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CONTRAST AND UNDERMATCHING AS A FUNCTION OF REINFORCER DURATION AND QUALITY DURING MULTIPLE SCHEDULES

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Eight pigeons pecked keys under multiple variable-interval two-minute variable-interval two-minute schedules. In Experiment 1, the reinforcers were 2, 4, or 8 seconds access to a food magazine. In Experiments 2 and 3, the reinforcers were grains that had been determined to be most-, moderately-, or non-preferred. Both positive and negative behavioral contrast occurred when the reinforcers in one component were held constant and the duration or type of reinforcer obtained in the other component varied. Undermatching occurred when the relative rate of responding during a component was plotted as a function of the relative duration of the reinforcers in that component.

Key words: multiple schedule, variable-interval schedule, reinforcer duration, reinforcer quality, behavioral contrast, undermatching, key peck, pigeons

Several theorists have proposed that reinforcer value governs responding during several schedules of reinforcement (e.g., Baum & Rachlin, 1969; Rachlin, 1973). Characteristics of reinforcers such as their rate, size, immediacy, and quality may contribute to their value. Changes in reinforcer value may regulate the responding that results in behavioral contrast during multiple schedules (e.g., Rachlin, 1973) and conformity to an equation proposed by Herrnstein (1970) during concurrent schedules.

Behavioral contrast may be defined as an inverse relation between the conditions of reinforcement in one component of a multiple schedule and the rate of responding during the other component (McSweeney, 1978). Positive contrast may be defined as an increase in the rate of responding during a constant component with a worsening of the conditions of reinforcement in the other, variable, component. Conversely, negative contrast may be defined as a decrease in the rate of responding during the constant component with improvements in the conditions of reinforcement in the variable component. McSweeney and Norman (1979) have argued that contrast should be measured relative to a baseline multiple schedule in which both components provide the same conditions of reinforcement as does the constant component of the schedule in which contrast is assessed.

Equation 1 represents the theory proposed by Herrnstein (1970) for concurrent schedules.

$$\frac{P_1}{P_1 + P_2} = \frac{R_1}{R_1 + R_2} \quad (1)$$

P_1 and P_2 are the rates of responding during Components 1 and 2, respectively, and R_1 and R_2 are the obtained rates of reinforcement. Equation 1 may be extended to other parameters of reinforcement by substituting a measure of those parameters for the rates of reinforcement. Multiple-schedule responding typically falls closer to indifference between the components than predicted by the equation when the components are long, but it may conform to

Experiment 1 was part of a doctoral dissertation submitted to the Department of Psychology, Washington State University, by R. H. Ettinger. It was to be presented at the 1980 meeting of the Association for Behavior Analysis, but the eruption of Mt. St. Helens intervened. Experiment 2 was part of a doctoral dissertation submitted to the Department of Psychology, Washington State University, by Wayne D. Norman. Experiments 2 and 3 were presented at the 1980 International Symposium on Recent Developments in the Quantification of Steady-State Operant Behavior at the University of Manchester. Reprint requests should be sent to Dr. Frances K. McSweeney, Department of Psychology, Washington State University, Pullman, Washington 99164.

the equation when components are short (Shimp & Wheatley, 1971; Todorov, 1972).

The present experiments examine Equation 1 and ask whether changes in the duration (Experiment 1) and the quality of reinforcers (Experiments 2 and 3) produce behavioral contrast during multiple schedules with long component durations. The experiments examine both positive and negative contrast to expand our knowledge of the factors which produce both types of contrast.

EXPERIMENT 1

Experiment 1 examines Equation 1 and asks whether behavioral contrast occurs when the amount of reinforcer provided by the components of a multiple schedule varies. Shettleworth and Nevin (1965) reported results that did not conform to Equation 1 when component durations were long. Merigan, Miller, and Gollub (1975) confirmed this for multiple schedules with long components (two minutes), but reported that responding conformed to Equation 1 when components were short (five seconds).

Several past studies have examined behavioral contrast when the amount of reinforcer was manipulated, but their results are equivocal. Three studies reported contrast (Gonzalez & Champlin, 1974; Hamilton & Silberberg, 1978; Kramer & Rilling, 1969), three did not (Jensen & Fallon, 1973; Mackintosh, Little, & Lord, 1972; Shettleworth & Nevin, 1965).

The failure to find contrast in the latter experiments may have occurred because the changes in the size of the reinforcers was not large enough. Several studies have reported that animals are relatively insensitive to changes in the size of reinforcers in response-independent (Balsam, Brownstein, & Shull, 1978) and concurrent schedules (Schneider, 1973; Todorov, 1973; Walker & Hurwitz, 1971; Walker, Schnelle, & Hurwitz, 1970). If this is also true of multiple schedules, then contrast might be hard to demonstrate when the size of the reinforcer is varied. Shettleworth and Nevin (1965) did observe a decrease in the rate of responding during the variable component when the amount of reinforcer supplied by that component decreased, indicating that their subjects were sensitive to the change in the amount of reinforcer. But the change may not have been large enough to produce contrast.

