BEHAVIORAL CONTROL BY AN IMPRINTED STIMULUS: LONG-TERM EFFECTS¹

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Newly hatched ducklings were exposed to imprinting procedures and subsequently trained to peck a key by presenting the imprinting stimulus as the reinforcing (response-contingent) event. Individual ducklings then lived in the apparatus under an arrangement in which each peck produced a 15-sec stimulus presentation. For all ducklings, key-pecks tended to occur in bursts, and as the duckling matured, burst length decreased and the interval between bursts increased. However, even when subjects were 60 days old, some responses still occurred.

Previous investigations reveal that when ducklings have been imprinted to a moving stimulus they can be taught to peck a key by using presentation of the imprinted stimulus as the response-contingent (reinforcing) event (Peterson, 1960; Hoffman, Searle, Toffey, and Kozma, 1966). The present study examined the enduring consequences of this training. More specifically, it sought to document the duckling's tendency to seek the imprinted stimulus over an extended (two-month) period of continuous access to the stimulus via key-pecks.

METHOD

Subjects

Five Peking ducklings (*A. platyrhynchos*) were hatched from eggs obtained from the C & R Duck Farm, Inc., Long Island, New York. They were hatched in isolation, and were initially maintained in individual brooder boxes, where they had continuous access to food and water and a 40-w light bulb for heat. Except for the periods of imprinting and key-peck training (see below) the ducklings were maintained in this environment for nine days, after which they were transferred to the test apparatus.

Apparatus

Each of two imprinting units was housed in a separate sound-treated and temperature-

controlled room. Figure 1 illustrates one of the imprinting units. Each consisted of a wooden box (6 by 3 by 2.5 ft) divided lengthwise into two compartments (6 by 1.5 by 2.5 ft); one was for the duckling and the other for the imprinted stimulus, separated by a partition of brass screening (#60 mesh). The lighting (a 40-w, 110-v G.E. cool white fluorescent bulb) in each compartment was arranged so that its interaction with the brass screening provided a one-way vision effect. When the light was on in the duckling's compartment, and out in the stimulus compartment, the reflection from the screen prevented the subject from viewing either the stimulus or the stimulus compartment; when the lighting was reversed, the contents of the stimulus compartment became visible from the duckling's compartment. The stimulus was "presented" by darkening the subject compartment, illuminating the stimulus compartment, and moving the stimulus at approximately 1 ft per sec back and forth along the length of its compartment. During stimulus withdrawal the stimulus was stationary, the stimulus compartment was darkened, and the subject compartment was illuminated. With this arrangement, the photometric brightness of the screen was approximately 1 ft lambert during stimulus presentation and approximately 4 ft lamberts during stimulus withdrawal.

The stimulus consisted of a white plastic milk bottle (3 by 3 by 8 in.) mounted over the superstructure of a model train engine which ran the length of the stimulus compartment on HO gauge track. The stimulus run could also be confined to a 3-ft section in the center of the compartment.

¹This research was supported by National Institute of Mental Health Grant Nos. MH 02433-07 and MH 23824. Reprints may be obtained from Howard S. Hoffman, Department of Psychology, The Pennsylvania State University, 117 Burrowes Building, University Park, Pennsylvania 16802.

Fig. 1. Apparatus for imprinting and key-peck training. The objects on the right side of the subject's alley are food and water dishes which were always present and filled.

An enclosed, back-illuminated Gerbrands' pigeon key was mounted just in front of the screen separating the subject's runway and the stimulus compartment. Its height above the floor of the runway was adjustable to accommodate different size ducklings. A bank of relays, steppers, and timers programmed stimulus presentations. Key-pecks and stimulus presentations were continuously monitored on an Esterline Angus operations recorder with a paper speed of 0.75 in. per hour. The rooms housing the apparatus were windowless and, except for the light emanating from the apparatus, were not illuminated. In addition, the walls were painted flat black to reduce distracting reflections and enhance the one-way vision effect of the screening in the apparatus. Except during the first few days from hatch, when the apparatus rooms were heated to approximately 95° F, the temperature was maintained at approximately 78° F.

Procedure

Imprinting. Immediately after hatch the ducklings were placed in their individual brooder boxes to dry. Each duckling was then exposed to six imprinting sessions, each lasting 45 min. During imprinting sessions the duckling was placed in the subject compartment with the stimulus visible and moving. At the end of each imprinting session the duckling was returned to its brooder box, where it remained until the next imprinting session began. For a given duckling, all imprinting sessions took place within 48 hr after hatch and were approximately equally spaced

(every 3 to 6 hr) throughout this period. The first session occurred within 6 to 8 hr after hatching to insure that the duckling was exposed to the moving stimulus during the critical period for imprinting. Hess (1964) has reported that if the initial exposure to the imprinted stimulus occurs after 24 hr of age, imprinting is not likely to occur. In the present study, the initial exposure occurred well within this limit.

