

**DIFFERENTIAL RESPONDING WITHOUT DIFFERENTIAL
REINFORCEMENT: INTENSITY DIFFERENCE,
CONTINUUM POSITION, AND REINFORCEMENT
DENSITY EFFECTS**

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The response rates of five groups of rats were observed during exposure to different intensities of a four kilohertz tone within a two-component multiple schedule of nondifferential reinforcement. Response rates were found to be higher during the multiple schedule component which contained the higher intensity tone. Larger differences in response rates between the two multiple schedule components occurred with greater intensity separations (30 versus 20 decibels). At the 30 decibel separation a low absolute magnitude produced larger response rate differences than a high absolute magnitude, while at the 20 decibel separation a high absolute magnitude produced larger response rate differences. Increases in reinforcement density were accompanied by decreases in response rate differences between high and low intensity components only when over-all response rates also increased.

Key words: stimulus intensity dynamism, stimulus control, bar pressing, rats

Previous research has consistently demonstrated that sound intensity, per se, is capable of controlling response rate (Blue, 1967; Pierrel, Sherman, Blue, & Hegge, 1970; Sadowsky, 1966). The energizing effects of intensive stimuli on responding, sometimes referred to as stimulus intensity dynamism (Gray, 1965), have been measured in two ways.

The first method compares the speed of acquisition of stimulus control in two discriminations which utilize the same stimuli. If two stimulus intensities are used as discriminative stimuli, the acquisition of stimulus control should be equivalent, regardless of which stimulus is positive (i.e., responses are reinforced in its presence, S+) and which is negative (i.e., responses are extinguished in its presence, S-). A dynamism effect is seen if there is faster acquisition for the discrimination in which the more intense stimulus is S+. Sadowsky (1966), Blue (1967) and Pierrel et al. (1970) studied the acquisition of stimulus control by rats to various intensities of four kilohertz (kHz) tones in a two-component multiple schedule of differential positive reinforcement. In general, for a given pair of stimulus intensities, acquisition was faster when the high intensity was used as the S+ than when the opposite was true. Similar results have been

reported by Kamin (1965) using a conditioned suppression paradigm.

This method, however, is not satisfactory because it depends upon transitory differences in speed of acquisition. Differences in speed of acquisition form the basis of measurement in this method because asymptotic performances for a given intensity pair are generally equivalent. (Cf., Pierrel et al., 1970). Thus, any factor which affects acquisition speed will affect the ability of this method to detect stimulus intensity dynamism. Unfortunately, those stimulus parameters which are of interest in investigating the dynamism effect (e.g., absolute magnitude and intensity separation of a stimulus pair) are also known to influence speed of acquisition (Frick, 1948; Pierrel et al., 1970; Raben, 1949), so that this method may produce a confounded measure of dynamism.

A second method, which avoids the potential confounding effects of the speed of acquisition measure, employs a multiple schedule of nondifferential reinforcement. In this method, dynamism effects are detected by comparing response rates during the various stimulus intensities: i.e., a higher response rate should occur during a higher intensity stimulus. Using this method Kieffer (1965) found that rats emitted a higher response rate in the presence of a buzzer than in its absence. Likewise, the "special group" of Pierrel et al. (1970) exhibited higher response rates in the presence of the most intense of three 4-kHz tones, and

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the lowest rates in the presence of the least intense tone. Blue, Sherman, & Pierrel (1971), also using rats, demonstrated a positive monotonic relationship between response rate and the intensity of a 4-kHz tone that varied from 60 to 100 dB. In each case, the effects were stable, suggesting that this method is suitable for steady-state studies of dynamism.

Those studies which have used the non-differential reinforcement method, however, have not been primarily addressed to a systematic exploration of stimulus variables. Thus, in the "special group" of Pierrel et al. (1970) and in the Blue et al. (1971) study, although a wide range of stimulus intensities was used, there was no attempt to manipulate the intensity difference and absolute magnitude of stimuli in an orthogonal factorial design. Moreover, the stimuli in these studies were presented in groups of three to nine stimuli per session rather than as unique pairs. Responses to stimuli are known to depend upon the context in which the stimuli occur, and specific examples of the influence of the number of stimuli presented in a test session can be found in both the human (Helson, 1964) and animal literature (Marsh, 1967; Raslear, 1975). It would seem advisable, then, to also control this variable in studying dynamism.

The present study overcomes these problems by manipulating intensity difference and absolute magnitude in a 2 by 2 factorial design in which each group of animals is presented with only one stimulus pair under a multiple schedule of nondifferential reinforcement. All other conditions were maintained as similar as possible to those in the acquisition studies of Pierrel et al. (1970) in order to facilitate comparisons. Finally, reinforcement density was also examined, since pilot work had indicated that this variable was of potential importance.

METHOD

Subjects

Twenty male albino Sprague-Dawley derived rats were purchased from Charles River Breeding Laboratories, North Wilmington, Massachusetts. Each group of four rats was 80 to 100 days old at the beginning of experimentation. Free-feeding weights were obtained for the rats over a period of seven days, following which they were given restricted access to food

until they were reduced to 80% of their free-feeding weights. Body weight was maintained at this level during the course of the experiment by the food reinforcers obtained in experimental sessions. Water was available at all times.

Apparatus

Four 12.8 cubic foot (.336 m³) refrigerator shells were similarly adapted for use as sound-deadened enclosures. Each was shock-mounted and lined on all interior surfaces with 2 inch (5.1 cm) Fiberglas boards covered with Fiberglas cloth. The floor of the enclosure was built-up with Fiberglas blocks and the remaining space partitioned into experimental and equipment sections. The equipment section contained a pellet dispenser (Davis Scientific Instruments, Model PD-104, or Physiological Electronics, Model 801F) and a motor-driven, retractable, response lever. The pellet dispenser was used to deliver Noyes 45-mg food pellets. The experimental section measured 13.5 in. wide by 23.5 in. high by 15.0 in. deep (34.3 by 59.7 by 38.1 cm). The animal cage was constructed from stainless steel rods spaced .5 in. (1.27 cm) apart, mounted in a .25 in. (.63 cm) Lucite frame. The cage was 8.0 in. wide, 5.8 in. high and 5.0 in. deep (20.3 by 14.7 by 12.7 cm). The response lever required a force of .027 N to operate a microswitch. A food cup was located 1 in. (2.54 cm) to the right and below the point of entry of the bar into the cage. A stainless steel pan containing 2 in. (5.1 cm) of Ab-Sorb-Dri bedding material was located below the cage. Centered 7.5 in. (19.1 cm) above the cage was a University Tweeter (model 4401) and 4.75-W incandescent house-light. The shells were ventilated by a sound-silenced ventilating unit (Industrial Acoustics Co.).

