POSITIVE AND NEGATIVE CONTRAST AS A FUNCTION OF COMPONENT DURATION FOR KEY PECKING AND TREADLE PRESSING

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Pigeons responded on several multiple schedules for food reinforcers. The duration of the components varied from four seconds to 16 minutes. The absolute size of positive (Experiment 1) and negative (Experiment 2) behavioral contrast varied inversely with component duration when key pecks produced the reinforcers. The absolute size of negative contrast varied directly with component duration, when treadle presses produced the reinforcers (Experiment 3). These results conform to theories that suggest that positive and negative contrast are symmetrical when pigeons peck keys. They also conform to theories that suggest that the same principles do not govern contrast when pigeons peck keys as when they press treadles. Finally, the results support the measurement of behavioral contrast by the differences between baseline rates of responding and the rates emitted when contrast is present.

Key words: behavioral contrast, component duration, multiple schedule, variable interval schedule, additive theories, key peck, treadle press, pigeons

Behavioral contrast is frequently reported when subjects respond on multiple schedules (e.g., Reynolds, 1961). Contrast may be defined as an inverse relation between the rate of responding during one, constant, component of a multiple schedule and the conditions of reinforcement obtained from the other, variable, component (Rachlin, 1973). Positive contrast refers to an increase in the rate of responding during the constant component with a worsening of the conditions of reinforcement in the variable component. Negative contrast refers to a decrease of 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 increases and decreases in the rates of responding or conditions of reinforcement should be measured relative to a baseline multiple schedule that provides the same conditions of reinforcement in both components.

Recently, research has focused on two questions about contrast. First, several studies have asked whether positive and negative contrast

are produced by symmetrical theoretical mechanisms. Rachlin (1973) and Herrnstein (1970) have presented theories which imply that they are. Schwartz (1975) has argued that they need not be. Second, many studies have asked whether contrast occurs similarly for all responses. Some theorists have implied that it should (e.g., Herrnstein, 1970). Others have implied that it should not (e.g., Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973).

To date, several studies have reported differences between positive and negative contrast and between contrast for different types of responses. Three studies reported differences between positive and negative contrast by finding one type of contrast under conditions that did not produce the other (Ettinger & McSweeney, 1981; McSweeney, 1978; Schwartz, 1975). Three other studies supported the argument that contrast occurs differently for different responses by failing to find positive contrast when pigeons press treadles under conditions that should have produced it if the subjects had pecked keys (Hemmes, 1973; McSweeney, 1978; Westbrook, 1973). The one study that did report positive contrast when pigeons pressed treadles is flawed (Bushnell & Weiss, 1980). Contrast was small, transient, and absent for some subjects. Further, baseline rates of responding were not recovered after the con-

trast phase of the experiment. Therefore, behavioral contrast could not be distinguished from fluctuations in responding over time.

However, none of these studies provides conclusive evidence for differences between positive and negative contrast or between contrast for different types of responses. Failures to find positive contrast for treadle pressing can be attributed to procedural problems with the studies or to minor differences between key pecking and treadle pressing such as their rate of occurrence (cf. Davison & Ferguson, 1978). Furthermore, arguments that attribute the asymmetrical data for positive and negative contrast to symmetrical theories can be developed (cf. McSweeney, 1978).

Intuitively, it seems that studies which examined changes in the size of contrast as a function of an independent variable would provide more conclusive evidence about the symmetry of contrast. Changes in behavior that showed similar functions when an independent variable was manipulated would be attributed to similar theoretical mechanisms. Changes in behavior that showed different functions would not be.

One independent variable that may control the size of behavioral contrast is component duration (e.g., Rachlin, 1973). The present experiments manipulated component duration and recorded changes in the size of positive (Experiment 1) and negative (Experiment 2) contrast for key pecking, and negative contrast for treadle pressing (Experiment 3). The measures of the size of contrast were based on the definition of contrast given at the beginning of this paper. The measure of positive contrast was the rate of responding emitted during the more favorable component of a multiple schedule minus the baseline rate of responding emitted when the schedule in the other component was the same. The measure of negative contrast was the rate of responding emitted during the less favorable component of a multiple schedule minus the baseline rate of responding emitted when the schedule in the other component was the same. These measures were used because they are consistent with several theories of behavioral contrast (e.g., Rachlin, 1973), and because they produced orderly results. However, there are many alternatives to the present measures (e.g., Staddon, in press).

EXPERIMENT 1

Functions relating the present measure of positive contrast to component duration have not been studied in any detail when pigeons peck keys. The results of many past studies suggest that the measure might change; but it is not clear how.

