RATIO REINFORCEMENT OF MATCHING BEHAVIOR[1]

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Three pigeons, previously trained to a high level of accuracy on matching-to-sample proce-
dures, were exposed to various schedules of ratio reinforcement for correct matches. Overall
accuracy was lower on fixed ratio than on regular reinforcement. There was a high incidence
of errors immediately after reinforcement on fixed ratio schedules with accuracy increasing as
the ratio progressed. This increase was found to be inversely correlated with the latency of the
observing response to the sample. By contrast, accuracy was high throughout the ratio on a
variable ratio schedule.

The matching-to-sample performance con-
sists of a chain of responses under stimulus
control, the last link of which requires a con-
ditional discrimination, in that the correct
response is determined by the relation be-
tween two stimuli. Ferster (1960) has shown
that this complex unit of behavior can be
maintained in pigeons by various schedules of
intermittent reinforcement, and that the rate
of emission of the behavior and the accuracy
of the matching response are related to the
schedule. In particular, he found that accuracy
was near chance under regular reinforcement
and improved on fixed ratio schedules.

Some other recent studies of matching be-
havior have shown that pigeons can acquire
an almost errorless performance under regular
reinforcement if a different procedure is
employed (Cumming and Berryman, 1961;
Berryman, Cumming, and Nevin, 1963). This
study is concerned with the effects of ratio
reinforcement on a matching performance
already learned to a high level of accuracy.

The effects of fixed ratio size on perform-
ance are analyzed, and, in addition, perform-
ance changes are related to the ordinal num-
ber of the trial on each ratio schedule.

METHOD

Subjects

Three white Carneaux hen pigeons, Nos.
177, 180, and 181, were maintained within

15 grams of 80% of their free-feeding weights
throughout the experiment. Before the start
of the experiment reported here, all three sub-
jects had had extensive histories of training
on matching-to-sample, including the follow-
ing procedures: (a) Randomized presentation
of simultaneous and delay matching condi-
tions for nine sessions (Berryman et al., 1963).
(b) Simultaneous matching with regular rein-
forcement for correct matches for 50 sessions
(the first 20 sessions of acquisition on this pro-
cedure are reported by Berryman et al., 1963).
(c) Simultaneous matching with reinforcement
for correct responses on fixed ratio 10 for
43 sessions.

All subjects had acquired the matching
performance on a procedure employing a 3-sec
blackout following incorrect responses, and a
25-sec intertrial interval. In the course of the
50 sessions on regular reinforcement (b above),
the blackout contingency was removed and the
intertrial interval reduced to 1 sec.

Bird 181 had given evidence of deviant per-
formance during exposure to the various
matching procedures reported by Berryman
et al., (1963) and was dropped from that ex-
periment. However, when given further train-
ing on the simultaneous condition, this sub-
ject acquired a performance which appeared
normal in all respects, and was accordingly
employed in this experiment.

Apparatus

The apparatus was the same as that used in
two previous studies (Cumming and Berry-
man, 1961; Berryman et al., 1963). On one wall
of a triangular aluminum cage were mounted

three keys (each of which could be separately illuminated with red, green, or blue light) and a grain magazine. Sound attenuation was provided by an enclosing box lined with fiberglas; ventilation and some masking noise were furnished by a blower.

Procedure

After a four month layoff, the subjects were exposed to the matching procedures outlined in Table 1 for five days per week, weight permitting. Reinforcement schedule, number of sessions, number of trials per session, and intertrial interval were programmed as indicated for each procedure.

Table 1

Experimental Design

Procedure	Reinforcement Schedule	No. of Trials per Session	Intertrial Interval	No. of Days
I	CRF	84	25	5
II	FR 3	420	1	10
I	CRF	84	25	3
III	FR 6	420	1	10
I	CRF	84	25	3
IV	FR 10	420	1	10
V	CRF	84	1	10
VI	VR 3	420	1	10

NOTE: Ratio size indicates the number of responses per reinforcement, not number of responses before establishment of the contingency. Thus, CRF and FR 1 are identical. Variable ratio 3 was generated by programming the following fixed ratios in random order: 1 (4 instances), 2, 3, 4, 5, 6 (2 instances each). The precise value for the mean of this set is 3.14.

