

Response summation in the pigeon

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Three experiments were performed to determine the effects of schedule of reinforcement on additive summation using pigeons as subjects. In the first experiment the subjects were reinforced on a VI 1-min schedule whenever either of two stimuli was present. Their simultaneous presentation produced response summation. In the second experiment key color and the schedule of reinforcement were changed in alternate sessions. When the reinforcement schedule was VI 30 sec, only one of the four subjects showed response summation. When the reinforcement schedule was VI 3 min, all four subjects showed response summation. In the third experiment, the subjects were reinforced on a VI 30-sec schedule whenever either of two stimuli was present. Their simultaneous presentation produced response summation in only one of three subjects. The results suggest that either high reinforcement frequency or high response rate sets a ceiling beyond which response summation is not observed.

A number of experiments have been performed in the past several years showing additive response summation using free operant procedures. In one of the most commonly used procedures, a subject's responses are intermittently reinforced when either of two stimuli are present. The simultaneous presentation of both stimuli causes the subject to respond at a higher rate than when either stimulus is presented alone. However, all of these studies have used rats as subjects (e.g., Meltzer & Freeman, 1971; Meltzer & Masaki, 1972; Miller, 1971; Miller & Ackley, 1970; Weiss, 1964, 1969, 1971). There have been only two partially successful demonstrations of response summation in pigeons. Hamm & Meltzer (1972) were able to show lower rates during combined negative stimuli than when either negative stimulus was presented alone. Rates were not higher when the positive stimuli were presented simultaneously. Long & Allen (1974) were able to demonstrate summation during extinction but could not maintain summation during conditioning. In these experiments we examined the conditions under which response summation in the pigeon could be maintained during conditioning as opposed to extinction and the effect of schedule of reinforcement on response summation.

EXPERIMENT I

Method

Subjects. Four White Carneaux pigeons were maintained at about 80% of free-feeding weight. Purina Pigeon Chow was both the maintenance diet and reinforcer.

Apparatus. The experimental chamber (BRS-Foringer) was 50 cm long x 35 cm wide x 35 cm high. The front wall contained a response key, 3 cm in diam, located 25 cm above the grid floor and 7.5 cm from the left wall. The food hopper was located behind a 5 x 4 cm opening centered on the midline of the front wall. Two lamps (GE 757) mounted behind a 7.5 x 35 cm piece of white Plexiglas at the top of the front wall served as a houselight. The intensity of the houselight

was 14.7 mL, as measured by an SEI photometer. The ambient noise level with the blower on was 77 dB (re: .0002 dynes/cm). A 1200-Hz tone could also be presented that raised the sound intensity to 89 dB. An in-line display unit was mounted directly behind the response key. Tape readers, electromechanical switching equipment, and counters were located in an adjacent room.

Procedure. The pigeons were conditioned to peck the key, which was transilluminated by white light, by means of an autoshaping procedure (Brown & Jenkins, 1968) during the first three sessions. The light behind the key never changed during the course of a session at any time during the experiment. Pigeons 6698 and 7895 were then reinforced for pecking on a VI schedule when either the tone or houselight was on. Each reinforcement consisted of a 4-sec presentation of the food hopper. In the absence of either stimulus, keypecks were not reinforced. This extinction condition remained in effect until 20 sec passed without a response. Either the tone or houselight was then turned on again. There were six 2-min tone presentations and six 2-min houselight presentations in each session. Four different sequences of stimulus presentations were used, and the sequence was changed between each session.

Pigeons 2813 and 2208 were treated in the same way except that the stimulus conditions were reversed. That is, both houselight and tone were on during the extinction periods, and the offset of either houselight or tone was correlated with the reinforcement schedule. This procedure was maintained for 36 sessions.

During the testing phase, three different stimuli were present during periods when the VI 1-min schedule was in effect. For the first two birds the stimulus was a houselight plus tone, houselight, or tone. The stimulus correlated with extinction was still no-houselight plus no-tone. For the last two pigeons the stimulus when the VI schedule was in effect was either houselight, tone, or no-light plus no-tone. The stimulus correlated with extinction was houselight plus tone. This procedure continued for 12 sessions. Four different stimulus sequences were used, with each sequence being used once in a four-session block. There were four presentations of each positive stimulus within each session and each presentation lasted for 2 min.

