CONCURRENT PERFORMANCES: RATE AND ACCURACY OF FREE-OPERANT ODDITY RESPONDING¹

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In pigeon's oddity performances, maintained by variable-interval reinforcement of pecks on the odd key of three keys in a triangular array, accuracy and response rate varied inversely with the rate of variable-interval reinforcement scheduled concurrently for pecks on a fourth, spatially isolated key. But when variable-interval and extinction components alternated in a multiple schedule for pecks on the spatially isolated key, oddity accuracy was greater during variable-interval components than during extinction components. Oddity response rate was not affected systematically by the alternating components. Changeovers between the oddity keys and the spatially isolated key were frequent during variable-interval components; responding occurred almost exclusively on the oddity keys during extinction components. This difference in performance during the two components was eliminated by arranging stimulus-correlated variable-interval reinforcement in the multiple schedule on the spatially isolated key: a stimulus was presented in the variable-interval components only when reinforcement became available, thereby reducing responding on this key to near-zero levels in both components while maintaining the variable-interval reinforcement. The effect of the multiple-schedule components on oddity accuracy was not altered, however, and thus apparently depended directly on concurrent reinforcement and not on differential sequential properties of concurrent responding during the two components.

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Studies of complex discriminated operants, as in matching-to-sample or oddity performances, have shown that responding can be brought under the discriminative control of relationships among stimuli (Skinner, 1950), and that the accuracy of this control depends upon the schedule of reinforcement (Cumming and Berryman, 1965; Ferster, 1960). Studies of concurrent operants have shown that increasing the reinforcement of one response reduces the rate of other, concurrently reinforced responses, and that, with reinforcement held constant, changes in the rate of one response are independent of changes in the rate of concurrent responses (Catania, 1963). The present experiments combine these two types of studies, by examining the effects of concurrent reinforcement and concurrent responding on the rate and accuracy of free-operant oddity performance in the pigeon.

GENERAL METHOD

Subjects

Four adult, male, White Carneaux pigeons were maintained at about 80% of free-feeding body weight. Pigeons 69 and 70 were about 1.5 yr old and Pigeons 3 and 115 were about 11 yr

old at the start of the experiments. All four pigeons had experimental histories of about five months of preliminary research on simple oddity performances; in addition, Pigeons 3 and 115 had extensive histories in operant research.

Apparatus

A pigeon chamber, with standard provisions for masking noise and ventilation (*cf.* Ferster and Skinner, 1957), was modified to contain four translucent Gerbrands keys, as illustrated in Figure 1. On the left side of the panel, three keys were arranged so that their centers formed an equilateral triangle, base up, with sides of 2 in. (5 cm). Each key could be lit by red or green 6-w ac lamps mounted behind it; hereafter, these keys are referred to as the oddity keys. A fourth, spatially isolated key was located 4 in. (10 cm) to the right of the bottom oddity key, center-to-center. This key could be illuminated by blue or white 6-w ac lamps mounted behind it, and is later referred to as either the VI key or the multiple-schedule key.

Each key was adjusted to operate at a force of about 15 g (0.14 N). A dc relay mounted behind the panel provided feedback clicks for key pecks. A standard Gerbrands mixed-grain feeder was centered below the keys. Reinforcement duration was 2.25 sec, during which the

feeder was operated and illuminated, and the keylights were off. No houselight was used in the chamber, because the several keys provided sufficient general illumination when lit.

Procedure

Throughout the experiments, daily sessions lasted 100 min or equivalently, when a multiple schedule operated, fifty 2-min components, excluding reinforcement duration. The pattern of illumination on the three oddity keys was either one key red and two keys green or one key green and two keys red. Pecks on the odd key of the three were reinforced according to a variable-interval (VI) schedule (Ferster and Skinner, 1957): reinforcement was scheduled for the first odd-key peck that occurred after a variable time had elapsed since the last reinforcement for an odd-key peck. Thus, the schedule operated for single, free-operant, odd-key pecks; no sample stimulus was used, and therefore the durations or sequences of successive stimuli on the keys placed no limits on the rate at which odd-key pecks could occur.