The three studies that did report contrast are also flawed or incomplete. Two studies manipulated both rate and amount of reinforcement (Gonzalez & Champlin, 1974; Kramer & Rilling, 1969). Therefore, their results do not isolate the effect of amount of reinforcer. Two of the studies did not find contrast for all subjects (Hamilton & Silberberg, 1978; Kramer & Rilling, 1969). Finally, the results of Gonzalez and Champlin's study may represent a fluctuation in responding over time as well as contrast. Baseline rates of responding were not recovered after the contrast manipulation.

The present experiment studied responding during multiple schedules when the size of the reinforcer varied. It tried to facilitate the appearance of contrast in two ways. First, subjects were maintained at 90% of their free-feeding weights, instead of the customary 80%. Lower levels of deprivation may reveal differences in the value of reinforcers that are obscured at higher deprivations (e.g., Young, 1959). Second, the two components of the multiple schedule were presented on different operanda. Contrast has been reported during multiple schedules that use two operanda when it has failed to occur during comparable single-operandum schedules (e.g., McSweeney, 1978). The use of two operanda also permitted comparison with the results of Merigan et al. (1975), who used a two-operandum procedure in some conditions.

METHOD

Subjects

Four adult homing pigeons maintained at approximately 90% of their free-feeding weights served. Body weights were maintained by supplemental feedings immediately after each daily experimental session. All subjects had previously responded on several multiple schedules.

Apparatus

The experiments were conducted in a Grason-Stadler three-key pigeon chamber (model No. 1122) enclosed in a sound-attenuating box. The two outer keys, which signaled the alternating component schedules, were separated by 14.5 cm, center to center. The center key was removed. Access to the grain hopper was through a 4.5- by 5-cm opening located centrally, 6 cm above the floor. The grain hopper was illuminated during grain presentations only. A shielded houselight located 6.5 cm to the left of and 4 cm above the left key was continuously illuminated. Masking noise was provided by a ventilation fan. Experimental events were programmed and recorded by conventional electromechanical equipment in an adjacent room.

Procedure

Because the subjects had previously responded on multiple schedules, they were placed directly on a series of multiple variable-interval two-minute variable-interval two-minute (mult VI 2-min VI 2-min) schedules presented on separate response keys. The left key was illuminated with red light and the right key with blue light throughout the experiment. The key lights alternated every 60 sec. Responses to the illuminated key produced brief feedback clicks and were recorded. Responses to the nonilluminated key had no effect and were not recorded.

Reinforcers consisted of access to the illuminated grain hopper containing mixed grain. They were scheduled according to a 12-interval series constructed by the procedure of Catania and Reynolds (1968, Appendix II). The keylight was off, responses were not recorded, and the components were not timed during hopper presentation. In the event that reinforcers were not collected at the end of one component, they were held over until the next presentation of that component.

During the first, third, and fifth phases (baseline), reinforcers consisted of 4-sec access to grain during both red and blue components. During the second phase, reinforcers consisted of 4-sec and 2-sec access to grain during red and blue components, respectively. During the fourth phase, reinforcers consisted of 4-sec and 8-sec access to grain during red and blue components, respectively.

All daily experimental sessions terminated after 20 reinforcers had been collected. Subjects responded in each phase until the response rates for all four pigeons stabilized. Responding was considered to be stable for each subject when rates of responding during the last five sessions of each phase all fell within the range of the rates of responding during previous sessions of the same phase. Responding was considered to be stable only when rates of responding during both red and blue components were stable.

Results

Figure 1 presents the rates of responding during the two components of each multiple schedule during the last five sessions of each phase. Rates are reported in responses per minute, computed by dividing the number of responses during a component by the total component time minus time when the magazine was presented. Table 1 presents the means of these response rates for each phase, as well as the number of sessions in each phase.

When the duration of the reinforcer in the variable component decreased from 4 sec to 2 sec, rates of responding during the variable component decreased only slightly. However, positive contrast occurred: responding during the constant component increased for all subjects. These rate increases, expressed as percentages above baseline rates, were 42, 40, 64, and 63% for Birds 1001, 5345, 1419, and 5533, respectively. The comparison baseline rates were computed by averaging the means of the response rates during the same component in the first and third phases (see Table 1). Periodic observations throughout all phases of the experiment showed that subjects collected all 2-sec reinforcers. This suggests that positive contrast resulted from changes in the duration of the reinforcers, not in their effective rate of occurrence.

