A NOTE ON
CHAINING AND TEMPORAL DISCRIMINATION[1]

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Four pigeons were exposed to a two-key DRL procedure. At the start of a trial, key A was illuminated. A response to the lighted key turned it off and simultaneously illuminated key B. Reinforcement was available for responses on key B which followed the initial key A response by more than 2 sec. In the course of exposure to these conditions, all birds acquired superstitious response chains on key A. The distribution of the number of responses on key A preceding a key B response and the distribution of intervals elapsing from the initial key A response to the key B response were of the same form. The suggestion is made that the superstitious responding on key A served to mediate the required delay interval. However, when intervals between successive key A responses were recorded for one subject, they were found to be regularly spaced in time. Thus, the problem remains of how this behavior is itself timed.

Studies of the differential reinforcement of low rates have commonly found that the distribution of inter-response times is sharply peaked, with a mode at or near the minimum interval required for reinforcement. Such a distribution is said to demonstrate the presence of a temporal discrimination, and questions about the nature of processes mediating this discrimination have often been raised. Using rats as subjects, Wilson and Keller (1953) observed chains of competing responses which effectively served to delay the required response until reinforcement was available, and Malott (1961) observed fairly stereotyped homogeneous chains during intervals between responses. Bruner and Revusky (1961) have succeeded in making such chains easily specifiable by providing their human subjects with additional manipulanda within a situation which made superstitious responses to them highly probable. However, neither Anger (1956), nor Kelleher, Fry and Cook (1959) were able to observe any systematic behavior during the inter-response intervals. All of these reports have been qualitative in nature; this note reports some quantitative data on superstitious chaining in pigeons which appears to mediate a required delay interval, and discusses some methodological problems related to these observations.

METHOD

After preliminary training to peck illuminated keys, three male white Carneaux pigeons were exposed to the following two-key procedure: the left key (key A) in a standard experimental chamber was illuminated with yellow light to indicate the start of a trial; when the pigeon pecked it, the light was extinguished and the right key (key B) simultaneously illuminated with red light. A response on key B was reinforced with 3 sec access to grain only if at least 2 sec had elapsed since the initial response on key A. If the key B response occurred before that time, the key light was extinguished and a 3 sec time out imposed. At the end of the reinforcement or time out, key A was illuminated again. Responses on key A were effective in illuminating key B and starting the interval only if key A was illuminated, and responses on key B were effective only if preceded by such a response on key A. The interval elapsing from the initial response on key A to the response on key B, and the number of extra responses on each key were recorded. Each bird was run daily if its weight was within 15 gm of 80% of its free-feeding weight. Each day's session was ended when the bird had received 100 reinforcements. A fourth pigeon was exposed to this procedure after special preliminary training, which will be described below.

RESULTS AND DISCUSSION

All three birds acquired the key A-key B chain immediately upon exposure to the procedure, and by the end of the first session were receiving reinforcement for about one-third of their responses. After five days, 80% of the key A-key B intervals were greater than 2.0 sec, with the distribution showing a mode between 2.5 and 3.0 sec for all subjects. The only important change observed during the next five days was a tendency for this distribution to become somewhat more sharply peaked, with the shorter intervals dropping out.

In the course of the first session, all three birds also acquired the superstition of pecking repeatedly on key A after the initial response before shifting to key B. These extra responses on key A were emitted in the presence of the S^D for responses on key B. At no time in the history of the birds had such responses been directly reinforced, nor were they in any way required by the programmed contingency. Nonetheless, this superstitious responding persisted for the entire time the birds were exposed to the procedure. The distribution of run lengths (the number of responses on key A from the onset of the key A light until the occurrence of a response on key B) was recorded from the second day of training. For each bird, this distribution became reasonably stable after five or six days, at least to the extent its mode appeared consistently at the same run length. The means and variances of these distributions were quite different from subject to subject, as might be expected of behavior not required by the procedure.

When these distributions were transformed to show the conditional probability that the subject would shift to key B after some number of responses on key A, given that at least that number had occurred,[2] it became evident that the distributions for all subjects were similar in form. The upper panel of Fig. 1 presents these conditional probability functions, cumulated for days seven through 10 of training. The probability of shifting to key B is an increasing function of run length for all subjects, the differences in slope being due to differences in rate. This increasing probability may be attributed to the fact that,

given some average rate of responding on key A, it is increasingly probable that the interval required for reinforcement on key B will have elapsed as the run length increases. This statement may be made quantitative if the distributions of inter-response times on key A and the time required to shift to key B are known.
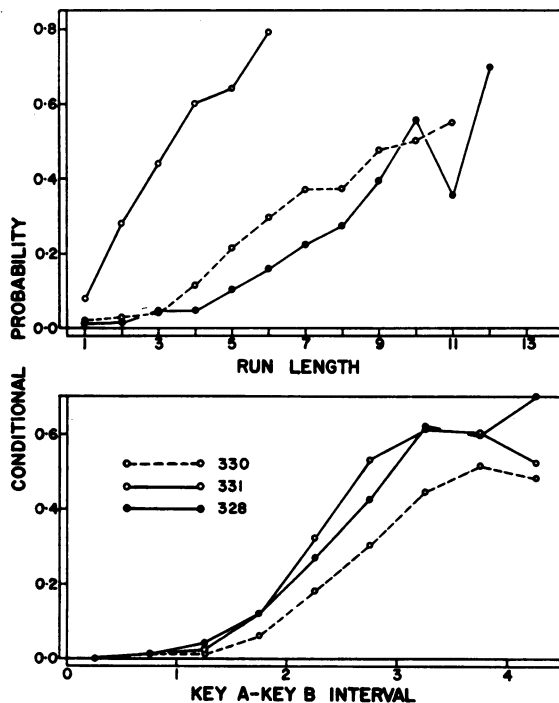

