

The effect of cycle length, interstimulus interval and probability of reinforcement in autoshaping

El efecto de la longitud del ciclo, el intervalo entre estímulos y la probabilidad del reforzamiento en el automoldeamiento¹

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ABSTRACT

The groups of pigeons, each with a different and constant reinforcement cycle, were exposed to the following manipulations: first, holding reinforcement probability constant at 1.00, the interval between reinforcement and a 4-sec neutral stimulus was gradually increased. Second, using a constant 4-sec interstimulus interval, probability of reinforcement was decreased. Third, at a constant 8-sec interstimulus interval, probability of reinforcement was again decreased. It was found that the rate during the stimulus was a monotonically decreasing function of lengthening the interstimulus interval. The rate during the stimulus was an inverted U function of decreasing reinforcement probability with a constant 4-sec interstimulus interval. When reinforcement probability was decreased at a constant 8-sec interstimulus interval, the rate during the stimulus decreased monotonically. The rates during the stimulus, for all procedures of the study, were a direct function of the reinforcement cycle length. These results are similar to those obtained in comparable situations where there has been a response-reinforcer contingency.

DESCRIPTORS: autoshaping, reinforcement cycle, interstimulus interval, probability of reinforcement, key peck, pigeon.

RESUMEN

Tres grupos de pichones, cada uno con un ciclo de reforzamiento constante y diferente, fueron expuestos a las siguientes manipulaciones: primera, manteniendo constante la probabilidad del reforzamiento en 1.00, se aumentó gradualmente el intervalo entre el reforzamiento y un estímulo neutral de 4 seg. Segunda, utilizando un intervalo entre

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estímulos constante de 4 seg., se disminuyó la probabilidad del reforzamiento. Tercera, con un intervalo entre estímulos constante de 8 seg., se disminuyó nuevamente la probabilidad del reforzamiento. Se encontró que la tasa durante el estímulo fue una función monótonicamente decreciente del aumento del intervalo entre estímulos. La tasa durante el estímulo fue una función U invertida de la disminución en la probabilidad del reforzamiento, con un intervalo entre estímulos constante de 4 seg. Cuando se disminuyó la probabilidad del reforzamiento con un intervalo entre estímulos constante de 8 seg., la tasa durante el estímulo disminuyó monótonicamente. Las tasas durante el estímulo, para todos los procedimientos del estudio, fueron una función directa de la longitud del ciclo del reforzamiento. Estos resultados son similares a los obtenidos en situaciones comparables en las que ha existido una contingencia respuesta-reforzador.

DESCRIPTORES: Automoldeamiento, ciclo del reforzamiento, intervalo entre estímulos, probabilidad del reforzamiento, picoteo en la tecla, pichón.

Conditioning procedures may be classified into two general categories. First, those conditioning procedures where reinforcement is contingent upon a response and, two, those where reinforcement is response independent or non-contingent. For clarity, the following definition can be used. Contingency refers to the case where the temporal distribution of responding determines the temporal distribution of reinforcements. Conversely, non-contingency refers to the case where the temporal distribution of reinforcement is not determined by responding (Schoenfeld and Farmer, 1970). According to this definition, operant conditioning belongs to the first category whereas classical and "superstitious" conditioning belong to the second. Also according to this definition, the procedure of autoshaping (Brown and Jenkins, 1968) belongs to the category of non-contingent reinforcement and therefore differs in this respect from operant conditioning procedures.

One technique to study the discriminative functions of a previously neutral stimulus (S^N) consists of "intruding" such a stimulus into the interval that separates successive reinforcers (S^R) (e. g., Skinner, 1938; Farmer and Schoenfeld, 1966). Working within the tradition of the t -system (cf., Schoenfeld *et al.*, 1972), Martin (1971) identified three variables of a generalized paradigm for stimulus intrusions. One variable is the lapse of time that separates S^N from S^R (the S^N - S^R interval). It has been shown that the rate of responding during S^N is a monotonic and decreasing function of lengthening the S^N - S^R interval (Martin, 1971). Two other variables that affect the degree of control exerted by S^N in "intruded stimulus" experiments are the probability values associated with S^N ($p(S^N)$) and S^R ($p(S^R)$). Nevin (1963), for example, has shown that the probability of responding during S^N decreased monotonically as $p(S^R)$ decreases.