When the chamber was closed and there was no imposed sound intensity, the ambient noise level in the mid-frequency range was 30 dB re 20 μ N/m², measured with a General Radio Sound Level Meter, Model 1551B, set to its "A" weighting scale. Within the animal cage, point-to-point differences in the intensity of a 4-kHz tone did not exceed 2 dB. These and all other calibrations of sound levels were made with a Bruel & Kajer Quarter-inch Condenser Microphone (Type 4136) in conjunction with a Bruel & Kajer Band Pass Filter (Type 1612) and a Bruel & Kajer Microphone Ampli-

fier (Type 2604). When using this equipment, the controls were set to RMS fast, linear 10-200,000 scale on the microphone amplifier, and the band pass filter was set to one-third octave around 4 kHz. Unattenuated sound levels were calibrated to be 100 dB re 20 $\mu\text{N}/\text{m}^2$ prior to the beginning of experimentation for each group of animals.

Sound generating, scheduling, recording, and ventilating equipment were located in adjacent rooms. Four kHz sinusoids of fixed intensity were produced by a Hewlett Packard Oscillator (Model 200CD). These were switched and amplified with a 50-msec rise/decay time. Signals from here were conducted through an attenuation panel, consisting of Daven Fixed Attenuators (T-691) and Potter and Brumfield relays (KHU17D12), where the signal could be attenuated by automatically switching in any of several attenuators. The signal was then distributed to four similar 2.0 watt amplifiers (custom built) which led to the speakers in the enclosures. The sound stimuli were presented as pulsed tones. The on-time was 1.5 sec and the off-time was 2.5 sec, as measured with a Hewlett Packard Electronic Counter (Model 5223L). All intensity changes occurred when the tone was in the "off" phase, eliminating audible switching transients. Bar insertion at the beginning of a session, sound levels and food reinforcement were scheduled by means of relay and timing circuits. Cumulative recorders, counters, printout counters, and an Esterline-Angus Event Recorder (model AW) were used to record data.

Procedure

Each group of four animals was studied separately over successive days. Bar training was accomplished on the first experimental day for each group. Each animal was placed in the experimental enclosure with the sound level set to infinite attenuation (no tone) and the response lever extended into the enclosure. Reinforcement was arranged to occur following the first response made after each 10-sec interval (Fixed Interval 10-sec). This schedule was in effect until the animals had collected 75 food pellets, whereupon the schedule was changed so that reinforcers would follow responses occurring after variable time periods averaging 2 min (Variable Interval 2-min). When each animal had received 75 to 80 pellets on the VI schedule, the animal was re-

turned to its home cage until all animals had completed this phase of the experiment. Then all rats were returned to the experimental enclosures where they remained until the completion of the experiment.

Groups I to IV. These groups were used to study the effects of intensity difference, absolute magnitude and within-session changes in reinforcement density on differential responding under nondifferential reinforcement. Two eight hour sessions were conducted daily from 12:00 midnight to 8:00 a.m. and from 12:00 noon to 8:00 p.m. The total time in each session was equally divided between two intensities of a 4-kHz tone. The intensities were selected so as to sample two intensity differences within two levels of absolute magnitude. Each group was exposed to only one pair of stimuli. This arrangement is shown in Table 1.

Table 1

Experimental design for investigating the effects of continuum position and intensity separation in Groups I to IV.

Decibel Difference	SOUND LEVELS IN DECIBELS Continuum Position	
	High	Low
30 dB	Group I: 100, 70	Group II: 90, 60
20 dB	Group III: 100, 80	Group IV: 80, 60

The stimuli were presented in a predetermined, counterbalanced sequence for periods of time ranging from 20 to 180 sec, with a mean of 72 sec. Independent of stimulus conditions, reinforcement was available according to a predetermined, counter-balanced sequence in which a VI 2-min schedule was in effect for half of the time and extinction was in effect for the remaining time. These arrangements permitted continuous comparison of response rates within each intensity condition under reinforcement and extinction schedules. During the four hours between sessions, the sound was off and the response levers were retracted. The animals were studied for a total of 80 experimental hours (5 days) under these conditions.

Group V. These animals were studied to determine the effects of between-session changes in reinforcement density on differential responding under nondifferential reinforcement.

Phase A: two four-hr sessions were conducted daily from 12:00 midnight to 4:00 a.m. and from 12:00 noon to 4:00 p.m. Reinforcement was available according to a VI 2-min schedule in each of two intensities of a 4-kHz tone (100 and 80 dB). During the eight hours between

Table 2
Partitioned Response Rates for Group I (100 dB, 70 dB)

