These data are more consistent with the view of exploration or stimulus seeking as a potent independent variable in behavior. However, it is not possible to judge from these data whether the genetic-environment interaction represented a genetic variation in a general factor of response to novel stimuli or whether it reflects specificity of genetic effects to the specific environment in which it is expressed.

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Behavioral contrast following gradual changes in schedule*

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The multiple schedule on which pigeons were reinforced was shifted from one value to another by a series of gradual steps. While reinforcement frequency was held constant in the presence of one stimulus, that in the presence of an alternated stimulus was gradually decreased for two of the pigeons and gradually increased for the third pigeon. Behavioral contrast occurred in each case. The performance of these pigeons on the terminal schedule did not appear to differ in any important respect from that of pigeons shifted directly from a baseline schedule to the terminal schedule.

Behavioral contrast occurs as a change in response rate in the presence of a stimulus following a change in schedule in the presence of a successively alternated stimulus. This form of interaction has been demonstrated reliably under a variety of procedures involving sudden discrete changes in schedule. The question arises as to what extent behavioral contrast depends upon a change between schedules, as opposed to the independent properties of the schedule in effect before and after this change. If the nature of the change as such is relatively unimportant, it should make little difference to the final performance how the change

between schedules is carried out. The present experiment investigated whether or not the production of behavioral contrast was disrupted by gradual, step-by-step changes in reinforcement schedule.

SUBJECTS AND APPARATUS

Three homing pigeons, maintained at 80% of their free-feeding body weights, were given daily sessions in a single-key operant chamber. The key was transilluminated with red or green light, and pecks on it having more than 15 g of force (.147 N) were recorded on counters and a cumulative recorder. Reinforcement consisted of 2.5-sec access to grain from a feeder mounted below the key. During reinforcement a magazine light was on and the key light was off. The experimental procedure was controlled automatically by electromechanical circuitry.

PROCEDURE

During successive 3-min periods, the key was alternately illuminated with red and green light. Thus, each stimulus occupied 30 min per hour session. Initially, 10 reinforcements per session were scheduled at variable intervals in the presence of each stimulus (multiple VI 3 min VI 3 min). Training under this schedule was continued until responding was judged to be sufficiently stable to provide a baseline. At this point, small progressive changes in reinforcement frequency in the presence of the red stimulus were made, while that in the presence of the green stimulus remained constant throughout.

In the case of Pigeon 026, reinforcement frequency in red was decreased by an average of .5 of a reinforcement every six sessions until extinction was in effect in the terminal schedule. Since there was no satisfactory way of presenting a half reinforcement, this was achieved, on the average, by varying the number of reinforcements by one on successive sessions. Thus, during the first six sessions following baseline training, the requirement of 9.5 reinforcements was met by arranging 10 reinforcements on odd-numbered sessions and 9 reinforcements on even-numbered sessions. The 20th change in reinforcement frequency following 114 sessions introduced the terminal schedule (VI 3 min Ext). Training was continued under this schedule for 36 sessions.

For Pigeon 15, reinforcement frequency in the presence of the red stimulus was decreased by one reinforcement per session every four sessions. Eight such changes in reinforcement frequency were made, so that the terminal schedule arranged four reinforcements per hour in red, .167 of total reinforcements under the multiple schedule. Training with this schedule (multiple VI 3 min VI 15 min) was continued for 14 sessions. For Pigeon 21, reinforcement frequency in red was increased eight times, every four sessions. The magnitude of each of these increments matched that of the corresponding decrements employed with Pigeon 15 in terms of relative frequency of reinforcement (the proportion of total reinforcements occurring in red). Thus, the terminal schedule for Pigeon 21 arranged 50 reinforcements in red, .833 of total reinforcements under the multiple schedule. Training with this schedule (multiple VI 3 min VI 6 min) was continued for 16 sessions. In this way, the terminal schedules for these two pigeons provided relative reinforcement frequencies in red equidistant from that under the baseline schedule (.5).