Given that the t -system originated within the context of operant conditioning, the effects of these variables are known primarily in situations where there has been the familiar R - S^R contingency. However, given that time is the central variable in t -schedules, it would be easy to study S^N - S^R and $p(S^R)$ in non-contingent situations such as autoshaping and thus establish their generality.

Within the t -system, cycle length (T) refers to the duration of a repetitive time cycle at the end of which S^R is delivered on a probabilistic basis. Although T cycle length has not been studied systematically in conjunction with $S^N - S^R$ and $p(S^R)$, there are indications that T might interact with $S^N - S^R$ and $p(S^R)$. Dews (1970), for instance, has shown that the rate of responding during an S^N "intruded" in any given segment of a fixed interval schedule is a direct function of the interreinforcement interval.

The present study therefore attempted to determine the effects of $S^N - S^R$, $p(S^R)$, T and their interaction as well in the autoshaping situation.

METHOD

Subjects

Nine female homing pigeons, one to three years of age, served as subjects in this investigation. The birds were obtained commercially from a member of the local colombophilus association and had no prior experimental history. After observing their *ad libitum* weight for approximately eight weeks, they were reduced to 80%. Thereafter, they were maintained at that same weight level throughout the course of the entire investigation.

Apparatus

The procedures of the present study were programmed automatically by means of standard laboratory solid state equipment (BRS&-LVE). The data were collected and processed by a microcomputer (Radio Shack's TRS-80) coupled with a commercially available interface system (LVB).

All pigeons were tested in the same conditioning cubicle (BRS/LVE Mod. No. SEC-002) which was installed in a room separate from the programming equipment as a precaution against undesirable noises. Only the central key of the intelligence panel (BRS/LVE Mod. No. PIP-014) was functional in recording pecks and presenting color stimuli. Key pecks of 25 N or more were sufficient to activate the response microswitch. Following the recommendation of Ferster and Skinner (1957), the drop pan of the cubicle was raised about three cms. to compensate for the small size of these birds. A masking noise was provided through the intelligence panel's speaker, at a level deemed sufficient, to further reduce outside auditory disturbances.

Procedure

Experimental sessions were conducted daily and the birds were always run in the same order. Each experimental session was initiated by a food

delivery and the simultaneous illumination of the response key and the houselight. The reinforcing event (S^R) which occurred on a probabilistic basis at the end of the T cycle consisted of a three second access to the lighted food tray which contained mixed grain. The "intruded" S^N event was presented 50 times in a session and consisted of the illumination of the response key by a red light for four seconds. In the absence of S^N , the response key remained illuminated green. Ten individual sessions were allotted to observe the effects of each experimental condition of the study. There were three successive phases to the research:

Phase 1. *Autoshaping of the response to S^N and shortening the T cycles.* Once all subjects had been "magazine trained" with the houselight on and the key darkened, they were exposed to the following autoshaping procedure: the S^R cycle length (T) was set at 64 sec, $p(S^R)$ at 1.00 and the four-sec S^N was "intruded" just before food delivery, such that the offset of S^N coincided with the onset of S^R , i.e., $S^N - S^R = 4$ sec. All pigeons were kept on this schedule for ten sessions. Next, they were ranked according to their average overall rate of key pecking during the last five sessions. The three subjects with the highest rate were classified as "fast" responders, the following three as "intermediate" and the last three as "slow" responders. Three groups of subjects were then formed by randomly assigning one pigeon from a given category to each of the groups. From session 11 through 20, cycle length (T) was reduced from 64 to 32 sec and from 64 to 16 sec for two of the groups. A third group remained fixed at $T = 64$. $p(S^R)$ was 1.00 and $S^N - S^R$ at 4 sec for all groups.

