first to the second block; (c) a blocks x sex interaction, $F(3, 572) = 9.769$, $p < .005$; (d) a second-order conditioning x blocks x sex interaction, $F(3, 572) = 2.877$, $p < .05$. Separate analyses of this second-order interaction showed that a blocks x sex interaction was present for the controls, $F(3, 186) = 12.365$, $p < .001$, but not for the experimentals, $F < 1$. In turn, separate analyses for blocks x sex interaction within the controls indicated that females were significantly superior to males on block 1, $t(62) = 2.43$, $p < .05$, but this sex difference had disappeared in the following blocks, $t < 1$ for blocks 2, 3, and 4.

UCS intensity between subjects.--The effects of between-Ss variation of UI

*For captions of this and following figures, see pages at the end of the report.

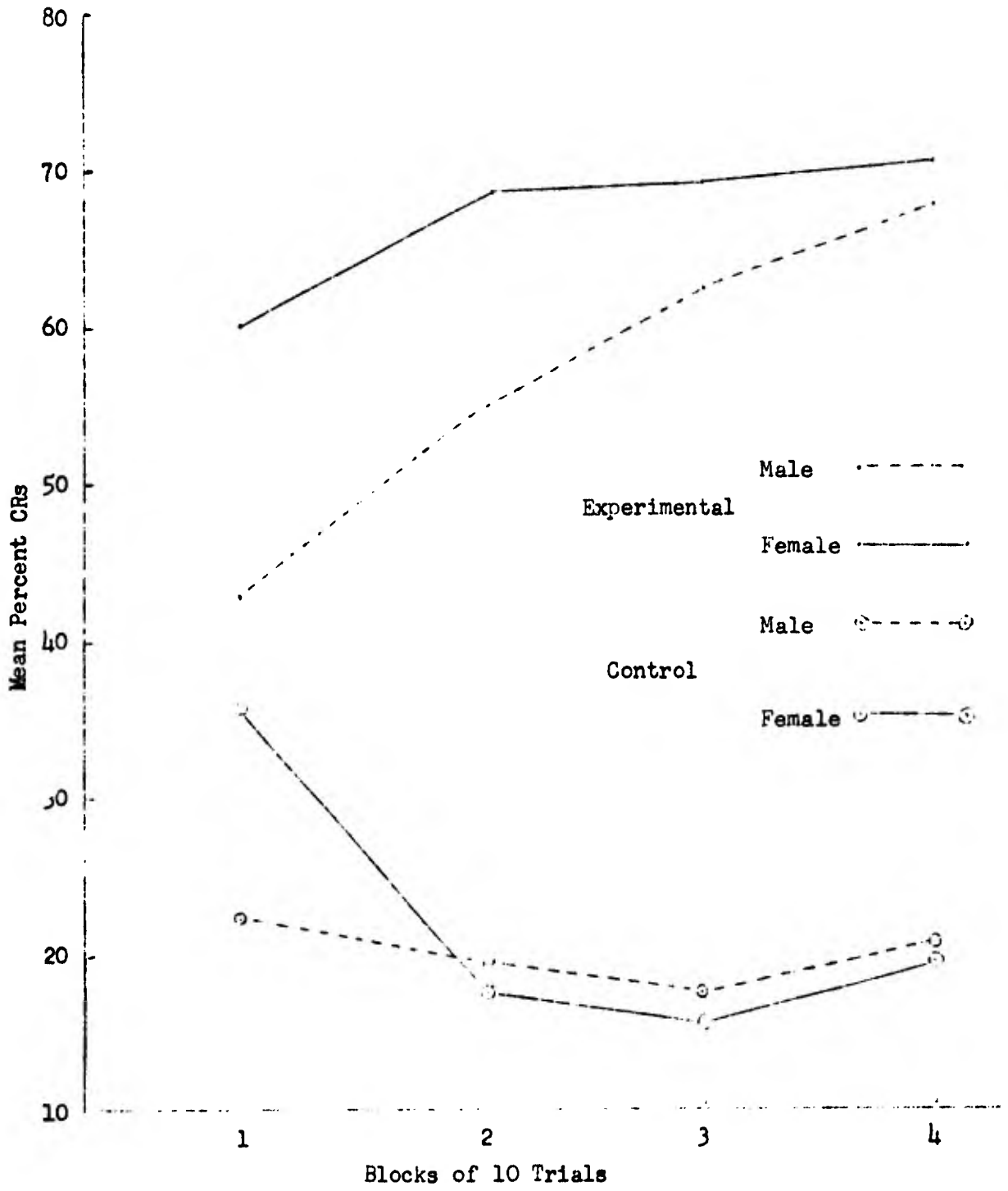


Figure 1

could be examined in those Ss for whom the UCS intensity was constant (CON). Fig. 2 shows the mean percentage CRs of these CON Ss in the control group (N = 32) as a function of the UI factor. A trial-blocks x UI analysis of variance on the arcsine transforms of individual percentage CRs indicated that only the blocks effect was significant, $F(3, 90) = 6.027$, $p < .001$, with performance seeming to be a U-shaped function of trial blocks. Both the UI and UI x blocks interaction effects failed to approach significance, $F < 1.4$.

The performance of the CON Ss in the experimental group (N = 64) is shown in Fig. 3, which includes sex as an additional counterbalanced factor. A three-way analysis of variance with UI, sex, and blocks as the factors indicated the following significant effects: (a) strong superior to weak UCS, $F(1, 60) = 21.984$, $p < .001$; (b) females superior to males, $F(1, 60) = 4.264$, $p < .05$; (c) a monotonic increase of performance over trial blocks, $F(3, 180) = 16.278$, $p < .001$. The apparent UI x sex interaction, suggesting that the sex difference was present only with the strong UCS, was not significant, $F(1, 60) = 2.125$, $p > .1$; all other interaction effects failed to approach significance, $F < 1.2$.

The between-Ss variation of UI could also be assessed in terms of the trials-to-criterion measure for the CON Ss during the 100%-reinforcement training trials which preceded the test series. Since, at this training stage, there was no difference between the treatments of the experimentals and controls, these groups have been combined in Fig. 4, which shows the distributions of the trials-to-criterion scores for the two groups of WEA and STR Ss, where N = 96 for each group. Because of the obvious departures from normality of the two distributions, the nonparametric mann-whitney U test was used to assess the difference between the two groups. The difference was significant, $U(96, 96) = 816$, $f < .05$, with fewer trials to criterion for Ss trained with the strong UCS.

Training differentiation.--The effect of TD, as represented by the difference

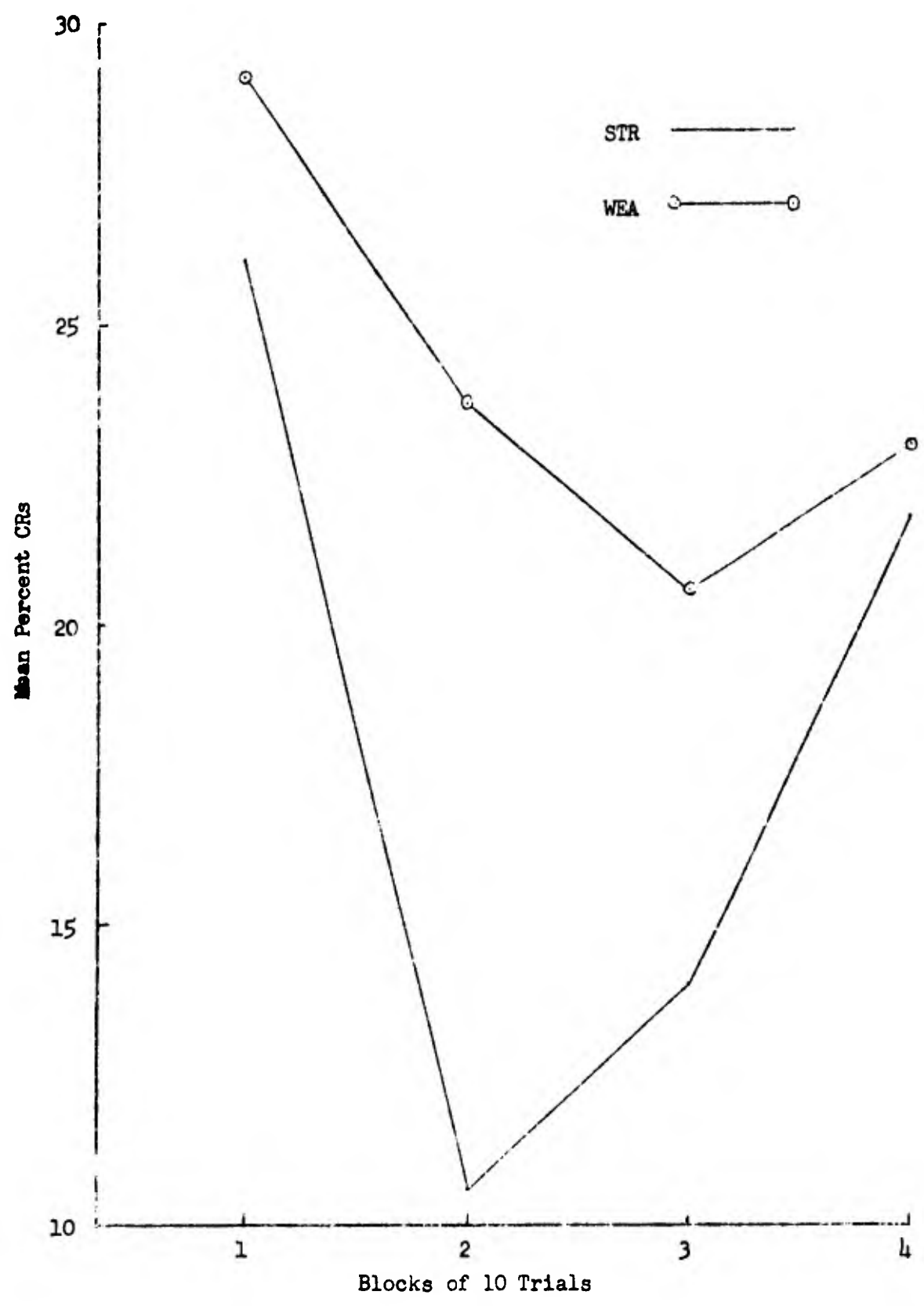


Figure 2

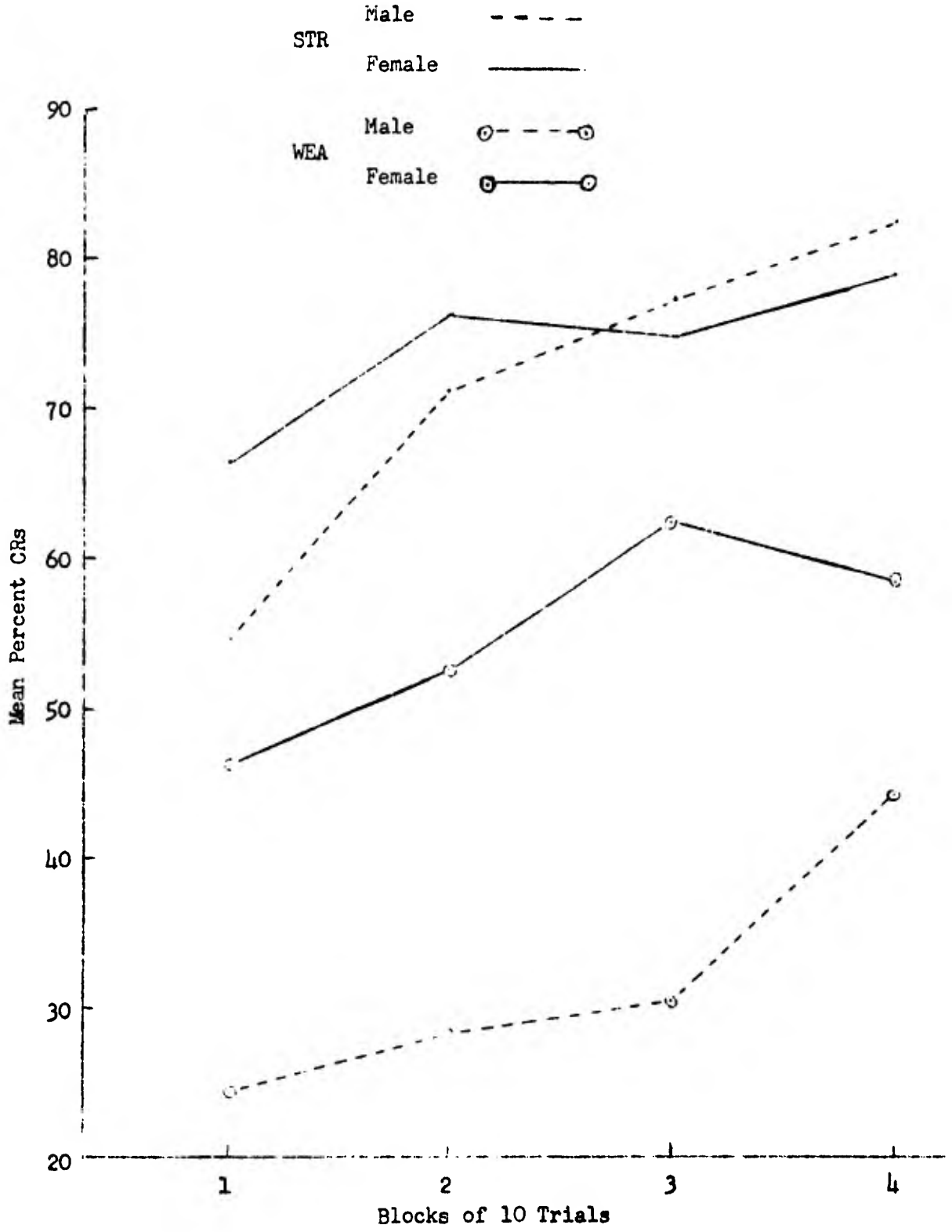
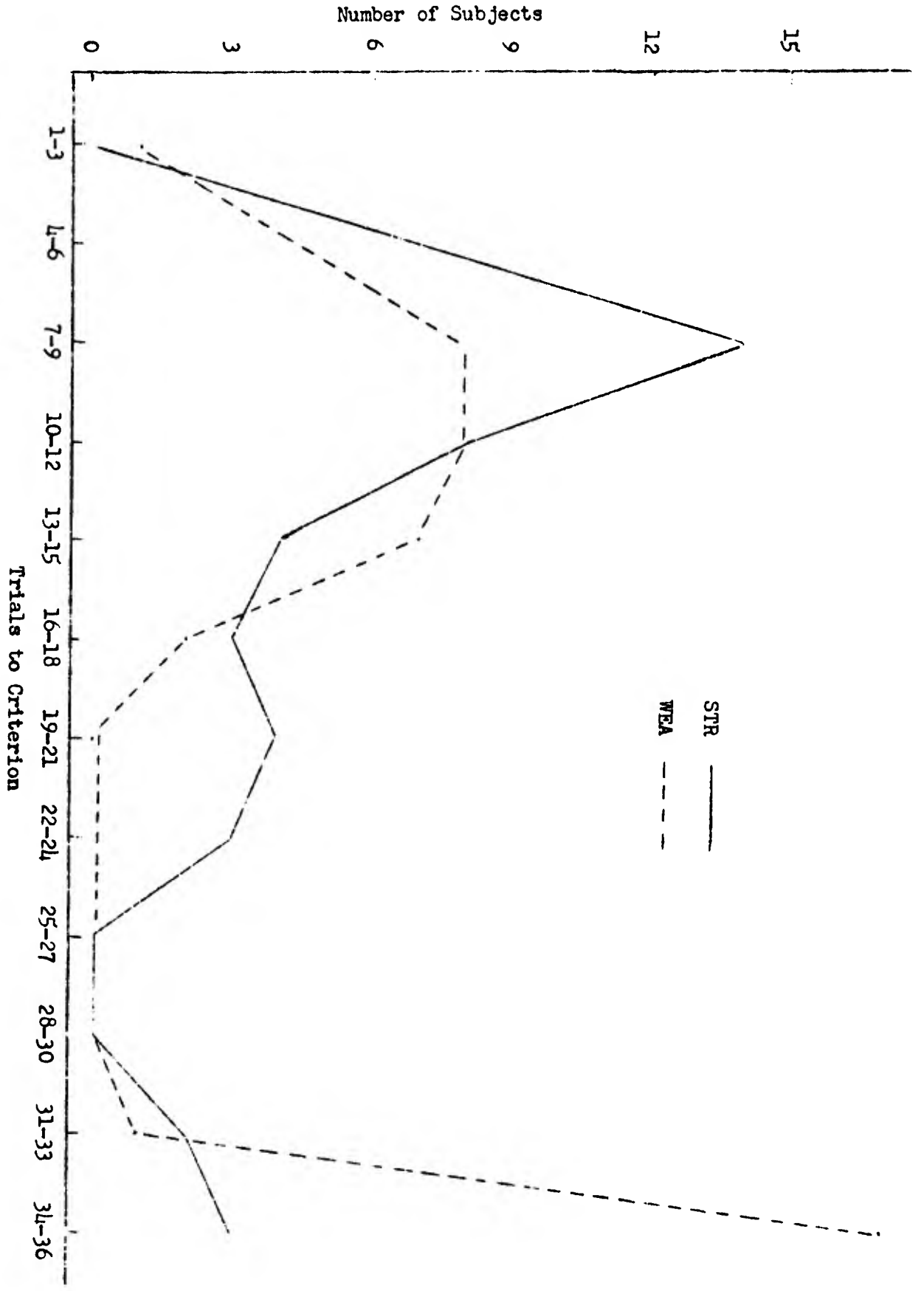


Figure 3



Trials to Criterion
Figure 4

between sets of $N(S,d)$ and $N(s,D)$ trials, was examined only in the experimental group during the 41-trial test series shown in Tables 1 and 2 above. The first analysis concerned the 64 S_s for whom the reinforcement schedule was non-identical (MV5), conditioning being measured at those test points where the variation between previous s and d values was in fact maximal (V5). Inspection of the MV5 orders in Table 2 above shows that trials 8 and 11 provide the source of the 1st suitable pair of $N(S,d)$ and $N(s,D)$ trials, while the 2nd pair of V5-type $N(S,d)$ and $N(s,D)$ trials have to be drawn either from trials 28 and 29 (Orders 1 and 2) or trials 26 and 27 (Orders 3 and 4). The left panel of Fig. 5 shows mean CR magnitude as a function of the TD ($N(S,d)$ vs $N(s,D)$), UV (VAR vs CON), and trials (1st vs 2nd) factors. Analysis of variance indicated significantly superior performance to $N(S,d)$ relative to $N(s,D)$ trials, $F(1, 62) = 34.037$, $p < .001$, and to 2nd relative to 1st trials, $F(1, 62) = 12.482$, $p < .001$. The remaining main effect of UCS variation (UV), as well as all interactions, did not approach significance, $F < 1$.