When the duration of the reinforcer increased during the variable component, response rates during that component increased only slightly, with the exception of Bird 1001. But negative contrast occurred: the rate of responding during the constant component decreased for all subjects. These response-rate decreases, expressed as percentages below baseline rates of responding, were 33, 20, 49, and 31% for Birds 1001, 5345, 1419, and 5533, respectively. The comparison baseline rates were the averages of the response rates during the same component in the third and fifth phases, (see Table 1).

Figure 2 presents the relative rate of responding during the constant component of the multiple schedule ($P_1/P_1 + P_2$) plotted as a function of the proportion of the total duration of reinforcers obtained from that component ($A_1/A_1 + A_2$). The relative rates of re-

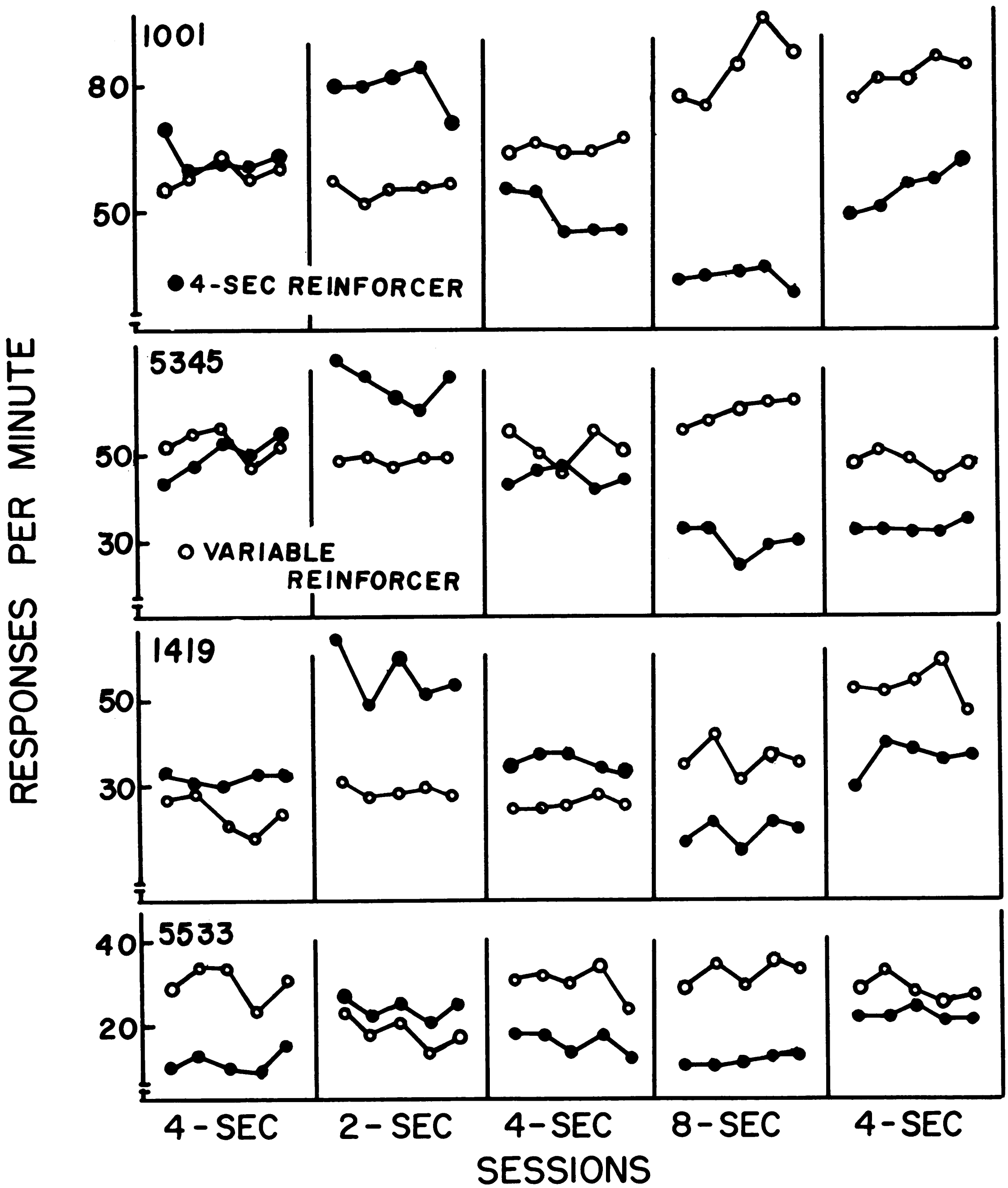

Fig. 1. Rates of responding during the components of each multiple schedule during the last five sessions of each phase of Experiment 1. Each graph presents results for a single subject. The x-axis indicates the duration of the reinforcers during variable components.

sponding were based on response rates in Table 1.

The points plotted in Figure 2 should fall on a straight line with a slope equal to 1.0 and a y-intercept of 0 if they conform to Equation 1 with size of a reinforcer substituted for rate. The solid diagonals in each graph represent the locus of points that conform perfectly to Equation 1.