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RESULTS AND DISCUSSION

Response rates in both components of the multiple schedules employed are plotted in Fig. 1. It should be noted that these data are very condensed. Each point represents the mean response rate over a block of six (Pigeon 026) or four (Pigeons 15 and 21) sessions. Mean response rates over the last block of sessions under nondifferential reinforcement are plotted at Session 0 on the abscissa and represent baseline levels of responding. A change in reinforcement frequency in the presence of the red stimulus was made in each block of sessions up to the vertical dashed line, which represents the introduction of the terminal schedules. It can be seen that a reduction in reinforcement frequency in the component correlated with red produced a reduction in response rate in the presence of this stimulus (Pigeons 026 and 15). Similarly, an increase in the frequency of reinforcement in this component produced an increase in response rate (Pigeon 21). While gradual changes in reinforcement frequency correlated with the red stimulus were continuing under the intermediate schedules, response rates in the constant reinforcement component (green) tended to be somewhat unsystematic. Response rates under these intermediate schedules are not the primary concern here, since they were under the influence of continual changes in reinforcement frequency in red.

The important data for present purposes are those relating to the production of behavioral contrast and the magnitude of such effects. Contrast effects were measured for each pigeon as the difference in response rate in the presence of the green stimulus between the baseline schedule (Session 0) and the terminal schedule. Baseline rates of responding are represented for each pigeon in Fig. 1 by the filled point at Session 0 and the horizontal dotted line extending from this point. Response rates in green that are higher than this level represent positive contrast in the case of Pigeons 026 and 15, while those lower than this level represent negative contrast in the case of Pigeon 21. Thus, the method by which contrast was measured here was exactly the same as that employed in procedures involving an immediate change in schedule.

It can be seen from Fig. 1 that, for each of the pigeons, response rate in the presence of green indicated a systematic contrast effect. Although the contrast effects exhibited by

Fig. 1. Response rates in the presence of the green (filled points) and red (open points) stimuli for each pigeon. The vertical line indicates the point at which the terminal schedules were introduced. Each point to the left of these lines represents mean performance over a block of sessions under a different frequency of reinforcement. The horizontal dashed lines are predictions from a previous study (see text).

Pigeons 15 and 21 were smaller in magnitude than that of Pigeon 026, they were quite reliable. In the case of Pigeon 15, response rate in green was higher than baseline level for the last 13 of the 14 sessions of training under the terminal schedule. For Pigeon 21, the response rate in green was lower than baseline level for the last 15 of the 16 sessions of training under the terminal schedule. Pigeon 026 showed a response rate in green that was higher in each of the last 30 sessions under the terminal schedule than it was under the baseline schedule. The greater magnitude of the contrast effect exhibited by Pigeon 026 corresponds to the greater relative frequency of reinforcement (1.0) correlated with green under the

terminal schedule employed. A comparison was made between the magnitude of contrast effects obtained here and those obtained with discrete changes in schedule. For this purpose, predictions were derived from a formulation of the relationships between response and reinforcement frequencies based on data from a previous study (Lander & Irwin, 1968). The predictions are plotted as horizontal dashed lines in Fig. 1. It can be seen that the obtained response rates closely approximated these predictions. In the case of Pigeon 026, the separation between the component response rates was less than predicted, the difference between obtained and predicted response rates being about the same in each component. In the case of Pigeon 15, the predictions slightly overestimated response rates in both components by about the same amount. Thus, the separation between these component response rates was very close to that predicted. For these pigeons, then, the magnitude of obtained increases in response rate in the presence of the green stimulus (positive contrast effects) was slightly less than that predicted, and there appeared to be slightly greater attenuation where the changes were most gradual (Pigeon 026). The negative contrast effect shown by Pigeon 21 was very close to that predicted. For present purposes, it is worth noting that the differences found between obtained and predicted contrast effects were small and were certainly within the range of variability found in previous studies (e.g., Reynolds, 1963).

Apart from the possibility of a very slight attenuation of the magnitude of contrast effects, there was no indication that performance on the terminal schedules here differed in any important respect from performance typically obtained following discrete changes in schedule. While it would be premature to say that the nature of the change between schedules has no effect on the production of contrast, the present results indicate that an immediate discrete change in schedule is not a necessary condition for the occurrence of behavioral contrast.

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