FIXED-INTERVAL PERFORMANCES WITH ADDED STIMULI IN MONKEYS¹

C. B. FERSTER² AND J. ZIMMERMAN

INDIANA UNIVERSITY MEDICAL CENTER

The performance of two monkeys, on fixed-interval schedules, was examined with a visual, an auditory and a combined auditory-visual clock. The clock, a voltmeter and/or a variable frequency tone, produced performances different in many aspects from those recorded earlier with pigeons. Instead of the sustained high rates of responding at the optimal settings of the clock, the monkeys' rates of responding were often extremely low even though a limited-hold contingency was utilized.

This paper describes the fixed-interval performances obtained in several experimental situations when an added visual and/or auditory clock accompanied the fixed-interval schedule. In the first experiment, a visual stimulus served as both a clock for an FI and a counter for an FR in a multiple schedule. The next experiments explored the combined control of the auditory and visual stimuli on an FI schedule alone. We expected that the combined visual auditory clock would produce closer control of the monkey's behavior than either clock individually because of the additional basis for the discrimination. When the visual and auditory stimuli were combined, however, the clock control was weakened rather than strengthened. A final experiment was then performed in which the nature of the interaction between the auditory and visual clocks was made more specific by a multiple schedule in which three of the components consisted of an auditory clock, a visual clock and a combined auditory-visual clock.

METHOD AND PROCEDURE

The subjects were two Rhesus monkeys, with free-feeding weights of approximately 8 kg. They were handled by a transfer cage. They were kept at 80% of free-feeding weights, and behavior was maintained by 0.67-gram whole-diet food pellets. These ani-

mals had had a history of over 2 yr with a pre-time-out stimulus on variable-interval reinforcement, concurrent VI FR, avoidance and escape of time-out, and avoidance and escape from resetting an added counter.

The experimental space consisted of a refrigerator on its side, divided into compartments by a partition on which magazine, telephone keys, and stimuli were mounted. The experimental space was approximately 24 × 15 × 24 in. high. The added stimulus was a 4-in., 30-V panel meter located just above the telephone keys. This meter was lighted from behind with green and red lamps correlated with an interval and ratio schedule, respectively. The face of the meter was modified by painting out all lettering and other marks except the scale. The visual clock consisted of deflection of the needle from 0-30 V, and the auditory clock was a complex tone generated by a multivibrator varying from 250 to 1600 cps.

The added stimulus was programmed by a stepping switch driving a potentiometer through an adjustable gear box. A cam and microswitch, on the same shaft as the potentiometer, programmed reinforcement. For fixed-interval schedules, the stepper was driven by a recycling timer with the gear box adjusted to produce a 200-step cycle of the potentiometer. Hence the potentiometer advanced every 3 to 5 sec, depending on the exact value of the fixed-interval schedule.

Experiment 1: A Multiple Clock and Counter

In the first experiment, the visual stimulus served as an added clock in the FI component

¹This research was carried out with the support of Grant G 19257 from the National Science Foundation.

²For reprints write C. B. Ferster, Institute for Behavioral Research, P.O. Box 412, College Park, Md.

and as an added counter in the FR component of a mult FI 10 FR 80 schedule in which the components alternated randomly. The auditory component of the clock was not used here.

As might be expected from the previous history with the added counter, the first effect of the multiple procedure was a high rate of responding in the fixed-interval component. The FR rate, in turn, showed inductive effects from the FI clock, with frequent pausing, negative acceleration, and low running rates. Eventually, the meter controlled the monkeys' performance as both a clock and a counter, depending on which color was present. Figure 1 shows the final performance on the multiple schedule. As might be expected from a clock, the fixed-intervals began with long pauses; the terminal rate was 1.5-2 sec for Monkey M7 and 0.5-1.5 sec for Monkey M4. Monkey M4's performance showed better conformance to the FI clock than the performance of M7; its FIs frequently were less scalloped than those of M4, especially when two intervals followed consecutively. Monkey M7's

performance showed instances of short bursts of responding at the FR rate during the terminal part of the FI, presumably because of induction from the fixed-ratio reinforcement. In a control experiment in which the clock remained at zero for part of a session, the control by the clock was grossly disrupted, showing that the FI scallop was largely based on control by the clock. The FR rates ranged from 2.5-3.0 Rs/sec. Therefore, the meter served as both an added clock and added counter in a compound discrimination. (Green plus meter equalled clock, and red plus meter equalled counter.)