With two colors available on each of three keys, six oddity configurations or problems were possible: red as the odd stimulus in any of three positions, with the remaining keys green, and green as the odd stimulus in any of three positions, with the remaining keys red. Five presentations of each of these six configurations were arranged in an irregularly ordered, recycling sequence of 30 oddity problems. A sample sequence is the following, in which 1, 2, and 3 respectively designate the upper left, upper right, or lower oddity key as the odd key, and in which R and G designate red or green as the odd color: 1G, 3G, 2R, 1R, 2R, 3G, 2G, 1G, 3R, 2R, 3G, 1R, 2G, 3G, 1R, 2G, 1G, 3R, 2G, 3R, 1G, 2G, 1G, 3R, 2R, 1R, 3G, 1R, 2R, 3R. Minor changes in the problem sequence were occasionally made during the course of the experiments, but are not discussed because they had no substantial effects upon oddity performance except, in some instances, in the session immediately following a sequence change.

The problem sequence included the following constraints: when a given color was the odd stimulus in one problem, the probabilities with which the same color or the other color was the odd stimulus in the next problem were approximately equal, but a given color was the odd stimulus in no more than three prob-

Fig. 1. Diagram of the panel. The three oddity keys were always illuminated either one key red and two keys green or one key green and two keys red. The spatially isolated VI or multiple-schedule key was illuminated either blue or white. VI --- variable interval. Details in text.

lems in a row; the odd stimulus never appeared on the same key in two successive problems, but when the odd stimulus appeared on one key in one problem, the probabilities with which it appeared on one or the other remaining keys in the next problem were approximately equal.

Different consequences were arranged for pecks on an odd key and for pecks on the other two keys. Each peck on an odd key produced a feedback click, changed the oddity problem to the next in the sequence, and, with exceptions noted below, was eligible for reinforcement according to the VI schedule. Pecks on either of the other two keys, designated as errors, did not produce a feedback click, did not change the oddity problem (correction procedure), and were not eligible for reinforcement. After an error, the next odd-key peck or, in a later procedure, the next odd-key peck and any that followed it within 0.5 sec, could not be reinforced; these odd-key pecks, however, continued to produce feedback clicks and to change the oddity problem to the next in the sequence. The constraint that the odd stimulus never appeared on the same key in two successive problems, which was included because it had produced substantial decrements in errors during preliminary research on oddity performance, eliminated the possibility of reinforcement after any succession of two or more pecks on a single oddity key.

The schedule that operated concurrently for pecks on the spatially isolated key was either a simple VI schedule, when this key was blue, or a multiple schedule in which VI reinforcement alternated with extinction (EXT), when this key was blue during VI components and white during EXT components. The VI schedule for this key and for the oddity keys operated independently, except that neither schedule operated during reinforcement. Both VI schedules were made up of 20 intervals selected according to the specifications of Catania and Reynolds (1968, Appendix II). When the VI schedules that operated for the oddity keys and for the spatially isolated key were equal, the sequence of intervals for one of the VI schedules was the reverse of the sequence for the other, so that reinforcements scheduled for the concurrent responses could not become synchronized. When the multiple schedule operated, reinforcements scheduled but not produced at the end of one VI component were

unavailable at the start of the next VI component.

During the experiments, a changeover delay or COD (Herrnstein, 1961) sometimes operated: the first peck on an oddity key after pecks on the spatially isolated key, or the first peck on the spatially isolated key after pecks on an oddity key, was not eligible for reinforcement and initiated a delay of 0.5 sec during which no subsequent pecks could be reinforced. The changeover delay reduced the extent to which pecks on any key could be maintained by reinforcement scheduled for pecks on other keys (*cf.* Catania and Cutts, 1963).

EXPERIMENT 1: ODDITY RATE AND ACCURACY DURING CONCURRENT VARIABLE-INTERVAL REINFORCEMENT.

Increasing the reinforcement of one response reduces the rate of other, concurrently reinforced responses (Catania, 1963), but only limited data are available on the effects of concurrent reinforcement on other measures than rate (*e.g.*, force: Chung, 1965; Levine and Loesch, 1967). In the present experiment, the schedule that maintained oddity responding was held constant, while the rate of reinforcement provided by a concurrent VI schedule was varied. Thus, the effect of concurrent reinforcement on both rate and accuracy of oddity responding could be examined.