The statistical analysis of the effect of the counterbalanced NC (nature-of-CS) factor in conjunction with the UV and TD factors required that the data represented in the left panel of Fig. 5 be broken down into 1st and 2nd trials, as shown, respectively, in the middle and right panels of the figure. Even this breakdown does not permit an immediate statistical assessment of the data in the form of a simple UV x TD x NC factorial design, because the distribution of S_s does not allow a split-plot model to be applied. Such a model is applicable, however, to an "interactive" factorial, in which the NC factor is reclassified so that it is connected to the TD factor. It has been shown that the statistical results from this interactive factorial are logically equivalent to the effects describable in the simple factorial terms of UCS variation, training differentiation, and nature of CS (Furedy, 1967). In these simple

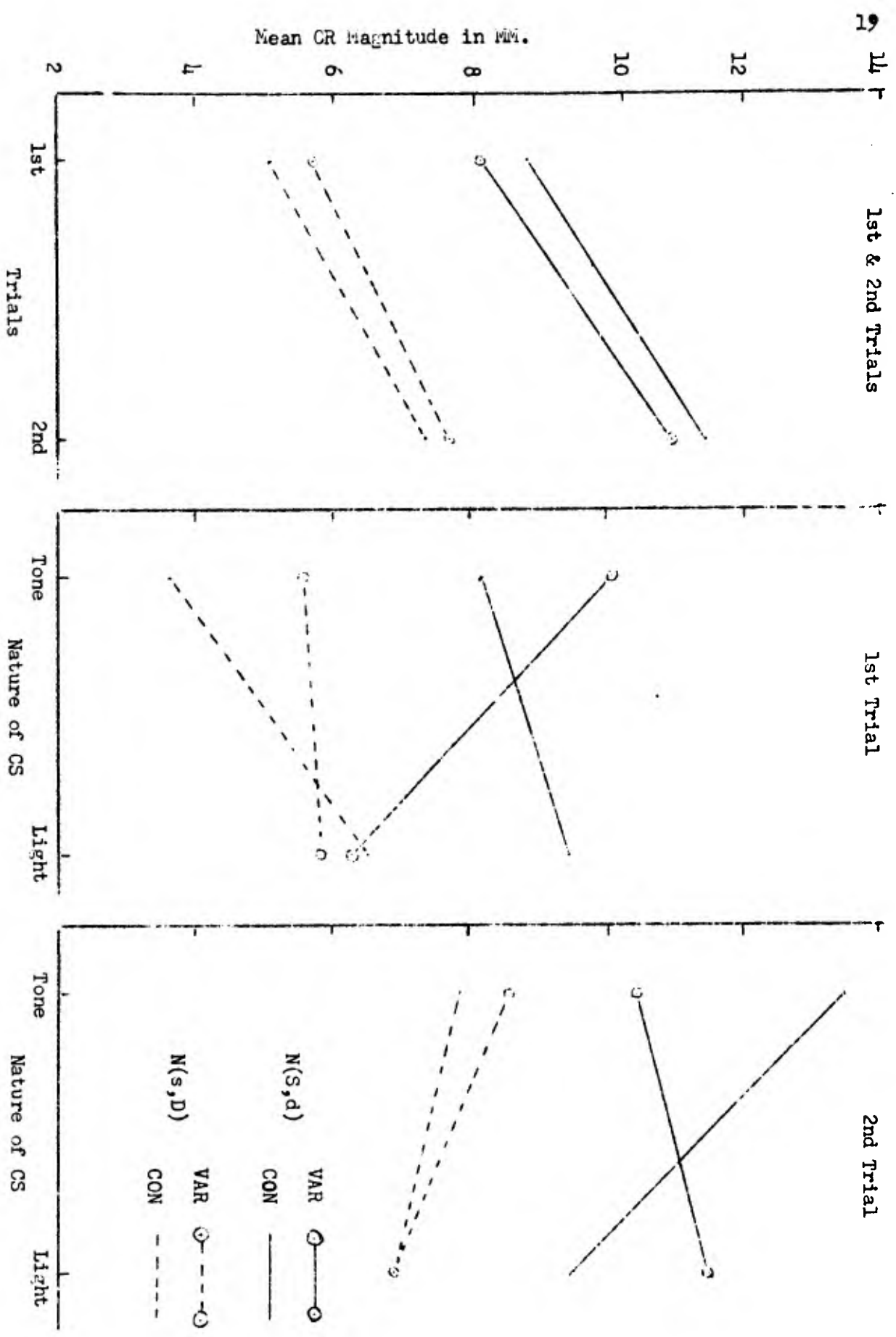


Figure 5

factorial terms, the 1st-trial results (middle panel) indicated significantly superior performance to $N(S,d)$ relative to $N(s,D)$ trials, $F(1, 60) = 12.631$, $p < .001$. The superiority of the tone (T) relative to the light (L) was not significant, $F(1, 60) = 2.123$, $p > .1$; the remaining effects, including all interactions, did not approach significance, $F < 1.2$. For the 2nd-trial results (right panel), the TD effect was again significant, $F(1, 60) = 25.632$, $p < .001$, with $N(S,d)$ superior to $N(s,D)$, while the NC effect was near-significant, $F(1, 60) = 3.792$, $p < .1$, with T superior to L; the remaining effects, including all interactions, did not approach significance, $F < 2.3$, $p > .1$.

The TD effect could also be tested in MV5 S_s at a point where the actual variation between previous number of s and d reinforced trials was only one (V1), a value which was not exceeded at any point along the test series given to the identical-reinforcement-schedule (MV1) S_s . Inspection of the MV5 orders in Table 2 above shows that the source of the 1st V1-type N trials is trials 20 and 23 (Orders 1 and 2) or trials 17 and 20 (Orders 3 and 4), while the 2nd V1-type trials have to be drawn from trials 35 and 38 (Orders 1 and 2) or 32 and 35 (Orders 3 and 4). Fig. 6 shows the data arranged and broken down in the same way as the V5 data in Fig. 5. The statistical treatment was the same as that of the V5 data, and yielded the following outcomes. The only significant effect from TD x UV x trials analysis (Fig. 6, left panel) was a superiority in performance to the 2nd relative to the 1st trials, $F(1, 62) = 6.621$, $p < .05$. The superiority of the $N(S,d)$ over the $N(s,D)$ trials was not significant, $F(1, 62) = 2.731$, $p > .1$, while all other effects failed to approach significance, $F < 1.3$. Considering the NC (T-L) variable, the 1st-trials results (middle panel) indicated that tone (T) was significantly superior to light (L), $F(1, 60) = 4.274$, $p < .05$, while there was a near-significant superiority of the $N(S,d)$ relative to the $N(s,D)$ trial, $F(1, 60) = 3.667$, $p < .1$; all other

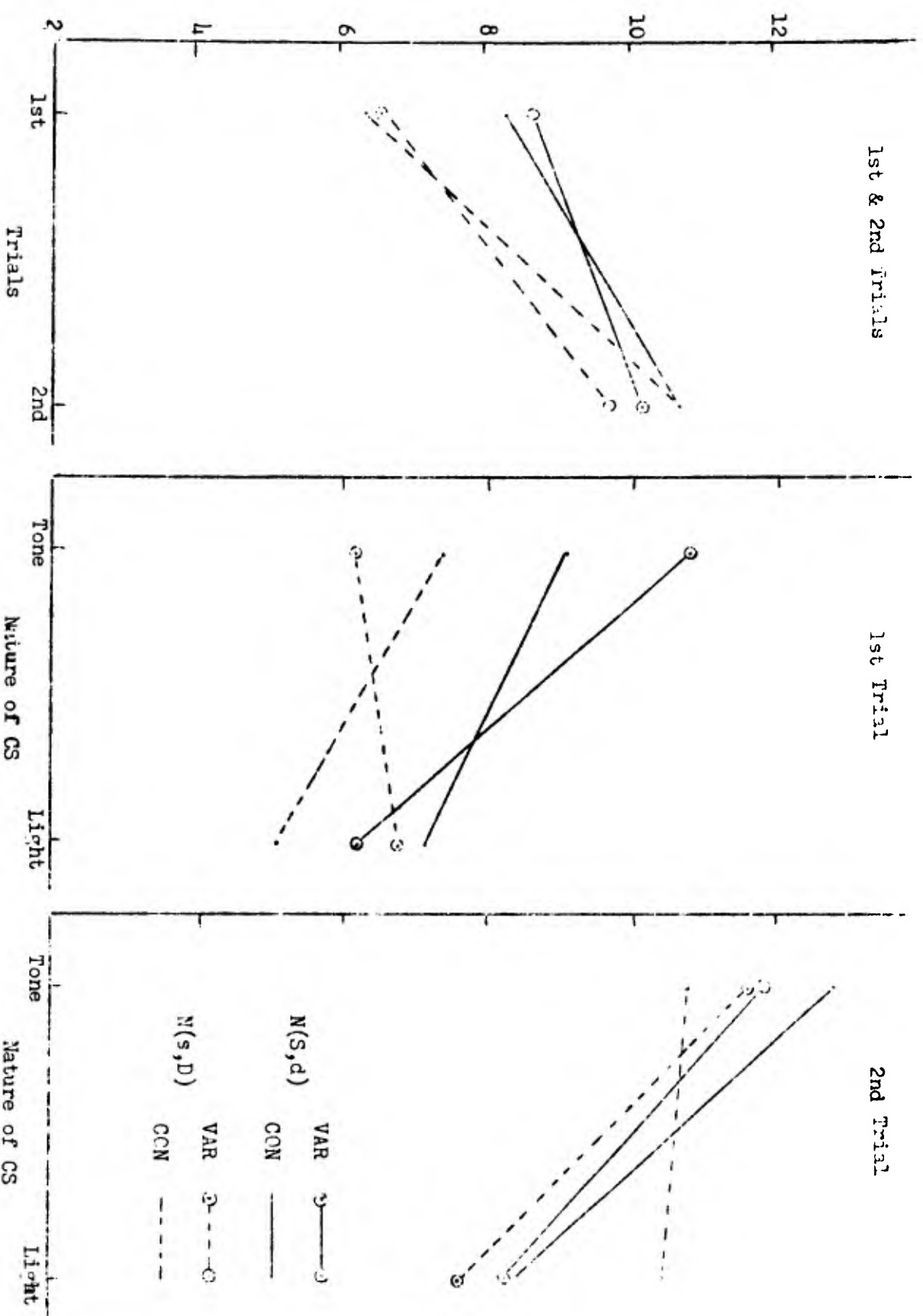


Figure 6

effects failed to approach significance, $F < 1$. For the 2nd trial (right panel), only the superiority of the T relative to the L was significant, $F(1, 60) = 11.933$, $p < .01$; all other effects, including that due to TD, failed to approach significance, $F < 1$.

The other half of the experimental group, for whom the reinforcement schedule was identical (MVI), were tested for TD at two stages along the 41-trial test series set out in the MVI orders in Table 1 above. The trials for the N(S,d) and N(s,D) trials in the 1st stage were drawn from trials 2, 5, 8, and 11 for all four orders; 2nd-stage N(S,d) and N(s,D) trials were drawn from trials 14, 15, 28, and 29 in Orders 1 and 2, and from trials 16, 17, 26, and 27 in Orders 3 and 4. Fig. 7 shows the data arranged and broken down in the same way as the V5 (Fig. 5) and V1 (Fig. 6) data of the MV5 Ss, except that the N(S,d) and N(s,D) measures for each S at each stage are based on two trials rather than one. The statistical treatment was also the same as that for the MV5 data. The only significant effect from the TD x UV x trials analysis (Fig. 7, left panel) was that of trials, $F(1, 62) = 7.853$, $p < .01$, with 2nd superior to 1st; all other effects failed to approach significance, $F < 2.4$, $p > .1$. As regards the NC variable, the 1st-trials results (middle panel) showed only a significant superiority of T over L, $F(1, 60) = 6.016$, $p < .05$, with all other effects failing to approach significance, $F < 1$. For the 2nd trials, the NC effect was insignificant, $F < 1$, as were all other effects, $F < 2.2$, $p > .1$.

To determine more directly how the TD effect was influenced by the MV factor (reinforcement schedule), and, within the MV5 group, by the V factor (actual variation between s and d values at point of testing), it is possible to obtain TD scores for each S at certain stages along the test series by taking algebraic differences between pairs of suitable N(S,d) and N(s,D) trials. Provided that the pairs are chosen so as to counterbalance for other factors such

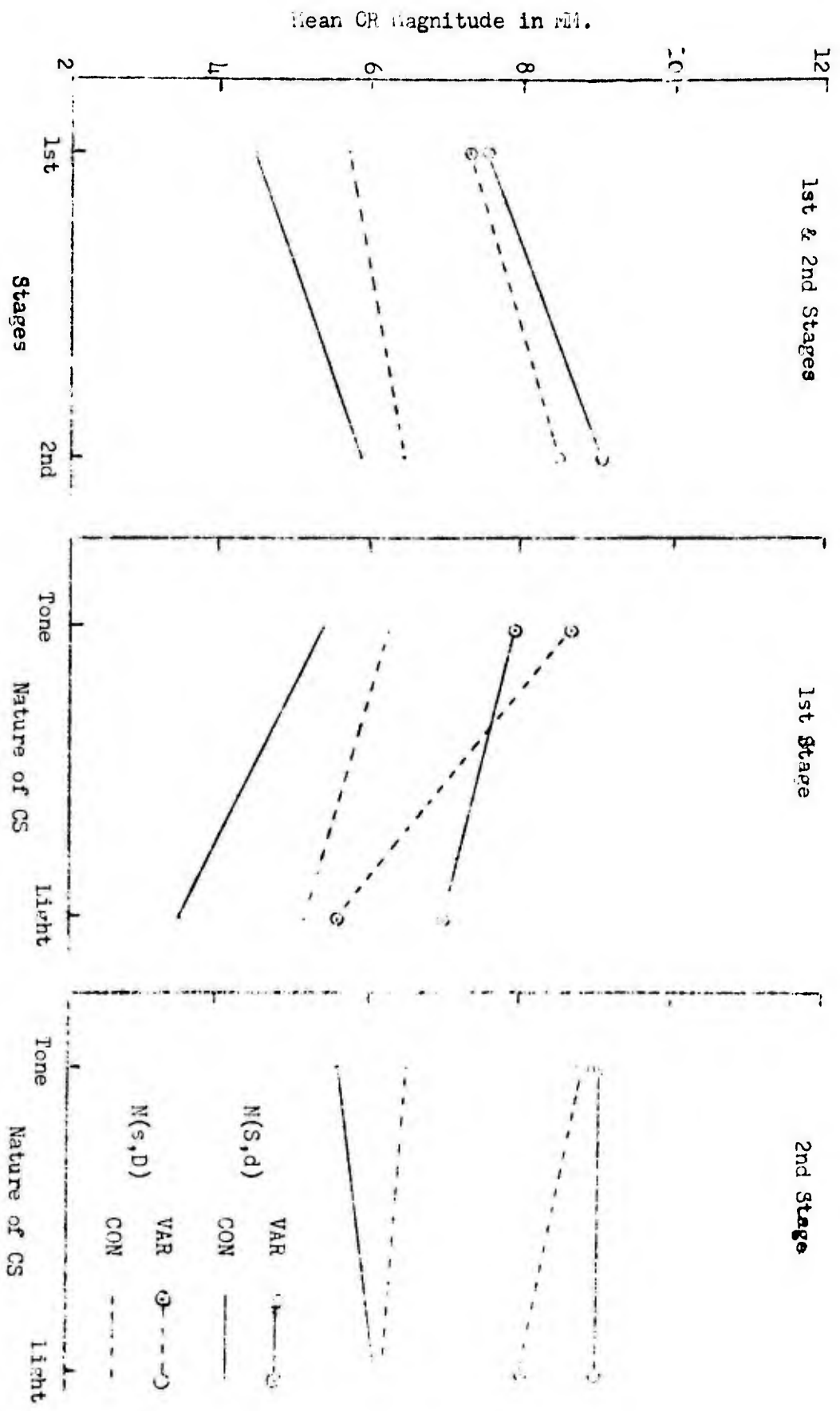


Figure 7

as nature of the CS and stage along the trials series, the positive mean value of these difference scores represents the degree of differentiation between the two CSs. Panel A of Fig. 8 shows this relative TD as a function of MV, UV (VAR-CON), and trial pairs (1st-2nd). The MV variable in Panel A includes both the MV and V factors, since the actual variation for the MV5 trials was 5. Thus, the 1st MV5 trial pairs were drawn from trials 8 and 11 of Table 2 above, while the 2nd MV5 trial pairs were drawn from trials 28 and 29 (Orders 1 and 2) or trials 26 and 27 (Orders 3 and 4); the MV1 trial pairs were drawn from the same numbered trials of the MV1 orders of Table 1 above. The MV x UV x trial-pairs analysis of variance indicated significantly better differentiation in the MV5 group than in the MV1 group, $F(1, 124) = 23.524, p < .001$, and a near significant MV x UV interaction, $F(1, 124) = 3.359, p < .1$, with the MV5-MV1 difference seeming to be larger in the CON than in the VAR group. All other effects failed to approach significance, $F < 1$.