Hours	RESPONSES PER MINUTE							
	VI Two Min.				Extinction			
	100 On	100 Off	70 On	70 Off	100 On	100 Off	70 On	70 Off
Rat 1								
8	26.95	22.27	20.89	17.80	26.84	22.56	22.58	19.72
16	23.91	19.99	20.40	18.15	26.84	22.19	22.87	19.68
24	33.42	24.85	22.60	18.72	35.20	24.92	24.47	21.19
32	31.11	24.72	22.53	19.85	31.69	26.39	24.64	20.95
40	17.40	12.69	10.07	8.80	18.71	13.01	10.98	9.44
48	17.75	12.44	9.75	8.84	18.89	13.87	10.40	9.13
56	17.98	13.05	6.75	5.76	20.62	13.37	7.91	7.53
64	28.80	21.31	13.55	12.25	27.75	21.21	14.53	12.97
72	13.78	10.83	6.91	6.63	16.09	12.32	6.15	5.40
80	21.60	15.08	11.95	10.47	22.11	15.52	10.73	9.01
MEAN	23.27	17.72	14.54	12.73	24.47	18.54	15.53	13.50
Rat 2								
8	26.27	24.93	24.60	22.89	33.33	28.04	29.84	27.53
16	27.22	24.52	24.69	24.57	33.11	28.96	32.20	29.48
24	29.27	26.48	26.89	25.73	36.15	34.36	35.44	31.64
32	34.38	33.00	29.47	27.96	43.67	40.63	45.02	40.67
40	26.33	26.01	25.93	24.89	33.67	34.27	30.47	29.41
48	29.64	29.76	35.42	34.07	38.60	38.75	39.91	37.40
56	29.31	30.72	31.11	29.69	40.89	40.00	42.53	39.01
64	37.73	36.91	34.51	32.45	44.11	43.05	46.71	42.92
72	54.53	48.15	49.29	46.84	62.15	56.39	61.15	55.87
80	55.42	51.53	55.91	52.96	66.55	63.49	69.07	63.23
MEAN	35.01	32.20	32.78	32.21	43.22	40.79	43.23	39.72
Rat 3								
8	32.35	26.47	28.31	25.27	33.11	26.87	32.31	27.07
16	36.91	30.83	34.84	29.83	38.55	32.35	38.60	32.68
24	44.80	39.71	43.22	40.48	49.22	42.63	47.33	41.37
32	42.67	38.79	41.44	38.96	45.09	41.65	43.87	42.19
40	47.84	43.45	47.78	44.29	53.24	48.59	50.91	47.05
48	47.40	44.11	48.13	45.88	47.98	47.04	50.78	49.01
56	45.58	42.79	43.58	40.60	52.69	48.63	48.78	43.56
64	49.35	49.03	46.13	43.04	54.44	53.61	51.00	46.57
72	49.62	48.99	44.24	42.83	53.27	53.40	47.93	45.45
80	30.75	31.15	28.93	27.31	38.09	39.36	33.69	31.09
MEAN	42.73	39.53	40.64	37.85	46.57	43.51	44.52	40.60
Rat 4								
8	40.00	36.68	39.31	35.48	41.29	37.36	38.95	36.76
16	36.44	34.53	36.02	35.04	38.87	37.15	35.20	34.00
24	55.75	47.99	45.29	42.77	56.93	49.39	51.42	46.29
32	73.49	67.96	67.13	63.59	78.93	70.85	71.13	66.92
40	61.75	57.84	51.24	48.48	68.09	62.60	62.11	57.11
48	43.15	45.19	42.24	40.23	53.98	55.13	54.67	49.96
56	32.80	31.00	24.18	23.15	37.95	35.55	38.24	34.55
64	36.31	36.72	32.51	30.12	47.20	46.17	44.78	42.27
72	38.89	39.85	36.11	33.63	44.13	46.61	44.00	40.53
80	30.22	33.51	31.91	30.31	34.38	38.35	39.35	35.84
MEAN	44.88	43.13	40.59	38.28	50.19	47.92	47.99	44.42

sessions, the sound was off and the response levers were retracted. All other conditions were the same as those for Groups I to IV. The animals were studied in this condition for 80 experimental hr (10 days). Phase B: the animals were studied for 80 experimental hr (5

Table 3
 Partitioned Response Rates for Group II (90 dB, 60 dB)

Hours	RESPONSES PER MINUTE							
	VI Two Min.				Extinction			
	90 On	90 Off	60 On	60 Off	90 On	90 Off	60 On	60 Off
Rat 5								
8	38.62	32.53	34.42	30.88	40.55	34.28	37.09	34.25
16	30.29	26.87	26.91	25.99	33.55	29.31	29.02	27.11
24	42.04	32.07	29.02	26.64	47.40	36.12	31.15	27.99
32	41.38	35.87	30.11	29.23	45.44	39.04	40.71	36.15
40	32.00	27.61	21.78	19.67	37.73	32.00	27.11	23.60
48	32.62	27.40	21.37	19.33	37.27	34.24	29.62	26.73
56	27.98	24.48	16.62	15.04	33.82	30.07	21.55	18.91
64	38.31	33.40	23.51	22.64	44.22	40.11	29.89	28.48
72	24.62	22.12	15.22	14.28	28.53	25.19	19.78	19.17
80	27.69	27.13	16.29	15.24	30.07	28.41	22.69	19.83
MEAN	33.55	28.95	23.56	21.89	37.86	32.88	28.86	26.22
Rat 6								
8	33.11	27.41	30.02	26.71	34.20	28.03	30.75	27.20
16	34.82	31.01	36.71	32.80	35.62	32.75	35.73	32.84
24	36.75	32.41	26.31	24.33	32.80	28.25	29.20	25.67
32	32.78	28.67	26.11	24.60	30.04	27.75	28.20	26.64
40	38.73	32.92	30.69	29.48	38.47	33.25	30.11	27.67
48	36.82	33.75	30.64	26.31	39.33	33.79	31.15	27.07
56	34.49	29.29	21.51	19.39	34.22	29.33	22.73	21.03
64	26.95	25.57	21.27	19.04	27.31	26.25	22.67	21.51
72	29.02	27.01	22.22	20.36	29.27	27.01	21.20	19.65
80	28.62	30.16	21.24	19.60	28.82	30.91	22.87	21.91
MEAN	33.21	29.82	26.67	24.26	33.01	29.73	27.46	25.12
Rat 7								
8	22.20	17.47	17.27	16.89	24.49	18.60	17.80	17.76
16	24.04	19.95	20.00	18.47	26.31	22.92	22.02	21.35
24	21.71	16.92	18.29	17.08	24.40	18.88	21.47	18.63
32	25.71	20.63	20.93	17.92	26.00	22.48	23.55	21.71
40	25.78	21.80	23.93	21.08	29.51	24.17	26.11	23.87
48	18.18	16.69	16.60	15.59	20.09	18.28	21.58	19.16
56	28.93	23.27	26.29	24.73	33.55	26.52	29.84	26.32
64	29.84	24.08	21.89	21.16	32.55	28.23	29.42	27.03
72	25.02	20.89	19.69	18.15	27.00	21.07	21.13	18.99
80	22.47	19.13	16.00	15.37	24.00	20.45	18.93	16.59
MEAN	24.39	20.08	20.09	18.64	26.79	22.16	23.19	21.14
Rat 8								
8	35.02	28.96	29.95	29.13	35.07	29.12	29.15	27.05
16	46.15	41.52	41.62	38.56	45.87	42.69	45.35	41.84
24	25.64	21.15	22.89	20.91	30.31	24.99	26.07	24.61
32	43.15	37.05	35.73	34.52	51.67	43.21	44.15	42.35
40	44.38	39.28	37.49	36.20	53.95	48.69	50.40	46.88
48	52.40	49.47	46.09	44.73	59.27	55.52	53.62	49.36
56	38.44	36.55	36.60	34.19	45.91	41.39	44.93	40.33
64	46.24	43.85	41.95	38.97	55.58	50.68	53.91	49.92
72	50.27	46.93	48.44	44.13	61.24	58.55	58.11	54.01
80	51.53	48.68	49.49	47.41	67.33	64.21	63.07	58.55
MEAN	43.32	39.34	39.03	36.87	50.62	45.91	46.88	43.49

days) under the same condition as Groups I to IV (reinforcement available according to a mixed VI 2-min, extinction schedule in each intensity). Phase C: the animals were studied for an additional 80 experimental hr (10 days) under the same conditions as in Phase A.

