POSITIVE BEHAVIORAL CONTRAST WHEN PIGEONS PRESS TREADLES DURING MULTIPLE SCHEDULES

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Pigeons were placed on multiple variable-interval 15-second variable-interval 15-second and on multiple variable-interval 15-second extinction schedules in which treadle presses produced food reinforcers. Positive behavioral contrast occurred. That is, rates of responding were higher during the variable-interval 15-second component when the other component was extinction than when it was another variable-interval 15-second schedule. These results contradict the findings of other studies, which failed to find positive contrast when pigeons pressed treadles for food reinforcers. They may also question the additive theories of behavioral contrast that predict that contrast should not occur in this situation.

Key words: positive behavioral contrast, multiple schedule, additive theories, food reinforcers, treadle press, pigeons

Positive contrast may be defined as an increase in the rate of responding emitted during one component of a multiple schedule with a worsening of the conditions of reinforcement obtained from the other component. McSweeney and Norman (1979) have argued that changes in the rates of responding and reinforcement should be measured relative to a baseline multiple schedule in which both components supply identical conditions of reinforcement.

Positive contrast has been easy to demonstrate for some responses, such as the key peck emitted by pigeons for food reinforcers (e.g., Reynolds, 1961), but it has been difficult to demonstrate for other responses such as the treadle press. Three studies have failed to find positive contrast when pigeons press treadles for food reinforcers (Hemmes, 1973; McSweeney, 1978; Westbrook, 1973). One study did report contrast, but it is flawed. Bushnell and Weiss (1980) reported positive contrast when pigeons pressed treadles for food or to avoid shock, but contrast was small, transient, and absent for some subjects. Also, baseline rates of responding were not recovered after the contrast phase of the experiment, making contrast impossible to distinguish from fluctuations in responding over time.

The failure to find positive contrast when pigeons press treadles has called into question the generality of behavioral contrast. It has also supported theories that predict that contrast will not occur for all responses (e.g., Rachlin, 1973) at the expense of theories that argue that it will (e.g., Herrnstein, 1970). In particular, the failure to find positive contrast has been taken as strong evidence for the additive theories of contrast (e.g., Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973). Although these theories differ in detail, all argue that positive contrast occurs when responses controlled by the stimulus-reinforcer relation add to or facilitate responses controlled by the response-reinforcer relation. Positive contrast does not occur when the two types of responses do not interact or interfere with each other. According to the additive theories, the response supported by the stimulus-reinforcer relation of a lighted key that signals food is a key peck (Brown & Jenkins, 1968). Because key pecks should not usually facilitate instrumental treadle presses, positive contrast should not be observed when pigeons press treadles for food reinforcers.

The present experiment asks whether the failure to find positive treadle-press contrast is an artifact of the procedural details used during past studies, rather than a fundamental property of treadle pressing, as argued by the additive theories. In particular, the experiment asks whether the failure to find contrast resulted from the relatively low rates of rein-

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forcement (i.e., 0, 30, or 60 reinforcers per hour) used in past studies. Two considerations suggest that providing higher rates of reinforcement might succeed in producing positive contrast. First, Davison and Ferguson (1978) have argued that the failure to find treadle-press contrast may result from the difficulty of detecting changes in the generally low rates of responding on treadles. If that is so, then contrast might be easier to demonstrate if the rates of responding were increased by raising the rates of reinforcement. Second, Staddon (in press) has argued that contrast is difficult to demonstrate for treadle pressing because treadle pressing is relatively insensitive to reinforcement. If that is so, then contrast might occur if this insensitivity were overcome by supplying higher rates of reinforcement.

METHOD

Subjects

Four homing pigeons maintained at 80 to 85% of their free-feeding body weights served. The subjects had pecked keys and pressed treadles in other experiments before this study began.

Apparatus

The apparatus was identical to the one used in McSweeney (1978). Two floor treadles were added to a standard three-key Grason-Stadler pigeon station, Model E6446C, enclosed in a Grason-Stadler Model E3125A-300 sound-attenuating chamber. Each treadle, a 5.2-cm diameter aluminum disc, was held in a resting position 2.6 cm above the enclosure floor by a strip of aluminum, which connected it to the wall containing the magazine. The aluminum strips were 7.7 cm long by 1 cm wide. They entered the wall containing the magazine 16.8 cm below each of the two outer response keys. The centers of the keys were located approximately 19 cm apart and 8 cm from one of the side walls of the apparatus. The treadles produced a brief feedback click when operated by a force greater than approximately .25 N applied to their centers. A houselight located in the upper-right corner of the wall containing the magazine illuminated the chamber throughout the session. White noise was present throughout the sessions. Electromechanical equipment located in another room scheduled the experimental events.