Three studies suggest that the size of positive contrast would vary directly with component duration. Williams (1974), Buck, Rothstein, and Williams (1975) and Williams (1979) found that several pigeons pecked keys at a higher rate later in the more favorable component of a multiple schedule than they did earlier in the component. If it is assumed that changing component duration alters only how much of the higher and lower response rates are sampled, then the rate of responding emitted during the more favorable component should increase with increases in component duration. Shorter components should sample the period of lower response rates for a larger proportion of their total duration than longer components. If the baseline rate of responding remained constant across the component, then the present measure of contrast would also vary directly with component duration.

On the other hand, a number of studies suggest that contrast should vary inversely with component duration. Ettinger and Staddon (Note 1), Killeen (1972), Kodera and Rilling (1976), Shimp and Wheatley (1971), Silberberg and Schrot (1974), Spealman (1976) and Todorov (1972) found that the rate of responding emitted during the more favorable component of a multiple schedule decreased with increases in component duration. Arnett (1973), Bloomfield (1967), Catania and Gill (1964), Malone and Staddon (1973), Hinson, Malone, McNally, and Rowe (1978), Innis (1978), Nevin and Shettleworth (1966), and Spealman (1976) indirectly supported this conclusion. They found that pigeons pecked keys faster at the beginning of the more favorable component than they did later in the component. If changing component duration alters only how much of the higher and lower response rates are sampled, then the rate of responding should vary inversely with component duration. Shorter components should sample the period of higher response rates for a larger proportion of their total duration. All of these

studies imply that contrast should decrease with increases in component duration, if the baseline rate of responding remained constant across the components.

The results reported by Kodera and Rilling (1976) suggest that the baseline response rates might remain constant, but they studied only two component durations. The present experiment systematically examined changes in the proposed measure of the size of behavior contrast as a function of component duration. Several conditions were conducted, and component duration varied over a wider range than in the earlier studies.

METHOD

Subjects

Five homing pigeons, maintained at 80 to 85% of their free-feeding body weights, served. Subjects 99, 61, and 63 were experimentally experienced. Subjects 1442 and 1473 were naive.

Apparatus and Procedure

The apparatus was a standard three-key, Grason-Stadler pigeon station, model number E6446C, enclosed in a Grason-Stadler, model number E 3125A-300, sound-attenuating chamber. The houselight was illuminated throughout the session and white noise was continuously presented. Electromechanical equipment located in another room scheduled the experimental events.

Subjects 1442 and 1473 were trained to eat from the food magazine. Then, key pecking was shaped by a successive approximations procedure. The experiment began when shaping had been completed. Shaping was not required for subjects 99, 61, and 63 because they had pecked keys in previous experiments.

The subjects responded on several series of mult VI 2-min VI 2-min, mult VI 2-min ext, and mult VI 2-min VI 2-min schedules. The set of three schedules was conducted in that order for each of the following component durations, presented in the following irregular order: 5-sec, 30-sec, 3-min, 16-min, and 8-min. The components of the multiple schedule were signaled by red and white lights alternating on the center response key. The red light always signaled the VI 2-min component; the white light signaled the VI 2-min or extinction component.

Pecks on the illuminated center response key produced a brief feedback click and reinforcers (5-sec access to a magazine containing mixed grain) when they were scheduled. Responses were not recorded and the keylight was extinguished during reinforcement, but the component timer did not stop. The stimulus appropriate to the next component appeared at the end of food presentations if the previous component had ended during that presentation. The other keys were not illuminated and pecks on them were ineffective. They did not produce feedback clicks or reinforcers and they were not recorded.

Sessions were conducted daily, six to seven times per week. They terminated after 30 food presentations for the mult VI 2-min VI 2-min schedules and after 15 food presentations for the mult VI 2-min ext schedules. Reinforcers were scheduled according to a 12-interval Fleshler and Hoffman series (Fleshler & Hoffman, 1962). Reinforcers that had become available, but were not collected during a component, were cancelled. They were not held over for the next appearance of that component to avoid presenting a higher rate of reinforcement at the beginning of a component than at other times.

Subjects responded on each schedule until responding stabilized. Responding was stable when the rates of responding emitted during the last five sessions for which that schedule was presented all fell within the range of the rates of responding emitted on the same schedule during the earlier sessions. That is, a range of rates of responding was calculated for each component of each multiple 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 during that component was considered to be stable for that subject 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 were stable. An average of 24.2 sessions were conducted for each schedule.

RESULTS AND DISCUSSION

Table 1 presents the mean rates of responding emitted during each component of each

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Table 1

Rates of responding in pecks per minute emitted during each component of each multiple schedule.