Results

Figure 1 shows each subject's response rate during each stimulus in blocks of four sessions each. All four

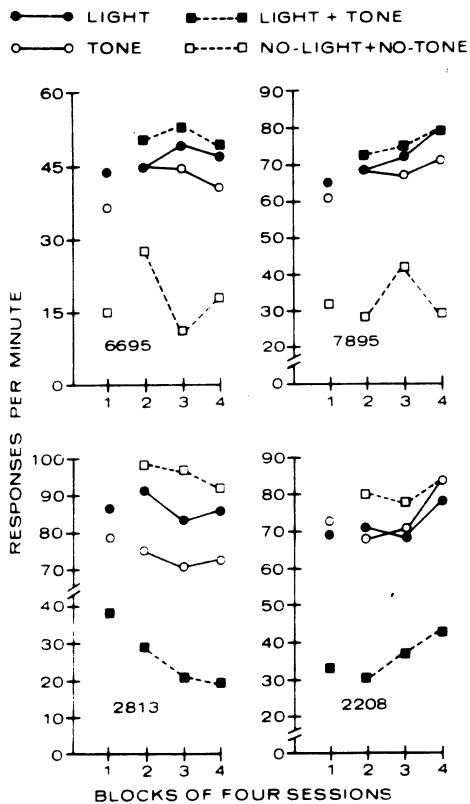


Figure 1. The mean response rates of each subject during the last four sessions before summation testing are shown in the points at the left of each graph. All subjects showed additive response summation during the first two blocks of testing. Pigeon 2208 had a slightly higher rate during the test stimulus than during tone in the last block of sessions, but the difference is too small to be visible.

subjects showed response summation.

An analysis of variance was performed in which each subject's mean response rate during the test stimulus was compared with its highest rate during either of the other two positive stimuli. For example, the rate at which Pigeon 2208 responded during the test stimulus was compared to its rate during light in the first block of test sessions, its rate during tone in the next block, and its rate during light in the final block. The subjects' mean rate during the test stimulus was significantly higher than their highest mean rate during either of the other two positive stimuli ($F = 16.54$, $df = 1/3$, $p < .05$). There was also a significant interaction between the stimuli and blocks of sessions ($F = 5.57$, $df = 2/6$, $p < .05$) which showed that response summation decreased over blocks of sessions. As Figure 1 shows, all four pigeons responded at a higher rate to the test stimulus than to either of the other stimuli during the first block of test sessions. Only two of them did so during the last block. When individual sessions were examined, Pigeon 6698 showed summation - defined as a higher rate during the test stimulus than during either of the other two stimuli - in 9 of the 12 test sessions, 7895 in 7 sessions, 2813 in 10 sessions, and 2208 in 9 sessions. Since light, tone, and the test stimulus were presented

for an equal amount of time in each session, one would expect the subjects to respond at their highest rate during the test stimulus by chance in one-third of the sessions. A binomial expansion showed that the chance probability of response summation in seven or more sessions was less than .2. The response summation shown in this experiment is important for several reasons. First, it confirms the generality of the summation phenomenon, and, second, it shows that pigeons will summate while the reinforcement schedule is being maintained.

EXPERIMENT II

We observed response summation in our first experiment, but Long and Allen (1974), who used similar stimuli and a VI 1-min schedule of reinforcement, failed to show response summation in the pigeon. There may have been differences in procedure which were responsible for the discrepant results, but Long and Allen (1974) may have been correct in asserting that if reinforcement frequency was too high there would be no summation. This experiment tested that hypothesis.

Method

Subjects and apparatus. The subjects and apparatus were the same as in the first experiment.

Procedure. During the first session of the experiment the key was always illuminated by a red light. Pigeons 6698 and 7895 were reinforced on a VI 30-sec schedule for pecking the key when either the tone or the houselight was on. They were never reinforced for pecking when neither the houselight nor tone was on. The no-houselight plus no-tone condition remained in effect until 20 sec passed without a keypeck, after which either the light or tone was turned on. There were six 2-min houselight presentations and six 2-min tone presentations in each session. Four different sequences of stimulus presentations were used and the sequence was changed each day.

During the second session the key color was green throughout the session and keypecks during either houselight or tone were reinforced on a VI 3-min schedule. In all other respects the procedures were the same as those used during the first session. Sessions in which the key was always red and the reinforcement schedule was VI 30 sec continued to alternate with sessions in which the key was always green and the reinforcement schedule was VI 3-min, until each condition had occurred nine times. The procedure was then changed so that the stimulus correlated with reinforcement for Pigeons 6698 and 7895 was either the tone, the houselight, or a compound of tone plus houselight. There were four 2-min presentations of each stimulus; each presentation of a discrimination stimulus was again separated by an interval of no-houselight plus no-tone which lasted until 20 sec passed without a response. Four different sequences of stimulus presentations were used. Sessions in which the schedule of reinforcement was VI 30 sec continued to alternate with sessions in which it was VI 3 min, for a total of 32 sessions (16 with each schedule).

