PURE TIMING IN TEMPORAL DIFFERENTIATION

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Temporal control appears to depend on whether the critical durations are those of stimuli or those of responses. Stimulus timing (temporal discrimination) supports Weber's law, whereas response timing (temporal differentiation) indicates decreasing relative sensitivity with longer time intervals. The two types of procedure also yield different conclusions in scaling experiments designed to study the functional. midpoint of two or more durations (temporal bisection procedures). In addition, the fractional-exponent power relation between emitted and required duration usually found with animals in differentiation experiments conflicts with deductions from formal analyses. The experiment reported here derived from considering differentiation arrangements as schedules of reinforcement. When analyzed from this perspective, the procedures are tandem schedules involving a required pause followed by a response, and it is the pause alone that involves temporal control. A choice procedure separated timing from responding, and enabled observations of pause timing in isolation. Pure temporal control in differentiation consisted of linear overestimation of the standard duration, and Weber's law described sensitivity. These results indicate that the two problems, the fractional-exponent power relations and the apparently different nature of sensitivity in differentiation and discrimination, disappear when temporal control is observed alone in differentiation.

Key words: response timing, temporal differentiation, Weber's law, DRO schedules, switching time, choice, key peck, pigeons

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Procedures for studying timing fall into two general categories. In one (stimulus timing or temporal discrimination), the experimenter presents a stimulus of some duration, and the animal then must respond. The animal might receive food for responses following only some durations, or following one response after certain durations and a different response after others. In any event, the relevant temporal property is that of an explicit antecedent stimulus. In the second class of procedures (response timing or temporal differentiation), reinforcers occur when the duration of a response meets some criterion. The critical temporal feature is the duration of behavior.

Although the two procedures might seem to provide alternative ways of studying general properties of temporal control, they yield different results. Consider the case of sensitivity to differences in duration. Weber's law is supported if the difference threshold divided by the standard is constant over a range of standards, or if psychometric functions superimpose, or if the standard deviation of judged or emitted durations divided by their mean is constant, because any of these indicate that a given proportional change produces the same level of accuracy. The Weber constant will vary with the particular statistical method, but the law can be tested by using any of them. When the discriminated duration of an antecedent stimulus is at issue, Weber's law holds (cf. Gibbon, 1977; Platt, 1979). Some cases may entail consideration of additional sources of variance, but this simply leads to a generalized form of the law (Church, Getty, & Lerner, 1976). However, when response durations are differentially reinforced, Weber's law is not confirmed. The coefficient of variation of response durations is neither constant, as predicted by the simple

form of Weber's law, nor does it decrease with longer means, as predicted by the generalized law. Instead, it increases with longer duration requirements (Cantor & Wilson, 1981; Platt, 1979; Zeiler, 1983). In short, sensitivity seems to differ depending on whether stimuli or responses provide the basis for assessing temporal control.

Different results with respect to Weber's law are not the only incompatible findings obtained with the two procedures. At one time scaling experiments seemed to show agreement between discrimination and differentiation, but on closer examination they have proven not to. These experiments, which required animals to classify durations into one of two categories, involved either stimulus timing or response timing. The interest was in the relation between physical and psychological time, and this took the form of determining whether a simple averaging rule (the arithmetic, geometric, or harmonic mean of the various durations) would describe where the series was divided. The bisection point appeared to approximate the geometric mean of two durations (Church & Deluty, 1977; Platt & Davis, 1983) or of ten durations (Stubbs, 1968, 1980) in either discrimination (Church & Deluty, 1977; Stubbs, 1968) or differentiation (Platt & Davis, 1983; Stubbs, 1980), thereby implying cross-procedural similarity in temporal scaling. However, further analysis shows that the similarity stems from the insensitive decision rules inherent in determining which of three means best fits the data. One mean might fit better than the others (judged by either visual or statistical analysis), but even that one might not be correct. The need is for a technique that permits a choice between averaging rules without requiring advance specification or preselection of the rules.

