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Temporal Factors in Successive Discrimination[1]

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Discrimination between successively presented red and green colours by pigeons was measured by the exponent of the power function relating ratios of responses in the two colours to ratios of reinforcers obtained by the responses. Values of the exponent were no different for conditions where stimulus presentation periods were 10 s or 60 s, and decreased over successive quarters of the 10-s or 60-s stimulus periods to the same extent. The degree of discrimination therefore decreased as a function of the proportion of the stimulus period rather than absolute duration since stimulus transition.

Successive discrimination poses the interesting problem of how the temporal gap between successive conditions is bridged. The discrimination is manifest as a difference in responding, and necessary conditions are discriminably different stimuli and different rates of reinforcers associated with the stimuli. Experimentally, the discrimination process is studied in a procedure where a pigeon (typically) sees successive red or green colours on a single response key. Pecks at red produce food reinforcers at one rate and pecks at green produce reinforcers at a different rate. Differences in responding in the two colours are usefully measured by ratios of responses. Lander and Irwin (1968) varied the difference in rates of reinforcers in the two colours over a wide range of values. They found that the ratio of responses was a power function of the ratio of reinforcers obtained in the two colours. The power function for successive discriminations (or multiple schedules) is $B_1/B_2 = q \cdot (R_1/R_2)^m$ (1), where B_1 and B_2 are frequencies of responses in red and green respectively, and R_1 and R_2 are frequencies of reinforcers obtained by B_1 and B_2 responses. The constant q reflects an overall tendency or bias to respond more in one colour than in another, and usually approximates 1.0 (no bias). The exponent m describes the sensitivity of the ratios of responses to changes in the ratios of reinforcers. For most successive discriminations, m ranges between about 0.3 and 0.5 (Davison & Ferguson, 1978; Lander & Irwin, 1968; Lobb & Davison, 1977; McLean & White, 1981, 1983; White, Pipe & McLean, 1984).

In previous studies we have suggested that the value of the exponent, m, provides a measure of discrimination independently of the effects of reinforcers. For no discrimination, m is zero and response ratios remain constant over the range of possible reinforcer ratios. The greater the extent of change in response ratios when reinforcer ratios are varied, the greater the discrimination and the larger the value of m. We validated our interpretation of m as a measure of discrimination by varying the size of the difference between line-orientation stimuli associated with different reinforcer rates in successive discriminations. The value of m increased systematically as the line orientations became more different (White, Pipe & McLean, 1983, 1984). A similar effect was reported for a forgetting procedure where m decreased with increasing difficulty of discriminating previously presented colours (Redman & White, 1985; White & Redman, 1983).

According to the suggestion that reinforcers obtained in the presence of one stimulus may affect behaviour occurring in the other (Herrnstein, 1970), or according to a relational view that attributes discrimination to stimulus comparison (Lawrence, 1963), the greater the temporal proximity of the discriminative stimuli, the greater the discrim-

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ination. The effects of temporal proximity have been examined in two ways. Firstly, by decreasing the duration for which successively alternating stimuli are presented on the response key, the average temporal distance between the stimuli is decreased and stimulus alternations are more rapid. Hence *m* should be greater for short stimulus durations (or components) than for long durations. This was the case in the first study to examine this possibility (Shimp & Wheatley, 1971), where values of *m* approximated 0.84 for 5-s durations and 0.56 for 30-s or 60-s durations (White, Pipe, McLean & Redman, 1985). More thorough studies by Charman and Davison (1982) and White et al. (1985) failed to replicate the effect reported by Shimp and Wheatley (1971). To date, the best conclusion is that *m* is about the same for short and long stimulus durations.

Secondly, temporal proximity has been examined by presenting stimuli for fixed durations and recording response frequencies at different times since stimulus transition. Soon after stimulus transition, the previous colour is temporally close to the prevailing colour, whereas some time after stimulus transition the colours are temporally distant. McLean and White (1981), Hunt (1985), Redman and White (1985) and White, Pipe and McLean (1984) recorded responses in successive subintervals of each stimulus presentation and found that *m* decreased systematically with increasing time since component transition. In McLean and White's (1981) study, *m* decreased from about 0.8 at the beginning of 90-s stimulus periods to about 0.3 towards the end of stimulus periods.