Table 4
Partitioned Response Rates for Group III (100 dB, 80 dB)

Hours	RESPONSES PER MINUTE							
	VI Two Min.				Extinction			
	100 On	100 Off	80 On	80 Off	100 On	100 Off	80 On	80 Off
Rat 9								
8	29.62	24.51	26.24	23.56	31.35	26.29	27.84	26.19
16	22.38	17.88	18.49	16.53	23.73	19.05	23.69	20.67
24	34.00	26.05	30.87	26.91	37.22	29.84	33.87	28.79
32	32.91	26.96	29.78	25.83	33.53	27.57	30.42	25.63
40	21.75	16.44	19.11	16.23	22.73	17.75	20.63	17.79
48	29.18	25.01	25.24	23.17	31.47	27.64	27.22	25.76
56	27.80	24.56	28.51	28.12	32.07	30.05	28.51	27.20
64	25.62	23.61	23.82	22.19	29.20	25.13	25.98	24.51
72	19.44	17.72	16.71	17.08	22.51	19.69	18.33	16.91
80	22.55	20.91	19.42	18.88	24.51	23.55	23.33	21.21
MEAN	26.63	22.37	23.82	21.85	28.83	24.66	25.99	23.47
Rat 10								
8	27.55	22.27	23.18	21.31	32.02	25.75	26.93	23.56
16	30.53	27.68	28.07	26.52	35.84	31.56	35.95	31.51
24	30.53	27.47	28.07	25.53	32.55	28.55	34.38	30.04
32	32.73	29.23	34.13	32.25	42.22	37.61	34.89	35.47
40	38.42	35.51	34.47	30.13	43.82	38.88	44.40	38.65
48	32.00	28.01	30.62	27.31	35.18	32.53	35.75	31.69
56	38.71	35.29	37.35	34.97	44.27	39.29	41.82	39.29
64	42.04	37.01	41.51	37.79	51.64	45.76	48.49	42.84
72	41.58	37.13	36.40	33.67	51.53	45.64	46.47	40.52
80	51.29	45.84	46.31	41.40	58.87	55.09	56.67	52.08
MEAN	36.54	32.54	34.01	31.09	42.79	38.07	40.57	36.55
Rat 11								
8	26.87	20.31	23.20	18.91	27.84	22.75	22.33	17.87
16	29.40	22.44	23.80	18.72	29.44	22.68	25.69	20.15
24	23.33	18.63	19.13	16.35	24.42	20.85	19.82	16.52
32	26.82	21.19	19.44	15.68	28.84	23.44	21.62	18.27
40	22.31	17.71	15.82	12.01	22.35	18.61	14.71	12.25
48	25.31	20.04	17.55	13.55	24.73	19.03	16.84	14.45
56	20.47	15.85	14.73	12.31	21.75	17.25	13.91	11.04
64	19.60	16.01	14.18	11.35	18.49	16.12	15.71	12.81
72	18.60	13.41	12.93	9.59	20.49	14.89	10.93	8.29
80	22.80	17.96	12.49	10.79	22.91	18.48	14.11	13.36
MEAN	23.55	18.35	17.23	13.93	24.13	19.41	17.57	14.50
Rat 12								
8	46.20	40.05	43.84	38.77	46.78	41.72	44.60	39.27
16	42.33	38.55	41.29	37.09	44.89	39.28	43.00	39.15
24	52.00	45.56	49.27	45.83	54.58	47.64	53.02	47.24
32	41.09	35.73	44.55	40.41	49.40	43.59	44.20	41.37
40	40.62	33.99	37.82	34.57	45.13	39.79	44.42	38.65
48	33.49	28.12	33.02	28.88	37.07	31.61	34.80	31.47
56	41.20	34.83	38.58	35.19	48.73	40.44	46.38	38.80
64	43.38	36.83	42.07	38.81	47.13	41.43	47.44	41.88
72	31.64	25.51	30.58	26.77	40.04	30.75	34.67	27.84
80	33.15	28.15	31.09	28.04	38.78	31.83	35.87	32.37
MEAN	40.51	34.73	39.21	35.44	45.25	38.81	42.84	37.80

RESULTS

Groups I to IV

Responses were recorded according to stimu-

lus intensity (high, low), reinforcement availability (VI 2-min, extinction), and tone phase (on, off) yielding eight response rates (response/min) per animal per 8-hr session. Ta-

Table 5
Partitioned Response Rates for Group IV (80 dB, 60 dB)