On all procedures, trials were initiated by illuminating the center key with red, green, or blue light. When the bird completed a fixed ratio of five observing responses on this key, both side keys were illuminated, one with the same hue as that on the center key, and the other with one of the two odd hues. All keys remained illuminated until the bird made a single response on either of the side keys, at which time all key lights were extinguished. (This is referred to above as the simultaneous condition.)

Under regular reinforcement (Procedures I and V), a response to the key of matching hue resulted in a 3-sec presentation of the grain magazine, followed by an intertrial interval during which all keys were dark and responses ineffective. A response to the key of non-matching hue was followed by a time out equal in length to the sum of the reinforcement duration and the intertrial interval. At the end of the intertrial interval, the next trial was initiated by the onset of the center key light. Thus, the time elapsing between trials was constant regardless of whether the side key response was to the matching or non-matching hue.

Under ratio reinforcement, a response to the side key of matching hue advanced the ratio programmer one step; a response to the key of non-matching hue had no effect. Only the response completing the required ratio was reinforced. A 1-sec intertrial interval followed each reinforcement. If the contingency had not been met, a response on either side key terminated the trial and started the 1-sec intertrial interval; thus, there were no immediate differential consequences of correct and incorrect responses, and the only effect of errors was to delay the availability of the next reinforcement.

The hue of the center key, the side on which the matching hue appeared, and the non-matching hue were changed randomly after each trial, through a cycle of the 12 possible stimulus conditions. The order within this cycle was not changed, since previous work had shown that pigeons in this situation do not base their responses on cues arising from the stimulus sequence. The use of such a non-correction procedure prevents any systematic patterns of responding, such as color or position habits, or simple alternation, from receiving better than 50% (chance) reinforcement.

RESULTS AND DISCUSSION

In the course of earlier experimentation, all three subjects had acquired matching accuracies of 96 to 98%, on a procedure employing blackouts for incorrect responses and a 25-sec intertrial interval. Removal of the blackout contingency and reduction of the intertrial interval to 1 sec had substantially no effect on the maintenance of this level of accuracy. However, the imposition of an FR 10 requirement reduced the accuracy of all three subjects by 8 to 20 percentage points, the effect being largely independent of intertrial interval over the 1 to 4 sec range investigated. There was no indication of recovery of accuracy in the course of the 43 days of ex-

posure. This result stands in marked contrast to that of Ferster (1960), who found improvement in accuracy with increasing ratio size up to FR 15. Accordingly, it was decided to redetermine the effects of various small fixed ratios on the matching performance. Since procedural parameters other than ratio size appeared to be relatively unimportant, a 1-sec intertrial interval was used.

When the subjects were reconditioned on Procedure I after a four-month layoff, they immediately recovered their former high levels of accuracy. When shifted to FR 3, all subjects showed a decline in accuracy from day to day, stabilizing after five or six days on the schedule. High accuracy was recovered immediately upon re-exposure to Procedure I, with a similar decline appearing on FR 6. The same result was obtained when the birds were again returned to Procedure I and then exposed to FR 10. The accuracy of matching on FR I, which followed immediately after FR 10, was not different from that obtained on Procedure I. Figure 1 presents the mean per cent correct matches as a function of ratio size for the last five sessions of exposure to all fixed ratio procedures with 1-sec intertrial intervals. The accuracy for all subjects was reduced on fixed ratios greater than 1. The effect of increasing ratio size above FR 3 was not clear, however, since Birds 180 and 181 showed improvement, and 177 a decrement. Data taken from Ferster (1960) for his subject 5Y show a steady increase in accuracy over the same range of ratios.