Panel B of Fig. 8 shows relative TD as a function of the same variables as those in Panel A, except that the MV variable does not include V as a factor. To obtain the required V1-type $N(S,d)$ and $N(s,D)$ trial pairs for the MV5 S_s , trials 20 and 23 (Orders 1 and 2) or trials 17 and 20 (Orders 3 and 4) from the MV5 orders were used for the 1st pair, while trials 35 and 38 (Orders 1 and 2) or 32 and 35 (Orders 3 and 4) were used for the 2nd pair. This time the MV variable, with V held constant, yielded no significant effect from the three-way analysis of variance, $F < 1$, and all other effects also failed to approach significance, $F < 1.1$.

The effect of varying V within the MV5 S_s is shown in Panel C of Fig. 8. The high-V ($V = 5$) $N(S,d)$ and $N(s,D)$ trials are drawn from the same source as MV5 trial pairs in Panel A. To obtain the low-V ($1 \leq V \leq 3$) $N(S,d)$ and $N(s,D)$ trial pairs from the MV5 orders, trials 2, 5, 14, and 15 (Orders 1 and 2) or 2, 5, 16, and 17 (Orders 3 and 4) were used for the 1st stage, while

Mean $[N(S,d) - N(s,D)]$ Scores in MM.

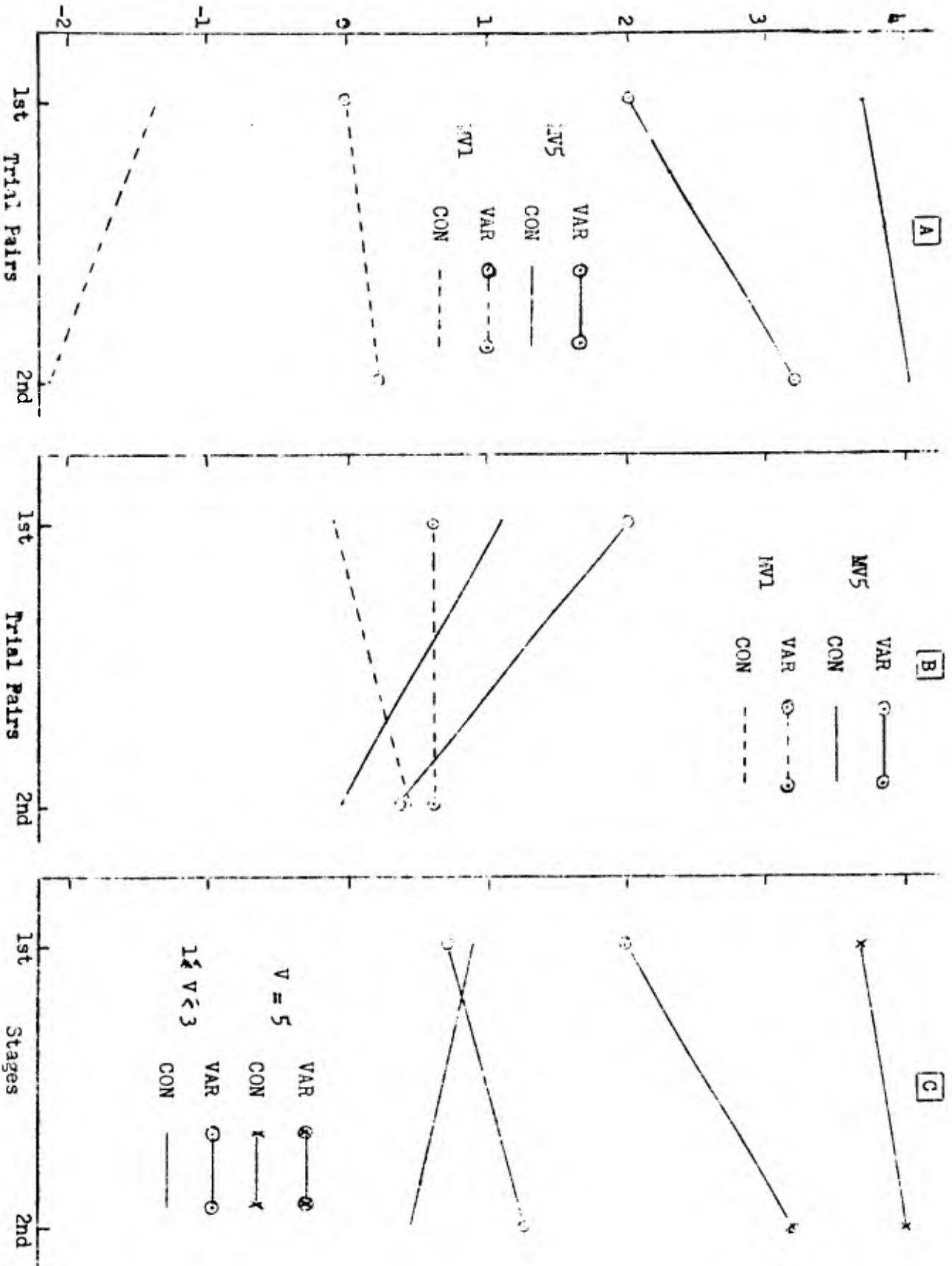


Figure 8

trials 20, 23, 32, and 35 from all four orders were used for the 2nd stage. Inspection of these trials in Table 2 above shows that for both stages, the mean V value for the low-V N(S,d) and N(s,D) trials was 2.5. The only significant effect yielded by the V x UV x stages analysis of variance was the greater TD on the high-V relative to the low-V trial pairs, $F(1, 62) = 11.440$, $p < .01$; all other effects failed to approach significance, $F < 1.2$.

The above results indicate that the nonidentical-reinforcement schedule (MV5) produced reliably greater TD than the identical-reinforcement schedule, although this difference did not persist when the actual variation (V) at the point of testing was held constant between the MV5 and MV1 schedules. To check whether the MV5-MV1 differences in TD were partly due to some overall difference in CR strength between the two MV groups, the mean percentage CRs of the experimental group over the first 40 trials of the 41-trial test series were examined as a function of the MV factor, as well as the factors of UV (VAR-CON) and sex (male-female). This data, plotted over four 10-trial blocks, is shown in Fig. 9. The UV x MV x sex x blocks analysis of variance performed on the individual arcsine transforms indicated that neither the UV effect nor the interaction between UV and blocks approached significance, $F < 1$. The only two significant effects were a monotonic increase of performance over blocks, $F(3, 360) = 29.567$, $p < .001$, and a sex x blocks interaction, $F(3, 360) = 3.151$, $p < .05$, with the sex difference apparently decreasing over blocks. The overall sex effect itself was near-significant, $F(1, 120) = 3.335$, $p < .1$, with females superior to males. All other effects failed to approach significance, $F < 2.48$, $p > .1$.

The effect of UV on overall response strength was examined in a similar way within the control group, as shown in Fig. 10. One difference between this and the preceding figure is that the sex factor has been dropped. The other,

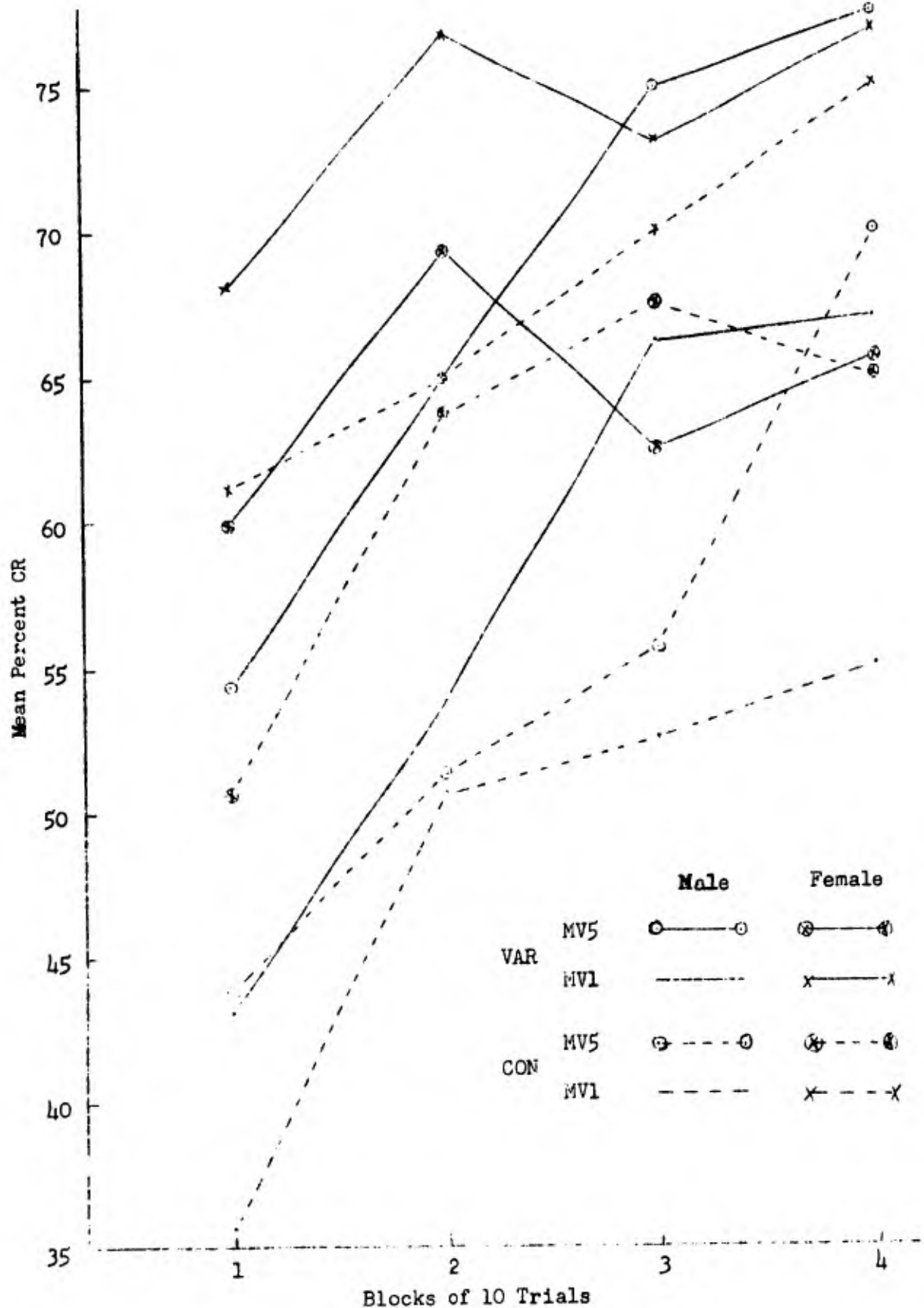


Figure 9

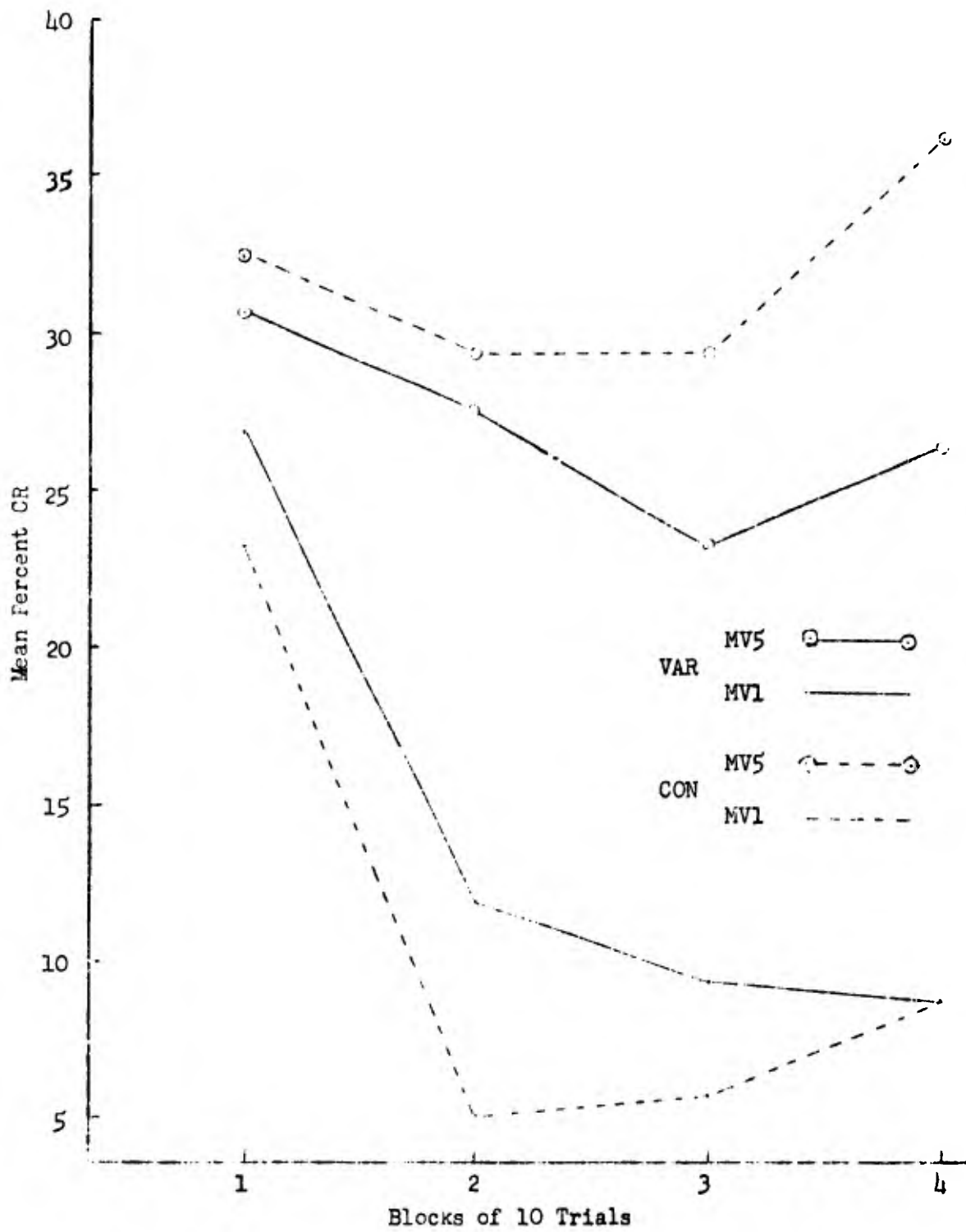


Figure 10

and more important, difference is, that within the control group, the MV variable does not involve a difference in reinforcement schedules or rate of CS-UCS pairings, since the CS and UCS are unpaired. The only difference between the MV5 and MV1 controls is that the stimulus pattern presented to the former is more predictable than that presented to the latter. The UV x MV x blocks analysis of the arcsine transforms of the scores depicted in Fig. 10 indicated the following significant effects: (a) MV5 group superior to MV1 group, $F(1, 60) = 9.331$, $p < .01$; (b) a decrease of performance over blocks, except for the last block, $F(3, 180) = 11.615$, $p < .001$; (c) an MV x blocks interaction, $F(3, 180) = 3.663$, $p < .05$, with the MV5-MV1 difference increasing over blocks. All other effects failed to approach significance, $F < 1$.

Extinction differentiation.--The effect of ED, as represented by the difference between suitably counterbalanced sets of (s,D)R and (S,d)R trials, could be tested only in the MV1 Ss of the experimental group. The test points used were those R trials in Table 1 above for which the preceding number of s and d N trials are specified. The left panel of Fig. 11 shows mean CR magnitude as a function of the ED ((s,D)R vs (S,d)R), UV (VAR vs CON), and trials factors. It will be noted that the trials factor is specified in terms of the sums of preceding s and d N trials. Analysis of variance indicated significantly superior performance to (s,D)R relative to (S,d)R trials, $F(1, 62) = 5.360$, $p < .05$, as well as a monotonic increase over trials, $F(3, 186) = 22.278$, $p < .001$. All other effects failed to approach significance, $F < 1.6$.