A least-squares technique was used to compute the best fitting straight lines for the data presented in Figure 2 (dashed lines). The equa-

Table 1

Mean number of responses per minute during each component over the last five sessions of each phase; and the number of sessions in each phase for Experiment 1.

Subject	Component	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
1001	constant	63.9	79.6	48.5	35.0	56.5
	variable	61.1	56.1	65.9	83.6	85.9
5345	constant	50.9	66.5	44.0	29.5	30.0
	variable	54.5	49.4	54.0	60.2	48.6
1419	constant	32.3	55.2	35.1	19.0	39.4
	variable	23.9	27.7	25.4	35.2	54.6
5533	constant	12.1	23.3	16.4	13.2	21.5
	variable	31.5	20.5	30.1	31.7	29.0
Number of Sessions		35	26	35	23	28
Constant reinforcer (red)		4 sec	4 sec	4 sec	4 sec	4 sec
Variable reinforcer (blue)		4 sec	2 sec	4 sec	8 sec	4 sec

tions of these lines appear on the figure. The lines accounted for 86, 84, 77, and 66% of the variance in the data for Subjects 1001, 5345, 1419, and 5533, respectively. The slopes of the lines are less than 1.0 and the y-intercepts are greater than 0 for all subjects. The median of the obtained slopes describing responding during the present schedules with 1-min components fell between the median slopes for multiple schedules with 2-min (median = .40) and 5-sec (median = .83) components in Merigan et al. (1975).

In order to determine whether the deviations from Equation 1 represented undermatching or bias (Baum, 1974), log (P_1/P_2) was also plotted as a function of log (A_1/A_2). The equations of the least-squares-fit lines were: $y = .97x - .09$, $y = .73x - .08$, $y = .95x + .05$, $y = .73x - .22$, for Subjects 1001, 5345, 1419, and 5533, respectively. Again, the slopes were less than 1.0, indicating undermatching, and the y-intercepts were not equal to zero, indicating bias.

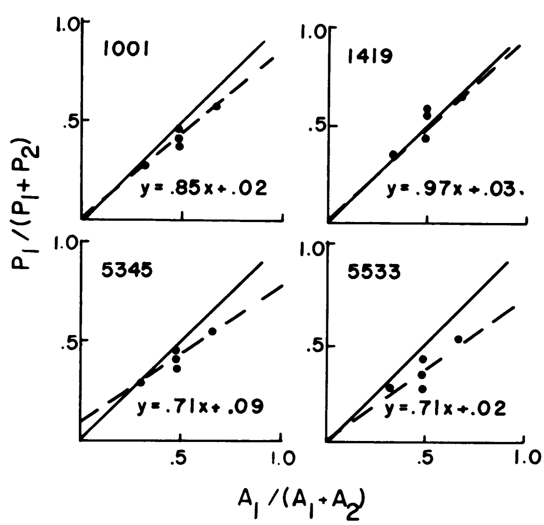

Fig. 2. Relative rates of responding during the constant component of each multiple schedule $(P_1/P_1 + P_2)$ plotted as a function of the proportion of the total duration of reinforcers obtained from that component $(A_1/A_1 + A_2)$. The rates of responding were taken from Table 1. The solid lines represent the locus of points that conform exactly to Equation 1; the dashed lines represent the least-squares best fit.

EXPERIMENT 2

Miller (1976) showed that presenting qualitatively different reinforcers during the components of concurrent schedules alters the value of the components. The present study asked whether presenting qualitatively different reinforcers during the components of multiple schedules produces behavioral contrast, as it should if reinforcer value also governs responding during those schedules.

Several past studies have used qualitatively different reinforcers to examine behavioral contrast in an instrumental response (Beninger, 1972; Beninger & Kendall, 1975; Premack, 1969; Woodruff, 1979). But none of the experiments showed that qualitative changes in reinforcers produce behavioral contrast. All of them changed the rate of reinforcement as well as its quality from one schedule to the next. Therefore, any contrast that did occur may have been produced by changes in the rate of reinforcement, rather than by changes in quality.

The present study manipulated the values of the components of multiple schedules by presenting qualitatively different grains during the components. Five grains were given during home-cage preference tests to determine three that could be rated as most-, moderately- or non-preferred. Then these three were presented in multiple schedules to determine if contrast occurred. Positive contrast was defined as an increase in responding for a moderately-preferred grain when the grain in the other component changed from moderately- to non-preferred. Negative contrast was a decrease in responding for the moderately-preferred grain when the grain in the other component changed from moderately- to most-preferred.

METHOD

Subjects

Four additional homing pigeons maintained at approximately 90% of their free-feeding weights served. Body weights were maintained by supplemental feedings of pigeon chow immediately following each daily experimental session. All subjects had previously responded on several multiple schedules. Again subjects were maintained at 90% of their free-feeding weights to facilitate the appearance of preferences for the grains.