Hours	RESPONSES PER MINUTE							
	VI Two Min.				Extinction			
	80 On	80 Off	60 On	60 Off	80 On	80 Off	60 On	60 Off
Rat 13								
8	29.82	27.65	30.42	28.75	33.44	31.00	34.04	31.07
16	29.89	28.09	30.24	29.68	35.11	33.37	37.60	34.79
24	42.58	38.68	42.95	39.83	46.91	41.99	48.64	43.51
32	33.42	29.89	30.69	29.29	38.73	34.96	38.67	35.99
40	35.22	32.20	31.89	31.64	44.22	40.61	44.51	40.48
48	41.40	38.56	41.55	38.43	50.47	47.45	50.42	47.49
56	39.51	38.53	41.40	38.87	51.69	46.09	52.44	48.12
64	45.82	42.75	46.31	44.08	54.13	50.36	53.27	48.77
72	35.84	32.77	36.67	35.01	48.44	46.29	48.09	44.47
80	50.31	46.53	48.00	44.59	60.22	55.37	59.51	54.69
MEAN	38.38	35.57	38.01	36.02	46.34	42.75	46.72	42.94
Rat 14								
8	20.64	18.44	19.71	18.45	22.49	20.00	21.29	18.99
16	21.71	18.53	20.80	18.85	22.42	19.61	22.95	21.31
24	12.22	9.80	11.42	9.99	14.42	12.44	13.13	11.80
32	16.93	14.57	17.49	16.17	20.38	18.91	20.29	19.37
40	19.33	16.23	19.09	17.41	22.60	19.65	22.00	19.23
48	15.15	12.29	16.87	15.07	18.31	16.57	20.82	17.95
56	16.47	15.09	14.62	14.37	20.35	17.25	19.11	17.69
64	15.09	12.35	13.20	12.64	19.35	16.04	18.42	16.97
72	14.31	11.47	13.69	12.33	19.35	16.51	18.27	16.19
80	18.73	15.57	17.78	16.60	24.51	21.28	26.00	22.47
MEAN	17.06	14.43	16.47	15.14	20.42	17.83	20.23	18.20
Rat 15								
8	12.73	11.89	12.51	11.01	14.87	12.08	14.62	12.25
16	20.31	18.11	19.78	17.67	21.80	20.36	23.00	21.16
24	12.95	11.60	15.31	13.36	17.93	15.24	16.11	14.29
32	14.53	13.92	12.58	12.17	16.51	14.64	15.62	15.48
40	18.35	16.81	16.71	16.97	22.98	21.43	23.24	21.21
48	16.75	15.13	15.98	15.07	19.33	17.41	20.07	18.95
56	24.02	22.55	22.84	21.89	27.89	25.03	30.67	27.16
64	28.87	27.35	30.11	25.91	31.82	29.40	30.58	29.83
72	34.27	30.52	36.40	34.80	44.98	41.68	44.67	41.01
80	11.98	11.08	10.62	10.03	14.02	13.05	11.35	10.13
MEAN	19.48	17.90	19.28	17.89	23.21	21.03	22.99	21.15
Rat 16								
8	26.22	23.49	24.07	21.65	33.04	27.15	29.58	25.09
16	35.35	31.23	34.29	31.07	44.29	38.01	46.58	51.76
24	29.55	26.68	27.40	25.23	36.22	31.51	32.18	30.32
32	38.51	35.08	38.71	35.41	46.51	42.92	46.64	42.68
40	30.00	25.53	27.98	26.59	41.09	34.61	34.64	31.71
48	30.35	27.40	29.22	25.83	34.24	30.30	33.44	29.89
56	47.22	41.93	45.09	41.83	52.00	45.57	52.35	48.35
64	37.58	34.56	35.95	32.51	41.93	37.23	39.95	35.43
72	22.04	18.83	20.24	18.59	24.13	21.07	19.98	19.27
80	39.15	35.41	39.55	36.83	42.40	37.27	40.11	35.51
MEAN	33.60	30.01	32.25	29.55	39.59	34.57	37.55	34.00

bles 2 to 5 present these response rates for each animal in Groups I to IV over 80 experimental hr. In order to assess the effect of stimulus intensity on the rate of responding, the mean difference in response rates between high and low intensities (response rate in high intensity minus response rate in low intensity) was

calculated from the data in Tables 2 to 5 within each of the other conditions: VI 2-min, extinction, tone on, tone off. A positive response rate difference within a condition, then, indicates that a higher response rate was maintained in the higher intensity stimulus. These data are presented in Figure 1 for each animal.

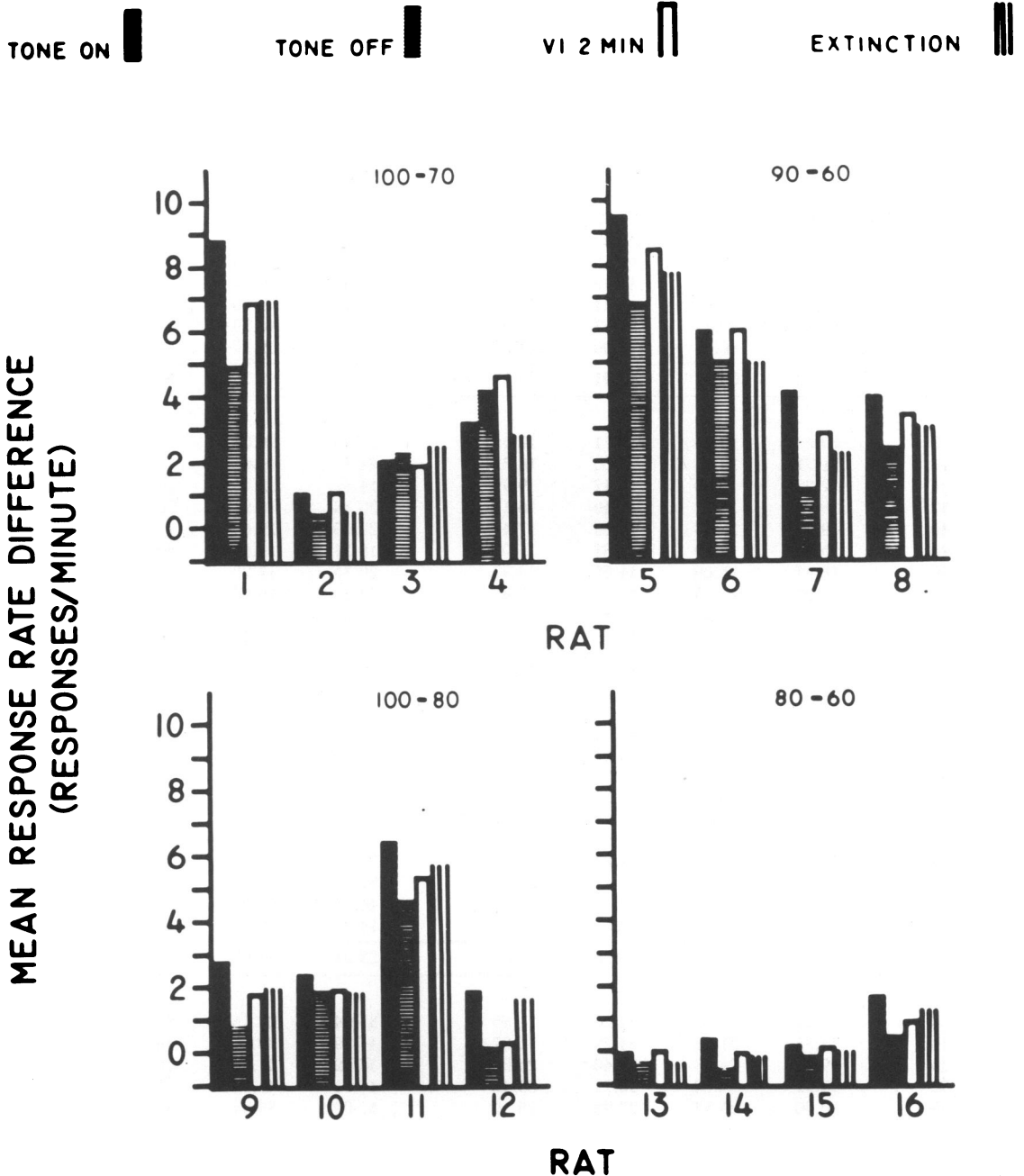


Fig. 1. Mean response rate differences for Groups I to IV as a function of stimulus intensity separation, continuum position, tone phase, and reinforcement availability.