Training. Each duckling received four key-peck training sessions between the third and sixth day from hatch. Training sessions lasted 1.5 hr each. The experimenter observed the duckling and presented the moving stimulus whenever the subject's behavior approximated the key-peck. During the initial period of training, stimulus presentation lasted 12 sec. Once the duckling pecked the key, stimulus presentation was reduced to 5 sec, and movement of the stimulus was confined to the center of the track. Finally, when the key-peck was well developed, duration of the stimulus presentation was increased to 15 sec.

Testing. The ducklings were tested individually. When a given duckling was nine days old it was placed in the apparatus and remained there in isolation until it was 60 days old. Food and water were continuously available and the programming arrangements were such that, in the absence of the stimulus, each key-peck produced a 15-sec stimulus exposure. (Pecks that occurred when the stimulus was visible did not, however, prolong stimulus presentation.) Except for routine cleaning and replacement of food and

water, the subjects were undisturbed throughout their period in the apparatus.

RESULTS

Figure 2 shows the average amounts of time the ducklings kept the stimulus in view across the period studied. The inset shows the data for a single subject and illustrates the extent to which functions based on averages can represent the individual's performance. Each point in the larger function represents the average exposure period per day across the five ducklings over a four-day period. Responding decreased over time in the apparatus. Beginning with an average exposure

time greater than 2 hr per day, the ducklings exhibited a nearly steady decline in pecking until their responses kept the stimulus in view less than 10 min per day in the final period. A single-factor repeated measures analysis of variance (Weiner, 1962) showed this trend to be statistically reliable ($F = 3.84$; $df = 12, 48$; $P < 0.01$).

Figure 3, a sample from the records of Subject C, illustrates response patterns characteristic of all ducklings as they matured. There was a tendency to maintain contact with the stimulus, once the stimulus had been presented. Thus, the stimulus was repeatedly sought in what appeared to be bursts of responding, rather than in isolated pecks.

Fig. 2. Average number of hours that the imprinted stimulus was kept in view when subjects had continuous access to the stimulus via a key peck; each peck caused the stimulus to appear for 15 sec. Each point represents the average exposure per day for the five ducklings across a four-day period. The inset shows the comparable data for a single duckling (Subject C).

Fig. 3. Sample records of key-pecks from Subject C during the 12th, 32nd, and 52nd day from hatch. Throughout this period each key peck yielded a 15-sec exposure of the imprinted stimulus.

The observed bursts of responses imply that response emission involves a form of sequential dependency. One way to determine whether or not a response pattern of this sort is reliable is to evaluate the first-order conditional probabilities exhibited by the data. Table 1 shows these probabilities. The data from days 13, 14, 15, and 16 for all subjects were analyzed. The response records were divided into small equal time units (1/64 in. = one unit = approximately 1.25 min).

Across the period studied, the probability that a given time unit contained one (or more) responses equaled 0.06. In addition, however, the probability of a unit containing a response, given that there was no response in the previous unit ($P_{r,\bar{r}}$), was 0.02. On the other hand, the probability that a given unit contained a response, when the previous unit contained one (or more) responses ($P_{r,r}$), was 0.63. Using a test for the difference between two probabilities, the difference between $P_{r,r}$ and $P_{r,\bar{r}}$ was found to be significant ($z = 21.84$; $P < 0.01$). Since $P_{r,r}$ would be expected to approximate $P_{r,\bar{r}}$ if responses were emitted independently of each other, the finding of a significant difference between these two conditional probabilities means that the sequential dependencies exhibited by the data are reliable. Thus, it can be concluded that there

Table 1

Conditional probabilities (across all ducklings) of key-peck responses on days 13 to 16, inclusive. During this period each response yielded a 15-sec exposure of the imprinted stimulus. P_r = the probability that a given 1.25-min interval contained one (or more) responses. $P_{r,\bar{r}}$ = the probability that a given interval contained at least one response, given that the preceding interval contained no responses. $P_{r,r}$ = the probability that a given interval contained at least one response, given that the preceding interval also contained at least one response.

Probability	Days from Hatch				Mean
	13	14	15	16	
P_r	0.06	0.05	0.07	0.06	0.06
$P_{r,\bar{r}}$	0.02	0.02	0.03	0.02	0.02
$P_{r,r}$	0.68	0.64	0.61	0.61	0.63

is a strong tendency for ducklings to seek the stimulus in burst-like sequence, rather than in single isolated short (15-sec) exposures.

To assess the possibility of a relationship between length of bursts and duration of the preceding interburst interval, a correlation was computed for the data obtained during days 13 to 16, inclusive. As in the estimates of the above conditional probabilities, measurements were taken from the event records. If no more than 1/64 in. (corresponding to 1.25 min) was visible between pen deflections, the responses were considered to be members

of a single burst; otherwise, they were considered to be members of separate bursts. When evaluated in this fashion, the relationship between burst length and the duration of the preceding interburst interval is slightly curvilinear ($\eta = 0.26$), but the value does not differ significantly from zero.