Collapsing the trials classification of the data in the left panel of Fig. 11 permits the influence of the NC (nature-of-CS) factor to be assessed in conjunction with the ED and UV factors, as shown in the right panel of the same figure. In addition to the significant ED effect, $F(1, 62) = 5.027$, $p < .05$, the analysis of variance also yielded a significant NC effect, $F(1, 62) = 13.281$,

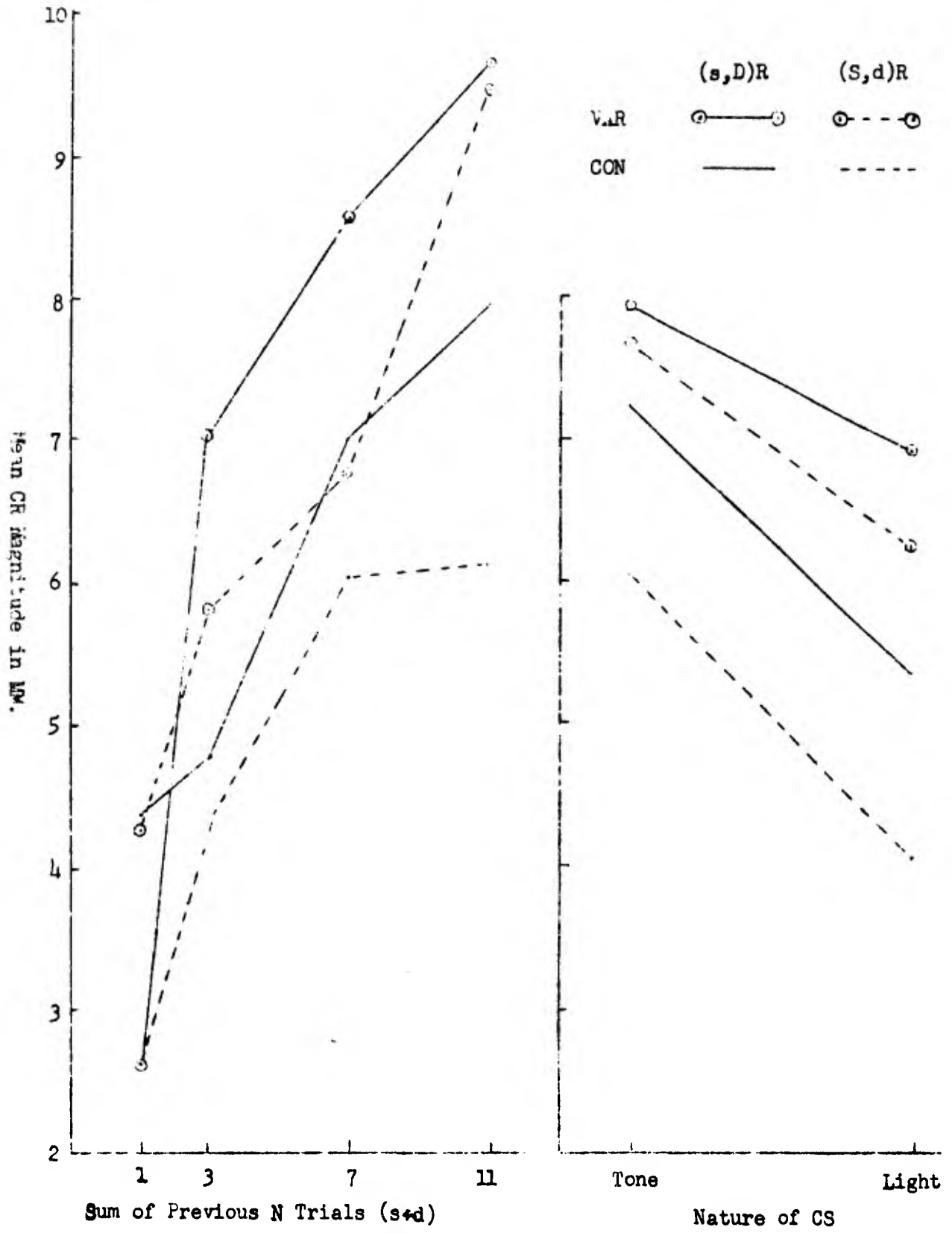


Figure 11

$p < .001$, with superior performance to the tone relative to the light. All other effects failed to approach significance, $F < 1$.

UCS intensity within subjects.--The effect of within-S UI variation could be examined in those experimental Ss for whom UCS intensity varied (VAR). Fig. 12 shows the mean CR magnitudes of these Ss on all N trials as a function of the UI factor, as well as of NC (tone-light), MV (MV5-MV1), and trials. The trials factor is specified in terms of the mean sums of preceding s and d training (R) trials. From Table 1 (or 2) above, the N trials for the first abscissal point are drawn from trials 2, 5, 8, and 11; those for the second abscissal point from trials 14-17, 20, 23, and 26-29; those for the third abscissal point from trials 32, 35, 38, and 41. The analysis of variance indicated the following significant, $p < .001$, effects: (a) greater CR to CS paired with strong (STR) than with weak (WEA) UCS, $F(1, 60) = 23.798$, this F value being of the same order of magnitude as the corresponding F of 21.984 obtained earlier for the between-S UI effect; (b) greater CR to tone than to light, $F(1, 60) = 15.725$; (c) monotonic increase over trials, $F(1, 60) = 17.306$. The apparent interaction between MV and UI, with greater UI difference for the MV5 than for the MV1 group, was not significant, $F(1, 60) = 1.369$, $p > .1$; nor did any other effects approach significance, $F < 1.5$, $p > .1$.

Discussion.

The reliably superior performance of the experimental group relative to the control group during the test series, as well as the significant divergence between these groups over trial blocks (Fig. 1), suggest that the CS-UCS pairing was effective in producing conditioning. Since the control Ss were run with an unpaired rather than a "truly random" arrangement of CS and UCS, a possibility pointed out recently has to be considered: that the difference between the groups may have been solely due to an inhibitory factor operating in the control

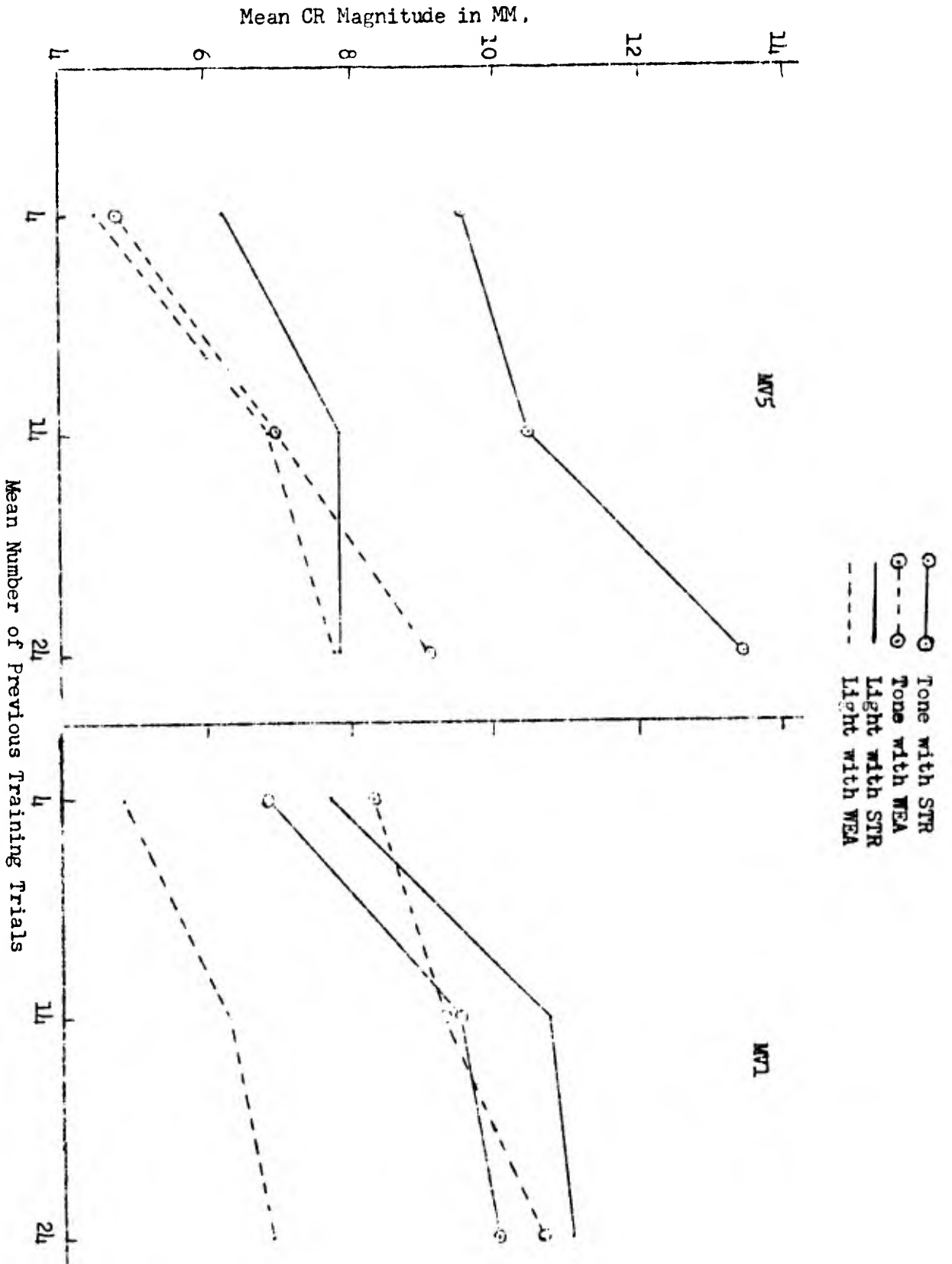


Figure 12

Ss through the CS becoming a signal for the absence of the noxious UCS (Rescorla, 1967, p. 73). However, the fact that under the paired CS-UCS condition the UCS intensity effect emerged reliably both between Ss (Figs. 3 and 4) and within Ss (Fig. 12), while there was no such reliable UCS-intensity effect under the unpaired condition (Fig. 2), suggests that the pairing operation, in its own right, was effective in producing conditioning.

Within the experimental group, Ss presented with the non-identical reinforcement schedule (MV5) showed clear evidence of training differentiation (TD) between the two CSs (Fig. 5), while Ss presented with the identical reinforcement schedule (MV1) did not (Fig. 7). That this difference between the MV5 and MV1 Ss was itself significant was shown by the reliable difference between the TD scores of the two groups in favor of the MV5 Ss (Fig. 8, Panel A). However, when TD was assessed in the MV5 group at points where the actual variation (V) was only that of the identical-reinforcement schedule (MV1) group, the superiority of N(S,d) over N(s,D) trials was not reliable (Fig. 6). Nor was the difference between TD scores of the MV5 Ss measured at V1 points and those of the MV1 Ss significant (Fig. 8, Panel B). Finally, the importance of the V factor independently of MV was confirmed by the reliably superior TD scores on high-V relative to low-V trials within the MV5 group (Fig. 8, Panel C). The reinforcement-schedule manipulation then, provided it was combined with varying the actual s : d difference at the point of testing (V), did reliably affect the degree of differentiation between the two CSs. On the other hand, there was no evidence from any of the results that the UCS variation (U) had any effect on the degree of training differentiation.

Although the TD tests indicated no cross-modal differentiation (CMD) between the physically dissimilar tone and light for the Ss run under the identical-reinforcement schedule, the extinction differentiation (ED) test did

indicate reliable CMD for these MV1 Ss, as shown by the significant superiority of the (s,D)R relative to the (S,d)R trials (Fig. 11). Since ED was not measured in the MV5 Ss, the influence of the MV variable on differentiation could not be assessed. The influence of the UV variable, on the other hand, could be measured, and, as in the case of TL, the UCS-variation manipulation did not affect the degree of extinction differentiation (Fig. 11).

Independently of the results of the TD and ED tests, there is clear, though indirect, evidence in the present experiment that, at least for the Ss run under the varied UCS intensity (VAR) condition, there was some degree of CMD (i.e., only partial generalization) between the two CSs. This evidence is provided by the reliable within-S UCS intensity effect which emerged for the VAR group of Ss, because some differentiation is a necessary condition for the emergence of any within-S treatment effect (Furedy, 1966, p. 3). Moreover, since the UV (VAR-CON) factor did not affect the degree of TD or ED, it is reasonable to assume that CMD occurred not only for the VAR, but also for the CON, Ss. While the emergence of the within-S UI effect in this experiment therefore rendered the TD and ED tests superfluous for determining the occurrence of CMD, these tests are not superfluous in other experiments where no within-S treatment effect emerges. For such experiments, however, the present results indicate that the outcomes of the TD and ED tests need not be identical. Hence, whenever possible, the experiment should be so designed that, in the event of a failure to obtain any within-S treatment effects, it is possible to apply both forms of the differentiation tests.

Since the test series constituted a partial reinforcement (67%) schedule, the emergence of the reliably greater CR strength for Ss trained with the stronger UCS is in apparent conflict with a reported inverse effect of UCS intensity upon partially reinforced eyelid conditioning (Boice & Boice, 1966). This conflict, moreover, is sharpened by the fact that like Boice and Boice's experiment,

and unlike the study of Koss and Spence (1960), where performance was a direct function of UCS intensity, the present study both used omitted rather than delayed UCSs on nonreinforced trials, and did not use a ready signal. The inverse effect of UI, according to Boice and Boice, is due to the greater amount of inhibition induced by the omission of the strong than of the weak UCS. This explanation implies at least that CRs on trials following reinforced trials be stronger than those to trials following non-reinforced trials, an implication which was confirmed by their data (Boice and Boice, 1966). The operation of this sort of inhibition could be examined in the present study by comparing relative CR strengths to three classes of trials, namely those immediately following one nonreinforced (N) trial, one reinforced (R) trial, and two R trials. In each S, performance on the three sorts of trials was measured at 10 points for each sort of trial along the test series specified in Tables 1 and 2 above. For Orders 1 and 2 (in both tables), the 30 points were drawn from trials 3-38 with the exception of trials 16, 19, 20, 27, 28, and 30; for Orders 3 and 4 (in both tables), the points were drawn from trials 3-38 with the exception of trials 15, 16, 18, 28, 31, and 32. Table 3 shows the mean percentage CRs (based,

Table 3. Mean percentage of CRs of CON Ss in experimental group

	Following one non-reinforced trial	Following one reinforced trial	Following two reinforced trials
260 v. STR UCS	63.	75.0	75.9
120 v. WEA UCS	35.3	45.9	48.4

for each S, on ten trials) of the STR and WEA groups on trials as a function of the three different immediately preceding reinforcement histories (IPRH). A two-way analysis of variance performed on the arcsine transforms of individual percentage CRs yielded highly reliable, $p < .001$, effects for UI, $F(1, 62) = 17.919$, with STR superior to WEA, and for IPRH, $F(2, 124) = 19.421$, with a monotonic, though negatively accelerated, increase of CR strength as a function of the number of immediately preceding reinforced trials. The UI x IPRH interaction, which is also implied by Boice and Boice's explanation of the inverse UI effect, but was not found by them (Boice and Boice, 1966), failed to approach significance in the present case.

In summary, the conditions for the CON Ss in the experimental group duplicated Boice and Boice's arrangement to the extent of using a partial reinforcement schedule, omitted UCS on nonreinforced trials, and no ready signal; their results were also duplicated as regards the emergence and non-emergence, respectively, of the IPRH and IPRH x UI interaction effects. The presently obtained function between performance and UI, however, was reliably direct, in contrast to their marginally significant inverse UI function. To resolve this discrepancy, it may be suggested that the present situation was not a true partially reinforced schedule, since it was preceded by a training session of continuously reinforced CS presentations. However, if the inverse UI effect depended on the introduction of partial, as contrasted with continuous, reinforcement, one would expect any direct UI effect at the introduction of the partial reinforcement schedule to be reduced as the partially reinforced series of trials progressed. This reduction in UI, as expressed in a UI x trial-blocks interaction, did not occur (Fig. 3). Considering that Fishbein (1967) also obtained a reliably direct UI effect in a partially reinforced (50%) eyelid conditioning experiment, it would seem that the connection between partial rein-

forcement and the inverse UI effect is as tenuous as the evidence for the existence of the inverse UI effect itself.

The within-Ss UI effect, tested on experimental Ss run under the VAR condition, was also reliably and directly related to CR strength (Fig. 12). Unlike the between-Ss UI effect, which was measured with the conventional percentage frequency method, the within-Ss UI effect was measured in terms of CR magnitude. However, as mentioned in the Results section above, the statistical sensitivity of the measures of the between- and within-Ss UI effects were of the same order, with highly significant F values ($p < .001$) being obtained for both effects.

To complete the measures (percentage vs. magnitude) x comparison-type (between vs. within) matrix, between- and within-Ss UI comparisons were carried out with magnitude and percentage, respectively, as measures in the experimental Ss. The between-Ss magnitude measures were taken from the same trials as those used for the percentage means above (Fig. 3); the obtained UI function was direct and significant, $F(1, 60) = 10.347, p < .005$. The within-Ss percentage measures were obtained by taking the first 20 STR and WEA trials from the 41-trial test series for each experimental S run under the VAR condition, and dividing both sets of 20 trials into 10-trial blocks; the UI function was again direct and significant, $F(1, 60) = 12.837, p < .001$. The results of the present study indicate, therefore, that CR strength under partial reinforcement is a reliably direct function of UCS intensity whether the intensity is varied within or between Ss, and whether the response measure is percentage frequency or a combination of frequency and amplitude, i.e., magnitude.