Fortunately, such a method is available. Arithmetic, geometric, and harmonic means all are special cases of the power mean, which is obtained by raising each value, X_j, to the power a, obtaining the average of these transformed values, and then taking this average to the $1/a$ power. The power mean is:

$$[(\sum_{j=1}^{n} X_j{}^a)/n]^{1/a}$$

If the power mean is unknown, it can be determined for any specified value of a. If the power mean is known but a is not, the value of a can be found by numerical methods such as the simple iterative procedures readily programmed on small computers. In that case, the calculated value of a indicates the nature of the averaging process. If the arithmetic mean is a correct description, $a = +1$; if the geometric mean is correct, a becomes vanishingly small; if the harmonic mean is accurate, $a = -1$. The exponent, therefore, discriminates between the three means and also indicates whether any one of them accurately describes the data.

A power mean analysis of the published bisection data was conducted by considering each bisection point as the mean of the imposed durations, and then an iterative procedure was used to identify the best-fitting exponent for each of the four studies. For two-stimulus discrimination (Church & Deluty, 1977), $a = +.13$; for ten-stimulus discrimination (Stubbs, 1968), $a = +.68$; for two-stimulus differentiation (Platt & Davis, 1983), $a = -.37$; for ten-stimulus differentiation (Stubbs, 1980), $a = -.81$. These results reveal a consistent difference between discrimination and differentiation, and they challenge the geometric mean as a general description of the results of bisection experiments. Although the exponents were not constant for a given type of procedure, they were positive for discrimination and negative for differentiation. This power mean analysis of the differentiation and discrimination versions of the bisection experiment agrees with the assessments in relation to Weber's law in showing that the two types of procedure provide conflicting information.

So far, the present discussion has emphasized the discrepant conclusions about temporal control that are generated by differentiation and discrimination procedures. Two other problems are raised by the basic data describing the relation between emitted response duration and the temporal demands

of the schedule in simple differentiation arrangements. Emitted duration typically turns out to have a fractional-exponent power relation to either the minimum duration required for reinforcement or the mean reinforced duration (Catania, 1970; DeCasper & Zeiler, 1977; Platt, 1979). The first problem is: How can this occur? In differentiation, two temporal properties are critical: the first is the controlling duration; the second is the ongoing duration of each response. Because the subject never is exposed directly to the duration requirement but receives a reinforcer only after emitting certain response durations, one might expect that reinforced duration would determine the subsequent durations. The actual controlling feature might be the minimum response duration required for reinforcer delivery (the duration requirement), or perhaps the average reinforced response duration, but in any case it is the temporal property of some subset of responses. Whatever it may be, that feature presumably determines the response durations emitted in the future. In short, one response duration determines another. The distinction between controller and controlled is a historical one and not a difference in kind. So even if physical and functional durations are not veridical but instead represent some scaling transformation, whatever transformation applies to previous durations should apply equally to present ones. This means that emitted duration should match the controlling feature instead of having a fractional-exponent power relation to it. The failure to obtain this temporal matching must mean that the controlling duration is unknown to the observer, even though the relation between emitted and required or reinforced duration can be described precisely.

The second problem is that Gibbon (1981) has shown through formal quantitative analysis that the fractional-exponent power relation cannot describe temporal control. Any plausible description requires linear data. So, whereas differentiation at first glance might seem to be a direct method for analyzing the relation between physical and func-

tional duration, the obtained data challenge its utility. Given the consistent power-function finding, the conclusion must be that differentiation procedures implicate additional factors.