A closer analysis of the performances of our subjects revealed that, as exposure to each FR schedule proceeded, the birds tended to make most of their errors on trials following shortly after reinforcement. Accordingly, a count was made of the number of correct matches for each successive trial number after reinforcement. Figure 2 shows the relation between accuracy of matching and ordinal position of the trial in the ratio run, cumulated for the last five days of exposure to each ratio procedure. It appears that the introduction of a fixed ratio contingency had the effect of reducing accuracy immediately after reinforcement to approximately chance levels. As the number of trials since reinforcement increased, accuracy also increased and approached its regular reinforcement level. The same trend appears for all three subjects on all fixed ratio schedules employed, with some individual differences. Bird 177 showed a
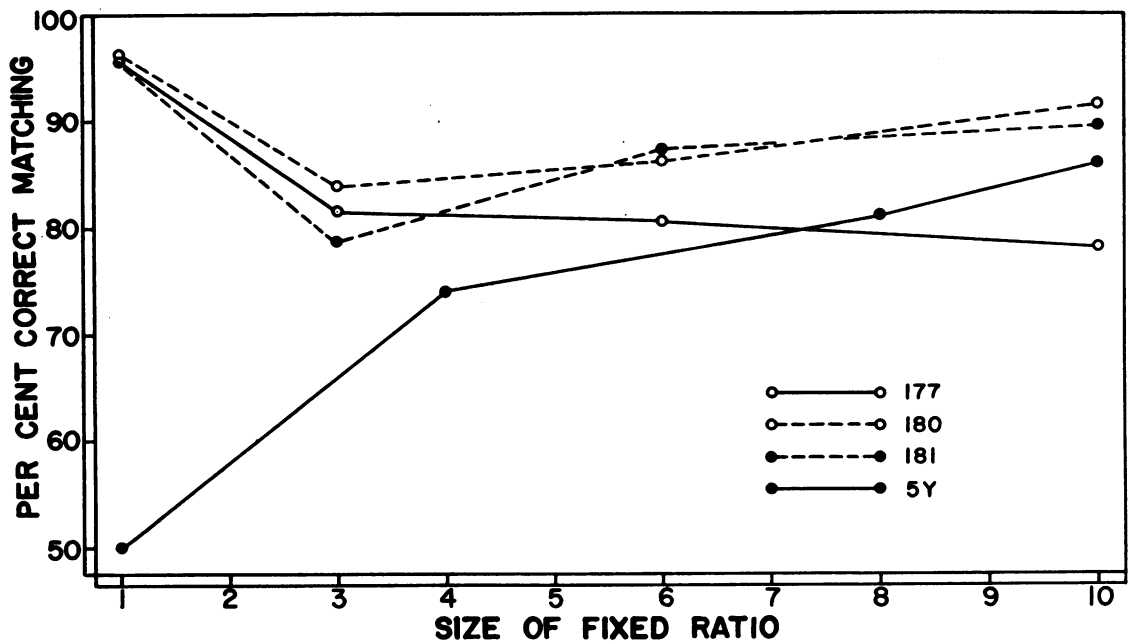
Fig. 1. The relation between accuracy of matching and size of the fixed ratio. Data for our subjects are means for the last five days of exposure to each schedule. Data from Ferster (1960) for his subject 5Y are plotted for comparison.

decrease in accuracy for any given trial as the ratio size increased, while Birds 180 and 181 showed little if any decline. All three subjects had high and substantially horizontal accuracy functions under variable ratio reinforcement, showing that the effect cannot be attributed to a reduced frequency of reinforcement alone.
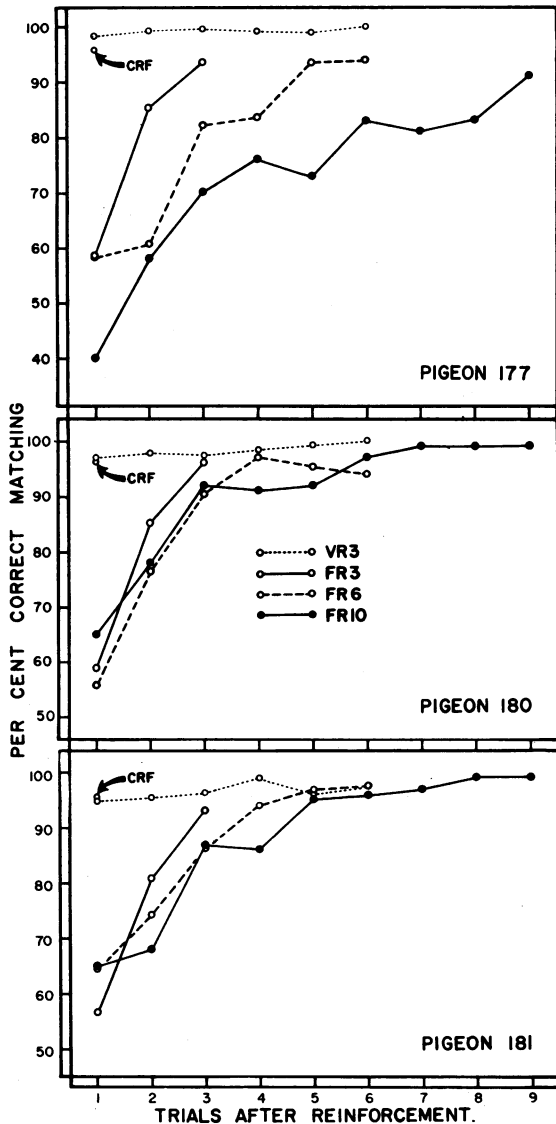