Among the incidental findings of interest is the way in which sex appeared to affect response strength. Consistent with a recent review by Spence and Spence (1966), who report that this variable has a significant, though relatively

weak, effect on eyelid conditioning, the superiority of females over the males was marginally significant ($p < .05$) over the CON Ss in the experimental group (Fig. 3). Other aspects of the data suggest, moreover, that the sex variable affects conditionability rather than being simply a function of females having a higher "operant" blink rate than males. Thus, the performance curves of all the experimentals and controls during the test series of trials (Fig. 1) indicated a second order interaction between blocks, groups, and trials, the source of which seemed to be that the sex difference disappeared in the control group as CS and UCS were no longer paired.

While the unpairing operation, as carried out on the controls during the test series, seemed to remove the differential sex effect, the same operation appeared to be responsible for the emergence of another effect: the reliably higher percentage CRs given by MV5 Ss relative to MV1 Ss during the test series in the control group only. It will be noted that the MV5 series contains longer sequences of the same CS (tone or light) than does the MV1 series. The present findings, since they were confined to the control Ss, suggest, therefore, that in the absence of conditioning operations, the frequency of responses occurring within the latency limits defining a CR is increased as a function of the length of predictable stimulus sequences presented in the trial series.

The final incidental result of interest is the tendency of the NC variable to affect conditioning, with tone producing greater responding. This effect, like that of sex, was not always significant, but taken together, the data do indicate that the counterbalancing of the NC factor was a necessary precaution in this experiment. That it was also sufficient is indicated by the general failure to find any interactions between NC and the other variables such as TD and UI (Furedy, 1967, p. 444). Nevertheless, while the tone-light difference did not therefore constitute a serious source of error in this

experiment, it is puzzling to find this variable present, since the two CSs had been psychophysically equated for intensity. The difference may lie in the fact that S, even when keeping his eyes open, can more easily exclude the light from his attention (by looking away) than he can the tone. If this is the case, it would be advantageous to use a general increase of room illumination rather than a small visual field as the visual CS in future experiments.

Experiment II: Autonomic CMD

The GSR, since it was the response in which complete generalization between tone and light (no CMD) had been previously found (Furedy, 1965), was the indicator of primary interest in the autonomic experiment. Although the basic approach was the same as that for the concurrently run eyelid study, certain characteristics of the conditioned GSR necessitated modifications as detailed below in the Method section. Of the other autonomic responses, the plethysmograph is most like the GSR in the sense that the form of both responses to stimulation is relatively clear: a decrease in resistance and in volume pulse magnitude for the electrodermal and plethysmographic responses, respectively. On the other hand, since the type of change in heart rate and respiration produced by stimulation is less obvious, there was a real problem in identifying the response to be measured in the case of these autonomic indicators, quite apart from any question of conditioning, or of conditioned cross-modal differentiation.

Method.

Experimental design.--While it was intended to test training differentiation (TD) as in the previous experiment, the test of extinction differentiation was abandoned here, because CR strength could not be measured on reinforced (R) trials. The joint factors of relatively long CR latency (over 1.5 sec. for the

GSR) and the one-sec. interstimulus interval (ISI) were responsible for abandoning the ED test. In addition, because of the relatively rapid rate of GSR response habituation (Kimmel, 1959), the 41-trial test series used for the eyelid experiment was shortened to 23 trials. The orders used, therefore, were trials 1 to 23 in Tables 1 and 2 above, with the modification that the left-hand side subscripts for R trials for the MVL orders have no relevance, since the ED test was not employed. The number of conditions and Ss were the same as those described in the skeletal-response study, except that the sex factor was not counterbalanced over any of the other conditions. The other difference between the two experiments was the method of unpairing CS and UCS for control Ss. The control procedure used in the eyelid study presents more trials to the control group than to the experimental group. Given that the total session length is equated, this means a shorter average intertrial interval (ITI) for the controls relative to the experimentals. Since the ITI is known to be inversely related to GSR strength for values up to 40 sec. (Prokasy and Ebel, 1964), it was considered important to prevent this factor from favoring the experimental group. Ideally, one would want to equate all factors between the two groups except for the association between CS and UCS, but it is clear that it is logically impossible to concurrently equate the ITI, total session length, and the number and nature of stimuli received by the experimental (association of CS and UCS) and control groups. It was therefore decided to try to ensure that any difference between the two groups (aside from the CS-UCS association) would favor the controls. To this end, the control Ss received the same trials with the same ITI as the experimentals, but the CS was omitted on all reinforced (CS-UCS) trials. This procedure equates the ITI, total session length, and number of shocks (sensitization) received. The rationale assumes that response strength decreases as a function of number of CS presentations (habituation),

so that, in this sense, the control group is favored over the experimentals.

Apparatus.--The surroundings of S, the 300-msec. tone and light stimuli used as CSs, and the GSR pickup were the same as described elsewhere (Furedy, 1968). The intensities of the tone and the lights were adjusted so as to produce approximately equal GSRs for a group of 5 pilot Ss. The 200-msec. UCS was a 1.0 (weak) or 2.5 (strong) milliamp shock delivered from a constant-current source designed and constructed at Indiana University. The shock electrodes, 8-mm. dia., Grass silver, and coated with saline jelly, were taped approximately one in. apart on the ventral surface of the right forearm. One channel of an Offner type-R was used to record the plethysmograph, which was picked up photoelectrically, as described elsewhere (Furedy, 1968). A second channel was employed for recording heart rate (HR). A Lead II arrangement was used to pick up HR with saline-filled electrodes being placed on areas of the right arm and left leg from which the hair had been removed. By means of an integrator coupler, the HR recording channel produced beat-by-beat rates ranging from 40 to 120 beats per sec. Respiration changes were picked up with a strain gage mounted on an elastic belt placed around the waist, and amplified onto the third channel of the dynograph. The paper speed (for all three responses recorded on the dynograph) was 5 mm. per sec. The ITIs and nature of the stimuli on each trial were controlled by a Western Union tape transmitter and a system of switches which was similar to that employed in Exp. I.

Subjects.--The experiment proper used 192 students from introductory psychology classes at Indiana University who served both to satisfy a course requirement and to earn \$1.00. In addition, there were 8 Ss from the same source who were used in a pilot study to be described in the Results section below.

Procedure.--Since conditioning in the GSR appears to occur over far fewer trials than for the eyelid response (Prokasy, 1965, p. 215), there was no

attempt to train Ss to some criterion before administering the test series of trials. The 23-trial test series were preceded only by one presentation of each CS in order to obtain a pre-training sensitivity index for the tone and the light.

At the outset of the experiment, E, before attaching the electrodes, told S that one of the stimuli would be a weak electric shock, and that, on being shown this stimulus, S could discontinue the experiment if he felt the shock to be too severe; less than one percent of the Ss discontinued on these grounds. After attaching the electrodes (and explaining the purpose of each), E showed S a $\frac{1}{2}$ -milliamp., manually-delivered shock of approximately $\frac{1}{2}$ -sec. duration, and then instructed S as follows:

All you have to do in this experiment is to sit here in a relaxed and natural manner. You should avoid movement as much as possible, especially with your arms and hands, but don't stay rigidly still to do this. In addition to the shock, I shall sometimes present a light and sometimes a tone during the session. The light will consist of a brief increase of illumination in the room. It will come from up there (point), but you'll see it without looking up, because the whole room will be illuminated. The tone will come from a set of earphones which I'll put on you now. At the moment you'll hear a noise through them (put on). Now, although I have told you to relax, you should not go to sleep. The session will last about 30 minutes, and if you go to sleep you will lose the dollar you are to be paid for this experiment. So I want you to look fairly straight ahead most of the time. I'll be watching you every now and then without you knowing when, and if I find that you've closed your eyes or gone to sleep, you'll forfeit your dollar.

Do you have any questions? I shall now leave you, and, after a little while, I'll let you know over the intercom that the session is starting.

Following instructions, Ss were presented with the initial CS-alone trials, which were followed by the 23-trial test series, where, for the control condition, the CS was omitted on R trials. When paired with the CS, the UCS followed CS onset by 1 sec. in a trace-conditioning paradigm. The ITI for all conditions was randomly varied between $37\frac{1}{2}$, 45 (mean), and $52\frac{1}{2}$ sec. The Ss were randomly allocated to groups and conditions until 192 Ss had been run, resulting in the

double and single replication, respectively, of all conditions in the experimental and control groups.

Results.

Response definitions.--The definitions of the electrodermal and plethysmographic responses were relatively simple and required no preliminary investigation. The GSR, a drop in skin resistance initiated between one and four sec. after stimulus onset, was transformed into conductance change (ΔC) scores in micromhos, a measuring method which has been used elsewhere (Furedy, 1963). The plethysmographic digital blood volume pulse change (VPC) was also measured in the same way as detailed elsewhere (Furedy, 1968). Briefly, this method involves defining the vasoconstriction as the algebraic difference between the pulse at response termination (minimal pulse) and that at response onset (maximal pulse) expressed as a percentage of the magnitude of the latter pulse.

To determine the form of the unconditioned response in the HR and respiration indicators, 8 SS were given 16 shock-alone trials in a series in which 8 strong and 8 weak shocks were ordered unsystematically. Inspection of the HR records did not make it clear whether the typical response to stimulation was an accelerative, decelerative, or some biphasic function. Indeed, it was not apparent that stimulation had a reliable effect on HR which could be distinguished from non-stimulus connected changes. In looking for the response, therefore, an equivalent pre-stimulus period was examined to determine the degree to which the post-stimulus changes could be attributed to stimulation. The post- and pre-stimulus periods were the 10 sec. intervals immediately following (F) and preceding (P) stimulus onset. Acceleration was defined as the difference in HR between the basal rate at the beginning of the 10 sec. period and the maximal HR period during the 10 sec. period; the maximal period itself was defined as the mean HR of the fastest beat and the beats immediately following

and preceding that beat. The measurement of deceleration was identical to that of acceleration except for the substitution of minimal for maximal Hk periods. In addition, to look at the possibility of a biphasic response, an overall change measure was used, which was the arithmetic sum of the acceleration and deceleration scores. The index of sensitivity of a given form of the response (acceleration, deceleration, or change) was simply the mean percentage of occasions that the F measure exceeded the P measure on a given trial. For change, deceleration, and acceleration, respectively, these indices were 46%, 48%, and 71%. Since it was possible that Ss varied consistently in their mode of response, a combined acceleration-or-deceleration scoring method was tried in which only 6 of the 8 Ss were scored for acceleration in their P and F records; the remaining two Ss, who showed higher decelerations than the others in their F records, were scored for differences in P and F decelerations. The combined mean percentage of (F > P) occurrences, however, was only 65%, which was less than the pure acceleratory index of 71%.

The HR response definition adopted was therefore based on maximum acceleration within 10 sec. following (F) stimulus onset. However, because of the obvious presence of "noise" (n) in the system, the response measure included an equivalent prestimulus (P) control period where the greatest acceleration from the onset of the control period was also measured. The HR acceleration was defined as a percentage-signal-detection (%SD) score where the n and signal-noise (sn) were represented, respectively, by the P and F responses. For any given trial, if the response to n (Rn) was less than the response to sn (Rsn), %SD was equal to $100(Rsn - Rn)/Rsn$; for $Rn > Rsn$, $\%SD = 100(Rsn - Rn)/Rn$. It will be noted that the %SD measure, which is symmetrically weighted for sn and n scores, varies about zero from +100 to -100, and that average signal-detectability of a given form of the response is indicated by the size of any positive mean %SD score.

Inspection of the respiration records of the same 8 Se again did not suggest any obviously reliable response to stimulation. In particular, there was no clear change in respiration rate following stimulus onset. However, the records did suggest the presence of a greater apneic period following stimulation, this period being the interval between the end of exhalation and the beginning of the next inspiration (E-I interval). This increased period of not-breathing seemed to take place during the first respiratory cycle following stimulus onset. Since these cycles and the stimulus presentations were not coordinated, the following signal-detection procedure was adopted for determining the sensitivity of the apneic response. Using that relatively sharply pointed peak marking the end of inspiration and the beginning of the next expiration (I-E peak) which was closest to stimulus onset as a reference point, two P and two F respiratory cycles, respectively, were examined with I-E peaks immediately preceding and following the reference I-E peak. The interval measured for each of the four cycles was that between the I-E peak and the beginning of the next exhalation. This "apneic" interval (AI) contains the inspiration as well as the true apneic period. However, the former period is usually fairly constant, while, in some cases, the end of inspiration is difficult to locate precisely. The inspiration period was therefore included in the AI interval. For each trial, the larger of the two F intervals was compared to the larger of the two P intervals. The mean percentage of time that the larger F AI score exceeded the larger P AI score was 75%. The respiration response definition adopted, in terms of the apneic interval (AI), was a %SD score constructed in the same way as the HR measure, except that the noise (n) and signal-noise (sn) responses were defined, respectively, in terms of the P and F AI scores.

Finally, it should be noted, that neither the HR nor the respiration measures of the pilot study seemed to indicate any differential responding as a

function of shock intensity. On the other hand, both the plethysmograph and the GSR did differentiate significantly between the two shock intensities, $p < .05$ and $p < .01$, respectively, by a sign test.

Conditioning and nature of CS.--The four panels in Fig. 13 show performance in the four autonomic response modes: electrodermal (GSR), plethysmographic (VPC), heart rate (HR) and respiration (RESP.). In each panel, mean performance is plotted for the initial pre-training, CS-alone trial (PREL) and the consequent two pairs of CS-alone (N) trials (1-2 and 3-4, respectively) which occurred during the 23-trial test series (see Tables 1 and 2 above). The two parameters in each panel are the conditioning (experimental-control) and NC (tone-light) factors.

A three-factor analysis of variance for unequal groups, using an unweighted-means solution (Winer, 1962) was applied to the GSR scores. The divergence between experimentals and controls over trials was significant as indicated by the conditioning \times trials interaction, $F(2, 380) = 8.274$, $p < .001$. In addition, performance to the tone was significantly superior to that to the light, $F(1, 190) = 8.385$, $p < .01$, and there was a significant increase of performance over trials, $F(2, 380) = 5.059$, $p < .01$. Finally, the superiority of the experimental relative to the control group was near-significant, $F(1, 190) = 3.351$, $p < .1$, as was the second-order interaction between the conditioning, nature-of-CS, and trials factors, $F(2, 380) = 2.644$, $p < .1$. The GSR panel of Fig. 13 indicates that this interaction arose from an apparent difference between the experimental and control groups with respect to the development of the tone-light difference over trials. All other effects failed to approach significance, $F < 1$.

The divergence between experimentals and controls over trials was also significant for the plethysmographic VPC, $F(2, 380) = 21.539$, $p < .001$, as was