Procedure

Because the subjects had pressed treadles in other experiments, they were placed directly on the following schedules, presented in the following order: multiple variable-interval 15-sec variable-interval 15-sec (VI 15-sec VI 15-sec), multiple VI 15-sec extinction (EXT), multiple VI 15-sec VI 15-sec, multiple VI 15-sec EXT, and multiple VI 15-sec VI 15-sec. For each schedule, reinforcers associated with the component listed first were obtained by pressing the treadle located to the subject's right as it faced the wall containing the food magazine. Reinforcers associated with the component listed second were obtained by pressing the left treadle. A two-treadle procedure was used because McSweeney (1978) found that it facilitated the appearance of negative treadle-press contrast.

The components of the multiple schedule alternated every 60 sec. A red light appeared on the response key above the left treadle when the component associated with that treadle was available, and a white light appeared on the response key above the right treadle when its component was available. Presses on the right treadle were not recorded during the component associated with the left treadle, and vice versa.

A 3-sec period during which no lights appeared on the key and no presses were recorded or produced reinforcers separated the presentation of the components during the first three multiple schedules. This period was included to prevent the time required to cross from one treadle to the other from confounding response rates (cf. McSweeney, 1982). It was removed during the last two multiple schedules to make sure that the observed positive contrast was not an artifact of this procedural detail.

The subjects responded on each schedule until five days of stable responding were recorded. Responding was considered to be stable when the rates of responding emitted during the last five sessions for which a schedule was presented fell within the range of rates emitted during that component in the earlier sessions. That is, a range of rates of responding was calculated for each component schedule by looking at the rates of responding emitted by a particular subject during all but the last five sessions for which that component was presented. Responding was considered to be

stable for that subject responding on that component if the rates of responding emitted during the last five sessions fell within this range. Responding was considered to be stable for a multiple schedule only when the rates of responding emitted during both components by all subjects were stable. An average of 47 sessions were conducted per schedule.

Reinforcers consisted of a 5-sec presentation of a magazine containing mixed grain. They were scheduled according to a 20-interval series constructed by the procedure outlined in Catania and Reynolds (1968, Appendix 2). The keylights were extinguished and no presses were recorded during food presentations. Reinforcers that had become available but had not been collected during a component were held over for presentation during the next appearance of that component. Sessions were conducted daily, five or six times per week. They terminated after 60 reinforcers had been delivered by the multiple VI 15-sec VI 15-sec schedules and after 30 reinforcers had been delivered by the multiple VI 15-sec EXT schedules.

RESULTS

Table 1 presents the rates of responding in presses per minute for each subject and for the mean of all subjects responding on each component of each multiple schedule. Response

rates were calculated by dividing the number of presses emitted during a component by the time for which that component was available minus the time during which the magazine was presented. The rates presented in Table 1 are the means of the rates emitted during the last five sessions for which each schedule was conducted. The schedules have been listed in the order in which they were conducted.

Table 1 shows that there was a large bias towards one treadle. Subjects responded an average of 10 to 20 responses per minute faster on the treadle that provided the variable rate of reinforcement than they did on the treadle that supplied the constant rate, even when the two treadles provided the same rate of reinforcement.

Table 1 also shows that responding on the variable treadle decreased but did not cease when responding on that treadle was placed on extinction. Subjects continued to emit an average of 10 to 15 responses per minute during the extinction component of the multiple VI 15-sec EXT schedule, but response rates did decrease. The rates of responding emitted during the extinction components of the multiple VI 15-sec EXT schedules were lower than the rates emitted during the comparable components of the surrounding multiple VI 15-sec VI 15-sec for all subjects and all comparisons. A one-way within-subject analysis of variance applied to these points was significant [$F(4, 12) =$

Table 1

Rates of responding (in presses per minute) emitted during each component of each multiple schedule for each subject and for the mean of all subjects.