		Schedule 5-sec Components			30-sec Components		
Subject	Component	VI 2-min VI 2-min	VI 2-min ext	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min ext	VI 2-min VI 2-min
99	VI 2-min	74.6	130.1	70.1	71.2	139.4	100.8
	other	72.3	28.3	84.1	98.4	40.0	78.0
61	VI 2-min	60.5	66.4	38.0	48.1	71.5	60.4
	other	54.4	8.0	55.5	71.4	9.9	48.7
63	VI 2-min	103.7	153.4	65.0	73.9	104.7	60.2
	other	92.0	44.9	83.7	93.6	14.1	46.4
1442	VI 2-min	30.6	47.2	32.8	38.8	49.0	44.2
	other	29.0	12.4	26.8	33.8	1.5	40.2
1473	VI 2-min	75.2	116.2	68.9	80.9	98.8	71.6
	other	73.2	14.2	67.6	83.5	11.2	58.5
mean	VI 2-min	68.9	102.7	55.0	62.6	92.7	67.4
	other	64.2	21.6	63.5	76.1	15.3	54.4

		Schedule 3-min Components			16-min Components		
Subject	Component	VI 2-min VI 2-min	VI 2-min ext	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min ext	VI 2-min VI 2-min
99	VI 2-min	83.9	106.6	68.8	75.4	91.7	86.6
	other	79.5	32.9	57.3	58.9	33.8	71.4
61	VI 2-min	61.4	57.1	52.2	54.7	56.6	54.8
	other	61.4	8.3	52.2	59.9	12.7	53.5
63	VI 2-min	65.6	66.1	68.5	63.9	74.0	83.4
	other	70.9	9.4	66.0	66.1	9.6	73.1
1442	VI 2-min	28.9	40.2	34.2	26.8	31.1	28.7
	other	23.2	7.3	22.2	17.8	4.5	22.6
1473	VI 2-min	74.6	72.5	67.8	71.9	93.9	72.1
	other	62.0	14.0	62.6	69.8	11.3	65.1
mean	VI 2-min	62.9	68.5	58.3	58.5	69.5	65.1
	other	59.4	14.4	52.1	54.5	14.4	57.1

		Schedule 8-min Components		
Subject	Component	VI 2-min VI 2-min	VI 2-min ext	VI 2-min VI 2-min
99	VI 2-min	78.2	80.4	66.3
	other	68.3	33.6	60.2
61	VI 2-min	53.5	44.7	52.0
	other	62.3	6.3	49.7
63	VI 2-min	77.9	62.3	74.6
	other	81.2	4.0	67.9
1442	VI 2-min	27.7	24.6	20.8
	other	27.4	5.0	21.9
1473	VI 2-min	60.1	77.2	62.3
	other	62.9	11.3	62.8
mean	VI 2-min	59.5	57.8	55.2
	other	60.4	12.0	52.5

multiple schedule, calculated over the last five sessions for which each schedule was available. Rates were calculated by dividing the number of responses emitted during each component by the time for which that component was available. The time for which the magazine was presented was excluded from all calculations.

Figure 1 presents the size of positive behavioral contrast plotted as a function of compo-

nent duration. The size of contrast was measured by the differences between the rates of responding emitted during the VI 2-min component of the mult VI 2-min ext schedules and the average rates of responding emitted during the red VI 2-min components of the surrounding mult 2-min VI 2-min schedules. The points must fall above the horizontal line in order to qualify as positive behavioral contrast. Points that fall below the line represent negative induction, defined as a decrease in the rate of responding emitted during one component with decreases in the rate of reinforcement obtained from the other component.

These results support two conclusions. First, Figure 1 and Table 1 show that positive contrast occurred. Twenty-two of 25 points in Figure 1 for individual subjects and all five points for the mean of all subjects fall above the horizontal line and therefore represent positive contrast.

Second, Figure 1 and Table 1 show that the size of positive contrast changed over the course of the experiment. Contrast was very large for the short component durations, ranging from about 15 to almost 60 responses per minute, with an average of more than 40. Contrast decreased to less than 20 responses per minute for longer component durations with some points falling below the line.

A one-way within-subject analysis of variance applied to the points plotted in Figure 1 confirmed the conclusion that the size of behavioral contrast changed as a function of component duration [$F(4,16) = 8.03$, $p < .01$]. T-tests for matched pairs showed that the size of contrast for each component duration was significantly different from that for each other component duration ($p < .05$) except for the 3-min component compared to the 8-min or 16-min components.

Figure 1 and Table 1 suggest that the size of positive contrast did change as an orderly function of an independent variable. This variable may be component duration. But it may also be the order of presentation of the schedules. The longer component durations tended to be presented later even though the durations were randomly scheduled. Therefore, the results might also indicate that the size of contrast decreased with successive measurements, rather than with component duration.