Apparatus

The test apparatus used in the home-cage preference test consisted of two containers, measuring 8.4 cm in diameter and 4.5 cm deep, mounted on a wooden board. The containers were separated by 8.5 cm.

The apparatus used during the multiple schedule was a locally made two-key, two-magazine, pigeon station enclosed in a sound-attenuating chamber. Two response keys, located in the front panel and separated by 20 cm center to center, presented the two components of the multiple schedule. The center of each key was 23 cm above the floor. Approximately .15-N force was required to operate each key. Access to each food magazine was through a 6.4-cm by 3.8-cm hole, located 8.5 cm from the floor of the chamber and directly below each key. The grain hoppers were illuminated during grain presentations only. A houselight, located in the front panel, continuously illuminated the chamber during sessions. Its center was 24 cm from the floor and 2.5 cm from the left side of the chamber. A fan provided ventilation and masking noise. Electromechanical equipment in an adjacent room programmed and recorded experimental events.

Procedure

Preference tests. Preference tests were conducted daily in the subjects' home cage to identify most-, moderately-, and non-preferred grain for each subject from among five alternatives. The five alternatives were oats, wheat, split peas, mixed grain, and cracked corn. Prior to the first preference test, subjects received 25 g of one of the five test grains each day, so that by the fifth day they had been familiarized with all 5 grains.

During preference testing, each possible pair of these five grains was presented to each subject four times, controlling for position. During each test session, 25 g of each of the two grains were placed in the two containers on the test apparatus. The test apparatus was then placed in the home cage for 5 min, then removed and the grain reweighed. The 5-min presentation was selected because subjects were observed to eat from both containers during a 5-min period.

Table 2 presents the median amount of each grain eaten by each subject calculated over all test sessions.

Kruskal-Wallis one-way analyses of variance showed that the amount of grain consumed by a subject did vary significantly with the type of grain ($p < .001$ for each subject). Therefore, the most-preferred grain was defined as the one that the subject ate the most of; the moderately-preferred grain was defined as the one that it ate the median amount of; and the non-preferred grain was defined as the one that it ate the least of. The most-preferred grain was split peas for Subject 2452, but mixed grain for all other subjects. The moderately-preferred grain was wheat, and the non-preferred grain was oats, for all subjects. Post hoc chi-square analyses confirmed that the amount of each of these grains eaten by a subject differed significantly from the amount of each of the other two grains eaten by that subject ($p < .05$).

Table 2

Median number of grams of each grain eaten by each subject over all presentations of that grain.

Subject	*Grain*				
	Mixed Grain	Peas	Wheat	Corn	Oats
2452	18.5	24.5	12.8	8.2	0.7
1451	18.3	12.6	9.3	3.0	0.4
0438	16.7	11.5	5.9	2.8	0.0
2461	17.8	10.4	8.8	4.4	1.3

Multiple schedules. The most-, moderately-, and non-preferred grains were then presented during the components of multiple schedules. Subjects were placed directly on a series of mult VI 2-min VI 2-min schedules in which the components were presented on separate response keys. A green light illuminated the right key and a red light illuminated the left key. Keylights alternated every 30 sec, instead of every 60 sec as in Experiment 1. Shorter component durations were used because they have been shown to facilitate the appearance of contrast (e.g., Shimp & Wheatley, 1971; Silberberg & Schrot, 1974). Responses to the illuminated key produced brief feedback clicks and were recorded. Responses to the nonilluminated key had no effect.

Reinforcers consisted of access to an illuminated grain hopper. They were scheduled according to a 12-interval series constructed by the procedure of Catania and Reynolds (1968, Appendix II). The keylight was off, responses were not recorded, and the components were not timed during hopper presentation. In the event that reinforcers were not collected at the end of one component, they were held over until the next presentation of that component.

During the first, third, and fifth phases (baseline), reinforcers consisted of 4-sec access to the moderately-preferred grain during both the red and the green components. During the second phase, the non-preferred grain replaced the moderately-preferred grain during the green component. During the fourth phase the most-preferred grain replaced the moderately-preferred grain during the green component. Daily experimental sessions terminated after 20 reinforcers had been collected. Each phase lasted 15 sessions.

Results

Figure 3 presents the rates of responding during the two components of each multiple schedule during the last five sessions of each phase. Rates of responding, reported in responses per min, were computed by dividing the number of responses during a component by the time that component was available minus the time when the magazines were presented. Table 3 presents the means of these response rates for each phase.