Subject	Component	Schedule				
		mult VI 15-sec VI 15-sec*	mult VI 15-sec EXT*	mult VI 15-sec VI 15-sec*	mult VI 15-sec EXT	mult VI 15-sec VI 15-sec
99	VI 15-sec	22.6	27.8	23.8	28.6	24.2
	VI 15-sec or ext	42.7	24.6	47.8	25.0	51.8
61	VI 15-sec	13.5	32.6	14.8	23.9	19.7
	VI 15-sec or ext	24.5	8.8	24.7	7.8	28.9
1442	VI 15-sec	13.3	24.5	9.7	24.2	8.0
	VI 15-sec or ext	25.5	9.0	28.4	15.2	34.1
1413	VI 15-sec	35.4	45.2	27.6	33.9	20.9
	VI 15-sec or ext	37.6	7.4	32.1	13.3	33.9
mean	VI 15-sec	21.2	32.5	19.0	27.7	18.2
	VI 15-sec or ext	32.6	12.5	33.3	15.3	37.2

*A 3-sec delay separated the components of this schedule.

51.11, $p < .01$]. T-tests for matched pairs showed that responding during the first extinction component was significantly different from responding during the corresponding VI 15-sec component of the preceding [$t(3) = 5.95$, $p < .01$] and following [$t(3) = 10.57$, $p < .01$] schedules. T-tests also showed that responding during the second extinction component was significantly different from responding during the corresponding VI 15-sec component of the preceding [$t(3) = 9.02$, $p < .01$] and following [$t(3) = 12.95$, $p < .01$] schedules.

Finally, Table 1 also shows that positive contrast occurred. The rates of responding emitted during the VI 15-sec components of the multiple VI 15-sec EXT schedules were greater than the rates emitted during the comparable components of the surrounding multiple VI 15-sec VI 15-sec schedules for all subjects and all comparisons. Again, a one-way within-subject analysis of variance applied to these points was significant [$F(4, 12) = 7.65$, $p < .01$]. T-tests for matched pairs showed that responding during the VI 15-sec component of the first multiple VI 15-sec EXT schedule was significantly different from responding during the corresponding component of the preceding [$t(3) = 3.91$, $p < .05$] and following [$t(3) = 4.17$, $p < .05$] multiple VI 15-sec VI 15-sec schedules. T-tests applied to responding during the VI 15-sec component of the second multiple VI 15-sec EXT schedule showed that it was also significantly different from responding during the corresponding component of the preceding [$t(3) = 4.09$, $p < .05$] and following [$t(3) = 3.09$, $p < .05$] baseline schedule.

Figure 1 examines the development of contrast over sessions. It presents the rates of responding in responses per minute during each component of the third, fourth, and fifth multiple schedules. Each set of axes represents the results for an individual subject. The left side of the figure (filled circles) presents response rates during the constant, VI 15-sec, component; the right side (unfilled circles) presents responding during the variable, VI 15-sec or EXT, component. The first five points plotted on each set of axes represent responding during the last five sessions for which the third multiple schedule (multiple VI 15-sec VI 15-sec) was available. The next 16 points represent responding during the first 16 sessions for which the following multiple VI 15-sec EXT schedule was presented. The final five points

represent response rates during the last five sessions for which the final multiple VI 15-sec VI 15-sec schedule was available. The horizontal lines represent the data presented in Table 1. They are the mean rates of responding emitted during a particular component for the last five sessions for which that schedule was available. Data have been presented in this way to make the presentation of these data as comparable as possible to that used by Hemmes (1973) and Westbrook (1973).

Figure 1 shows that responding during the extinction component decreased and that positive contrast appeared within 16 sessions of exposure to the multiple VI 15-sec EXT schedule. In fact, the horizontal lines plotted in Figure 1 for the extinction component show that response rates during that component had dropped in 16 sessions to approximately the point they would reach after all sessions for all subjects except 1413. For Subject 1413, response rates decreased only three more responses per minute over the additional sessions. The horizontal lines plotted in Figure 1 for the constant component show that contrast reached the same height during the first 16 sessions that it would reach after all sessions for all subjects except 1442. Response rates increased only an additional three responses per minute for that subject over all sessions.

DISCUSSION

Large biases developed during the present experiment. Subjects pressed one treadle approximately 10 to 20 responses per minute faster than they pressed the other for the same rate of reinforcement. Such biases are not uncommon in the multiple schedule literature, and they may be larger for two-operanda procedures, such as the present one, than for one-operandum procedures. For example, Charman and Davison (1982) found that the bias toward one component was approximately 10 responses per minute when a single-operandum procedure was used and 15 responses per minute when a two-operanda procedure was used.