McLean and White's (1981) effect is robust, but seems to be inconsistent with the absence of an effect on *m* of shortening overall stimulus durations. If a short stimulus duration sampled the same pattern of behaviour that occurred in the same interval of an otherwise longer stimulus duration, *m* for the short duration would be greater than *m* for the long duration. White, Pipe, McLean and Redman (1985) showed that not only were values of *m* about the same for short and long stimulus durations, but *m* for the first 15 s of 60-s durations was greater than for short 15-s durations. That is, behaviour patterns in short stimulus durations may not mimic those at the beginning of longer durations. It is therefore possible that McLean and White's effect does not occur for short durations. The present experiment was conducted to compare the pattern of change in *m* over subintervals of a short 10-s stimulus duration to the pattern obtained for a 60-s duration.

Method

Subjects

Five adult homing pigeons were maintained at 80 percent of their free-feeding weights. All had prior experience in the same successive-discrimination procedure as used here (White et al., 1985). Grit and water were available in the living cages and supplementary feeding ensured maintenance of the prescribed weights. Daily sessions were conducted for each bird if its weight was within 15g of the prescribed weight.

Apparatus

A sound-attenuating experimental chamber with dimensions of 32 by 34 by 36 cm contained an interface panel with a central 2.5-cm response key, 25 cm from the grid floor, and also a second response key that remained unlit and inoperative. There was no houselight. The centre response key could be illuminated red or green except during reinforcement. A force of 0.15 N was sufficient to operate the key and each response was followed by a 0.04-s offset of the keylight. A central hopper opening allowed 2.5-s access to wheat, during which the hopper was illuminated. Experimental events were controlled and recorded by solid-state apparatus located in an adjacent room.

Procedure

All birds were introduced directly to the first condition in the first session, owing to their prior-training in the same procedure as used here. In each session, red and green alternated in direct succession on the centre key. In the presence of green, responses were reinforced according to one variable-interval (VI) schedule, and in the presence of red, responses were reinforced according to another, independent, VI schedule. Schedules were constructed from a constant-probability progression with 12 intervals. Reinforcers set up in one stimulus period, but not obtained until the end of the period, were held over until the next presentation of the same colour. The nominal values of the VI schedules were VI 240-s in green and VI 48-s in red in one condition, and VI 48-s in green and VI 240-s in red in a second condition. For these conditions, red and green stimulus periods were 10 s, and 144 green periods alternated with 144 red periods in each 48 min session. Data from these conditions were compared to the results of seven reinforcement conditions with 60-s stimulus periods for the same subjects, reported by White et al. (1985, conditions 1-7). The conditions from White et al. were conducted in exactly the same way as the present conditions, except that 24 green periods alternated with 24 red periods in each 48-min session. In both sets of conditions, responses were recorded in quarters of each stimulus period, that is, in successive 15-s subintervals of the 60-s periods, or in successive 2.5-s subintervals of the 10-s periods. Reinforcers were not recorded separately in subintervals because they were scheduled to occur randomly in time, and therefore with equal probability in successive subintervals. We therefore assumed that the probability of a consistent temporal pattern in obtained reinforcers, sufficient to produce a reliable effect on responding, was negligible.

Each condition continued until the performance of each bird was stable. As in the study by White et al. (1985), the stability criterion was that each condition continued for at least 20 sessions and until the stage where, in each of five consecutive sessions, responses maintained by the richer VI schedule as a proportion of total responses did not differ by more than 5% from the mean response proportion for the five sessions. In the conditions with 10-s stimulus periods, the numbers of sessions required to satisfy the stability criterion were, for each of the five birds respectively, 27, 28, 29, 25 and 30 for the VI 240-VI 48 condition, and 20, 26, 22, 28 and 20 for the VI 48-VI 240 condition.

Results and Discussion

Analyses for individual birds were based on the total response frequencies in each of the 2.5-s subintervals of 10-s stimulus periods, and also total reinforcer frequencies obtained in 10-s periods, summed over the last five sessions of each condition. These data represented stable performance and are given in Table 1 for the conditions with 10-s stimulus periods. Data from the same birds for successive 15-s subintervals of 60-s periods are given in White et al. (1985) where the same analysis was conducted. Reinforcer totals in the present conditions (means of 25.8 and 108.3 for the VI 48-s and VI 240-s conditions respectively) approximated those for comparable conditions in White et al. (1985) (means of 27.1 and 111.6). Table 1 shows that increasing reinforcer rate in one colour produced a concomitant increase in response rate in that colour, whereas in the alternated component reducing reinforcer rate reduced response rate. Comparisons between the data in Table 1 and those reported by White et al. (1985) did not reveal any obvious differences in the patterns of responding between conditions with 10-s and 60-s stimulus periods.