Fig. 2. Accuracy of matching as related to the ordinal number of the trial since reinforcement, for FR 3, FR 6, FR 10, and VR 3. CRF (FR 1) accuracy is plotted for comparison. All points are means for the last five days of exposure to each schedule.

It is clear that the relations between accuracy and trials since reinforcement, and the individual differences therein, are sufficient to account for the overall accuracy functions (Fig. 1). It remains to account for the differences between our results and those of Ferster (1960), in particular for the remarkably different performances under regular reinforcement. Ferster's procedure differs from ours in several respects: (1) only two stimuli, red and white light, were employed; (2) the center key light was extinguished when the observing response was made and the side keys illuminated (this is equivalent to the "zero delay" procedure described by Berryman et al., 1963); (3) there was no intertrial interval; (4) a brief flash of the magazine light followed correct responses which were not reinforced because the schedule contingency had not been satisfied, and a 1-sec blackout followed errors; and (5) a correction procedure was used, in that the side and color of the matching stimulus are changed randomly only after a correct response has been made.

The first three differences may be relatively unimportant. The smaller number of stimuli should, if anything, make acquisition of high accuracy easier. Data from Berryman et al. (1963) show that pigeons can acquire very nearly as high a level of accuracy under the zero delay condition as under the simultaneous condition, although acquisition may be slower. The results presented here show that at least the maintenance of an accurate matching performance is independent of the length of the intertrial interval, although this variable may be important in acquisition. The effects of brief secondary reinforcement for correct responses, or blackout for errors, cannot be determined at this time.

The use of a correction procedure may be very important, however, since it permits the subject to receive better than 50% reinforcement for a performance which is not based on the relation between the discriminative stimuli at all. If, for instance, the pigeon follows the pattern of responding on the right key after reinforcement, and shifting to the left key if this response is followed by blackout, two-thirds of the responses will be reinforced. Other systematic patterns of responding can be suggested, many of which may receive sufficient reinforcement to be maintained. In the absence of a detailed trial-by-trial analysis

of the behavior on both CRF and FR schedules, it is impossible to determine the effects of intermittent reinforcement on the matching performance when a correction procedure is used.

Ferster reports that his subjects performed at "approximately chance levels" on CRF. In preparing Fig. 1, it was assumed that this refers to 50% correct, although data from Ferster and Appel (1961) obtained with the same procedure indicate that accuracy may be substantially below 50% on regular reinforcement if a brief blackout for incorrect responses is employed.

Ferster (1960) has reported that fixed ratio reinforcement of matching-to-sample produces break-and-run behavior similar in kind to that obtained with simple responses. All three subjects in the present experiment also developed post-reinforcement pauses during the first few days of exposure to each fixed ratio

schedule. This development proceeded concurrently with the reduction in accuracy on trials immediately after reinforcement, suggesting a correlation between the strength of the entire response chain and accuracy. On Day 9 of exposure to FR 10, the time elapsing between onset of the center key light and the occurrence of the fifth observing response on that key (which produced the side key stimuli) was recorded. This measure is referred to as the center key latency, and may be taken as an inverse measure of observing response strength. The mean center key latency was determined for each ordinal trial number after reinforcement. It was found that the center key latency decreased systematically to an asymptote with increasing ordinal trial number, giving a curve much like the inverse of the accuracy functions (Fig. 2).