Accuracy itself can be measured in terms of rates (*cf.* Skinner, 1950). It is given by the differential rates of those responses that are designated as correct responses and those that are designated as errors. In the case of accuracy measures, correct responses are maintained by reinforcement, but errors, by definition, are responses not eligible for reinforcement. The available evidence on how concurrent reinforcement affects response rate, however, cannot be extended directly to effects of concurrent reinforcement on accuracy, because concurrent reinforcement does not necessarily affect unreinforced responding, or responding during extinction, as it affects responding maintained by reinforcement (*cf.* Catania, 1969; Leitenberg, Rawson, and Bath, 1970). The present experiment, therefore, extends the analysis of concurrent interactions by examining the effects of concurrent reinforce-

ment on the component responses of a complex discriminated operant.

METHOD

Odd-key pecks were maintained by a VI 180-sec schedule of reinforcement. Concurrently, the schedule operating on the spatially isolated key, designated the VI key, was varied as indicated in Table 1. Each schedule on the VI key was maintained for 11 to 14 daily sessions, with variations determined by the work schedules of laboratory personnel. An exception was the extinction (EXT) schedule, which was maintained longer so that the criterion period did not include sessions during which response rates on the VI key were decreasing markedly.

During these schedules, both a changeover delay and a post-error delay operated: the first peck after a changeover or after an oddity error was ineligible for reinforcement and initiated a delay of 0.5 sec, during which subsequent pecks could not be reinforced.

Table 1

Schedule sequence in Experiment 1. A VI 180-sec schedule (20 rft/hr) operated on the oddity keys for odd-key pecks. The VI schedules shown operated concurrently for pecks on the spatially isolated VI key.
VI --- variable interval; EXT --- extinction

Schedule on VI key		Sessions
Sec	Rft/hr	
180	20	11
60	60	14
240	15	13
120	30	11
EXT	0	24

RESULTS

Figure 2 shows per cent errors, total response rate, and error rate on the oddity keys (unfilled symbols), and response rate on the VI key (filled circles), as a function of the rate of reinforcement (rft/hr) scheduled for the VI key. In general, the VI key response rate increased as a negatively accelerated function of the scheduled rate of reinforcement (lower frames). Increasing VI key response rates were accompanied by decreasing concurrent rates on the oddity keys. With the exception of Pigeon 115, for which the effect was small, the largest VI key reinforcement rate, 60 rft/hr, reduced the oddity response rate to about half the rate when 0 rft/hr (EXT) was scheduled for the VI key. The functions are similar in

form to those obtained with standard two-key concurrent VI schedules (Catania, 1963).

For all four pigeons, the oddity key response rate was lower than the VI key rate over most of the range of VI key schedules, including the point at which both schedules were equal (20 rft/hr). The VI key performance, however, included successions of pecks on the single key, whereas performance on the oddity keys included frequent switching from one oddity key to another, presumably because the sequencing of oddity key problems arranged that only the first of two or more successive pecks on a single oddity key was eligible for reinforcement (*cf.* General Method). Observing behavior such as scanning the oddity key stimuli may also have contributed, together with the frequent switching, to the relatively lower rate of oddity key responding.

The reduction in oddity key rate by increasing VI key reinforcement was accompanied by an increase in the proportion of oddity errors (upper frames). The effect was generally small (especially Pigeons 69 and 70) and each pigeon's data included reversals. Nevertheless, the trend was consistent across all four pigeons (*e.g.*, in all four cases, lines of best fit to the data had positive slope). It is consistent with this finding that the rate of oddity key errors was proportionately less affected by VI key reinforcement than the rate of correct oddity key

Fig. 2. Performance maintained on the oddity keys and on the spatially isolated VI key as a function of the reinforcements per hour (rft/hr) scheduled for pecks on the VI key, for four pigeons. Odd-key pecks were reinforced according to a VI 180-sec schedule. The upper frames show errors on the oddity keys as a percentage of the total pecks on oddity keys; the lower frames show rates of responding (resp/min) on the oddity keys (unfilled symbols) and on the VI key (filled circles). Oddity rates separately show both total odd-key pecks (circles) and errors (triangles). Data are arithmetic means over the last five sessions at each schedule value. VI --- variable interval.

responses. Across pigeons, in fact, the rate of oddity errors (triangles) did not vary systematically with the VI key reinforcement rate (*e.g.*, lines of best fit had a small positive slope for Birds 3 and 69, and a small negative slope for Birds 70 and 115).