Experiment II: The Development of FI 4 Behavior With a Complex Added Clock

Following Experiment I, both monkeys were run on FI 4, with a clock consisting of both the meter and the tone. Despite the same reinforcement conditions, general conditions of the experiment, and level of deprivation, the final clock performance consisted of a very low overall rate of responding, with pausing frequently extending as much as 10 min past

Fig. 1. The last recorded performance on mult FI 10 FR 80 with a clock and counter, respectively. Each record contains the middle part of the experimental session.

Fig. 2. Record A: Final performance, for M4, on FI 4 with the combined auditory-visual clock. The arrows indicate where the reinforcements became available. Records B and C: Final performances for M7 and M4 respectively, after the limited-hold contingency was added. The arrows indicate intervals where no reinforcement occurred because the monkey did not press the key during the critical 3-sec interval.

the time when a response might be reinforced. Figure 2A shows the final performance for Monkey M4 on the auditory-visual clock. The fixed-interval segment at *a* shows an instance where the clock remained at the maximum setting for over 5 min without the monkey's responding. Some instances of anomalous bursts of responding occurred after reinforcement, as at *b*, *c* and *d*. Frequent segments, however, as at *e*, *f* and *g*, showed very close control of the behavior by the clock, with responding occurring only during the final few seconds of the interval. The second monkey, M7, showed a similar performance.

A limited-hold reinforcement contingency was added to the FI 4 schedule. Under this condition, the reinforcement is available only for a brief period of time after it is set up. Failure of the subject to respond during this limited-hold (LH) period results in loss of the reinforcement and the reset of the fixed-interval. The addition of a limited-hold reinforcement contingency produced better conformance of the performance to the clock. Records B and C show the final performance

for M7 and M4, respectively, after 14 sessions of FI 4 LH 3 sec. Both animals were closely controlled by the clock. Although only a few responses were made per interval, only a small number of reinforcements were missed (indicated by the arrows on the figure). For M7, responding occurred only during the final 30-45 sec, whereas for M4 the clock control was even more exact, with most responses occurring in the last 10 sec.

Experiment III: A Comparison of the Auditory and Visual Clock

After the development of the final performance with the combined auditory-visual clock, the visual clock was removed and performance was developed with the auditory clock alone. At first, the duration of the limited-hold had to be increased to 60 sec because of poor initial control by the auditory clock. Then, the limited-hold was reduced to 30, 15, and finally, 5 sec. Record A of Fig. 3 shows the last performances with the auditory clock for both M4 and M7 on FI 4 LH 5 sec. Monkey M4's overall rate of responding was very low, but

most reinforcements were still received despite the limited-hold contingency. Many responses occurred during the middle part of the FI, however, unlike the final performance with the auditory-visual clock. Monkey M7 responded at a higher rate than M4 and conformed less to the clock. This performance of M7 proved to be at an intermediate stage of development, however, because with more extended reinforcement on the auditory clock, its performance more closely resembled that of M4. The extent of control by the auditory clock was proved by removing the clock altogether; Record B shows the performance for both monkeys after seven sessions with no added clock. Monkey M4, whose behavior was under closer control by the auditory clock, showed a large increase in responding. On the other hand, the performance of M7, which was less controlled by the auditory clock, showed less change.

In the session following that of Record B, the visual clock was added; Record C shows the first-session performance. Very close control by the clock developed almost immediately for both animals. The control by the visual clock (Fig. 3C) was similar to that of the combined auditory-visual clock (Fig. 2B

and 2C). Consequently, at this degree of exposure to visual or auditory clocks, control was closer with the visual clock, especially for M7. As in the previous experiments, Monkey M7's rate was higher, with less control by the clock.