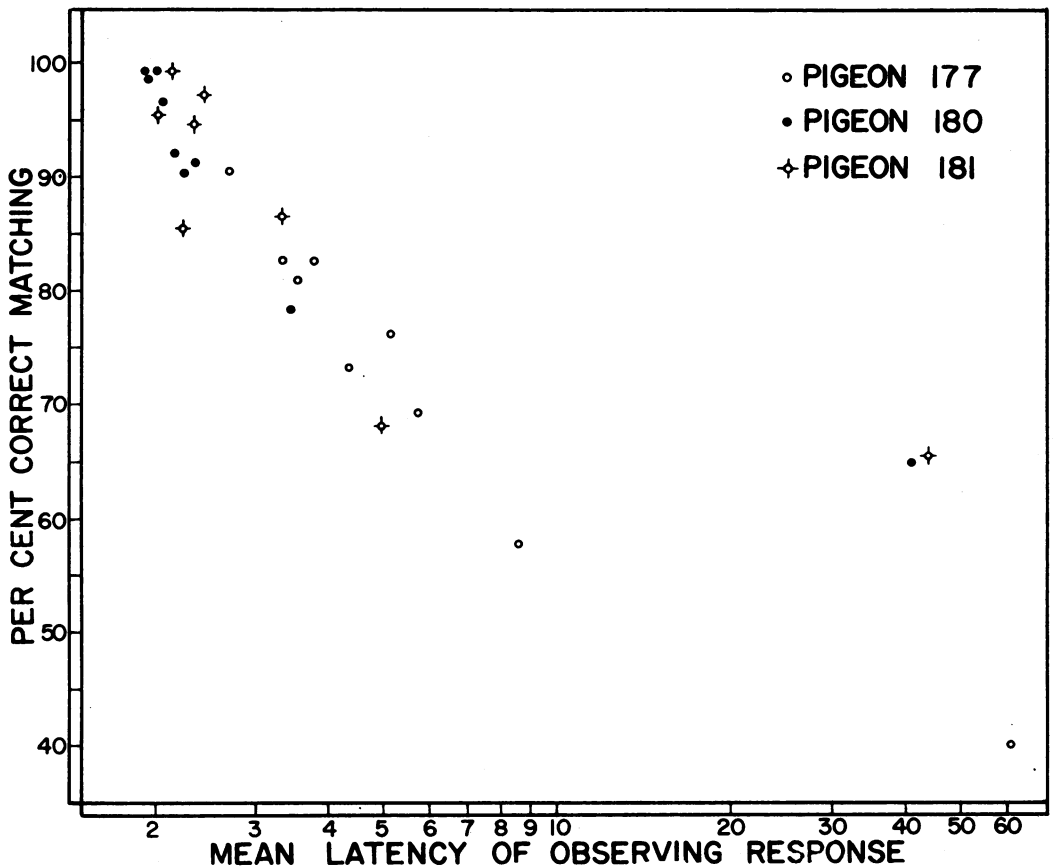This finding differs somewhat from that with fixed ratio reinforcement of a simple

Fig. 3. The correlation between mean observing response latency in seconds (on a logarithmic scale) and mean accuracy of the subsequent match for each ordinal trial number since reinforcement, for Day 9 of exposure to FR 10.

response, in which there appears to be little if any change in inter-response times as a function of ordinal position in the ratio. However, it is in general agreement with Kelleher's (1958) finding that observing response strength is weakened when the discriminative stimuli are uncorrelated with reinforcement. It also accords with the data of Ferster and Skinner (1957) on chained schedules, which suggest that response strength in the first component of the chain is weakened when the response produces a stimulus correlated with a lower density of reinforcement.

When the mean accuracy on each ordinal trail was plotted against the mean center key latency on that trial for each subject, a high negative correlation was evident. Figure 3 shows that the correlation was almost perfect for all trials except the first after reinforcement, in which case the center key latency includes the post-reinforcement break. It is worth noting that the data for all three subjects fall along the same line, and that Bird 177, which had the lowest overall accuracy on FR 10, also has the greatest mean latency. The linearity of the relation between per cent correct and log latency is clear. Thus, it appears that observing response strength is an excellent predictor of the accuracy of the subsequent discrimination in this situation. This finding agrees with the suggestion of Holland (1958) of a correlation between observing re-

sponse rate and probability of detection, but in his procedure a decrement in observing response rate had the effect of reducing the frequency with which the discriminative stimulus was physically presented. In our procedure, the side key stimuli are presented on every trial, but the control they exercise over the observing response in their capacity as conditioned reinforcers, and their discriminative control over the side key responses appear to co-vary with a precision that cannot be accounted for at this time.

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