DISCUSSION

An increase in the rate of VI key reinforcement reduced both the rate and the accuracy of concurrent oddity responding. The effect on accuracy came about because VI key reinforcement produced a proportionately greater decrease in correct oddity responses, which were eligible for reinforcement, than in oddity errors, which were ineligible for reinforcement. This finding is consistent with previous data (*e.g.*, Catania, 1969; Leitenberg, Rawson, and Bath, 1970) that indicate concurrent reinforcement does not affect unreinforced responding in the same way as reinforced responding.

EXPERIMENT 2: ODDITY ACCURACY DURING THE CONCURRENT OPERATION OF A MULTIPLE SCHEDULE

The reduction in reinforced responding by an increase in the reinforcement of concurrent responses is observed when a pair of simple schedules operates concurrently (*e.g.*, as in concurrent VI VI schedules). This effect is not necessarily observed, however, when changes in concurrent reinforcement occur within a multiple schedule, in which two or more component schedules operate in alternation each in the presence of a different stimulus (*e.g.*, Catania, 1962). For example, when a multiple VI EXT schedule operates for a pigeon's pecks on one key, and a simple VI schedule operates concurrently for pecks on a second key, the rate of pecking on the second key may remain relatively constant, even though this rate is sometimes accompanied by reinforcement and a high rate of responding on the other key (during the VI component of the multiple schedule), and sometimes by no reinforcement and little responding on the other key (during the EXT component of the multiple schedule). The present experiment therefore examined oddity accuracy during the concurrent operation of a multiple schedule, in which a VI component alternated with an EXT component on the spatially isolated key. On the basis of

the data from Experiment 1, it might be assumed that oddity accuracy would be lower during the VI component, when concurrent reinforcement was available, than during the EXT component, when concurrent reinforcement was not available; this assumption was not confirmed.

METHOD

In actual chronology, Experiment 2 preceded Experiment 1. The procedure is outlined in Table 2. At this point in the research, the pigeons had no history of either concurrent responding or reinforced pecking on the spatially isolated key, hereafter designated the multiple-schedule key. Responding was therefore established separately on the oddity keys and on the multiple-schedule key before the schedules were combined concurrently. First, during VI 60-sec reinforcement of oddity key pecks, the multiple-schedule key was dark and inoperative. Then, the oddity keys were made dark and inoperative, and a multiple VI 120-sec EXT schedule was introduced on the multiple-schedule key. The key was blue during its VI component and white during its EXT component; components lasted 2 min, excluding reinforcement duration. The VI 60-sec reinforcement of oddity key pecks was next reinstated, with the multiple-schedule key again dark and inoperative. Finally, the schedules for the oddity keys and the multiple-schedule key were introduced concurrently. The mean intervals of the VI schedules were then increased as indicated in Table 2.

During the concurrent operation of the schedules, the first peck after a changeover was ineligible for reinforcement and initiated a delay of 0.5 sec, during which subsequent

Table 2

Schedule sequence in Experiment 2. The multiple-schedule key was blue during its VI component and white during its EXT component. Keys were unlit when inoperative. Details in text. VI --- variable interval; EXT --- extinction; mult --- multiple.

Oddity keys	Multiple-schedule key	Sessions
VI 60-sec	INOPERATIVE	38
INOPERATIVE	mult VI 120-sec EXT	23
VI 60-sec	INOPERATIVE	29
VI 60-sec	mult VI 120-sec EXT	7
VI 90-sec	mult VI 120-sec EXT	5
VI 120-sec	mult VI 120-sec EXT	4
VI 180-sec	mult VI 180-sec EXT	8

pecks could not be reinforced (COD 0.5-sec). When the oddity keys were operative, the first peck after an oddity error was also ineligible for reinforcement, but in this experiment it did not initiate a post-error delay.

RESULTS

Figure 3 shows oddity accuracy, in terms of per cent errors, during both the VI and EXT components of the multiple schedule, for each of the 24 sessions of concurrent scheduling in Experiment 2. The data for a given session are shown by a pair of connected circles. The circle on the left represents performance during the VI component, and that on the right performance during the EXT component. Thus, a connecting line of positive slope indicates that oddity accuracy was greater (fewer errors) during the VI component than during the EXT component. The dashed horizontal lines show performance over the preceding five sessions, when VI 60-sec reinforcement was scheduled for oddity responding in isolation.