Phase 2. *Increasing the $S^N - S^R$ interval.* During this second phase, each group was exposed to a series of longer $S^N - S^R$ intervals while $p(S^R)$ was held constant at 1.00 in all groups. The cycle length (T) this time differed among the three groups. The series of $S^N - S^R$ values studied for each group was the following: for group $T = 64$ sec: 4, 6, 8, 12, 16, 24, 32, and 48 sec. For group $T = 32$ sec: 4, 6, 8, 12, 16, and 24 sec. For group $T = 16$ sec: 4, 6, 8, and 12 sec. After the completion of each series, one value of $S^N - S^R$ (four sec) was run again for all animals.

Phase 3. *Decreasing $p(S^R)$ with $S^N - S^R$ at 4 and 8 sec.* The redetermination of the data at $S^N - S^R = 4$ sec of the preceding phase served as the starting point to study the effects of decreasing $p(S^R)$ for all groups. While a given cycle length remained fixed as the group parameter, $p(S^R)$ was reduced from 1.00 to .03 in geometric steps, i. e., 1.00, 0.50, 0.25, 0.12, 0.06 and 0.03. The $S^N - S^R$ interval remained fixed at 4 sec for all groups. After the $p(S^R)$ series was completed, $p(S^R)$ was set at 1.00 once again. Simultaneously, $S^N - S^R$ was increased from four to eight sec. The value of $p(S^R)$ was decreased once again in geometric steps from 1.00 to 0.03. This time $S^N - S^R$ was held constant at eight sec. Again, a redetermination of the data was obtained at $p(S^R) = 1.00$ after the completion of the last series.

RESULTS

In all phases of the experiment, most pigeons responded only during the 4-sec S^N (i. e., the pigeons appeared to "track" S^N through the T cycle). Figure 1 shows the rate of responding during S^N in the form of individual and group averages. Since the group and the individual functions are similar, the following analysis will be based on the group data.

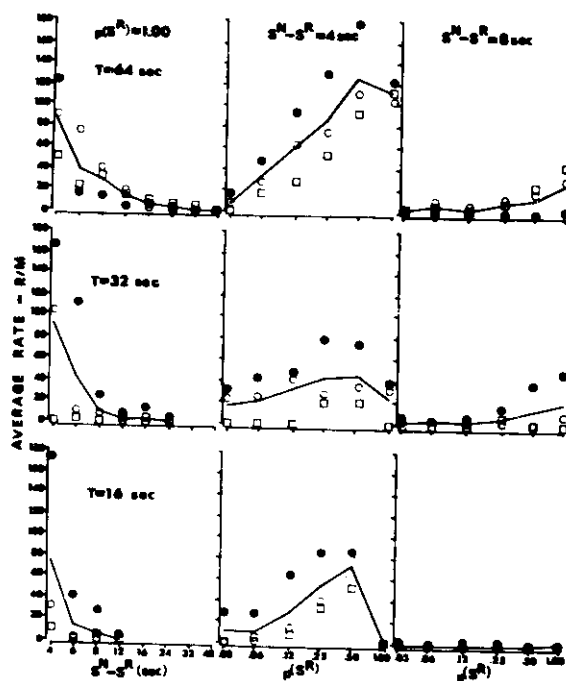


Figure 1. Average rate of responding during S^N for all experimental conditions. The line in each panel shows the group average whereas the symbols show the individual data. These functions are based on the last five sessions for each procedure. Note that the scale on the abscissa shows each value of the variable spaced equally.