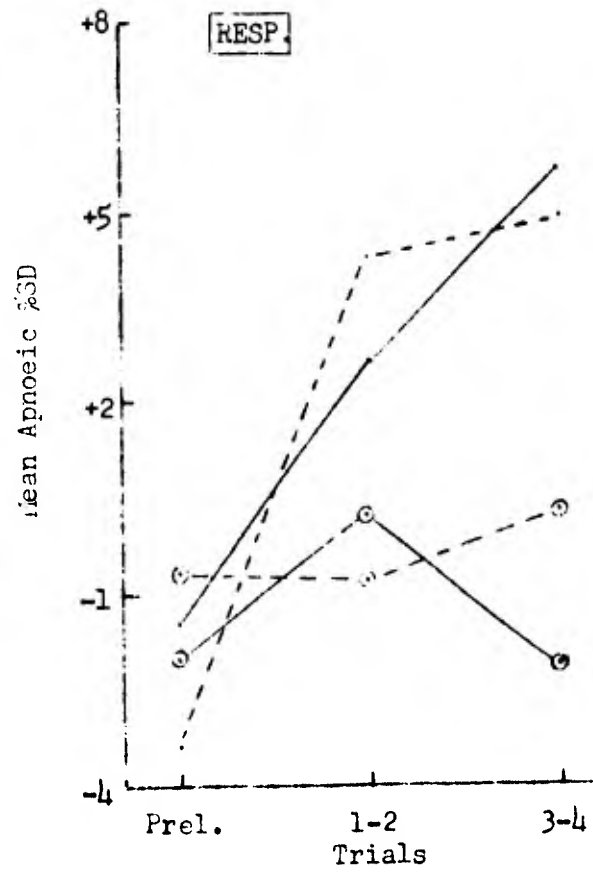
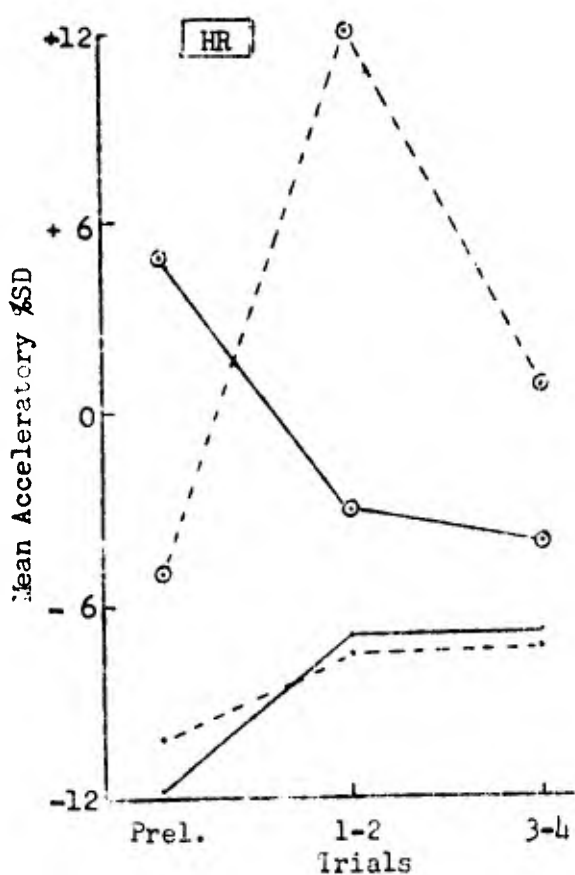
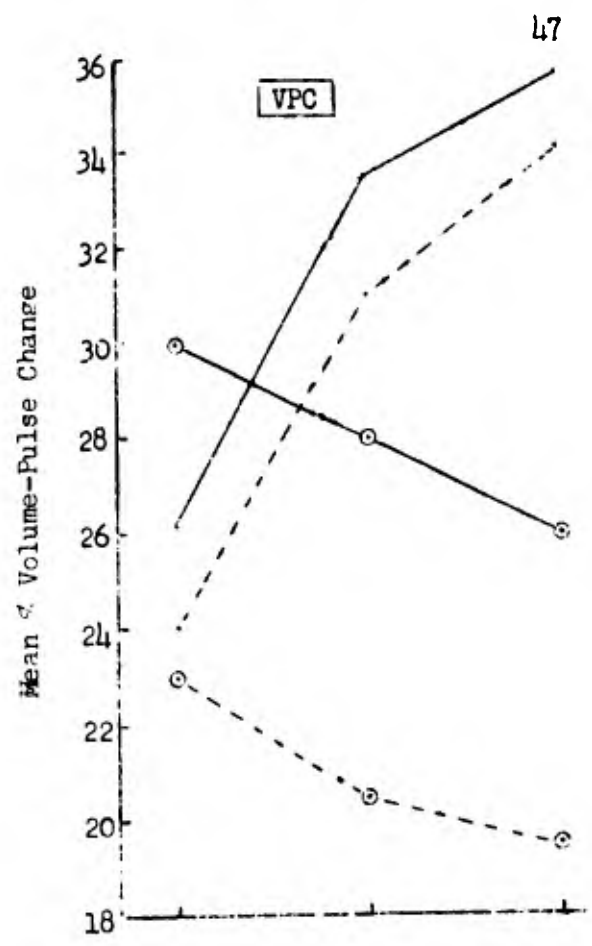
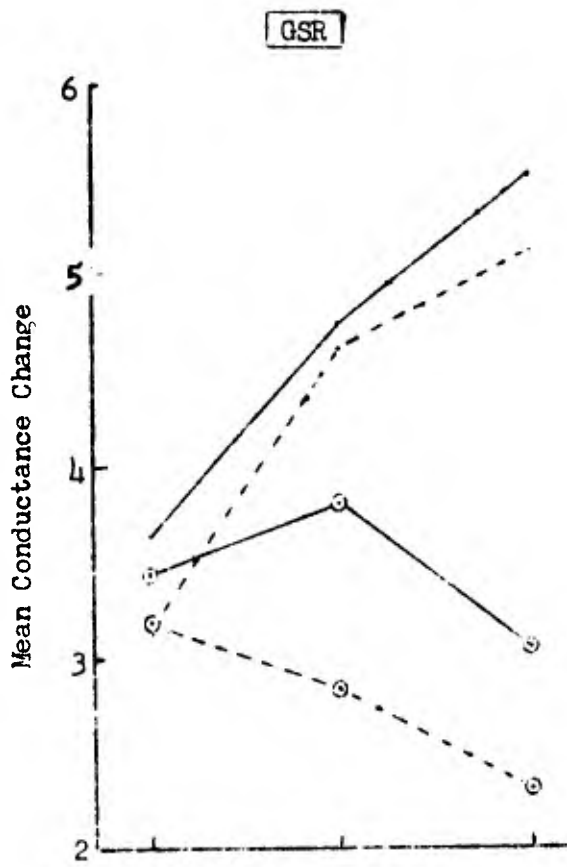


Figure 13

the superiority of tone over light, $F(1, 190) = 28.298$, $p < .001$, and the increase of performance over trials, $F(2, 380) = 3.892$, $p < .05$. However, unlike GSR, the VPC showed a significant nature-of-CS x conditioning interaction, with the T-L difference being smaller for the experimental (paired CS-UCS) group than for the controls. All other effects failed to approach significance, $F < 1.8$, $p > .2$.

Statistical analysis was not applied to the HR data, because, not only do the means depicted in Fig. 13 not show any conditioning trend, but the obtained mean %SD values do not suggest that the response following the stimulus (signal-noise) was any greater than that preceding the stimulus (noise). For these reasons, also, no further examination of the HR results were made in connection with other aspects of the experiment to be reported below.

The respiration (RESR) means in the lower right panel of Fig. 13 also show relatively low %SD values, but the apparent divergence between experimental and control groups over trials does indicate a conditioning trend. The three-way analysis of variance showed that this conditioning x trials interaction only approached significance, $F(2, 380) = 2.681$, $p < .1$, although the overall superiority of the experimental relative to the control group was significant, $F(1, 190) = 5.766$, $p < .05$, despite the inferiority of the experimentals on the initial CS-alone trial (PREL). There was also a significant trials effect, $F(2, 380) = 4.622$, $p < .05$, with a monotonic increase over trials. All other effects failed to approach significance, $F < 1$. Although the evidence for conditioning in respiration was not nearly as convincing as that for GSR or VPC, and although the apneic respiratory response itself to the CS was very small in comparison to non-stimulus-connected fluctuations (noise), respiration was included with the GSR and VPC in the examination of other effects to be described below.

UCS intensity between subjects.--The three panels of Fig. 14 show electrodermal, plethysmographic, and respiratory performance, respectively, of the two sets of 32 experimental Ss for whom the paired shock was always strong (STR) and weak (WEA), respectively. The NC factor (tone-light) is the other parameter, while the two pairs of CS-alone (N) trials following the initial CS-alone trial are shown on the abscissae. For added precision, a covariance adjustment based on initial, pre-training response levels, was applied to the UI (STR-WEA) between-Ss comparison in the analysis of variance. For the GSR, the (adjusted) UI effect did not reach significance, $F(1, 61) = 2.012, p > .1$ ($r = .518$ between initial and training GSR levels), although the direction of the effect was in the expected direction. The only significant effect was an increase of responding over trials, $F(1, 62) = 4.201, p < .05$; all other effects failed to approach significance, $F < 1$.

The UI effect in the VPC did not approach significance, $F < 1$ ($r = .687$ between initial and training VPC levels). There were near-significant, $p < .1$, effects due to NC (T superior to L), $F(1, 62) = 3.870$, and to a second-order NC x UI x trials interaction, $F(1, 62) = 3.115$. The VPC panel indicates that the form of this interaction arose from T being superior to L in all cases except trials 1-2 with the WEA group. All other effects failed to approach significance, $p > .1$. Respiration indicated no significant UI effect, $F < 1$ ($r = .109$ between initial and training RESP. levels), nor did any other effects approach significance, $F < 1$.

The data for the two sets of 16 control Ss in the STR and WEA groups are plotted in Fig. 15 in the same way as for the experimentals in the previous figure. The same statistical analyses as those performed for the experimental Ss indicated that the inverse UI effect on the GSR (STR inferior to WEA) did not approach significance, $F < 1$ ($r = .367$ between initial and training GSR levels),

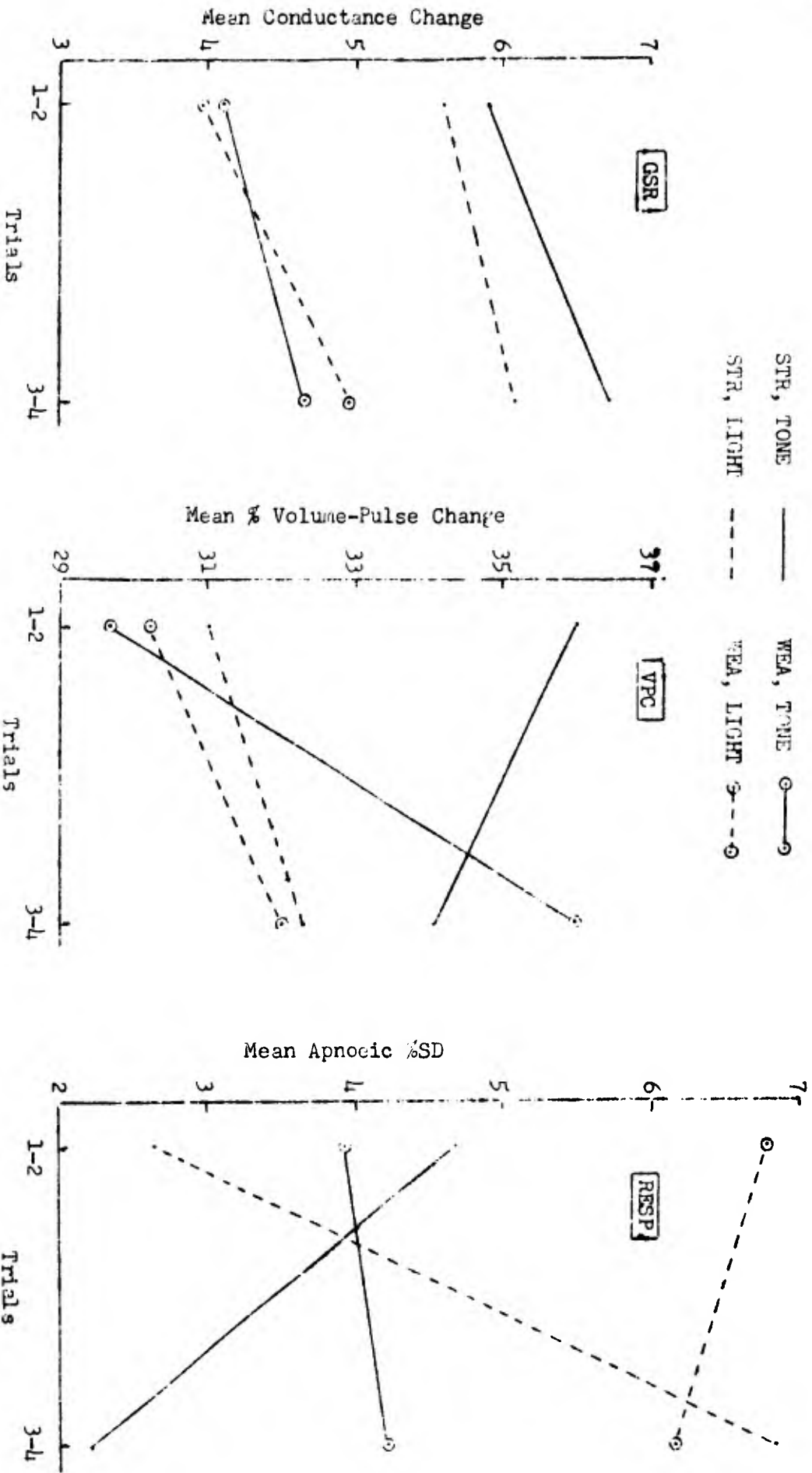


Figure 14

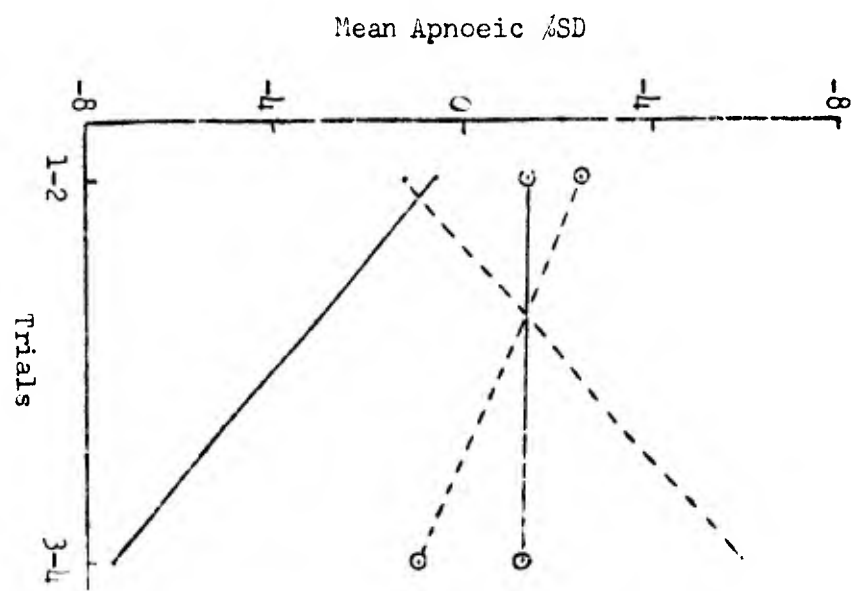
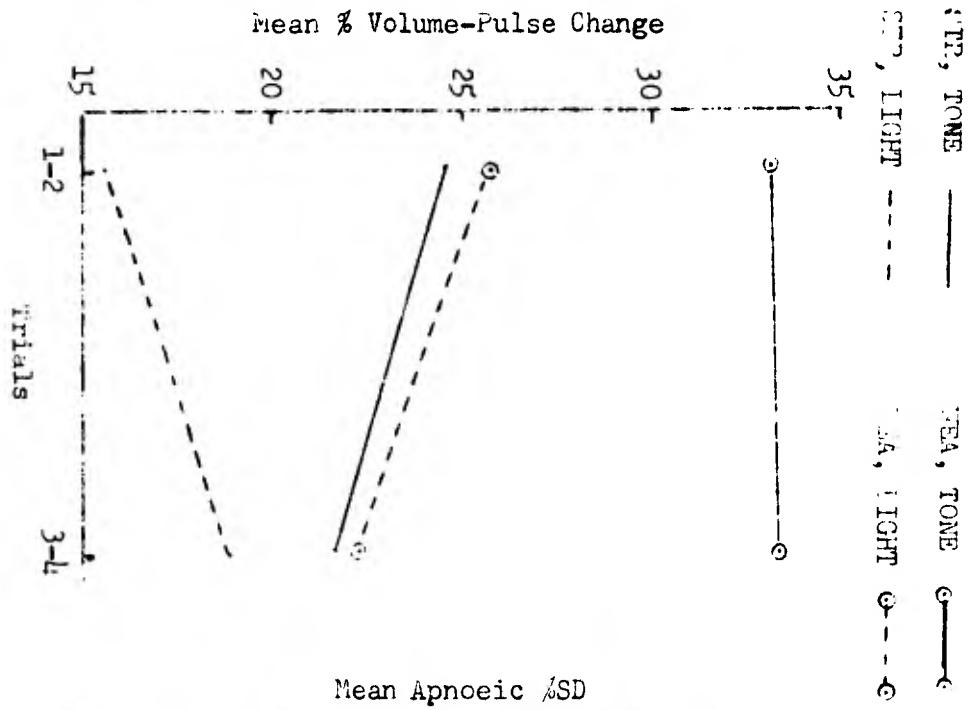
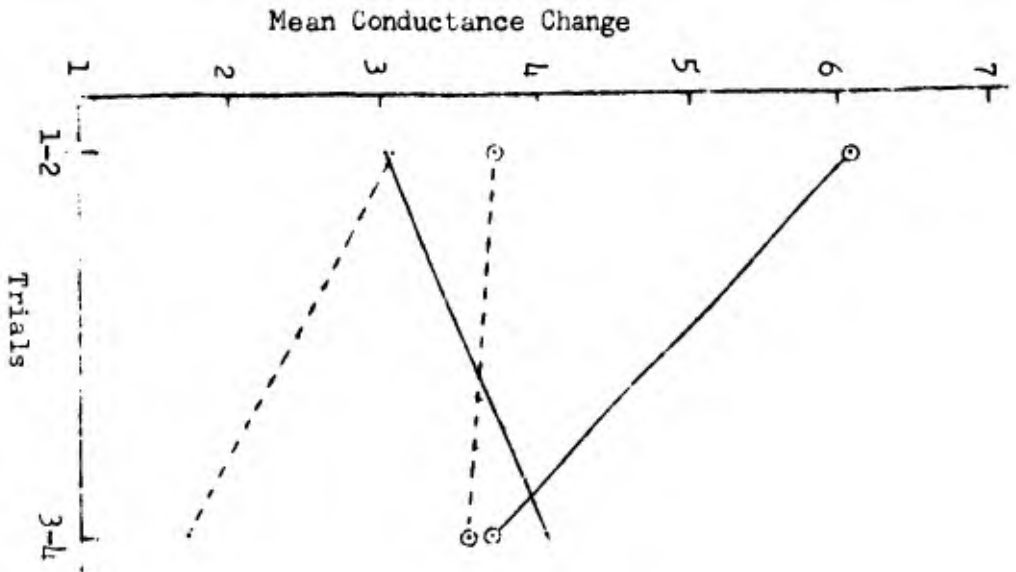


Figure 15

but there were significant $p < .05$, GSR effects due to NC, with T superior to L, $F(1, 30) = 4.464$, to trials, with a decrease of responding over trials, $F(1, 30) = 5.927$, and to a second-order UI x NC x trials interaction, $F(1, 30) = 5.545$. Inspection of the left panel of Fig. 14 indicates that the source of this interaction was that the decrease over trials was present mainly with the T for the WEA group and with the L for the STR group. Finally, the GSR analysis indicated a near-significant, $p < .1$, UI x trials interaction, $F(1, 30) = 3.141$, with a greater decrease over trials for the WEA than for the STR group.