Experiment IV: A Multiple Schedule

All of the fixed-interval, limited-hold performances were then compared in a four-component multiple schedule in which all components were first FI 6 LH 5 sec and then FI 12 LH 5 sec. In the first component, reinforcement occurred on the FI without any added stimuli. The auditory clock occurred in the second, the visual in the third, and the combined auditory-visual in the fourth. Figure 4 presents the final performance for both animals on the FI 6 and FI 12 multiple schedules. In the FI 6 performance without the clock, many of the reinforcements were not received because of the limited-hold contingency. Where reinforcement did occur, the rate of responding was higher than that of any of the performances elsewhere, including the auditory clock performance. The closest added stimulus control was by the combined auditory-visual and the visual clock. Although

Fig. 3. A comparison of FI 4, limited-hold 5 sec, with the auditory clock (Record A), no clock (Record B), and the visual clock (Record C). The arrows indicate intervals which ended without reinforcement because no response occurred in the limited-hold. Each record contains the middle part of the experimental session.

M4's auditory performance approached the visual, this animal missed five out of 18 possible reinforcements on the auditory clock alone (at the arrows). Monkey M7 consistently responded at a higher rate in the auditory component than in the visual component or the combined auditory-visual component.

Fig. 4. Final performance on the multiple schedule, limited-hold 5 sec. The left column contains the FI 6, and the right column the FI 12 performances. The entire experimental sessions are shown.

The FI 12 performance confirmed the FI 6 results. However, M4's generally lower rate of responding resulted in many missed reinforcements, especially in the first component without clock, and even in the third component with the visual clock. Again, M7 consistently responded at a higher rate in the auditory component than in the visual component. Furthermore, under these conditions, M7 consistently responded more in the combined auditory-visual clock than in the visual clock alone, presumably as a result of induction from the auditory clock.

DISCUSSION

After observing that a visual added stimulus could serve as both an added clock and an added counter in a multiple FI FR schedule (Experiment-I), three experiments were per-

formed to describe and compare FI performance developed with the visual clock, an auditory clock and a combined auditory-visual clock.

In Experiment II, FI 4 performance was examined using the combined clock. The final performance differed markedly from those recorded earlier with pigeons (Ferster and Skinner, 1957). Instead of the sustained, high rates of responding at the optimal clock settings, the monkeys' rates were so low that many reinforcements occurred with a single response and often this lone response occurred considerably after the reinforcement was set up. Even when a limited-hold contingency was added to the FI, the rates of responding did not approach the magnitudes obtained in the previous pigeon experiments.

In Experiment III, FI 4 LH 5 sec performance on the separate auditory and visual clocks were compared. Although the final performance on the auditory and visual clocks were similar, the control by the auditory clock developed at a much slower rate, particularly with M7.

In Experiment IV, a multiple schedule was used to compare the FI performance on all three clocks. All components of the multiple were at first FI 6 LH 5 sec and then FI 12 LH 5 sec. In the FI 6 multiple, the added stimulus control was closer with the combined auditory-visual clock and the visual clock than with the auditory clock. The latter results were especially true for M7. The FI 12 multiple results confirmed the FI 6 results in part. Monkey M4, however, missed many reinforcements in the visual component presumably because of an extremely low rate of response generated in that component. Monkey M7 again showed least control by the auditory clock, but under these conditions, the visual clock controlled more closely than the combined auditory-visual clock. This performance by M7 may have represented an intermediate stage of development. The performance of M4 in early sessions on the FI 12 multiple was markedly similar to that presented as the final performance of M7, *i.e.*, higher in all components than in the final performance. Furthermore, at the former stage of development, the rate of response was highest in the auditory component, next highest in the combined auditory-visual component, and lowest in the visual component.

Perhaps the final behavior of M7 and the early behavior of M4 might be accounted for by an induction from the auditory component to the auditory-visual component. This would account for a response rate in the combined component which was intermediate between the auditory rate and the visual rate.

"Closeness of control" by the two modalities could not be compared unless the stimuli were varied parametrically. The results obtained may hold only for the specific conditions examined. Nevertheless, the auditory

range covered the frequencies in which (in humans) the differential limen is lowest. Hence, it is likely that further extension of the auditory range would have either little effect or exaggerate the results with these procedures.

REFERENCE

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

Received April 18, 1962