Rate of responding during S^N was a monotonic and decreasing function of the $S^N - S^R$ interval for all groups. The rate of responding was generally higher and approached zero more slowly in the group that had T constant at 64 sec, while the rate was lower and approached zero more rapidly in the group with T = 16 sec. The function obtained with T constant at 32 sec was intermediate between the other two groups. It should be noted that after lengthening the $S^N - S^R$ interval, responding was decreased to near zero levels in all groups. The reinstatement of $S^N - S^R = 4$ sec with $p(S^R)$ constant at 1.00 (the last data points of the first $p(S^R)$ series) caused a large increase

in rate for the group with T constant at 64 sec. For the group with T constant at 32 sec, the increment in responding was comparatively smaller. For the group with $T = 16$ sec, the reinstatement of $S^N - S^R = 4$ sec over a ten-day period had a negligible effect. Longer values of T , therefore, seemed to facilitate the recovery of high rates of responding after these had been lowered by lengthening the $S^N - S^R$ interval.

Decreasing $p(S^R)$ from 1.00 to .50 using $S^N - S^R = 4$ sec as a parameter produced an increment in responding in all groups. Further reductions in the value of $p(S^R)$ produced steady decrements in responding in all groups. The group that had T constant at 64 sec responded at higher rates than the groups where T was fixed at 32 and 16 sec, both of which key-pecked at about the same rate at most values of the variable.

When $p(S^R)$ was decreased again, this time using $S^N - S^R = 8$ sec as a parameter, the rate of responding during S^N was a monotonic and decreasing function of $p(S^R)$ for all groups. For all groups as well, the rates of responding at all $p(S^R)$ values were lower when $S^N - S^R$ was 4 sec. The interaction between $p(S^R)$ and T was quite prominent during this phase of the experiment. This set of values resulted in the virtual disappearance of responding for the group that had T constant at 16 sec. The same set of values, however, still supported some responding in the groups where T was 32 and 64 sec.

DISCUSSION

Martin (1971) found that the rate in S^N is a monotonic and decreasing function of lengthening the $S^N - S^R$ interval in random-interval and fixed-interval schedules. In the present study, the effects of increasing $S^N - S^R$ were investigated while $p(S^R)$ was held constant at 1.00. It was found, as in Martin's study, that the rate in S^N was a monotonic and decreasing function of increasing the $S^N - S^R$ interval. In addition, the effects of the $S^N - S^R$ variable were also investigated under three values of T . The effect of T was small but nevertheless noticeable. The group with T fixed at 64 sec responded during S^N more frequently than the group where T was 32 sec, which in turn had higher rates than the group with $T = 16$ sec. The effects of $S^N - S^R$ had not been investigated in autoshaping until very recently. Lucas *et al.* (1981) found that rate in S^N decreased steadily when the "trace" interval was lengthened. In the study by Lucas *et al.* an attempt was also made to determine the interaction between $S^N - S^R$ and various "intertrial intervals." but this interaction turned out to be marginally significant. It is unclear why T had a prominent effect in the present research and not in the study by Lucas *et al.*

Nevin (1963) studied the effects of decreasing the $p(S^R)$ associated with an "intruded" S^N in a chained schedule. He found that the probability of responding during S^N decreased monotonically as $p(S^R)$ was reduced. Zeiler (1972) also found that the response rate first increased and then decreased