The procedure was the same for Pigeons 2813 and 2208, except that the stimulus associated with extinction was houselight plus tone and the stimulus presented when the reinforcement schedule was in effect was either houselight, tone, or no-houselight plus no-tone.

Results

All four subjects learned to discriminate between the stimuli associated with the VI 30-sec and the VI, 3-min schedules. The first points on Figure 2 show

response rates during the light, the tone, and the extinction stimulus before the testing procedure began. Rates were far higher when the VI 30-sec schedule was used.

The test session data were analyzed just as they were in Experiment I. The rate at which each subject responded to the test stimulus during each block of sessions was compared with the rate during either of the other two positive stimuli, depending on which one was higher. The mean rate during the test stimulus was 65.4 responses/min and the mean highest rate during the other two stimuli was 61.7 responses/min. This difference was significant ($F = 10.17, df = 1/3, p < .05$) and meant that response summation had been demonstrated. However, there was also a significant interaction between the schedule of reinforcement and the stimulus conditions ($F = 10.18, df = 1/3, p < .05$). When the schedule was VI 30 sec, the pigeons responded at a mean rate of 70.1 responses/min during the test stimulus and a mean rate of 70.9 responses/min during either light or tone, whichever was the stimulus in which the subject responded most rapidly in the same block of sessions. When the schedule was VI 3 min, the rates during the test stimulus and the next highest rates were, respectively, 60.8 responses/min and 52.5 responses/min. A test for simple main effects at each level of the interaction (Winer, 1971, p. 544) showed that the difference between rates during the test stimulus and the next highest rates during either of the other positive stimuli was significant when the schedule was VI 3 min ($F = 20.12, df = 1/6, p < .01$); there was no significant difference between the two rates when the schedule was VI 30 sec.

Table 1
Number of Sessions in Which Each Subject Showed Response Summation*

Pigeon	Schedule	
	VI 30 Sec	VI 3 Min
6698	16	18
7895	4	14
2208	6	13
2813	6	18

Note—There were 20 test sessions during which the schedule of reinforcement was VI 30 sec and 20 test sessions during which the schedule was VI 3 min.

*Defined as a higher rate during the test summation than during either of the other discriminative stimuli.

The number of individual sessions in which each subject responded at its highest rate during the test stimulus is shown in Table 1. As in the first experiment, there were equal numbers of presentations of each of the three positive stimuli—light, tone, and the test stimulus. Response summation would have been expected in one-third of the test sessions by chance. A binomial expansion showed that the probability of response summation in 10 or more of the 16 test sessions using each schedule was less than .02. By this criterion, all four subjects showed response summation when the schedule was VI 3 min but only Pigeon 6698 showed summation when the schedule was VI 30 sec.

EXPERIMENT III

The results of the preceding experiment are open to two different interpretations. One is the Long and