The data show that the oddity performance was consistently more accurate during concurrent VI components than during concurrent EXT components. (Similar results were also obtained in later experiments with *mult* VI 60-sec EXT, *mult* VI 90-sec EXT, and *mult* VI 240-sec EXT operating concurrently with VI 180-sec reinforcement of oddity key responding, except that the accuracy difference was not reliable for Pigeon 3 concurrent with *mult* VI 60-sec EXT, and for Pigeon 69 concurrent with *mult* VI 240-sec EXT; these data are otherwise largely redundant with those in Fig. 3, and have not been included here for economy of presentation.) Of the 96 sessions represented in Figure 3 (24 for each pigeon), oddity responding was more accurate during VI than during EXT components in 88 sessions, and three of the exceptions occurred during the first two sessions of concurrent scheduling. There were, however, no consistent or long-lasting effects of the novelty of concurrent scheduling on oddity accuracy in the early sessions of the procedure (*cf.* Stubbs and Thomas, 1966).

Oddity performance was more accurate during the VI component than during the EXT component of the multiple schedule, even though concurrent reinforcement was available during the VI component but not during the EXT component (*cf.* Figure 2), and even

though performance during the VI component consisted of frequent switching between the oddity keys and the multiple-schedule key, whereas performance during the EXT component consisted of responding almost exclusively on the oddity keys. For convenience of presentation, consideration of the rates of responding on the several keys during each component is deferred to Experiment 3; for the present purposes, it is sufficient to note that rates on the multiple-schedule key during its EXT component were near zero through all sessions, and that data to be presented in Experiment 3 show that the difference in oddity accuracy during the two components did not depend on changes in response rate on the oddity keys or on the multiple-schedule key.

The data in Figure 3 are based upon all oddity key responses, and therefore include both initial errors, or errors on the first peck on a particular problem, and perseverative errors, or repeated errors on a given presentation of a problem (*cf.* correction procedure, General Method). The percentage of oddity errors was therefore also calculated as per cent initial errors, by excluding perseverative errors, and as per cent perseverative errors, by considering only those pecks that were preceded by an error. Both of these measures, like the overall percentage, showed that oddity performance was more accurate during the VI than during the EXT components of the multiple schedule. Thus, the effect of the multiple-schedule components on overall oddity accuracy was not the derivative of an effect restricted either to initial oddity or to perseverative oddity errors. (Correlated changes in initial errors, perseverative errors and total errors were also obtained with data from Experiments 1 and 3.)

Throughout the experiments, errors were also analyzed in relation to problem sequences and to odd-key color and position. No systematic error patterns were consistently observed across pigeons, although idiosyncratic error patterns were sometimes observed transiently for a particular pigeon. Thus, no attempt was made to relate these error patterns to the different oddity accuracies during the multiple-schedule components. Even if the stimulus control of oddity responding sometimes depended on problem sequence or other factors, however, the effect of multiple-schedule components would be as well illustrated by modi-

Fig. 3. Oddity accuracy for four pigeons during the initial 24 sessions with a multiple VI EXT schedule operating concurrently for pecks on the multiple-schedule key. During these sessions, the schedule for odd-key pecks was changed from VI 60-sec to VI 180-sec, as indicated along the abscissa. The multiple-schedule VI component began as VI 120-sec, and changed to VI 180-sec in the same session as the oddity keys schedule. Oddity errors are shown as a percentage of the total pecks on oddity keys. Each session is represented by a connected pair of circles: per cent oddity errors during the VI component of the multiple schedule on the left, and during the EXT component on the right. A connecting line of positive slope indicates that oddity accuracy was greater (fewer errors) during VI components than during EXT components on the multiple-schedule key. The dashed lines show per cent oddity errors during the last five sessions of the preceding schedule, when the VI 60-sec schedule for odd-key pecks operated in isolation. VI --- variable interval; EXT --- extinction.

fication of this control as by modification of oddity responding *per se*.