Modaresi (1982) suggested a possible explanation for large biases during two-operanda procedures. He found that rats sprayed material towards the side of the chamber through which the experimenter inserted them into the apparatus. Modaresi argued that spraying may

Fig. 1. Rates of responding in responses per minute during each component of the third, fourth, and fifth multiple schedules. Each set of axes represents the results for an individual subject. The left side of the figure (filled circles) presents response rates during the constant, VI 15-sec component; the right side (unfilled circles) presents responding during the variable, VI 15-sec or EXT component. The first five points plotted for each set of axes represent responding during the last five sessions for which the third multiple schedule (multiple VI 15-sec VI 15-sec) was available. The next 16 points represent responding during the first 16 sessions for which the following multiple VI 15-sec EXT schedule was presented. The final five points represent response rates during the last five sessions for which the final multiple VI 15-sec VI 15-sec schedule was available. The horizontal lines represent the mean rates of responding emitted during that component for the last five sessions for which that schedule was available.

have been a defensive behavior against the experimenter because of the aversiveness of the handling procedure. If the front of the apparatus was aversive to the present subjects, they may have avoided it. This would lower their response rates on the constant treadle, located towards the front of the apparatus, producing the present bias.

Regardless of the explanation for bias, positive contrast did develop in the present experiment. The appearance of positive contrast in this study is theoretically important because it increases the generality of positive contrast by extending it to another response and because it questions the rejection of the theories that predict that contrast will occur for all responses. But, the appearance of positive contrast also raises a large number of questions.

The present results raise the question of why contrast appeared in the present study but failed to occur in several past studies (Hemmes, 1973; McSweeney, 1978; Westbrook, 1973). Differences in results between the present study and that of McSweeney (1978) are particularly surprising because the two studies used similar procedures, the same subjects, and the same apparatus. Nevertheless, seven procedural differences between the studies may explain the difference in results. First, McSweeney (1978) did not schedule a 3-sec interval between the components; the present study did during the first three multiple schedules. Second, McSweeney (1978) used components that were 2 min long; the present experiment employed 60-sec components. Third, McSweeney (1978) used subjects which had not previously pressed treadles; the present experiment used subjects which had had extensive experience. Fourth, sessions ended after 20 or 40 reinforcers in McSweeney (1978); they ended after 30 or 60 in the present experiment. Fifth, sessions were conducted six or seven times per week in McSweeney (1978) but five or six times per week in the present experiment. Sixth, McSweeney (1978) conducted an average of 30 sessions per schedule using these subjects; the present study conducted 47. Finally, McSweeney (1978) used VI 2-min and extinction-component schedules; the present experiment used VI 15-sec and extinction components.

Although the first six differences between the studies cannot be completely ruled out, they are unlikely to account for the differences in results. If the presence of the interval be-

tween the components produced contrast, then contrast should not have occurred during the present fourth or fifth schedules that did not employ this interval. But it did occur. If contrast occurs when components are short but not when they are long, then contrast should have been observed by Westbrook (1973) using 30-sec components and by Hemmes (1973) using 1-min components. But it was not. If contrast occurs only when subjects have had extensive experience pressing treadles, then it should have appeared for Hemmes' two subjects that had had previous experience pressing treadles and pecking keys. But it did not. If contrast occurs only when subjects are given a large number of reinforcers (i.e., 30 or 60) per session, then it should have also occurred when Hemmes (1973) provided an average of 30 or 60 reinforcers per session. But it did not. If differences in the number of sessions conducted per week produced the difference in results, then positive contrast should have been observed by McSweeney (1978). But it was not. Five sessions per week were occasionally conducted in the present study, and seven sessions per week were occasionally conducted by McSweeney (1978), but almost all of the data in both studies were obtained by conducting six sessions per week. Finally, if too few sessions were conducted by McSweeney (1978), then contrast should not have appeared in Figure 1. But it did. Figure 1 showed that contrast developed within 16 sessions in the present experiment. Sixteen sessions is comparable to the number conducted by Hemmes and by Westbrook and less than that conducted by McSweeney (1978).

Although it requires further study in an experiment that systematically varies the rate of reinforcement and records changes in the size of treadle-press contrast, differences in the rates of reinforcement programmed for the component schedules remain the most likely explanation for the differences in results. The multiple VI 15-sec VI 15-sec and multiple VI 15-sec EXT schedules used in the present study provided a much higher programmed rate of reinforcement than the multiple VI 2-min VI 2-min, multiple VI 2-min EXT, multiple VI 1-min VI 1-min, and multiple VI 1-min EXT schedules used in the three studies that failed to observe positive contrast. Further support for the idea that the programmed rates of reinforcement can influence the observation of

contrast comes from Reynolds (1963) and Spealman and Gollub (1974), who found that the programmed rates of reinforcement influenced the observation of contrast when key pecking produced reinforcers.