When the reinforcer presented during the variable component changed from the moderately-preferred (wheat) to the non-preferred grain (oats), rates of responding during that component decreased for all subjects. Positive contrast also occurred: the rates of responding during the constant, moderately-preferred, component increased for all subjects. These rate increases, expressed as percentages above baseline rates, were 33, 21, 48, and 21% for Birds 2452, 2451, 0438, and 2461, respectively. The comparison baseline rates were computed by averaging the means of the rates of responding during the same component in the first and the third phases, as reported in Table 3. Observations of subjects during Phase 2 showed that they collected all reinforcers, suggesting that positive contrast was produced by changes in the quality of the reinforcers rather than by changes in their effective rate of occurrence.

When the reinforcer presented during the variable component changed from the moderately-preferred (wheat) to the most-preferred grain (split peas for Subject 2452 and mixed grain for the others), the rate of responding emitted during this component did not change systematically. Response rates increased for two

Table 3

Mean number of responses per minute during each component over the last five sessions of each phase for Experiment 2.

Subject	*Component*	*Phase 1*	*Phase 2*	*Phase 3*	*Phase 4*	*Phase 5*
2452	constant	24.5	40.6	29.8	24.8	32.0
	variable	40.7	7.5	28.4	42.2	31.2
2451	constant	15.0	20.3	17.0	14.3	9.9
	variable	22.6	7.0	31.3	14.5	14.9
0438	constant	22.7	62.6	42.5	45.6	44.8
	variable	42.7	34.1	75.4	66.6	66.7
2461	constant	25.1	31.8	24.8	27.6	15.6
	variable	12.4	4.8	11.7	17.6	12.5
Constant reinforcer (red)		wheat	wheat	wheat	wheat	wheat
Variable reinforcer (green)		wheat	oats	wheat	mixed grain or peas	wheat