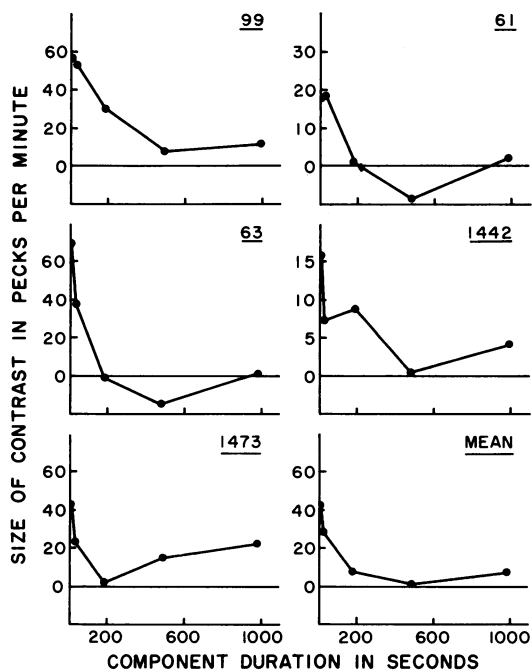Other studies have also reported that contrast disappears over time (e.g., Bloomfield,

Fig. 1. Positive contrast in pecks per minute as a function of component duration in seconds for each subject and for the mean of all subjects in Experiment 1. Positive contrast was measured by the difference between the rate of responding emitted during the VI 2-min component of the mult VI 2-min ext schedule and the mean rate of responding emitted during the comparable components of the mult VI 2-min VI 2-min schedules conducted for that component duration.

1967; Nevin & Shettleworth, 1966). But, these studies probably do not imply that the present measure of contrast should decrease with successive measurements. First, studies reporting a decrease in contrast did not define contrast as it was defined here. For example, Nevin and Shettleworth (1966) studied local contrast rather than the present overall contrast (cf. Innis, 1978). Studies that have used definitions more similar to the present one have not found decreases in contrast over time (e.g., Hearst, 1971; Selekman, 1973). Second, contrast typically disappeared in a few sessions in the studies reporting its disappearance. But more than 100 sessions were conducted before the size of contrast decreased in this study. Third, those studies did not recover the baseline rates of responding after contrast had disappeared. Therefore, it is not known whether the size of contrast did actually decrease over time or whether the baseline rate of responding decreased.

The present experiment should be replicated in a study that does not confound component duration with running order even though it is unlikely that running order produced the results. If the results were replicated, they would be consistent with earlier studies, which showed that the rates of responding emitted during the more favorable component of a multiple schedule decreased throughout the component (Arnett, 1973; Bloomfield, 1967; Catania & Gill, 1964; Hinson, Malone, McNally, & Rowe, 1978; Innis, 1978; Malone & Staddon, 1973; Nevin & Shettleworth, 1966; Spealman, 1976), and with studies that showed that response rates decreased with increases in component duration (Ettinger & Staddon, Note 1; Killeen, 1972; Kodera & Rilling, 1976; Shimp & Wheatley, 1971; Silberberg & Schrot, 1974; Spealman, 1976; Todorov, 1972). The present results would not be consistent with the results reported by Williams (1974), Buck, Rothstein, and Williams (1975) and Williams (1979). The reason for the differences between Williams' results and those of other studies is not known.

EXPERIMENT 2

Experiment 2 examines the size of negative contrast as a function of component duration when subjects peck keys for food reinforcers. No past study has examined this question in any detail. Innis (1978) and Spealman (1976) reported that the rates of responding emitted later in the less favorable component of a multiple schedule were higher than those emitted earlier. If changing component duration changes only how much of the higher and lower response rates are sampled, then response rates should be lower for short-duration less favorable components. Short-duration components should sample the period of lower responding for a larger proportion of their total duration. Ettinger and Staddon (Note 1), Killeen (1972), Spealman (1976), and Todorov (1972) directly supported this conclusion by reporting lower rates of responding during short-duration less favorable components than during longer ones. Again, if it could be assumed that the baseline rate of responding emitted during a multiple schedule with equivalent components would not change as a function of component duration (cf. Kodera & Rilling,

1976), then the present measure should decrease as component duration increases.

METHOD

Subjects

Four experimentally experienced pigeons, maintained at 80 to 85% of their free-feeding body weights served as subjects.

Apparatus and Procedure

The apparatus was identical to the one used in Experiment 1. The subjects were placed directly on a series of multiple schedules because they had pecked keys for food reinforcers in past experiments. All of the procedural details of these schedules were identical to those used in Experiment 1 with the following exceptions. First, subjects responded on several series of mult VI 2-min VI 2-min, mult VI 2-min VI 15-sec, and mult VI 2-min VI 2-min schedules. A white light always signaled the constant, VI 2-min component; a red light signaled the other component. Second, the set of three schedules was conducted in the order given for each of the following component durations presented in the following random order: 3-min, 5-sec, 16-min, and 30-sec. Third, sessions terminated after 20 food presentations for the mult VI 2-min VI 2-min schedules and after 40 food presentations for the mult VI 2-min VI 15-sec schedules. Fourth, each schedule was presented for an average of 41.8 sessions.

RESULTS AND DISCUSSION

Table 2 presents the mean rates of responding emitted during each component of each multiple schedule. Rates were calculated as they were for Table 1.