as a function of decreasing the percentage of fixed intervals ending with food in a fixed interval schedule. The effects of varying $p(S^R)$ has been investigated in at least two autoshaping studies (Gonzalez, 1974; Perkins *et al.*, 1975). In both studies S^N and S^R have been held temporally contiguous. These investigations have shown that the probability of responding during S^N (Gonzalez, 1974), as well as the rate of responding (Gonzalez 1974; Perkins *et al.*, 1975), tend to decrease with small values of $p(S^R)$. Also, in the two studies, the rate in S^N was higher at $p(S^R)$ values of .50 and .30 than at $p(S^R)=1.00$. The effects of decreasing $p(S^R)$ when S^N and S^R remain contiguous are therefore similar in autoshaping and in situations where reinforcement is response-contingent. However, just how the function which relates rate in S^N to $p(S^R)$ is influenced by different values of T remained to be determined. One part of the present study therefore closely replicated Gonzalez' procedure but included different values of T as a parameter of the $p(S^R)$ variable. The results obtained in the present research were similar to those mentioned above. When $p(S^R)$ was decreased from 1.00 to .50, holding S^N-S^R constant at 4 sec, the rate of responding during S^N increased in all groups. Further decrements in the value of $p(S^R)$ resulted in monotonic decrements in the rate of responding during S^N . During this first $p(S^R)$ series, the effects of T were twofold. One, larger values of T favored a faster recovery of original rates during the redetermination obtained at $S^N-S^R=4$ sec and $p(S^R)=1.00$, which served as the starting point for the manipulation of $p(S^R)$. Two, longer values of T were also associated with higher rates of responding at all values of the $p(S^R)$ variable.

In the present study, the typical autoshaping situation was conceptualized at the extreme of the potential convergence between S^N-S^R and $p(S^R)$. This is to say, as the case where S^N and S^R stand contiguous and $p(S^R)=1.00$. Therefore, the effect of $p(S^R)$ was also determined while S^N was being held temporally separated from the point where S^R was delivered probabilistically. Here again, three values of T were studied as parameters of the $p(S^R)$ variable. In this phase of the study, responding persisted at substantial levels only for those groups with the longer values of T , thus confirming the association between longer values of T and higher rates in S^N . In those groups where the pigeons pecked frequently during S^N , rate of responding was a slowly decreasing function of the $p(S^R)$ variable. The effects of decreasing $p(S^R)$ at different values of the S^N-S^R interval has been investigated in $R-S^R$ contingent procedures by Martin (1971). He found that when $p(S^R)$ was decreased at different values of the S^N-S^R interval, responding during S^N was controlled almost exclusively by the latter variable. Under such circumstances, responding at all values of the $p(S^R)$ variable decreased as a function of lengthening the S^N-S^R interval. It can thus be concluded that the results of the present research are also in agreement with those of Martin.

Finally, the effects of T seem also to be similar in autoshaping and in experimental situations where there is an $R-S^R$ contingency. It has been shown that the rate of responding during a stimulus "intruded" in different

portions of a fixed interval schedule is a direct function of the value of the interreinforcement interval (Dews, 1970). The results of the present study are in agreement with those of Dews. In this research, lengthening the S^N-S^R interval produced a rapid diminution of responding during S^N . Decreasing $p(S^R)$ with $S^N-S^R=4$ and 8 sec also produced decrements in responding. The decremental effects of these variables were, however, clearly diminished in the groups with the longer values of T . The effect of cycle length had been previously investigated in autoshaping by Terrace *et al.* (1975) and Perkins *et al.* (1975). These authors found that when S^N and S^R remain contiguous and $p(S^R)$ is held constant at 1.00, the rate of responding during S^N was an increasing function of the value of the "intertrial interval." The results of the present research are therefore also in agreement with those of Terrace *et al.* and Perkins *et al.*

In general, the results of the present investigation seem to be similar, as far as responding during S^N is concerned, to those obtained in other "intruded stimulus" research that have incorporated the $R-S^R$ contingency. There was, however, one notable difference, in this study, as in other autoshaping studies (e.g., Lucas *et al.*, 1981), responding in the absence of S^N was very infrequent. By comparison, in most if not all of the experiments where there has been an $R-S^R$ contingency, responding is rather frequent before and after S^N . The cause of this difference is unclear but seems related to the conspicuous presence versus absence of an $R-S^R$ contingency. If this is the case, it would still have to be determined which aspect of the $R-S^R$ contingency is responsible for the effect. This is to say, the concept of contingency can be analyzed into two potential parameters. One is the dependency of S^R upon responding and the other, the lapse of time that separates R from S^R . These are two different variables that may be examined in future research to account for the virtual absence of responding before or after S^N in autoshaping experiments.

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