Fig. 1. Upper panel: conditional probability of response on key B as a function of run length on key A. Lower panel: conditional probability of response on key B as a function of key A—key B interval in seconds.

The lower panel of Fig. 1 presents the distributions of intervals elapsing from the initial response on key A to the response on key B, similarly transformed to show the conditional probability of response on key B as a function of time since the key A response.[3] For all three subjects, the probability of response is an increasing function of time. There is considerable similarity between the forms of the interval and run length distributions for each subject. This suggests that the number of responses in the run on key A may serve to mediate the delay required before the response

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[2] This conditional probability measure has been employed by Mechner (1958) to indicate the cohesiveness of a response run.

[3] This transformation is similar to the IRTS/OP measure employed by Anger (1956) to determine the probability of response from time t_1 to t_2, given that the inter-response time is equal to or greater than t_1.
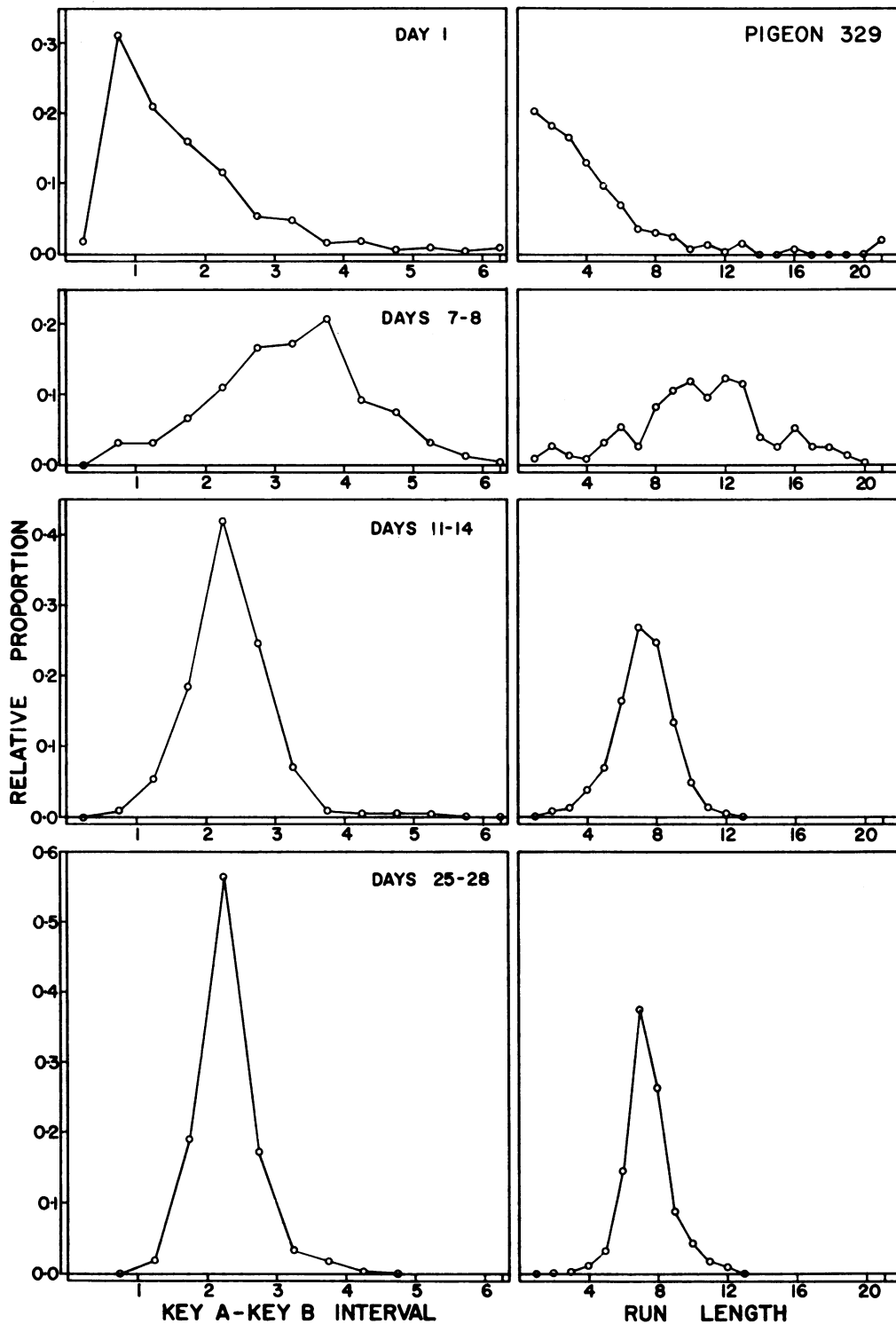
Fig. 2. Relative frequency distributions of key A—key B interval in seconds and run length on key A for successive stages of training. Intervals greater than 6 sec and run lengths greater than 20 responses are plotted at the extreme right of each distribution.

on key B can receive reinforcement, in much the same fashion as the chains observed by Wilson and Keller (1953) and Bruner and Revusky (1961).