Figure 2 presents the size of negative behavioral contrast plotted as a function of component duration. The size of contrast was measured by the differences between the rates of responding emitted during the VI 2-min components of the mult VI 2-min VI 15-sec schedules and the average rates of responding emitted during the same components of the surrounding mult VI 2-min VI 2-min schedules. The points must fall below the horizontal line to qualify as negative contrast. Points that fall above the line would represent positive induction, defined as an increase in the rate of responding emitted during one component with

Table 2

Rates of responding, in pecks per minute, emitted during each component of each multiple schedule.

Subject	Component	Schedule 3-min Components			5-sec Components		
		VI 2-min VI 2-min	VI 2-min VI 15-sec	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min VI 15-sec	VI 2-min VI 2-min
6443	VI 2-min	22.4	4.4	19.3	39.1	17.6	53.0
	other	44.9	51.0	41.6	45.7	119.8	59.4
3174	VI 2-min	39.3	15.3	26.0	46.5	8.4	51.6
	other	42.4	50.3	39.4	49.4	103.7	60.4
1530	VI 2-min	41.0	24.0	32.3	73.8	12.0	80.8
	other	61.9	68.8	54.9	67.4	130.0	81.2
60	VI 2-min	13.7	25.2	36.6	22.4	14.2	57.1
	other	32.1	77.9	37.7	25.6	85.2	52.8
mean	VI 2-min	29.1	17.2	28.6	45.4	13.0	60.6
	other	45.3	62.0	43.4	47.0	109.7	63.5

Subject	Component	Schedule 16-min Components			30-sec Components		
		VI 2-min VI 2-min	VI 2-min VI 15-sec	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min VI 15-sec	VI 2-min VI 2-min
6443	VI 2-min	57.0	45.3	54.9	27.9	26.4	57.8
	other	59.6	79.6	57.0	27.9	90.8	59.0
3174	VI 2-min	38.0	40.6	54.4	40.7	35.3	41.4
	other	46.4	56.1	60.7	47.4	96.5	52.7
1530	VI 2-min	80.6	73.1	80.9	57.4	69.5	96.0
	other	75.6	58.0	81.6	64.6	89.4	103.5
60	VI 2-min	71.9	39.0	46.5	29.8	34.6	73.2
	other	73.3	54.5	50.2	29.3	109.3	84.7
mean	VI 2-min	61.9	49.5	59.2	39.0	41.5	67.1
	other	63.7	62.1	62.4	42.3	96.5	75.0

increases in the rate of reinforcement obtained from the other component.

Again, these results support two conclusions. First, Figure 2 and Table 2 show that negative contrast occurred. All points plotted in Figure 2 fall below the horizontal line and therefore represent negative contrast.

Second, Figure 2 and Table 2 show that the size of negative contrast changed with component duration. Contrast was large for the 5-sec component, ranging from 26 to 65 responses per minute, with an average of 40. Contrast decreased to 6 to 20 responses per minute, with an average of 11 for the 16-min component.

Again, a one-way within-subject analysis of variance applied to the points plotted in Figure 2 confirmed the conclusion that the size of negative contrast changed as a function of component duration [$F(3,9) = 5.77$, $p < .05$]. T-tests for matched pairs showed that the size of contrast for the 5-sec component was significantly different from that for each other com-

ponent duration. But, t-tests also showed that the size of contrast did not change significantly from the 30-sec to the 3-min or to the 16-min component durations.

Changes in the size of negative contrast over time cannot explain the present results. Component durations that produced contrast effects of similar sizes were conducted at both the beginning and the end of the experiment; and the 5-sec component duration, which produced different results, was conducted towards the middle. Therefore, the present results show that the absolute size of negative contrast decreases with increases in component duration. These results are compatible with those of the earlier studies, which reported that the rates of responding emitted later in the less favorable component were higher than those emitted earlier (Innis, 1978; Spealman, 1976), and with the studies which reported lower rates of responding during short duration less favorable components than during longer ones (Ettinger

& Staddon, Note 1; Killeen, 1972; Spealman, 1976; Todorov, 1972).

The symmetry of the results presented in Figures 1 and 2 is compatible with symmetrical theories of positive and negative contrast when pigeons peck keys. The absolute size of both positive and negative contrast varied inversely with component duration.

EXPERIMENT 3

Experiment 3 examines the size of negative contrast as a function of component duration when pigeons press treadles for food reinforcers.

METHOD

Subjects

Four of the five pigeons used in Experiment 1, maintained at 80 to 85% of their free-feeding body weights, served. Subject 63 died before the experiment began.