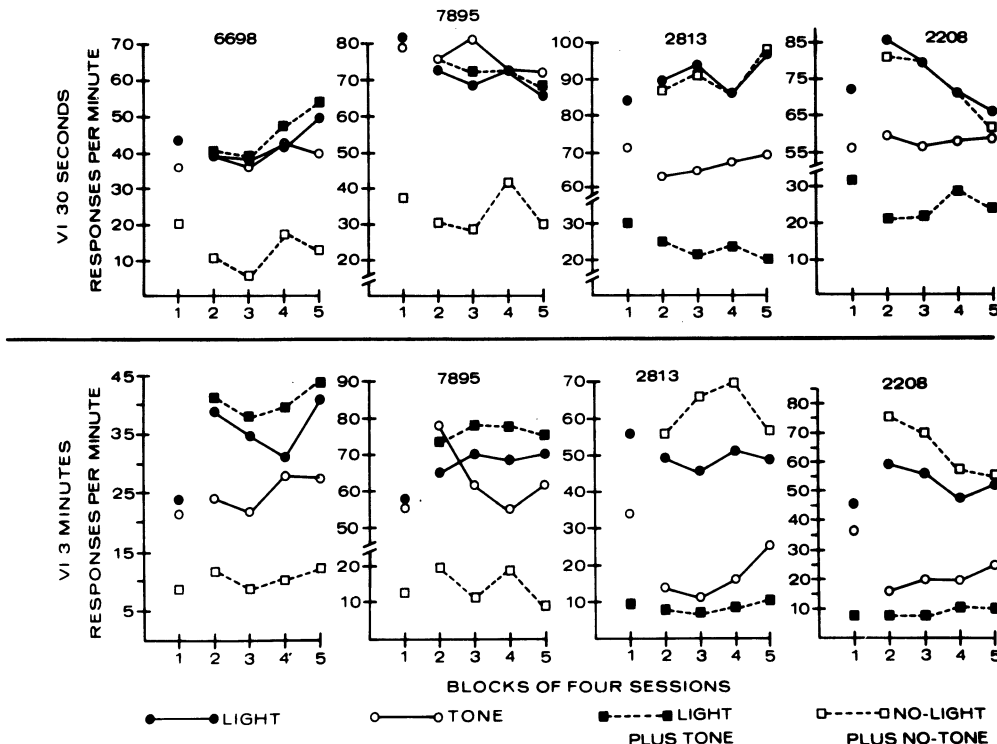
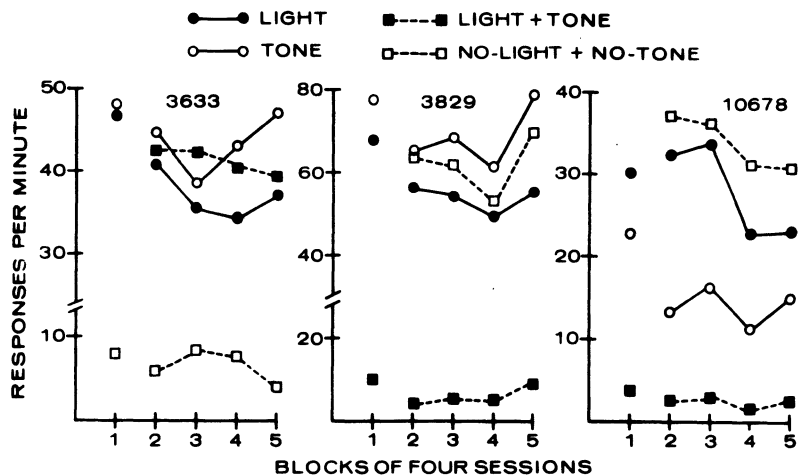


Figure 2. The upper panel shows that only Pigeon 6698 developed consistent response summation when the schedule was VI 30 sec. The lower panel shows that all subjects summated when the schedule was VI 3 min.

Figure 3. Pigeon 10678 developed consistent response summation. Neither of the other subjects did so.



Allen (1972) hypothesized that high reinforcement frequency leads to a ceiling on response rate and prevents response summation. The alternative is that the pigeons failed to show response summation during the VI 30-sec sessions because they were able to discriminate them from the VI 3-min sessions and there was some type of contrast effect which prevented summation. A direct test of that hypothesis would involve testing subjects who had been reinforced only on a VI 30-sec schedule.

Method

Subjects and Apparatus. Three naive pigeons, 3633, 3829, and 10678, were reduced to 80% of their free-feeding weight. The apparatus was the same as in the first two experiments. The key was always illuminated by a white light.

Procedure. The autoshaping procedure was used to establish the keypeck response during the first three sessions. All three subjects were then shifted to a discrimination procedure in which responses were reinforced with 4 sec of access to the hopper on a VI 30-sec schedule when either the houselight or tone was on. There were six presentations of each stimulus and each presentation lasted for 2 min. Between each positive stimulus, a stimulus correlated with extinction was presented until 20 sec had passed without a response. For Pigeon 3633, this stimulus was no-houselight plus no-tone; for the other two subjects it was houselight plus tone. A total of 32 sessions used this procedure.

During the rest of the experiment, each subject was exposed to three different stimuli associated with reinforcement rather than two. For Pigeon 3633 the additional positive stimulus was houselight plus tone; for the other two subjects it was no-houselight plus no-tone. There were four 2-min presentations of each positive stimulus in each session, and four different stimulus sequences were used in successive sessions. No other aspects of the procedure were changed. There were 16 sessions.

Results

Figure 3 shows that there was no consistent evidence of response summation across subjects. The results of an analysis of variance similar to that used in the first experiment showed no significant differences between rate during the test stimulus and the next highest rate during either of the other two positive stimuli.

When data from individual sessions were examined, Pigeon 10678 was found to have responded at its highest

rate during the test stimulus in 11 of the 16 test sessions. Pigeons 3633 and 3829 each responded at their highest rates during the test stimulus in four sessions. A binomial expansion showed that the chance probability of response summation occurring in 11 sessions was less than .01, so we concluded that only one of the three subjects in this experiment showed response summation.

DISCUSSION

These data showed clearly that, as the frequency of reinforcement on a VI schedule increased, the probability that response summation would occur decreased. This is precisely what Long and Allen (1974) had suggested would happen. It also shows that there is a ceiling effect on the response summation phenomenon. Pigeons do show response summation just as rats do and the response summation can be maintained during conditioning.

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