The inverse UI effect shown in the VPC panel of Fig. 1 was near-significant, $F(1, 29) = 3.862$ ($r = .547$ between initial and training VPC levels), $p < .1$, and the T was significantly superior to the L, $F(1, 30) = 11.117$, $p < .005$; all other effects failed to approach significance, $p > .1$. The respiration analysis indicated no significant UI effect, $F < 1$ ($r = -.159$ between initial and training RESP. levels), nor did any other effects approach significance, $p > .1$.

Training differentiation.--The effect of TD, as represented by the difference between sets of N(S,d) and N(s,D) trials, was examined only in the experimental group. The first analysis concerned those Ss for whom the reinforcement schedule was identical (MV1) for the two CSs during the 23-trial test series. For later comparison purposes with the MV5 Ss, the test points used were trials 8 and 11 from Table 1 above, since it was at these points that the variation was maximal in the MV5 Ss. The left-hand column of panels in Fig. 16 show mean performance in the three autonomic modes as a function of the TD, UV (VAR-CON), and NC (T-L) factors. Since no difference was found between the mean N(S,d) and N(s,D) response levels for the GSR, the F value for the TD effect was zero; nor did any of the other effects approach significance, $F < 2.2$, $p > .1$. The superiority of the N(S,d) trials relative to the N(s,D) trials in the VPC did not approach

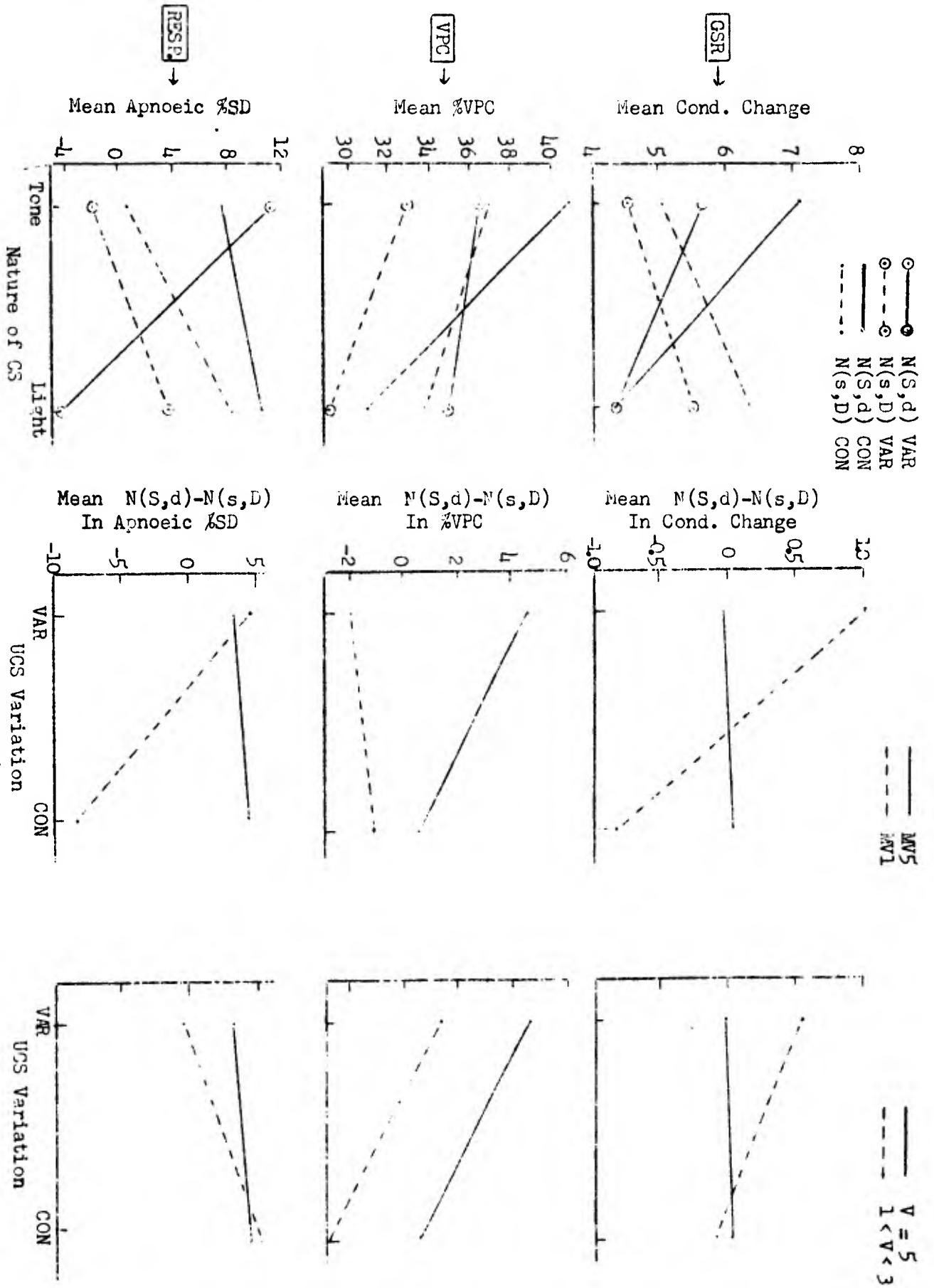


Figure 16

significance, $F(1, 60) = 1.042$, $p > .1$, and, apart from a near-significant superiority T relative to L, $F(1, 60) = 3.036$, $p < .1$, none of the remaining VPC effects approached significance, $F < 1$. In the respiratory mode (RESP), the superiority of the VAR relative to the CON \underline{S} s was near-significant, $F(1, 60) = 2.900$, $p < .1$; the TD and all other effects failed to approach significance.

Since none of the above comparisons indicated any evidence of cross-modal differentiation for the MV1 \underline{S} s, the next step was to determine whether there was any more differentiation manifested by the MV5 \underline{S} s. For these comparisons, TD difference scores were obtained for each experimental \underline{S} by taking algebraic differences between pairs of N(S,d) and N(s,D) trials drawn from trials 8 and 11 from Tables 1 (MV1 \underline{S} s) or 2 (MV5 \underline{S} s) above. It will be noted that the s : d variation (V) was maximal (V5) for the MV5 \underline{S} s at these points. The middle row of panels in Fig. 16 shows this relative TD in the three autonomic modes as a function of the MV (MV5-MV1) and UV (VAR-CON) factors. In the GSR, the mean TD of the MV5 group was inferior to that of the MV1 group, although the MV x UV analysis of variance indicated that this effect did not approach significance, $F < 1$. There were near-significant, $p < .1$, effects due to UV, $F(1, 124) = 3.562$, with greater TD in the VAR than in the CON group, and to a UV x MV interaction, $F(1, 124) = 3.751$, with the VAR-CON effect seeming to be present only for the MV1 \underline{S} s. The analysis of the VPC results indicated that none of the three effects of MV, UV, and MV x UV interaction approached significance, $F < 1.3$, $p > .1$. Similarly, there were no significant effects on TD in the respiratory mode, $F < 1.8$, $p > .1$.

Since the above tests of the MV variable included the V factor itself, the failures to find significant MV effects in any of the three response modes suggested that the actual s : d variation (V) would not affect TD. However, the effect of V was examined for the MV5 \underline{S} s in case this within- \underline{S} comparison proved

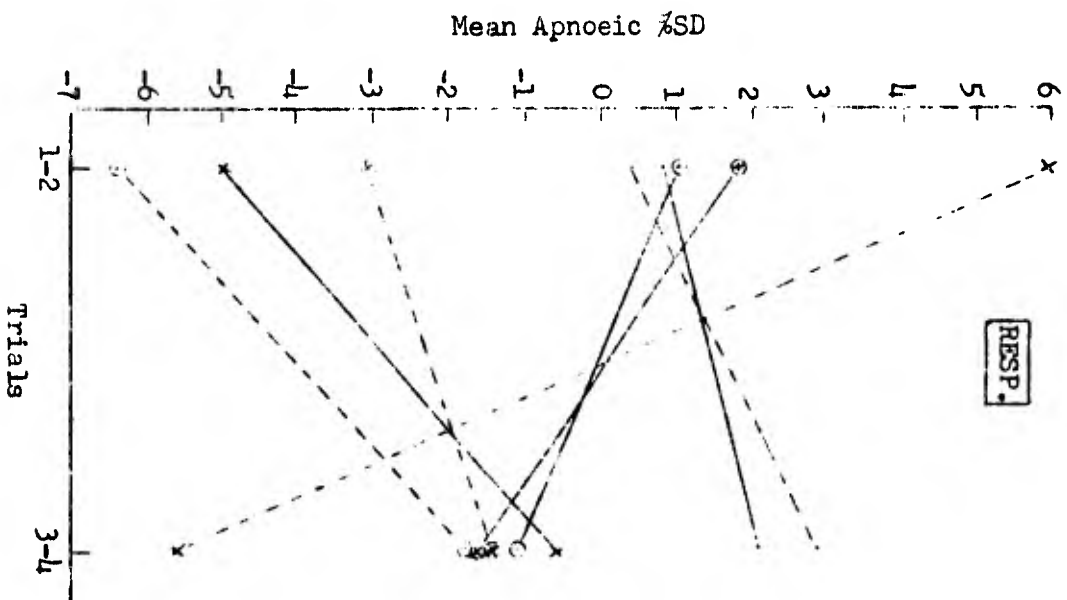
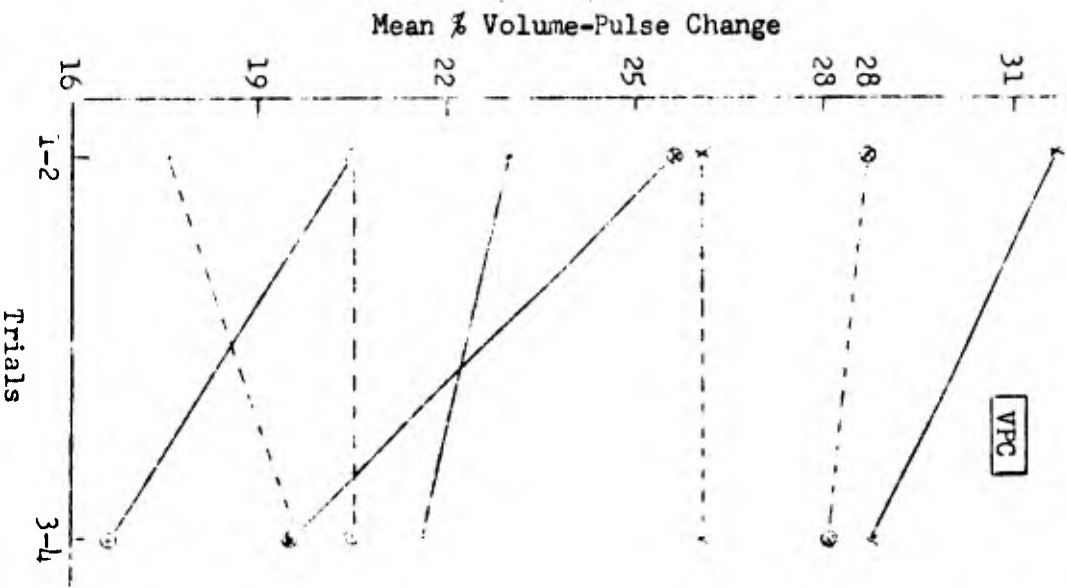
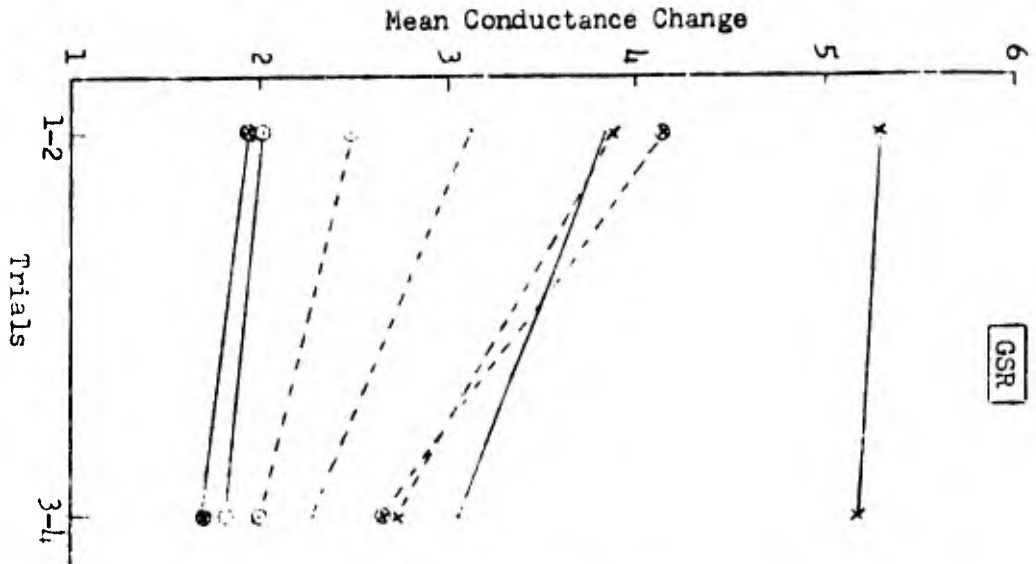
to be more sensitive than the previous between-S comparison. The high-V ($V = 5$) $N(S,d)$ and $N(s,D)$ trials were drawn from trials 8 and 11 of Table 2 above. To obtain the low-V ($1 \leq V \leq 3$) $N(S,d)$ and $N(s,D)$ trial pairs, all the remaining N trials of the 23-trial test series were used, so that the mean V value of the low-V trials was 2. The right-hand column of panels in Fig. 16 shows the mean TD difference scores in the three response modes as a function of the V (high-low) and UV (VAR-CON) factors. In the GSR, the mean TD on high-V trials was less than that on low-V trials, although the two-way analysis of variance indicated that neither this V effect nor the MV and MV x V interaction effects, approached significance, $F < 1$. In the VPC, the high-V trials did produce greater TD than did the low-V trials, but again, neither this V effect, nor the remaining two effects, approached significance, $F < 1.4$, $p > .1$. The respiratory mode results, like the VPC, indicated greater TD on the high-V than the low-V trials, but again, none of the three effects approached significance, $F < 1$.

Since the MV5-MV1 variation had no effect on TD in any of the three response modes, it was decided to check whether any TD differences may have been obscured by certain overall differences in CR strength between the two MV groups. Fig. 17 shows the mean GSR, VPC, and RESP. performance of the experimental Ss on CS-alone (N) trials as a function not only of the MV factor but also of the UV (VAR-CON), NC (T-L), and trials factors. For added precision, the between-Ss MV and UV effects were adjusted by covariance analysis on the basis of pre-training, initial response levels. For the GSR, the (adjusted) MV effect was near-significant, $F(1, 123) = 2.864$, $p < .1$ ($r = .533$ between initial and training GSR levels), with superior performance by MV5 Ss. The only significant effect was an increase in performance over trials, $F(1, 124) = 6.188$, $p < .05$; all other effects failed to approach significance, $F < 1.9$, $p > .1$. For the VPC,

the (adjusted) UV effect was near-significant, $F(1, 123) = 3.389$, $p < .1$ ($r = .611$ between initial and training VPC levels), with superior performance by VAR Ss. There were also significant, $p < .05$, effects due to NC, $F(1, 124) = 4.069$, with T superior to L, and to trials, $F(1, 124) = 5.008$, with an increase in performance over trials. All other effects failed to approach significance, $F < 1.5$, $p > .1$. For the respiratory mode, no effects approached significance, $F < 2.1$, $p > .1$ ($r = .098$ between initial and training RESP. levels).

The influence of the MV and UV factors on response levels was also examined in control Ss, the mean performance of whom is shown in Fig. 18. The same mode of analysis was applied as that for the experimental Ss. For the GSR, there were significant, $p < .01$, effects due to NC, $F(1, 60) = 7.099$, and to trials, $F(1, 60) = 7.990$, with T superior to L, and an increase of responding over trials, respectively. There was also a near-significant second-order MV x UV x NC interaction, $F(1, 60) = 3.634$, $p < .1$, which seemed to arise from the T being markedly superior to L under all combinations of the MV x UV conditions except for the MV5 Ss given variable-intensity (VAR) shocks. All other effects failed to approach significance, $F < 2.2$, $p > .1$ ($r = .483$ between initial and training GSR levels). For the VPC, the only significant effect was the markedly superior performance on T relative to L trials, $F(1, 60) = 20.233$, $p < .001$; all other effects failed to approach significance, $F < 2.1$, $p > .1$ ($r = .568$ between initial and training VPC levels). For the respiratory mode, no effects approached significance, $F < 2.1$, $p > .1$ ($r = -.052$ between initial and training GSR levels).

UCS intensity within subjects.--The effect of within-Ss UI was examined in those experimental Ss for whom UCS intensity varied (VAR). Fig. 19 shows mean performance in the three autonomic modes of these Ss as a function of the UI factor, as well as of NC (T-L), MV (MV5-MV1), and trials. The analysis of the



VAR & CON: o & .
 MW5 & MW1: — & - -
 Tone & Light: x & .