In general, the decline in total responding seen in Fig. 2 represents two processes: a decrease in burst length and an increase in the length of the interburst interval. Figure 4 and 5 illustrate these effects when bursts and the intervals between them are defined according to the criteria used in the previous evaluation of η .

Figure 4 shows the average burst length per day across birds for each four-day block. The

inset shows the data for Subject C. A single-factor repeated measures analysis of variance was used to assess the reliability of the trend seen in Fig. 4. It yielded ($F = 2.29$; $df = 12, 48$; $P < 0.05$); hence, it can be concluded that the decline in burst length is statistically reliable. Figure 5 shows the average interburst interval per day averaged across four-day blocks. The data for Subject C is illustrated in the inset. The results of a single-factor repeated measures analysis of variance indicated that the observed increase in interburst interval is also statistically reliable ($F = 5.40$; $df = 12, 48$; $P < 0.01$).

Finally, to determine possible cyclic effects in the overall tendencies to peck the key, the data across the 13 four-day blocks were ana-

Fig. 4. Average duration of response burst per day. Throughout the period studied, each response (key peck) yielded a 15-sec exposure of the imprinted stimulus. Each point represents the average burst duration per day for the five subjects across a four-day period. The inset shows the comparable data for a single duckling (Subject C).

Fig. 5. Average interval between bursts of key-pecks. Throughout the period studied each key-peck yielded a 15-sec exposure of the imprinted stimulus. Each point represents the average interburst interval per day for the five ducklings across a four-day period. The inset shows the comparable data for a single duckling (Subject C).

lyzed for differences during various periods of the day. The mean duration of stimulus exposure which occurred during the first half of each day (midnight to noon) was compared with the mean stimulus exposure in the second half of the day, across all the days studied. A *t*-test for related means revealed no significant difference in the response tendencies between these two periods ($t = 0.29$; $df = 51$; $P > 0.05$). Moreover, a comparable analysis of the several 6-hr periods (midnight to 6 A.M., 6 A.M. to noon, *etc.*) also failed to yield statis-

tically reliable differences in any of the six possible comparisons ($t \leq 1.53$; $df = 51$; $P > 0.05$ in all cases).

DISCUSSION

The lack of cyclic effects in the overall rate of pecking may reflect the lack of a day-night cycle in the test room illumination. Presumably, given experimenter-controlled illumination changes, cyclic effects might emerge.

The absence of a relationship between burst

length and the length of the preceding interburst interval seems more difficult to understand. If, as suggested earlier (Hoffman *et al.*, 1966), the tendency to seek an imprinted stimulus increases as a function of the duration of its absence, and if that tendency decreases as a function of extended stimulus presentation, one would expect a positive relationship between burst length and the length of the preceding interburst interval. The absence of this relationship in the present data suggests that the interpretation is probably too simple. Shaeffer and Premack (1961) reported that when rats have free access to water, they tend to drink in bursts; but Shaeffer and Premack failed, as did the present study, to detect a significant relationship between burst length and the length of the preceding interburst interval. Apparently, the variables that control drinking, like the variables that control the subject's tendency to seek an imprinted stimulus, are more complex than previously supposed.

Clear, overall conclusions emerge from these data. Once key-pecking for an imprinted stimulus has been established, the behavior persists over an extended period. Fabricius and Boyd (1952, 1953) found that Mallard ducklings which had previously shown a strong "attachment" to an imprinted stimulus failed to follow it after 10 days from hatch. Similarly, Moltz and Rosenblum (1958) found that in Peking ducklings the tendency to follow an imprinted stimulus began to diminish after eight days and had all but disappeared by 15 days. On the basis of those findings, pecking for the imprinted stimulus was expected to cease much more rapidly than seen here. It should be noted, however, that the present study evaluated a learned behavior (the key peck) that occurred in the absence of the imprinted stimulus and which resulted in its

presentation. Previous investigators, on the other hand, evaluated an unlearned behavior (following) that occurred in the presence of the imprinted stimulus, and which served only to keep the subject close to the stimulus. Moreover, in the present study, the subjects were permitted continuous access to the imprinted stimulus (via a key peck); the earlier studies tested subjects for relatively short intervals. Any or all of these factors might be responsible for the extended period of responding observed here. It is of interest that the period during which substantial pecking was obtained in the present study corresponds to the time required for the subjects to mature. Peking ducks grow rapidly and by 60 days of age are almost full size; they are fully feathered and have started quacking rather than peeping. The persistence of pecking throughout this period seems to attest to the strength of the processes that develop during imprinting procedures.

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Received 13 February 1967