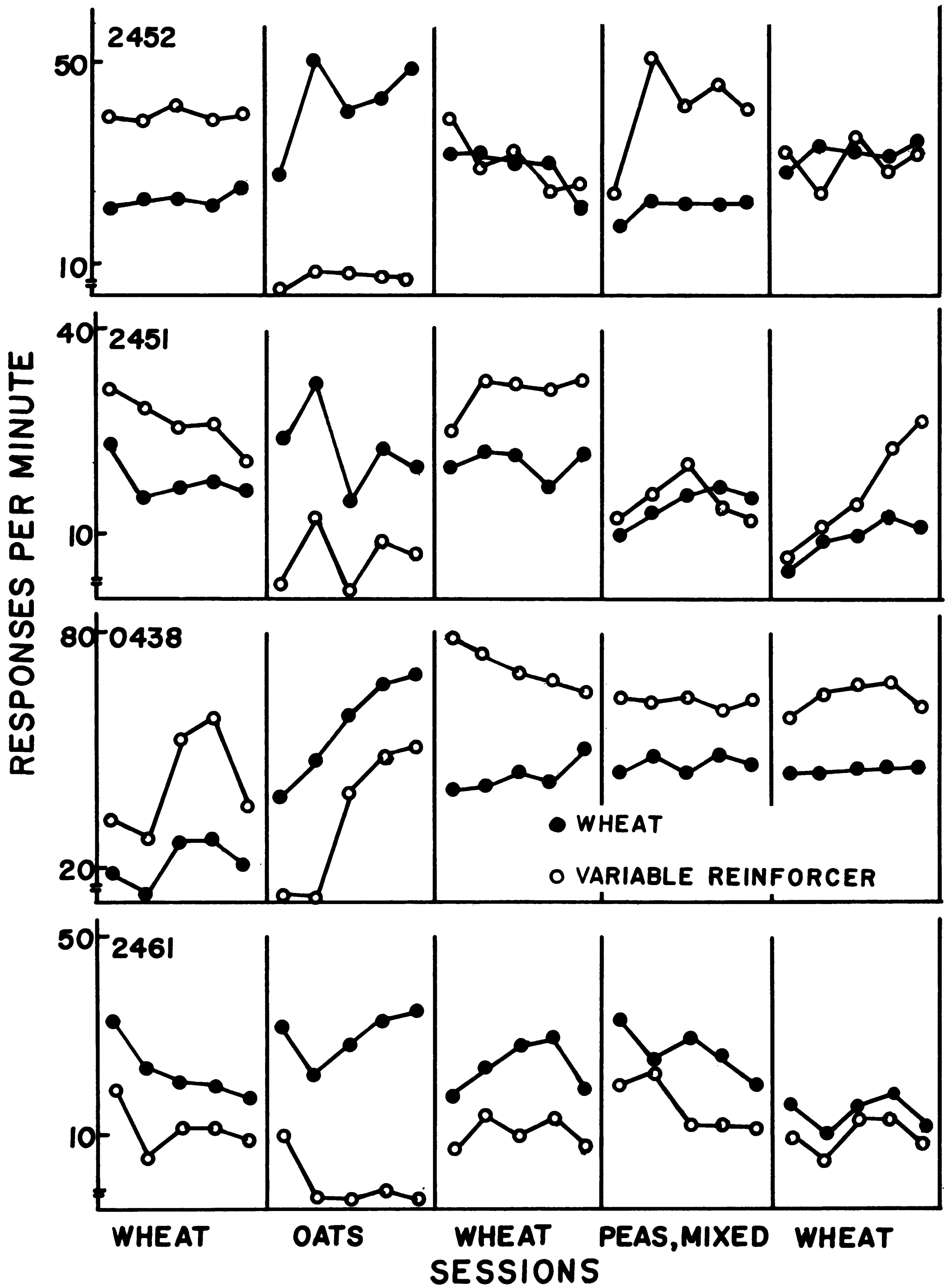

Fig. 3. Rates of responding during the components of each schedule during the last five sessions of each phase of Experiment 2. Each graph represents results for a single subject. The x-axis indicates the type of reinforcers presented during the variable component.

subjects and decreased for the other two. Furthermore, negative contrast did not occur. That is, the rate of responding during the constant, wheat, component did not decrease consistently. Rates decreased for two subjects and increased for the other two.

EXPERIMENT 3

Positive contrast was observed in Experiment 2 when the reinforcer presented during the variable component changed from the moderately-preferred to the non-preferred grain. However, negative contrast was not observed when the variable reinforcer changed from the moderately-preferred to the most-preferred grain. The failure to find negative contrast in a situation which produced positive contrast conforms to Schwartz's argument that positive and negative contrast may not be produced by the same variables (Schwartz, 1975). But the failure to find negative contrast may have also resulted from a failure to produce large enough differences in the value of the reinforcers. In support of this explanation, the one subject (2452) which showed a decrease in response rate that could be labeled negative contrast also showed the clearest increase in responding when the most-preferred grain was substituted for the moderately-preferred one. Other subjects might have also shown negative contrast if the change of reinforcers had been as large for them as it apparently was for Subject 2452.

Experiment 3 examined this explanation for the results of Experiment 2. It produced larger differences in value between the components by substituting the non-preferred for the moderately-preferred grain in the baseline schedule, and in the constant component of the schedule in which contrast was assessed.

METHOD

Subjects

The same subjects and maintenance conditions used in Experiment 2 also served here.

Apparatus and Procedure

The apparatus, procedure, and preference assignments were the same as those for the multiple schedule in Experiment 2. The only difference occurred in the particular reinforcers presented during the components and in the number of sessions conducted for each phase.

During the first and third phases (baseline), reinforcers consisted of 4-sec access to the non-preferred grain (oats) in both components. During the second phase, the most-preferred grain (split peas for Subject 2452 and mixed grain for the others) was substituted for the non-preferred grain during the green component. Subjects responded until responding stabilized for each phase. Stability was determined by the criterion used in Experiment 1.

RESULTS

Figure 4 presents the rates of responding during each component of each multiple schedule over the last five sessions of each phase. Rates of responding were computed as they were for Experiment 2. Table 4 presents the means of these rates of responding and the number of sessions in each phase.

When the reinforcer presented during the variable component changed from the non-preferred to the most-preferred grain in Phase 2, rates of responding during this component increased for all four subjects. Negative contrast, defined as a decrease in the rates of responding during the constant component, also occurred for three of the four subjects. These rate decreases, expressed as percentages below baseline rates, were 61, 93, and 81% for Birds 2452, 2451, and 0438, respectively. Again, the comparison baseline rates were computed by averaging the means of the rates of responding during the same component in the first and the third phases (see Table 4). Responding increased during the constant component in Phase 2 for the one subject which did not show negative contrast (2461), but this increase cannot be distinguished from a general upward trend in the rate of responding. Baseline response rates were not recovered for this subject when baseline conditions were reintroduced in Phase 3. Rather, response rates increased consistently for this subject across all phases of the experiment.

Observations of the subjects during all phases of the experiment showed that the subjects collected all reinforcers, suggesting that negative contrast was produced by changes in the quality of the reinforcers presented during the components, not in their effective rate of occurrence.