DISCUSSION

In Experiment 1, an increase in concurrent reinforcement tended to reduce oddity accuracy, although the effect was small and somewhat variable. In the present experiment, the relationship was reversed: oddity performance was more accurate when concurrent reinforcement was available, during the VI component of the multiple schedule, than when concurrent reinforcement was not available, during the EXT component of the multiple schedule. The VI and EXT components differed in the rates and temporal patterns of responding, as well as in the availability of concurrent reinforcement. Experiment 3, therefore, was devoted to an experimental analysis of the variables that operated upon oddity accuracy during the VI and EXT components of the multiple schedule.

EXPERIMENT 3: SEPARATING THE EFFECTS OF CONCURRENT REINFORCEMENT AND CONCURRENT RESPONDING ON ODDITY ACCURACY

Previous research has shown that the rates of responding maintained by concurrent VI schedules depend upon the availability of concurrent reinforcement, and not upon competition between concurrent responses. For example, when reinforcement availability is signalled in one of two concurrent VI schedules, the responding maintained by that schedule can be reduced to negligible levels without changing the rate of reinforcement (stimulus correlated or SC VI schedules, in which the pigeon's key lights only when reinforcement has been scheduled for the next peck: Catania, 1963; Rachlin and Baum, 1969). An increase in the reinforcement scheduled by either a standard or a stimulus-correlated VI schedule reduces the rate of concurrent responding, but the change from the high rate of responding maintained by a standard VI schedule to the negligible rate maintained by an equal stimulus-correlated VI schedule has no effect on the rate of concurrent responding. The present experiment therefore used a stimulus-correlated VI schedule, in the VI component of the multiple schedule that operated on the spatially isolated key, to separate the effects of concurrent reinforcement and concurrent responding on oddity accuracy.

The experiment also examined the effects of the changeover delay, and of the alternation between two different overall rates of reinforcement (the higher rate during the VI component of the multiple schedule, when reinforcement was scheduled for both the oddity keys and the multiple-schedule key, and the lower rate during the EXT component of the multiple schedule, when reinforcement was scheduled only for the oddity keys).

METHOD

Table 3 summarizes the major procedures of Experiment 3. In actual chronology, this experiment followed Experiment 1 after 35 intervening sessions of other concurrent schedules. The first condition duplicated the concurrent schedules of Experiment 2 (Figure 3). The VI component of the multiple schedule was then changed to a stimulus-correlated (SC) VI 180-sec schedule, in which the multiple-

schedule key was dark except when a VI reinforcement was scheduled, when it was lit blue; the multiple-schedule key remained white throughout its EXT components. After 20 sessions with the SC VI schedule, the standard VI schedule was reinstated. Throughout these sessions, both changeovers and oddity errors were not eligible for reinforcement, and initiated a delay of 0.5 sec, during which period of time subsequent pecks could not be reinforced.

Subsequent procedures included replications with SC VI 180-sec, substitution of VI 90-sec and SC VI 90-sec in the VI component of the multiple schedule, removal of the COD, and sessions of EXT for oddity responding and for multiple-schedule responding. For ease of presentation, these procedures are not presented in detail in Table 3.

After the intervening procedures, the original concurrent schedules were reinstated, except that the COD no longer operated. In both this and the final procedure, however, oddity errors continued to initiate a delay of 0.5 sec, during which subsequent pecks could not be reinforced.

In the final procedure, again without the COD, the concurrent schedules were altered so that the overall rate of reinforcement was constant at 20 rft/hr throughout both components of the multiple schedule. During the VI component, both oddity key and multiple-schedule key pecks were reinforced according to VI 360-sec schedules (10 rft/hr each); during the EXT component, only oddity key pecks were reinforced, but according to a VI 180-sec schedule.

RESULTS

The general properties of the concurrent performance are illustrated in Figure 4, which compares two methods of data presentation. The cumulative records, on the left, show that oddity performance consisted of relatively continuous responding, whereas multiple-schedule performance consisted of periods of responding during VI components alternating with periods of no responding during EXT components; changeovers were frequent during VI components, but occurred rarely during EXT components, when responding was restricted almost exclusively to the oddity keys. The bar graph on the right, which illustrates the same general properties of the concurrent perform-

ance, separately shows the rates on the oddity keys (unfilled bars) and on the multiple-schedule key (filled bars) during the VI and the EXT components of the multiple schedule. Oddity accuracy, shown as per cent errors during each component (unfilled circles) is superimposed upon the response-rate data; as in Figure 3, a connecting line of positive slope indicates that oddity performance was more accurate (fewer errors) during the VI than during the EXT component of the multiple schedule.