From Figure 1 it is apparent that a higher response rate was typically maintained under the higher intensity stimuli as indicated by the positive response rate differences that occurred in each of the four conditions. This was the case for 13 of 16 animals. Notably, the three animals which showed little or no response rate differences were all in the 80 to 60 low absolute magnitude group.

The main effects of intensity difference, absolute magnitude, tone phase, and reinforcement availability can be best assessed by comparing mean response rate differences in each of these conditions separately, as is shown in Figure 2. Figure 1 can be consulted to examine the same variables between groups or in individual animals. From Figure 1 and Figure 2A it is clear that the 30-dB intensity separations maintained larger response rate differences than the 20-dB separations. The effects of absolute magnitude, on the other hand, depend upon the intensity separation. A high absolute magnitude produced more dynamism at the 20-

dB separation, while a low absolute magnitude produced larger rate differences at the 30-dB separation. In 14 of 16 animals (see Figure 1) differential responding was greater when the tone was on, and Figure 2B shows that, across conditions, there was more dynamism during tone-on periods than during tone-off periods. Reinforcement availability did not appear to affect dynamism systematically. Figure 2C shows little difference in differential responding between VI 2-min and extinction components, and examination of Figure 1 shows that there was no consistent effect of this variable across animals. These observations are supported by acceptable levels of statistical significance obtained using a nonparametric analysis of variance summarized in Table 6 (Bradley, 1968, pp. 138-141).

It can be seen from Tables 2 to 5 that the highest response rate within any stimulus usually occurred during its on-phase. This suggests that the stimuli are modulating response rates within the on-off cycle. This is important

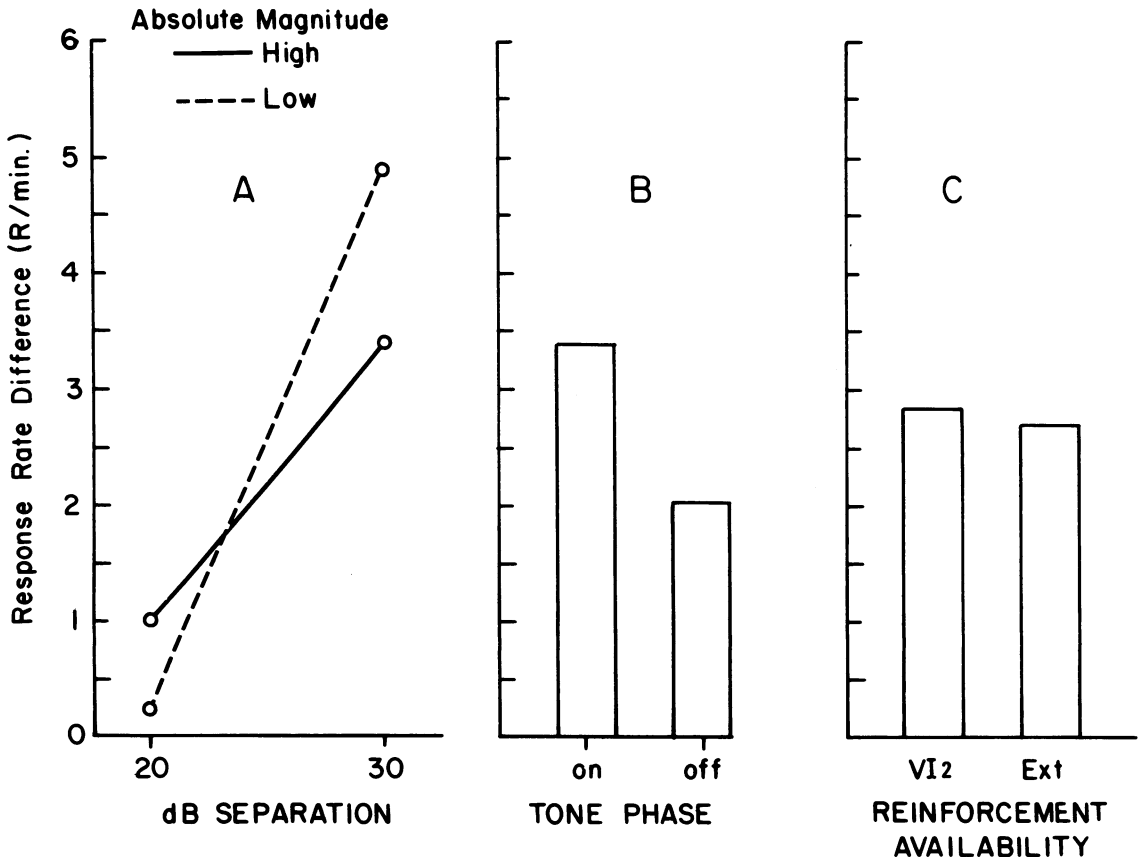


Fig. 2. Mean response rate difference as a function of absolute magnitude and intensity separation (Panel A), tone phase (Panel B), and reinforcement availability (Panel C).

Table 6

Summary of the nonparametric analysis of variance of the data of Groups I to IV.

Comparison	Test	P
Intensity Separation	Wilcoxon	<.025
Continuum Position	Wilcoxon	>.05
Intensity Separation X Continuum Position	Wilcoxon	<.05
Tone Phase	Sign	<.01
Reinforcement Availability	Sign	>.10

since it is well established that abrupt auditory stimuli elicit an unconditioned "startle" response in rats (Fleshler, 1965; Hoffman & Searle, 1968; Prosser & Hunter, 1936; Moyer, 1963). At high intensities (119 dB) this startle response does not habituate completely, even after long periods of time (11 hr) and fairly short (1 min) interstimulus intervals (Hoffman & Searle, 1968). If a rat is maintaining close contact with a response lever, as is probable on a VI schedule of reinforcement, the startle response could be translated into responses on that lever. Since the probability of

a startle response increases with stimulus intensity (Fleshler, 1965), it is possible to have a higher response rate in the higher intensity of a stimulus pair. In order to assess this possibility, hour long records of responding were also obtained for each animal in Group I using an Esterline Angus Event Recorder. The total on-off cycle time, 4.0 sec, was divided into .5 sec bins, with the first three bins corresponding to the on-phase and the last five bins to the off-phase of the stimuli. Figure 3 presents the percentage of total responses occurring in each .5 sec bin for the high (100 dB) and the low (70 dB) intensity stimuli. It can be seen that all animals showed some degree of response modulation within the on-off cycle for both intensities: the probability of a response increases to a peak within the tone-on period, and then the probability decreases during the tone-off period. The peak probability of a response, however, occurs within 1.0 to 1.5 sec, whereas the startle response is consistently elicited within 15 msec of tone onset (Fleshler, 1965).