If it were clearly established that the use of a high rate of reinforcement did produce positive contrast, then further experiments could explain how the high rates of reinforcement exerted their effect. One possible explanation is that using high rates of reinforcement facilitated discrimination between the components of the multiple schedules. Subjects might find it easier to discriminate higher rates of reinforcement from extinction than lower rates, and contrast would be easier to demonstrate if discrimination were good. Response rates during the two components of the multiple schedules would change in the same direction, not in the opposite direction required for contrast, if subjects could not tell the components apart.

A study should directly test the relation between discrimination and contrast, but comparing the level of discrimination in the present study with that in McSweeney (1978) provides little support for this idea. Although it is difficult to compare the degree of discrimination across studies that differ in response rates and bias, the most obvious measures of discrimination suggest either that discrimination was better in McSweeney (1978) than in the present study, or that the two studies were not systematically different. For example, if discrimination is measured by the ratio of the rates of responding in the components of the multiple schedules, then discrimination was slightly better in McSweeney (1978) than in the present experiment, contradicting the hypothesis. The ratios of the response rates during the components of the present multiple VI 15-sec EXT schedule were 1.1, 3.7, 2.7, 6.1, and 2.6 for Subjects 99, 61, 1442, 1413 and the mean of all subjects, respectively. (Subject 1413 was labeled 1473 in McSweeney [1978].) The ratio of the rates of responding during the components of the multiple VI 2-min EXT schedule in McSweeney (1978) were 1.4, 6.4, 4.4, 6.4, and 3.0 for the same subjects in the same order. The larger ratios achieved in McSweeney (1978) might indicate that responding was more different for the components in that study and therefore that discrimination was better. If discrimination is

measured by the difference between the rates of responding emitted during the two components, then discrimination was not significantly different between the two experiments. Differences between the rates of responding emitted during the two components of the multiple VI 15-sec EXT schedule were 3.2, 23.8, 13.5, 37.8, and 20.0 responses per minute, for Subjects 99, 61, 1442, 1413 and the mean of all subjects, respectively. Differences between the rates of responding in the two components of the multiple VI 2-min EXT schedule in McSweeney (1978) were 7.0, 15.2, 2.6, 20.0, and 13.7 for the same subjects in the same order. The absence of a systematic difference in the size of these numbers for the two experiments may imply that discrimination was not systematically different in the two experiments.

Further studies should test the discrimination explanation for the appearance of contrast more carefully. The biases observed in the present experiment may well obscure differences in discrimination. Experiments should also test alternative explanations for the effect of high rates of reinforcement. For example, the present data do not differentiate between Staddon's argument that treadle pressing is generally insensitive to reinforcement and Davison and Ferguson's argument that treadle pressing occurs at such a low rate that contrast is difficult to detect. Presumably, if Staddon is correct, then treadle pressing would change little with changes in reinforcement, regardless of the schedule. If Davison and Ferguson are correct, then treadle pressing should be sensitive to changes in reinforcement if it occurs at a high enough rate.

Further studies should also examine implications of the present results for the additive theories of behavioral contrast. The present results are troubling for the additive theories that may predict that positive contrast should not occur when pigeons press treadles for food reinforcers. They are particularly troubling because the additive theories' most obvious explanation for the present contrast is incorrect. The additive theories might argue that the key pecks controlled by the stimulus-reinforcer relation facilitated the treadle presses controlled by the response-reinforcer relation in the present experiment, but not in other experiments, because of the physical arrangement of the apparatus. The response key to which the subjects should direct their stimulus-

controlled pecks was located directly above the treadle in the present study. Therefore, subjects might have accidentally operated the treadle while directing responses to the lighted key. However, if this were true, then positive contrast should have also occurred during McSweeney (1978) which used the same apparatus. But it did not.

Further tests must be conducted before the present results can be taken as conclusive evidence against the additive theories. McSweeney, Ettinger, and Norman (1981) have argued that the additive theories should be tested by a summation procedure in which the response-reinforcer and stimulus-reinforcer relations are first established independently and then combined. If the additive theories are correct, then the response rate during the summation test should be higher than that during the response-reinforcer relation presented alone, whenever positive contrast is observed. The summation test should not yield a higher response rate than the response-reinforcer relation presented alone when contrast is not observed. The additive theories should not be conclusively dismissed until these tests are conducted.

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