Figure 18

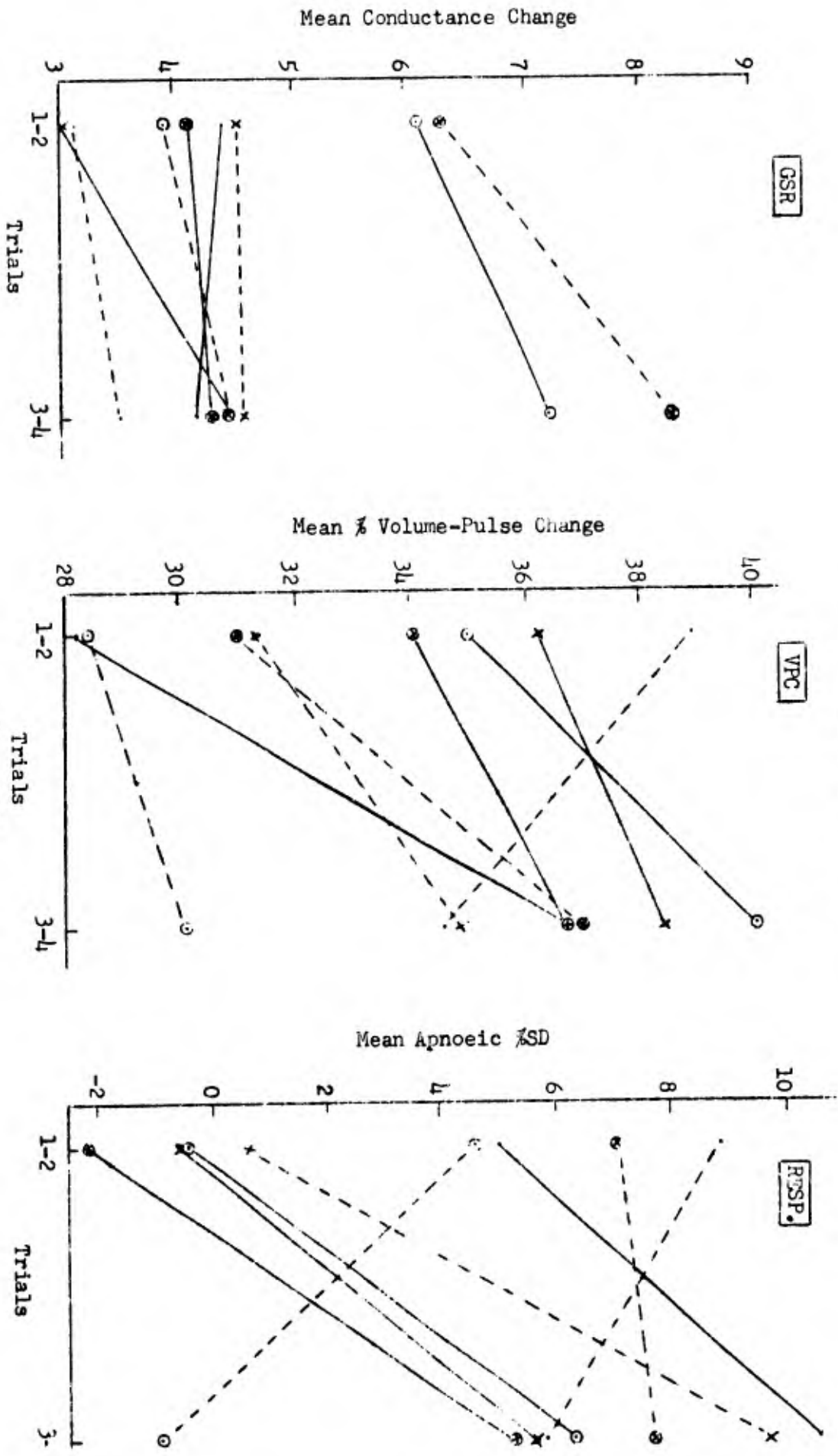


Figure 19

GSR data indicated that no effects approached significance, $F < 2.3$, $p > .1$. However, in the VPC, there was significantly superior performance to CSs paired with the strong (STR) UCS relative to those paired with the weak (WEA) UCS, $F(1, 60) = 4.713$, $p < .05$, as well as a significant MV x UI interaction, $F(1, 60) = 4.684$, $p < .05$. There was also a near-significant increase of performance over trials, $F(1, 60) = 3.492$, $p < .1$; all other effects failed to approach significance. Separate analyses of the MV x UI interaction showed that STR was significantly superior to WEA within the non-identical reinforcement (MV5) S_s , $F(1, 30) = 10.120$, $p < .01$, but the UI effect was not significant within the MV1 S_s , $F < 1$. In the respiratory mode, there was only a near-significant increase of performance over trials, $F(1, 60) = 2.792$, $p < .1$; all other effects failed to approach significance, $F < 2.7$, $p > .1$.

Discussion.

As regards the electrodermal (GSR) and plethysmographic (VPC) response modes, the highly reliable divergence over trials between experimentals and controls (Fig. 13) suggests that the CS-UCS pairings did produce conditioning, provided one accepts the assumption stated above, that the omitted-CS method used for the control group could only have introduced non-associative factors favoring that group. The tone produced reliably greater GSRs and VPC responses than did the light, and these tone-light differences appeared to be greater in the control than in the experimental group. However, the nature of this NC x conditioning interaction in the GSR and the VPC was not such as to undermine the view that reliable associative electrodermal and plethysmographic conditioning had occurred in the present experiment.

In contrast, the HR data did not indicate any conditioning, even in terms of the trends exhibited by the means of the 192 S_s as plotted in Fig. 13 above. Indeed, there was no suggestion that the presence of the CS produced any greater

acceleratory HR response than that which occurred in the absence of the CS. At the same time it must be recognized that the method employed in this study to look for conditioning in the various response systems assumes a similarity of form between the UCR and the CR, whereas much of the HR conditioning literature suggests that while the UCR is always an acceleration, the CR can be deceleratory in form (e.g., Black, 1965; Zeaman and Smith, 1965). The HR tracings following CS onset were examined for such decelerations in the present study, but no obvious trends were apparent. It was not deemed worthwhile to undertake more subtle statistical investigations in search of such non-acceleratory CRs, because of the danger that one can always find some statistically significant trend in any set of data provided enough aspects of that data are examined. However, to allow for the possibility of non-acceleratory CRs, it is safer to interpret the present results only as suggesting that, even with large samples, a UCR-like CR does not emerge as a reliable laboratory phenomenon in HR conditioning.

Some degree of respiratory conditioning, in its apneic form, did emerge from the results (Fig. 13), as indicated by the near-significant divergence of experimentals from controls over trials, and the marginally significant superiority of the former relative to the latter group over all trials. However, when one recalls the number of Ss needed to obtain these levels of significance, the reliability of apneic human conditioning is not strikingly impressive.

Turning now to the question of training differentiation (TD) within the experimental group, as manifested by superior performance on N(S,d) relative to N(s,D) trials, there was no evidence for such differentiation in any of the three response modes which were examined (Fig. 16, left column of panels) for Ss run under the identical reinforcement schedule (MV1). Nor did the data suggest that for Ss presented with the non-identical reinforcement schedule (MV5), TD was any greater than for the MV1 Ss (Fig. 16, middle column of panels).

Finally, the manipulation of the V factor independently of MV was also ineffective in influencing TD for any of the three examined autonomic modes (Fig. 16, right column of panels). The only hint that varying the reinforcement-schedule factor between CSs, and hence between CSs paired with different intensity UCSs, may have influenced the degree of differentiation was the significant $UI \times MV$ interaction obtained for the plethysmographic mode (Fig. 19, middle panel), an interaction which indicated the presence of a within- S UI effect only for S_s presented with the non-identical reinforcement schedule ($MV5$). However, apart from this isolated result, the data, taken together, did not indicate either that cross-modal autonomic differentiation had occurred, or that either the reinforcement-schedule manipulation or the UCS-variation manipulation was effective in increasing the degree of differentiation.

On the face of it, the apparent lack of cross-modal differentiation indicates that, as in the earlier GSR experiment which used only an identical reinforcement schedule (Furedy, 1965), the two physically dissimilar CSs were the same for the three conditioned autonomic responses examined in the present study, even under those conditions where the reinforcement schedule was non-identical ($MV5 S_s$). Because these results are both unexpected and not in line with those obtained from Exp. I with the skeletal eyelid response, it is worth considering an alternative interpretation of the lack of obtained differences between $N(S,d)$ and $N(s,D)$ trials, a lack which was described at the outset as indicating total generalization of training between the two CSs. Implicit in such an interpretation is the assumption that the gradients of conditioned autonomic generalization of the sort reported by Hovland (1937) constitute a phenomenon which is both reliable and whose basis lies simply in the processes involved in simple associative conditioning. Recently, however, both the reliability (Epstein and Burstein, 1966) and apparent simplicity (Corman, 1967) of this phenomenon have been

challenged. The basic idea behind these suggestions is that in addition to the factor of the associative, generalized CR, the strength of which is directly related to the similarity between the test CS and the originally reinforced CS, another factor is also involved in determining the magnitude of the observed autonomic response to the test CS. This additional factor is the partially habituated orienting reaction (OR) to the reinforced CS, and the influence of this OR factor is opposed to that of the associative CR factor, because the strength of the OR to the test CS is inversely related to the similarity between the reinforced and test CSs. Admitting the presence of such an OR factor therefore makes it impossible to predict the simple conditioned generalization gradient, since the magnitude of the observed autonomic response has to be seen as depending on the two opposing factors of associative conditioning and "partial OR inhibition" (Corman, 1967, p. 240).

The interaction of such opposed forces can be plausibly applied to the $N(S,d) : N(s,D)$ outcomes of the present autonomic experiment. Thus, while the associative factor of previous number of reinforced trials favors the $N(S,d)$ set of trials, the OR-inhibition factor favors the $N(s,D)$ set of trials, since there has been less exposure (and hence inhibition) to the CS being tested than to the different CS from that being tested. The phenomena on which the OR-inhibition account ~~are~~ based, i.e., the inhibition and disinhibition of the autonomic components of the OR to stimulus repetition and change, respectively, are themselves not clearly understood (Furedy, 1968), but in the present case the notion of OR inhibition has enough cogency for one to doubt the validity of the $N(S,d) : N(s,D)$ test of TD for autonomic CMD. Moreover, it is not easy to suggest ways of overcoming this difficulty, because the operations thought to produce autonomic conditioning appear to be closely related to those thought to influence OR inhibition. However, the use of a longer interstimulus interval (ISI) of at least

8 sec. may provide more informative results concerning autonomic CMD, not only because this longer ISI would permit assessment of ED as well as TD (as in Exp. I with the eyelid response), but also because of the possibility that some of the multiple responses observed with the use of such longer ISIs may be shown to be independent of the influence of CR processes.

As regards the effects of varying UCS intensity, despite the relatively clear conditioning effect with the GSR and VPC, the between-Ss UI manipulation for the CON Ss of the experimental group failed to produce reliable differences in either of these two autonomic response modes, or in the respiratory mode (Fig. 15). Since varying shock intensity between 1.0 and 2.5 milliamps represents a considerable portion of the range of variation that it is possible to use with human Ss, and since the sample sizes of the two groups of 32 Ss in each group are quite large, the present failure to obtain orderly results with respect to the between-Ss UI variation speaks poorly for the sensitivity of human autonomic conditioning as an index of stimulus differences.

Failure to obtain a reliable between-Ss UI effect in the GSR has been reported by Wickens, Allen, and Hill (1963), who varied the shock intensity over the same current values as those used here, and whose ample size of 40 Ss in each of the STF and WEA groups is comparable to that used in the present study. More recently, however, Wickens and Harding (1965) have reported that a within-Ss UI manipulation did produce reliable differences, despite the possible lack of adequate differentiation between the CSs, a differentiation which they did not assess. In the present study, the within-Ss UI manipulation, except for the plethysmograph, failed even to produce trends in the expected direction (Fig. 19). The lack of differentiation between the CSs may have been responsible for this failure, but no definitive conclusion is possible in the light of the failure to obtain reliable between-Ss UI effects, effects which did occur

clearly with the eyelid response in Exp. I.

Apart from the conditioning operation, the only other relatively effective manipulation of the GSR and VPC response was an unintended source of variation: the nature of the CS (NC). Although not significant in all cases, the superiority of the tone over the light emerged fairly reliably in the various analyses of the results, a fact which indicates that, as in Exp. I, the counterbalancing of the NC factor was a necessary precaution. Moreover, again as in Exp. I, although there were isolated instances of NC interactions of NC with some other variables, there were no significant interactions of NC with TD or UI, indicating that the counterbalancing for the NC, in this experiment, was a sufficient method of control (Furedy, 1967).

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Figure Captions

Fig. 1. Mean percentage CRs of experimental (N = 128) and control (N = 64) Ss during the test series of trials. (CS-UCS pairings occurred with a 67% and 0% frequency for the experimentals and controls, respectively.)

Fig. 2. Mean percentage CRs of control Ss given unpaired and constant-intensity (CON) strong (STR) or weak (WEA) UCSs during the test series of trials.

Fig. 3. Mean percentage CRs of experimental Ss for whom a constant-intensity (CON) strong (STR) or weak (WEA) UCS was paired with a CS with a 67% frequency during the test series of trials.

Fig. 4. Frequency distributions of trials-to-criterion scores of two groups of 96 Ss for whom a strong (STR) or a weak (WEA) UCS was paired with a CS with a 100% frequency during the training series of trials.

Fig. 5. Mean CR magnitude of experimental Ss run under the non-identical reinforcement schedule (MV5) and measured at trials of maximal s : d variation (V5) during the test series of trials. (The data shown in the left panel are broken down by trials in the middle and right panels which show, in addition to other effects, the effect of the nature-of-CS factor.)

Fig. 6. Mean CR magnitude of experimental Ss run under the non-identical reinforcement schedule (MV5) and measured at trials of minimal s : d variation (V1) during the test series of trials. (This figure is plotted under the same conditions as Fig. 5.)

Fig. 7. Mean CR magnitude of experimental Ss run under the identical reinforcement schedule (MV1) during the test series of trials. (This figure is plotted under the same conditions as Fig. 5, except for the substitution of stages for trials.)

Fig. 8. Mean TD scores $N(S,d) - N(s,D)$ in mm. as a function of both MV and V (Panel A), MV alone (Panel B), and V alone (Panel C), measured during the test series of trials.

Fig. 9. Mean percentage CRs of all experimental Ss during the test series of trials.

Fig. 10. Mean percentage CRs of all control Ss during the test series of trials.

Fig. 11. Mean CR magnitude of experimental Ss run under the identical reinforcement schedule (MV1) as a function of the ED, UV, and trials (left panel) or NC (right panel) factors, measured during the test series of trials.

Fig. 12. Mean CR magnitude of experimental Ss for whom a varied-intensity (VAR) UCS was paired with the two CSs with a 67% frequency during the test series of trials. (The two panels represent the levels of the MV factor, while the UI and NC factors are represented as parameters in both panels.)

Fig. 13. Electrodermal (GSR), plethysmographic (VPC), heart-rate (HR), and respiratory (RESP.) performance on CS-alone (N) trials as a function of conditioning (present vs. omitted CS on CS-UCS trials) and nature of CS (tone vs. light). (For experimentals and controls, $N = 128$ and $N = 64$, respectively.)

Fig. 14. GSR, VPC, and RESP. performance on CS-alone trials following initial CS-alone presentations of those experimental Ss for whom a constant-intensity (CON) strong (STR) or weak (WEA) UCS was paired with the CS with a 67% frequency. (The two factors of UCS intensity and nature of CS are represented as parameters in the three panels.)

Fig. 15. GSR, VPC, and RESP. performance on CS-alone trials following initial CS-alone presentations of those control Ss for whom UCS intensity (UI) was CON. (This figure is plotted under the same conditions as Fig. 14.)

Fig. 16. GSR, VPC, and RESP. training-differentiation (TD) effects in experimental group for MV1 Ss (left column), for all experimentals as a function of MV (middle column), and for MV5 Ss as a function of V (right column). (For details, see text.)

Fig. 17. GSR, VPC, and RESP. performance of all experimental Ss on CS-alone trials following initial CS-alone presentations.

Fig. 18. GSR, VPC, and RESP. performance of all control Ss on CS-alone trials following initial CS-alone presentations.

Fig. 19. GSR, VPC, and RESP. performance on CS-alone trials following initial CS-alone presentations of those experimental Ss for whom a varied-intensity (VAR) UCS was paired with the two CSs.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Psychology Department Indiana University Bloomington, Indiana		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3 REPORT TITLE Cross-Modal Generalization in Human Skeletal and Autonomic Classical Conditioning			
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Original Research			
5 AUTHOR(S) (Last name, first name, initial) Furedy, John J.			
6 REPORT DATE December 1967		7a. TOTAL NO. OF PAGES 71	7b. NO. OF REFS 27
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.		8a. ORIGINATOR'S REPORT NUMBER(S) Technical Report No. 22	
		8b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10 AVAILABILITY/LIMITATION NOTICES Distribution of this document is unlimited.			
11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY Dept. of the Navy Office of Naval Research Washington 25, D. C.	
13 ABSTRACT The extent of cross-modal generalization (CMG) was examined under identical and non-identical reinforcement schedules for tone and light as the two CSs. In Exp. I, the skeletal eyelid response of 128 Ss was conditioned with a 500-msec. CS-UCS interval, where an infra-orbital shock served as UCS. Exp. II employed a 1-sec. CS-UCS interval for 128 Ss with a forearm shock as UCS, and GSR, digital volume pulse change (VPC), heart rate, and respiration as the autonomic responses. Both experiments included groups of 64 Ss run as controls for conditioning, and this was reliably obtained in Exp. I. In addition, CMG in the eyelid CR was a reliable function of the reinforcement-schedule manipulation, as well as of within- and between-Ss manipulations of UCS intensity. In Exp. II, only the GSR and the VPC responses indicated reliable conditioning, but even with these responses the other factors shown to be effective in Exp. I did not produce reliable differences.			