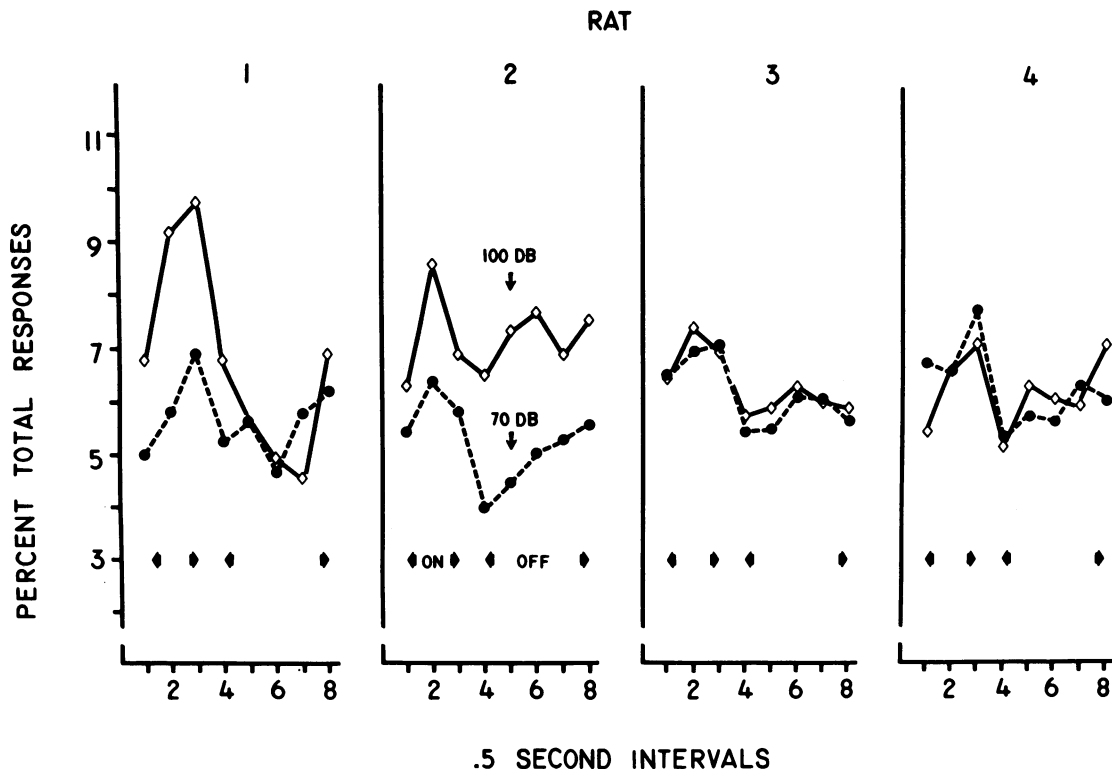


Fig. 3. Percent total responses occurring during successive .5 sec bins for each rat in Group I during the 100-dB and 70-dB stimuli. Bins 1 to 3 represent the tone-on phase, while Bins 4 to 8 represent the tone-off phase.

Group V

Figure 4 presents the mean response rates for the 100-dB and 80-dB tones and the difference of the mean response rates for each animal of Group V. Each mean is based upon 80 hr of training. Phases A and C were the same condition: Multiple VI 2-min, VI 2-min. The schedule used in Phase B was Multiple [(mixed VI 2-min, extinction) (mixed VI 2-min, extinction)], the same as was used for Groups I to IV. Since Group III was exposed to the same intensities and reinforcement schedule as Group

V in Phase B, the difference of the mean response rates for each of the Group III animals are also presented in Figure 4 for comparison.

It should first be noted that the schedule used in Phase B is essentially equivalent to a Multiple VI 4-min, VI 4-min schedule in that the density of reinforcement is half that in the Multiple VI 2-min, VI 2-min schedule. It can be seen from Figure 4 that this schedule does, indeed, produce the decrease in response rate that would be expected under a shift from a VI 2- to a VI 4-min schedule (Ferster & Skinner, 1957). In all but one case (Rat 20) re-