Fig. 4. Sample concurrent performance for Pigeon 3, illustrating the relationship between cumulative records (left) and graphic presentation (right). Pecks on oddity keys, including errors, are cumulated in the upper record; pips show reinforced odd-key pecks. Pecks on the multiple-schedule key are cumulated in the lower record; pips show reinforced VI component pecks. Both records are offset downward during the EXT component of the multiple schedule. The event-pen record (COs) shows changeovers from the oddity keys to the multiple-schedule key. On the right, the unfilled bars separately show the rates of oddity key pecks during the VI and during the EXT components of the multiple schedule. The filled bar shows the rate on the multiple-schedule key during its VI component; the rate during its EXT component was negligible. Per cent oddity errors and rate of changeovers (COs, in one direction only) are also represented. Both presentations show rates of responding on both the oddity keys and the multiple-schedule key during both components of the multiple schedule. The graphic presentation also shows, as in Figure 3, oddity accuracy during both multiple-schedule components. VI --- variable interval; EXT --- extinction; mult --- multiple schedule.

The data for each pigeon in each of the four conditions of Experiment 3 are shown in Figure 5 in the same format as the bar graph of Figure 4. For each pigeon, oddity performance was more accurate during the VI than during the EXT component of the multiple schedule in repetitions of the concurrent schedules both with a COD (column 1) and without a COD

Table 3

Schedule sequence in Experiment 3. Abbreviations as in Tables 1 and 2. SC VI --- stimulus-correlated VI: the key lit only when reinforcement was scheduled for the next peck, and was otherwise dark. The alternation of the two oddity key schedules in the final condition was synchronized with the alternation of the respective multiple-schedule components. Details in text.

<i>Oddity keys schedule</i>	<i>Multiple schedule</i>	<i>COD</i>	<i>Sessions</i>
VI 180-sec	mult VI 180-sec EXT	0.5 sec	35
VI 180-sec	mult SC VI 180-sec EXT	0.5 sec	20
VI 180-sec	mult VI 180-sec EXT	0.5 sec	6
—	—	—	199*
VI 180sec	mult VI 180-sec EXT	None	38
VI 360-sec/VI 180-sec	mult VI 360-sec EXT	None	21

*Intervening procedures, briefly noted in the text.

Fig. 5. Data from four pigeons over the last five sessions of several concurrent oddity and multiple-schedule procedures, presented in the format illustrated in Figure 4. Column 1 shows performances maintained by the baseline schedule. A VI 180-sec schedule operated for odd-key pecks, a multiple VI 180-sec EXT schedule operated for the multiple-schedule key, and changeovers initiated a changeover delay (COD) of 0.5 sec. Column 2 shows the effect of eliminating the COD. Column 3 shows the effect of changing the VI component of the multiple schedule to a stimulus-correlated (SC) VI 180-sec schedule. Column 4 shows the effect of arranging schedules in which total reinforcement was constant during the two components of the multiple schedule. Details in text; abbreviations as in Figure 4.

(column 2), with SC VI 180-sec substituted for VI 180-sec, which reduced responding on the multiple-schedule key to negligible levels without affecting rates of reinforcement (column 3), and with overall rates of reinforcement held constant across the two components of the multiple schedule (column 4). Data from the earlier exposure to the schedules of column 1 (Experiment 2, Figure 3) and from later exposures (including Table 3, line 3) were comparable to the data shown in Figure 5; similar data to those shown in columns 1 and 3 were also obtained with VI 90-sec and SC VI 90-sec in the multiple schedule, except for somewhat higher rates on the multiple-schedule key during VI 90-sec components, but these data have been omitted from Figure 5 for economy of presentation.

Although the availability of concurrent reinforcement during the VI component of the multiple schedule had consistent (though small) effects on oddity accuracy across all conditions of Experiment 3, it did not have consistent effects on the rate of oddity responding: the rate of oddity responding during the VI component (left unfilled bar) was lower than the rate during the EXT component (right unfilled bar) in only seven of the 16 cases shown in Figure 5. In this respect, the data confirm earlier findings demonstrating that the rate of one response may be independent of the rate of other, concurrent responses (Catania, 1961, 1963). Both oddity and multiple-schedule rates tended to be lower with no COD than they were with COD 0.5-sec (*cf.* Catania, 1962), but these overall differences in rate, as with the differences in oddity rate between components, did not eliminate or reverse the difference in oddity accuracy between components.