Estimates of m in Equation 1 were obtained by finding the slope of the line between the data points for the pair of reinforcement conditions, using logarithms (base 10) of response ratios in each subinterval and logarithms of ratios of reinforcers obtained in green and red. When the analysis was conducted for response ratios in the whole 10-s stimulus period, the result confirmed the previous conclusions of Charman and Davison (1982) and White et al. (1985) that m does not change with stimulus-period duration. Average values of m reported by White et al. (1985) were 0.34 for 60-s periods and 0.35 for 15-s periods. In the present 10-s conditions, m averaged 0.28.

Table 1

Response Frequencies in Successive Subintervals of 10-s Stimulus Periods and Reinforcer Frequencies Summed for the Last Five Sessions of Each Condition. Condition 1 used VI 48-s (Red) CI 240-s (Green) Schedules and Condition 2 used VI 240-s (Red) VI 48-s (Green) Schedules

	Responses in Green				Responses in Red				Reinforcers	
Condition	1	2	3	4	1	2	3	4	Green	Red
Bird R1 1.	1110	1188	1276	1341	1852	1749	1741	1683	22	103
2.	1592	1621	1557	1505	934	1100	1197	1258	87	39
Bird R2 1.	940	1783	2236	2223	2220	2101	2106	1952	23	118
2.	2851	2626	2554	2347	1417	1826	2096	2173	104	32
Bird R3 1.	788	1480	1975	2138	2733	2580	2464	2327	22	120
2.	2809	2458	2348	2211	1528	1967	2241	2387	113	27
Bird R4 1.	653	796	895	933	1247	1172	1211	1213	23	105
2.	1492	1463	1420	1333	482	565	655	813	110	30
Bird R5 1.	970	1142	1178	1247	2120	1984	2290	2080	22	129
2.	1906	1781	1682	1675	1183	999	1367	1578	94	27

Figure 1 shows values of *m* for successive subintervals of 10-s stimulus periods and for the 60-s stimulus periods reported by White et al. (1985). In both cases, *m* decreased systematically across the component subintervals, $F(3,12)=26.3$, $p<.001$. Two features of the result in Figure 1 are of particular interest. First, McLean and White's (1981) effect was evident for the 10-s stimulus periods, despite their short duration. Thus *m* decreases systematically with increasing time since stimulus transition for both very short and long durations. Second, the change in *m* over subintervals is very similar for the 10-s and 60-s stimulus periods. A repeated-measures analysis of variance showed that *m* did not differ for short versus long durations, $F(1,4)=3.1$, $p>.05$, and in particular, the possibility of steeper functions for short components (Figure 1) was disconfirmed by the nonsignificant interaction between durations and subintervals, $F(3,12)=2.0$, $p>0.5$. That is, *m* decreases over subintervals of short and long durations to the same extent. It is therefore the proportion of a stimulus period that determines the value of *m*, not the absolute duration since stimulus transition. In the first quarter of the stimulus period, *m* values are the same, whether the first quarter lasts for 2.5 s or 15 s. The reduction in *m* as the stimulus period progresses from the time of stimulus transition, occurs in relation to the proportional duraton of the stimulus period.

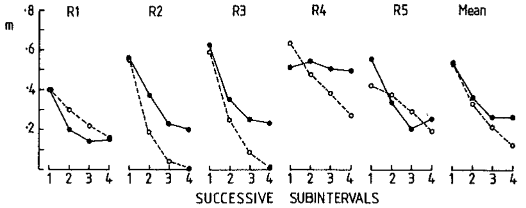

Figure 1. Extent of discrimination, m, as a function of successive 2.5-s subintervals of 10-s stimulus periods (unfilled circles) or 15-s subintervals of 60-s stimulus periods (filled circles), for individual birds and for the mean bird. Data for 60-s stimulus periods are taken from White et al. (1985).

The absence of an effect on *m* of overall duration of stimulus periods suggests that average temporal distance between stimulus periods does not directly contribute to the discrimination. This conclusion is consistent with the finding that the reduction in *m*, and hence a reduction in the level of discrimination, across subintervals is a function of the proportion of the stimulus period rather than absolute stimulus duration since stimulus transition. That is, absolute stimulus duration is unimportant either to the overall level of discrimination or to the change in discrimination since stimulus transition; it is important only insofar as there is an adjustment in the extent of discrimination at different times since stimulus transition to suit the prevailing duration of the stimulus period. When there is a short time until the next stimulus transition, there is a shortlived burst of differential responding at the beginning of the period. When there is a long time until the next transition, differential responding persists over a longer time since the last stimulus transition. The discrimination is therefore modulated by average time between stimulus periods in that it provides a temporal context for the change in discrimination since stimulus transition.

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