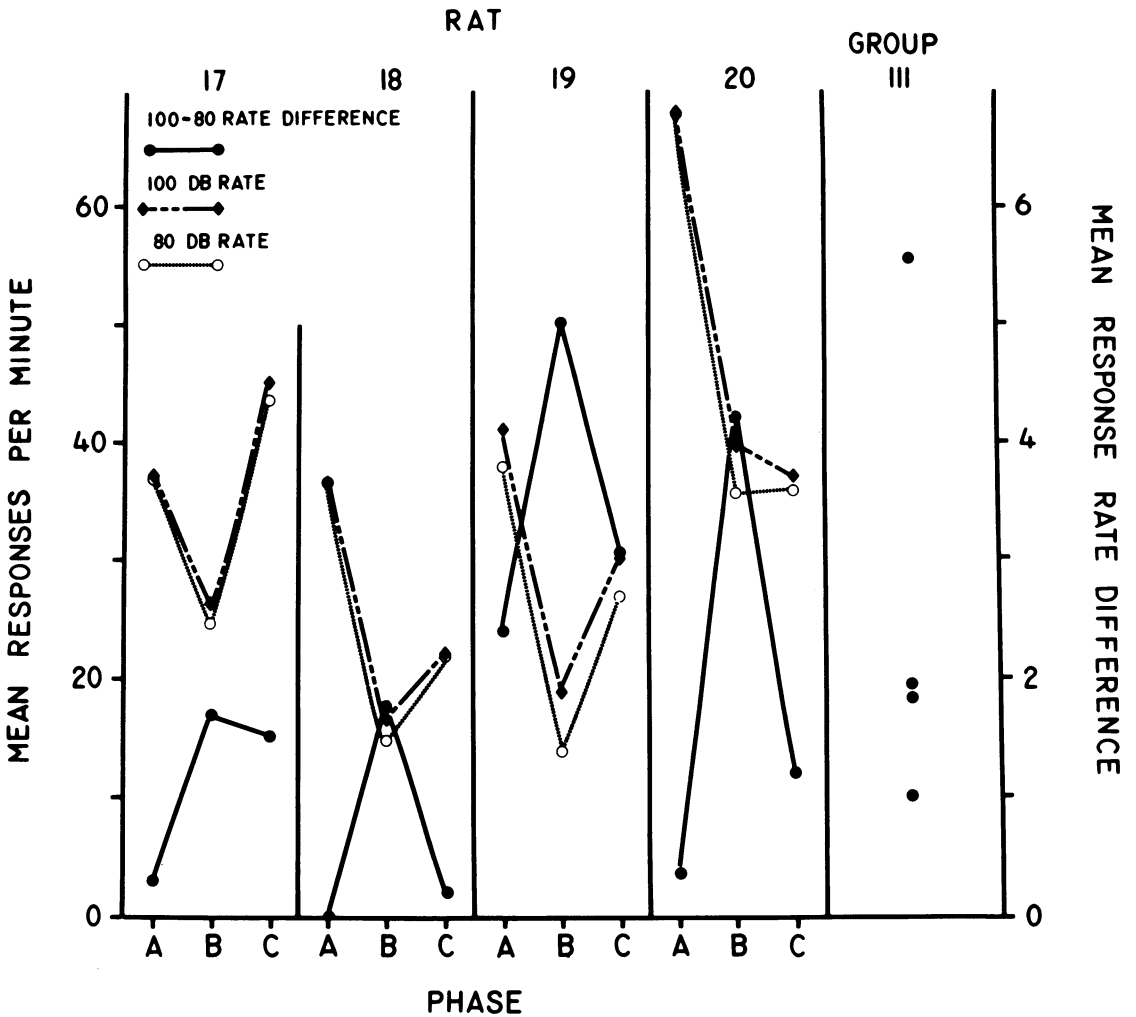


Fig. 4. Mean response rates of Group V rats during the 100-dB and 80-dB stimuli, and the mean response rate differences between those stimuli. During Phases A and C the same schedule of reinforcement was in effect in each stimulus condition as was used with Groups I to IV. This schedule, in effect, reinforced a response on the average of once every four min. During Phase B a Variable Interval 2-min schedule was in effect in each stimulus condition. Mean response rate differences for the animals of Group III, which was exposed to the same stimulus intensities, are also shown for comparison.

sponse rate increased again when the denser reinforcement schedule was reinstated. It is also apparent that a decrease in the density of reinforcement was accompanied by an increase in the amount of differential responding of Group V. A reinstatement of the Phase A conditions resulted in a decrease in differential responding, although, as with the response rates, recovery was not complete.

DISCUSSION

Intensity Separation and Continuum Position Effects

The influence of intensity separation and continuum position on differential responding maintained solely by differences in stimulus intensity (i.e., stimulus intensity dynamism) has been unclear in other research (Pierrel et al., 1970). Previously, stimulus intensity dynamism effects were detected from differences in discrimination acquisition so that direct measurement of response rates as a function of intensity was not possible. Furthermore, the magnitude of dynamism effects was difficult to estimate since the effects were obscured when acquisition was complete. The direct observation of response rate as a function of stimulus intensity in the absence of differential reinforcement was demonstrated by Pierrel et al. (1970) in the "special group" and by Blue et al. (1971). However, neither of these studies attempted to isolate the influence of intensity separation and absolute magnitude. The results of Groups I to IV indicate that a larger intensity separation of stimuli produces more differential responding (and, hence, dynamism) than a smaller intensity separation. Furthermore, the relative importance of absolute magnitude depends upon the intensity separation of the stimuli. There is a clear interaction of intensity separation with absolute magnitude (see Table 6). At the low intensity separation, a high absolute magnitude produces more differential responding, whereas the opposite is true at the high intensity separation.

The present pattern of results adds support to the conclusions of Pierrel et al. (1970) concerning the relationship between physical stimulus intensity and "loudness" for the rat. They found that the amount of differential responding that two stimuli could maintain in a two-component multiple schedule of differential reinforcement was dependent upon

intensity separation and absolute magnitude. Thus, for stimuli separated by 10 dB, a 70 to 60 dB pair would maintain a lower level of differential responding than a 100 to 90 dB pair. Since the decibel scale is logarithmic, this violates the prediction of Fechner's Law that equal decibel separations are equally discriminable. The absolute magnitude effect of the present study also indicates that a logarithmic spacing of auditory stimuli does not provide a totally adequate description of "loudness" growth for the rat.

An alternative description of loudness growth for the rat has been suggested recently by Pierrel-Sorrentino and Raslear (1980). Their research indicates that loudness, L , is related to sound intensity, I , as follows:

$$L = kI^{.35},$$

where k is a scale constant. If response rate is controlled by loudness, as defined above, then the response rate differences of each animal should be a positive linear function of the loudness difference between each stimulus pair. There is a moderate positive correlation between the loudness differences and the rate differences of individual animals ($r = .43$, $df = 14$, $t = 1.78$, $p < .05$), which is in agreement with the proposed scale.

Reinforcement Density Effects

The results of Group V demonstrate that, within-subjects, *decreases* in reinforcement density are accompanied by *increases* in stimulus intensity dynamism. However, response rates also covary with changes in reinforcement density. The observation that dynamism effects are smaller when response rates are high suggests that the reduction in dynamism may be the result of a response rate "ceiling effect", rather than changes in reinforcement density. That is, when baseline rate is already high, it is difficult to produce further increases in rate. Therefore, the inverse relation of dynamism to reinforcement density may be an artifact. Put differently, are reinforcement density changes capable of controlling dynamism independent of variations in response rate? The results of Groups I to IV suggest that reinforcement density, per se, is ineffective in controlling dynamism. For these groups (see Figure 2C) no reliable differences in dynamism were found between VI 2-min and extinction components, and response rates between those com-

ponents also changed very little (3.95 responses/min). On the other hand, the schedule manipulations of Group V, which produced a large change in dynamism, also produced large changes in response rate (15.2 responses/min).

Since changes in response rate form the basis of measuring dynamism in the method used here, uncontrolled variations in response rate can confound or obscure the measurement of dynamism. A group which has very high response rates might then show a smaller dynamism effect than an identical group which responded at a lower rate. In the present study, the mean response rates of Groups I to IV were all comparable (Wilcoxon, nonparametric analysis of variance $p > .05$ for all main effects and interactions), so that the effects reported are probably due to manipulations of the variables of interest rather than to variations in response rates.

In conclusion, when differential reinforcement has been eliminated as a source of behavioral control, stimulus intensity, per se, is capable of maintaining differential responding. Such differential responding is a function of the difference in stimulus intensities and the absolute magnitude of the stimuli. Reinforcement density, on the other hand, does not appear to directly influence such differential responding.

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Received July 12, 1979

Final acceptance July 18, 1980