DISCUSSION

The data of Figure 5 rule out the COD, the rate of responding on the multiple schedule key, and the alternation of different overall rates of reinforcement as determinants of the more accurate oddity performance during VI than during EXT components of the multiple schedule. In ruling out these possibilities, the data also make it implausible to attribute the effect to detailed temporal patterns of responding. For example, in the initial concurrent schedules (Figure 5, column 1), oddity responding during VI components consisted of rapid bursts separated by pauses during which responding occurred on the multiple schedule key, whereas oddity responding during EXT components consisted of slower but steadier responding restricted to the oddity keys. It therefore might be argued that some aspect of this difference in responding generated the difference in accuracy. In the SC VI condition (Figure 5, column 3), however, responding on the multiple-schedule key was negligible during both VI and EXT components; during the SC VI component, switching to the multiple-schedule key occurred only once every 180 sec, on the average, when reinforcement became available and the key lit. Thus, throughout both components, oddity key responding was essentially uninterrupted by periods of responding on the multiple-schedule key. Nevertheless, the difference in oddity accuracy was observed in this condition as in the others.

During the SC VI component of the multiple schedule, oddity responding may have been interrupted frequently by observing responses under the control of the illumination of the multiple-schedule key. Rachlin and Baum (1969) suggested that such responding is probably not critical in concurrent interactions, and visual observation of the pigeons in the present research did not reveal any consistent head movements that were specific to SC VI components. Even if some type of observing behavior occurred, it is not clear how it could account for the similar effects of both VI and SC VI components of the multiple schedule and for the difference of these effects from those in Experiment 1, nor is it clear why it should be assumed that the behavior would be restricted to SC VI components when observing responses during EXT components could presumably be reinforced by the onset of

either VI or SC VI components. Thus, the appropriate conclusion from the present data appears to be that the effect on oddity accuracy depends directly on the availability of concurrent reinforcement, but that this availability must alternate frequently with periods of unavailability, as in the EXT component of the multiple schedule. Although data are not available, it may be assumed that the effect on oddity accuracy would be attenuated by increases in the duration of multiple-schedule components.

GENERAL DISCUSSION

These experiments demonstrate that stimulus control can be modified by the availability of concurrent reinforcement. The relationships are complex, and it would be premature to interpret them solely in terms of different effects of concurrent reinforcement on those responses maintained by reinforcement (correct responses) and those not maintained by reinforcement (errors). In fact, it may be inappropriate to refer to errors as responses not maintained by reinforcement. If correct responses and errors in the oddity performance are regarded as two classes of responses and if the former class is strongly maintained by occasional immediate reinforcement scheduled for odd-key pecks, the latter class may be best described not in terms of a failure of stimulus control over unreinforced responses, but rather as a class of responses that is weakly maintained, incidentally, by the delayed reinforcement that occurs when oddity errors are followed at some later time by other, reinforced responses. The rates of responses that are followed by different delays of reinforcement are not reduced in equal proportions when the rate of concurrent reinforcement increases (Chung and Herrnstein, 1967). Thus, to the extent that correct responses and errors are followed by different delays of reinforcement, a change in concurrent reinforcement predicts a change in the proportion of errors. The present interactions may therefore be amenable to quantitative analyses similar to those proposed by Herrnstein (1970), but such an analysis would require more assumptions about actual delays of reinforcement after errors and about the values of several constants than could be justified by the available data.

The finding that stimulus control can be modified by the availability of concurrent reinforcement has both precedent (Carter, 1968; Catania, 1961, Figure 2) and implications. For example, situations in which concurrent reinforcement reduces errors may provide a useful supplement to available ways of establishing errorless discriminations (Terrace, 1963), and further analyses of the effective variables may have applications to those situations in which distractions have been shown to facilitate rather than impair human performance (e.g., Ellis, Hawkins, Pryer, and Jones, 1963; Gould and Schaffer, 1967, p. 199; Turnure, 1969).

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