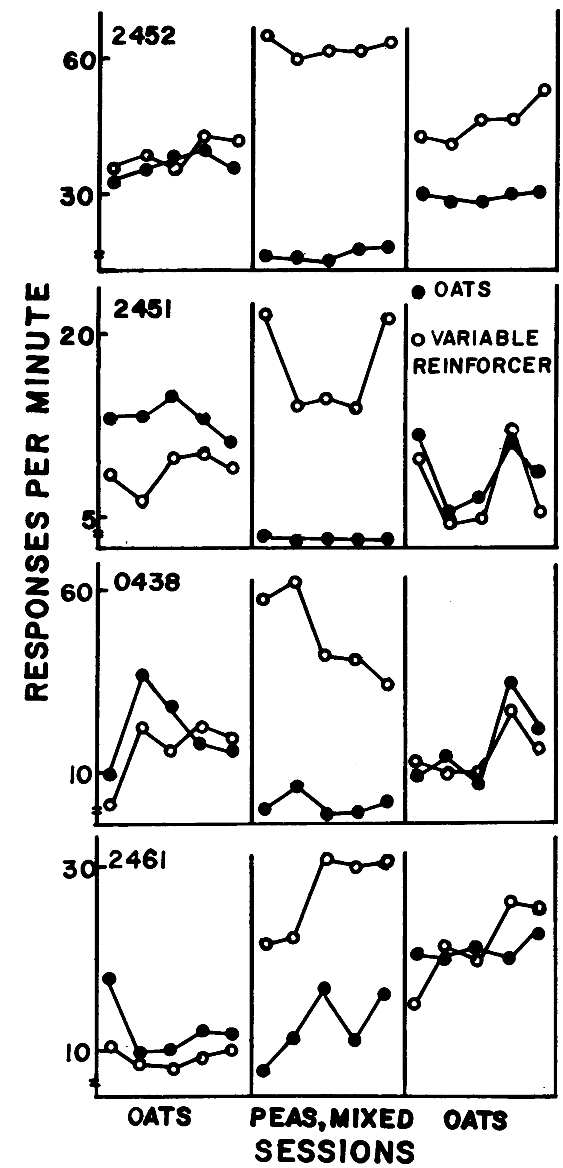

Fig. 4. Rates of responding during the components of each schedule during the last five sessions of each phase of Experiment 3. Each graph represents the results for a single subject. The x-axis indicates the type of reinforcers presented during the variable component.

GENERAL DISCUSSION

The present results expand our understanding of the factors which produce contrast by showing that both positive and negative contrast occur when the duration or quality of the reinforcer varies during a two-operandum multiple schedule. They also extend the deviations from Equation 1, reported by Merigan et al. (1975), to a multiple schedule with a different component duration.

The present findings of deviations from Equation 1 when the amount of reinforcer varied, and of contrast when both the amount and quality of the reinforcer varied, are consistent with the conclusion that changes in the amount and quality of reinforcers change responding similarly to changes in the rate of reinforcement. This, in turn, suggests that a general concept of reinforcer value, which includes the rate, amount, and quality of a reinforcer, may be useful in describing the way in which reinforcers govern behavior (e.g., Baum & Rachlin, 1969; Rachlin, 1973). This conclusion must be qualified in two ways, however.

First, the present two-operandum (all experiments), two-magazine (Experiments 2 and 3) procedures differ from the one-operandum, one-magazine procedures usually used to investigate the effect of rate of reinforcement on contrast and Equation 1. Only future experiments will reveal whether the single and double procedures differ in trivial or more fundamental ways. For example, future experiments might reveal that the only difference between the two procedures is that the two-operandum, two-magazine schedule facilitates discrimination between the components. In that case, the results of the present procedures might be classified with those of one-operandum procedures which produced good discrimination to support a general concept of reinforcer value. Alternatively, future experiments might find that the two types of procedures govern responding in fundamentally different ways. In that case, the present results should not be included with those of one-operandum schedules to support conclusions about reinforcer value.

Second, the limits of the concept of reinforcer value are not known even if the present results do support such a concept. Recently, several authors have proposed that reinforcers may differ in substitutability. Further, reinforcers that are substitutable for one another may govern behavior differently from those that are not (e.g., Hursh, 1980; Rachlin, Kagel, & Battalio, 1980). The definitions of substitutability differ from author to author and are beyond the scope of this paper. But, as an example, replacing one type of food with another represents a substitutable change, whereas replacing food with water represents a nonsubstitutable change. If it is true that substitutable

Table 4

Mean number of responses per minute during each component over the last five sessions of each phase, and the number of sessions for each phase during Experiment 3.

Subject	Component	Phase 1	Phase 2	Phase 3
2452	constant	38.4	13.3	30.1
	variable	41.0	60.9	51.2
2451	constant	13.2	0.7	7.8
	variable	8.6	19.6	6.8
0438	constant	20.9	4.0	21.0
	variable	15.6	48.9	16.6
2461	constant	13.2	13.3	21.6
	variable	8.7	31.8	23.0
Number of sessions		22	22	24
Constant reinforcer (red)		oats	oats	oats
Variable reinforcer (green)		oats	mixed grain or peas	oats

changes do not alter behavior similarly to nonsubstitutable changes, then the results of the present experiment, which employed a substitutable change, may not generalize to experiments which change the quality of the reinforcers in nonsubstitutable ways.

Finally, the present results bear on the question of whether positive and negative contrast are symmetrical (e.g., Rachlin, 1973; Schwartz, 1975). This question will be resolved only by much more research. But the present results are consistent with a symmetrical theory because both positive and negative contrast appeared under symmetrical circumstances (i.e., when the amount and quality of the reinforcer were improved and worsened, respectively).

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