Apparatus

The same apparatus used in McSweeney (1978) was used here. It was a standard three-key Grason-Stadler pigeon station, model E6446C, enclosed in a Grason-Stadler, model E3125A-300, sound-attenuating chamber. Two floor treadles were added to the enclosure. 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

The procedural details were similar to those of Experiment 1, with the following excep-
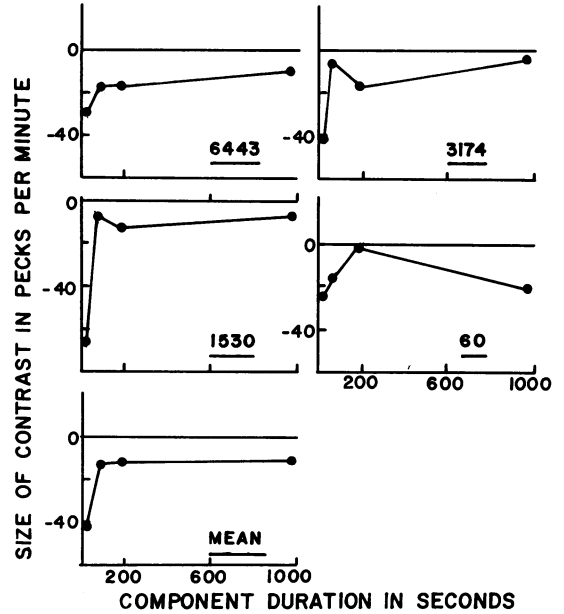

Fig. 2. Negative contrast in pecks per minute as a function of component duration in seconds for each subject and for the mean of all subjects in Experiment 2. Negative contrast was measured by the difference between the rate of responding emitted during the VI 2-min component of the mult VI 2-min VI 15-sec schedule and the mean rate of responding emitted during the comparable components of the mult VI 2-min VI 2-min schedules conducted for that component duration.

tions. First, the subjects were not trained to press the treadles because they had been trained to do so in a previous study (McSweeney, 1978). Rather, they were placed directly on a series of mult VI 2-min VI 2-min, mult VI 2-min VI 30-sec, and mult VI 2-min VI 2-min schedules. Presses on one treadle produced the reinforcers for one component; presses on the other produced reinforcers for the other component. A two-treadle procedure was used because McSweeney (1978) did not find contrast using only one treadle but did find it using two. The mult VI 2-min VI 30-sec schedule was used instead of the mult VI 2-min VI 15-sec schedule used in Experiment 2 because McSweeney (1978) found that the former schedule produced more negative contrast than the mult VI 2-min VI 15-sec schedule.

The set of three schedules was conducted in the order in which they are listed, for each of the following component durations presented in the following random order: 20-sec, 16-min, 4-sec, and 1-min. The components of the mul-

tiple schedule alternated. The constant VI 2-min component was always presented on the treadle located to the subject's left as it faced the experimental panel. This component was signaled by the red light. The other component was presented on the right treadle and signaled by white light. The lights appeared on the response keys located directly above each treadle. A 3-sec timeout during which the keylights were extinguished and treadle presses were not recorded or reinforced, separated the two components. This was included to insure that the time required to walk from one treadle to the other would not be included in calculating the size of contrast. If it were, it would distort the measures more for shorter than for longer components, making the results difficult to interpret.

Sessions terminated after 20 reinforcers had been presented for the mult VI 2-min VI 2-min schedule and after 40 reinforcers for the mult VI 2-min VI 30-sec schedules. Again, subjects responded on each schedule until responding had stabilized, which required 53.5 sessions on the average.

RESULTS AND DISCUSSION

Table 3 presents the mean rates of responding emitted during each component of each multiple schedule. Rates were calculated as they were for Table 1. The points for the 2-min component duration were taken from McSweeney (1978), which used the same subjects and a similar procedure. The procedure differed mainly in not separating the components by the timeout used in the present experiment.

Figure 3 presents the size of negative behavioral contrast plotted as a function of component duration. The size of contrast was measured by the differences between the rates of responding emitted during the VI 2-min component of the mult VI 2-min VI 30-sec schedules and the average rates of responding emitted during the same components of the surrounding mult VI 2-min VI 2-min schedules. The points must fall below the line to qualify as negative contrast. Again, points that fall above the line would represent positive induction, as defined in Experiment 2.

These results support two conclusions. First Figure 3 and Table 3 show that negative contrast occurred for longer component durations. All of the points for the 20-sec, 1-min, and 16-min component durations are below the hori-
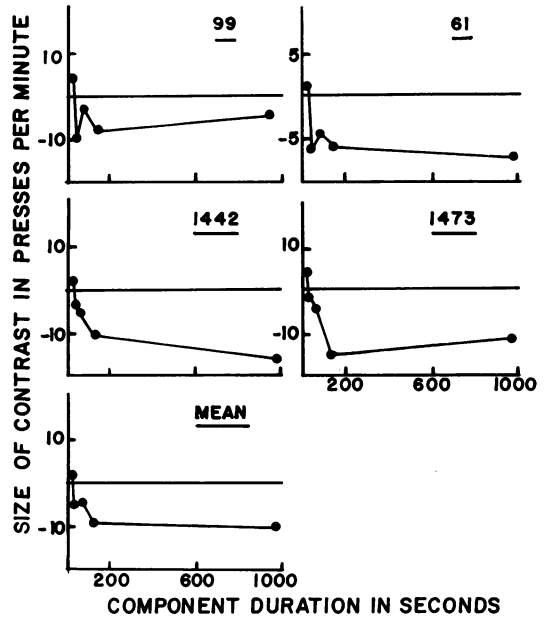