In order to determine the systematic relations between chaining and temporal discrimination, it is necessary to rely on observation of response-response correlations in which one term of the correlation—the response chain—is not under experimental control and may vanish at any time, as other response chains receive superstitious reinforcement and replace it. However, if both the chain and the delay interval are required for reinforcement, one may learn nothing about the relation between chaining and the resulting temporal discrimination except that they occur.

Experience with other birds on similar procedures in our laboratory has shown that the establishment of superstitious chains on key A is by no means inevitable. Accordingly, the following procedure was devised in an attempt to insure the acquisition and maintenance of such chains. A fourth pigeon (No. 329) was shaped to peck key A in the presence of a green key light, and then given 500 reinforcements on a random ratio schedule with a constant probability of reinforcement for each response of ⅑. (This generates a geometric distribution of ratios with a mean of 9. During this training, key B was dark.) The bird was then shifted to the procedure described above, with the exception that the key A light changed from yellow to green after the initial response. By the end of the first session, the bird made many extra responses on key A before shifting to key B. The run length was highly variable and about one third of the responses on key B received reinforcement. The average rate of responding on key A was maintained virtually unchanged for 28 sessions.

The development of this bird's performance is shown in Fig. 2. On day one, the distribution of key A—key B intervals showed a high proportion of short intervals with an essentially exponential decline. By days seven and eight, there was a high proportion of intervals much longer than the required minimum of 2 sec, and the conditional probability functions for the run length and interval distributions have the same form as those presented in Fig. 1. Days 11 through 14 showed a well-developed

temporal discrimination, with the mode of the distribution between 2.0 and 2.5 sec. The only change after 14 more days of training was a further peaking of the distribution. The correlation of the timing of responses on key B with the associated distributions of run length on key A was evident throughout the 28 days of training.
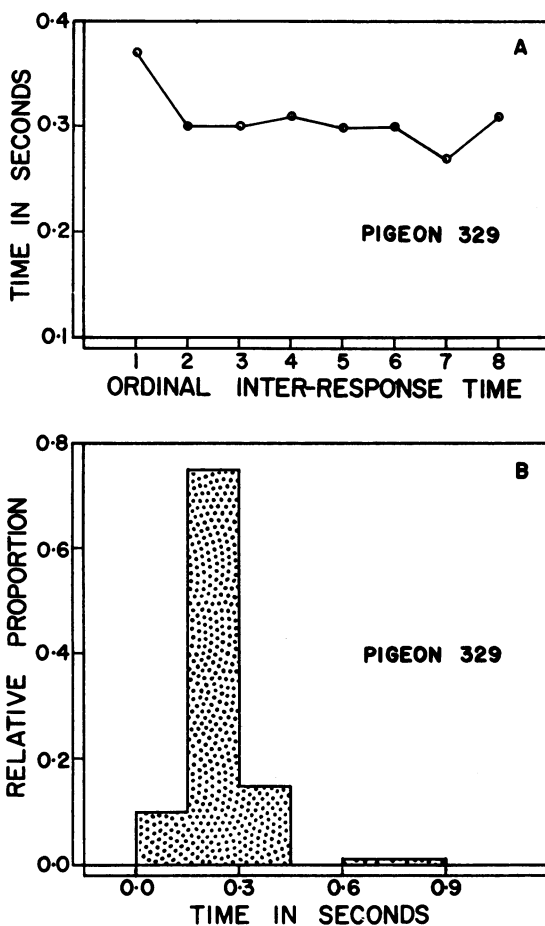

Fig. 3. Upper panel: mean inter-response time on key A as a function of ordinal position in the run.
Lower panel: relative frequency distribution of all inter-response times on key A.

On day 25, a record of the inter-response times on key A was taken. The upper panel of Fig. 3 shows that there is no significant change in the mean IRT as a function of its ordinal position in the run. Accordingly, all key A IRTs were lumped to obtain the distribution in the lower panel of Fig. 3. This distribution shows considerable stereotypy of rate on key A, despite the fact that there is no

rate contingency in effect. The relative invariance of these inter-response times means that the number of responses on key A is a reliable indicator of elapsed time, and thus may serve to mediate the fine temporal discrimination observed in the last stages of training.

Although these data strongly suggest that the temporal discrimination of one response may be based on the length of a chain of other responses, the finding that the latter responses may themselves be regularly spaced in time leads to an infinite regression. It is therefore necessary to inquire into the conditions for the invariance of inter-response times, on which the chaining account of temporal discrimination depends.

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