Fig. 3. Negative contrast in presses per minute as a function of component duration in seconds for each subject and for the mean of all subjects in Experiment 3. Negative contrast was measured by the difference between the rate of responding emitted during the VI 2-min component of the mult VI 2-min VI 30-sec schedule and the mean rate of responding emitted during the comparable components of the mult VI 2-min VI 2-min schedules conducted for that component duration.

zontal line in Figure 3 and therefore represent negative contrast. Induction may have occurred for the very short, 4-sec, component: all of the points plotted in Figure 3 fall above the horizontal line for this duration. But the small size of the induction (2.9 responses per minute on the average), and the failure of response rates to clearly increase for all subjects when the VI 30-sec schedule was substituted for the VI 2-min schedule during the variable component, make it difficult to argue that this is really induction rather than a failure to find negative contrast.

Second, the size of contrast changed with changes in component duration. Contrast was large for the longer durations, averaging 9.5 and 9.4 responses per minute for the 2-min and 16-min components respectively. It was smaller for the shorter components, averaging 4.0 and 5.3 responses per minute for the 1-min and 20-sec components respectively.

A one-way within-subject analysis of variance applied to the points in Figure 3 confirmed the significance of the changes in the

Table 3

Rates of responding, in presses per minute, emitted during each component of each multiple schedule.

Subject	Component	Schedule 20-sec Components			16-min Components		
		VI 2-min VI 2-min	VI 2-min VI 30-sec	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min VI 30-sec	VI 2-min VI 2-min
99	VI 2-min	26.2	8.9	10.0	15.3	14.2	21.7
	other	21.8	13.2	8.1	21.1	26.3	14.8
61	VI 2-min	20.2	9.4	10.4	14.8	11.3	21.4
	other	15.2	16.6	7.9	19.0	26.9	16.9
1442	VI 2-min	17.1	9.4	10.6	16.6	4.4	23.4
	other	12.8	14.0	14.4	13.7	22.0	19.6
1473	VI 2-min	18.6	11.9	9.0	10.4	4.0	18.7
	other	13.5	19.6	7.4	20.1	34.4	15.6
mean	VI 2-min	20.5	9.9	10.0	14.3	8.5	21.3
	other	15.8	15.8	9.5	18.5	27.4	16.7

Subject	Component	Schedule 4-sec Components			1-min Components		
		VI 2-min VI 2-min	VI 2-min VI 30-sec	VI 2-min VI 2-min	VI 2-min VI 2-min	VI 2-min VI 30-sec	VI 2-min VI 2-min
99	VI 2-min	13.2	23.3	25.3	32.6	28.4	28.7
	other	18.4	15.5	15.1	21.0	23.1	22.4
61	VI 2-min	11.6	14.2	13.2	21.0	15.5	18.4
	other	13.7	19.8	10.3	18.7	24.7	16.5
1442	VI 2-min	16.3	18.4	18.2	26.0	21.6	27.7
	other	24.9	15.9	9.9	14.6	20.8	19.2
1473	VI 2-min	13.4	17.5	12.8	28.3	23.9	28.0
	other	19.5	31.6	15.9	28.1	37.2	25.6
mean	VI 2-min	13.6	18.4	17.4	27.0	22.4	25.7
	other	19.1	20.7	12.8	20.6	26.5	20.9

Subject	Component	Schedule 2-min Components (taken from McSweeney, 1978)		
		VI 2-min VI 2-min	VI 2-min VI 30-sec	VI 2-min VI 2-min
99	VI 2-min	24.6	18.0	26.0
	other	18.9	37.8	21.9
61	VI 2-min	15.8	12.3	20.2
	other	24.1	25.1	27.0
1442	VI 2-min	17.2	7.7	19.5
	other	18.4	22.5	18.6
1473	VI 2-min	25.0	9.0	21.5
	other	15.6	29.8	18.2
mean	VI 2-min	20.6	11.7	21.8
	other	19.2	28.8	21.4

size of contrast with component duration [$F(4,12) = 9.68$, $p < .01$]. T-tests for matched pairs showed that the size of contrast for each component duration was significantly different from that for each other component duration ($p < .05$) except that the 20-sec component did not differ from the 1-min, 2-min, and 16-min components, and the 2-min component did not

differ significantly from the 16-min component.

Again, changes in component duration, rather than fluctuations over time, appear to have produced the significant changes in the size of contrast. For example, the 1-min component duration that was conducted last produced results intermediate to those of the

20-sec and 16-min components, which were conducted first.

Differences between the results presented in Figures 2 and 3 suggest that the same theoretical processes do not govern negative contrast for treadle pressing and key pecking. If the same processes had governed both types of responding, then Figure 3 should have resembled Figure 2, but it did not.

However, procedural differences between Experiments 2 and 3 may have also produced the results. The experiments differed in three major ways. First, the discriminative stimuli were located on the response operandum in Experiment 2, but not in Experiment 3. Second, pecking only one key produced reinforcers in Experiment 2, but pressing two treadles produced reinforcers in Experiment 3. Third, a timeout separated the components in Experiment 3 but not in Experiment 2.

The role of these procedural differences in producing the differences in results should be investigated by repeating Experiment 2 using a two-key timeout procedure and by replicating Experiment 3 with the discriminative stimuli on the treadles. But, two arguments question whether changing the procedure would produce similar functions for key pecking and treadle pressing. First, results similar to those reported in Figure 2 have been found using a two-key multiple schedule (Ettinger & Staddon, Note 1). Therefore, it is unlikely that the use of a two-key procedure would make the results for key pecking similar to those for treadle pressing. Second, the data for treadle pressing when the components were two minutes long were taken from a study that did not introduce a timeout between components. If the introduction of the timeout produced large changes in the size of negative contrast, then the point for the two minute component should have been different from those for the other durations. But, it was not.

GENERAL DISCUSSION

The present results support three major conclusions. First, the results conform to symmetrical theories of positive and negative contrast when pigeons peck keys for food reinforcers (e.g., Herrnstein, 1970; Rachlin, 1973). The size of positive and negative contrast probably would not change so similarly as a function of component duration if similar theoretical

mechanisms did not control them. However, this conclusion should be strengthened by investigating positive and negative contrast as a function of several other variables before strong conclusions are drawn.

The symmetry of positive and negative contrast should also be studied for other instrumental responses. Positive contrast was not studied as a function of component duration for treadle pressing in these experiments. Therefore, no conclusions can be drawn about the symmetry of positive and negative contrast for that response. However, the difficulty of producing positive treadle-press contrast in the past (Hemmes, 1973; McSweeney, 1978; Westbrook, 1973) suggests that positive and negative contrast may not be symmetrical for treadle pressing. If so, then conclusions about the symmetry of contrast have limited generality.

Second, the present results conform to theories that suggest that behavioral contrast may be different when pigeons press treadles and peck keys (e.g., Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973). If the same theoretical processes produced contrast in both cases, then the functions relating the size of negative contrast to component duration should have been the same for key pecking (Figure 2) and treadle pressing (Figure 3) but they were not.

Examining the present data in more detail provides additional evidence that key pecking and treadle pressing obey different laws. Shimp and Wheatley (1971) and Todorov (1972) varied component duration for multiple schedules in which the components provided different rates of reinforcement. They reported that the relative rates of pecking emitted during the components approached the relative rates of reinforcement obtained from the components, as the components became shorter. A similar trend appears in the present data for negative contrast when pigeons pecked keys, but the opposite trend occurred when they pressed treadles. For the mean of all subjects pecking keys in Experiment 2, the difference between the relative rates of responding and the relative rates of reinforcement were 0, .19, .11, and .33 for the 5-sec, 30-sec, 3-min, and 16-min components, respectively. For the mean of all subjects pressing treadles in Experiment 3, the comparable differences were .27, .19, .26, .09, and .04 for the 4-sec, 20-sec, 1-min, 2-min, and 16-min component durations, respectively.

Differences in the relation between the relative rates of responding and reinforcement for key pecking and treadle pressing are consistent with the idea that the two responses obey different laws. But, this relation should be examined more carefully in studies specifically designed for that purpose before strong conclusions are drawn. The present experiment was not specifically designed to examine the relation between the relative rates of responding and reinforcement. Therefore, the results may be distorted by fluctuations in responding that occurred during the baseline multiple schedule that intervened between successive points. The results of Experiment 1 emphasize the need for caution. The relative rates of key pecking failed to systematically approach the relative rates of reinforcement as components became shorter in this experiment, even though they did in Experiment 2. If fluctuations in responding produced this failure, then similar problems may have occurred in Experiments 2 and 3. The results of these studies should be replicated in experiments explicitly designed for this purpose before they are accepted.

Third, the present results support the usefulness of measuring contrast by the difference between a baseline rate of responding and the rate when contrast is present. A useful measure of any type of behavior should vary as an orderly function of the variables that control that behavior. The present measure of contrast varied as an orderly function of component duration. Again, however, the measure should be tested in many more situations. It is too early to tell whether the measure will generally prove orderly, or whether it will be more useful than alternative statistics such as ratios of the rates of responding (cf. Staddon, in press).

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