The idea that procedures for studying timing may involve nontiming processes is not novel. Church et al. (1976) asserted that animals may not always be attending to time, and that even when they are, motor time and latency to begin and stop timing may complicate the results. This hypothesis applies equally to differentiation and to discrimination, but other writers have pointed to processes that may be unique to differentiation. Platt (1979) hypothesized that a duration-minimizing tendency competes with timing. Senkowski, Vogel, and Pozulp (1978) asserted that because a response is reinforced when it is timed appropriately, the reinforcer also strengthens the tendency just to make that response without regard to time. Zeiler (1981) stated that animals alternate between timing and emitting the reference response as if no duration requirement exists. These last two views suggest that the need to respond after the criterion duration has elapsed may obscure the true nature of temporal control. What is necessary to observe timing itself in differentiation, then, would be a procedure that makes the measurement procedure independent of nontemporal characteristics of the response.

Construing differentiation arrangements as schedules of reinforcement leads to a method for observing timing. A differentiation procedure involves a series of two requirements occurring according to a tandem schedule: A specified time period must elapse in which the reference response is withheld, and then the reinforcer follows the next response. The tandem schedule, therefore, begins with DRO (differential-reinforcement-of-not-responding), where "not responding" refers to the absence of a particular response for a specified duration, and ends with occurrence of that response. Because timing involves the pauses produced by the DRO component, the way to study it would seem to be via simple DRO schedules.

However, in a preliminary experiment, when six pigeons were given a series of six conditions, each involving 10 sessions with one DRO schedule (different conditions required 5, 10, 20, 40, or 80 s without a keypeck for food to be delivered), the birds did not respond at all in 33 of the 36 conditions, and no bird responded more than twice per session in the remaining three. Continuous pausing precluded analysis of the duration of individual timed pauses. The interesting information was that DRO could completely eliminate responding and that responses early in the time interval in differentiation procedures are not due to an autoshaping-like effect.

The present experiment used a different procedure to observe the duration of individual DRO pauses. Instead of having only a DRO schedule, DRO served as one element of a two-component concurrent schedule. Only one component prevailed at a given instant, but the pigeon could choose which was in effect at any time by emitting a switching response (cf. Findley, 1958). Each food delivery was preassigned to one of the two components, and it remained assigned there until collected. No external stimulus indicated the component to which the food delivery had been assigned, so the pigeons had nothing other than elapsed time to reveal whether food was or was not available in the DRO component. Information about timing was derived from the time taken to switch out of the DRO (timing) schedule in the absence of food delivery. That time presumably indicated discrimination of the required pause duration having elapsed, for the pigeon then switched to the other schedule. Five pause-duration requirements determined the function relating switching time to DRO value, and three probabilities of reinforcer assignment to the DRO indicated whether the function was influenced by relative reinforcer frequency.

METHOD

Subjects

Three experimentally naive White Car-

neaux pigeons were maintained at 80% of their free-feeding weights.

Apparatus

The experimental chamber contained two horizontally arrayed response keys located above the food aperture. Each key operation required a force of 0.18 N. The left key (schedule key) could be transilluminated by either white, red, or green lamps; the right key (switching key) was illuminated by a white lamp. At all times a houselight provided dim general illumination, and white noise masked extraneous sounds. Experimental events were scheduled and recorded by a Digital Equipment Corporation PDP-8F minicomputer.

Procedure

Each pigeon was trained to peck both keys by the method of successive approximations. Then, pecks on the switching key illuminated the response key with white light, at which time pecks on the response key were followed by food delivery. The schedule on the response key was random interval (RI), with the value gradually raised to 60 s by having the computer make food available for the next response each 1.2 s with a probability of .02. During the entire experiment food cycles were 3 s, and sessions ended after 30 food deliveries. After shaping was concluded, the experiment proper began.

At the beginning of a session and after each food delivery, the schedule key became either red or green with $p = .5$. When the key was red, a DRO schedule was in effect; when the key was green, the RI 60-s schedule prevailed. Each switching-key response changed the color of the schedule key. At the beginning of each session and after each food delivery, the next food presentation was assigned to one of the schedules by a probability gate. If assigned to DRO, the first pause in red that lasted the specified duration produced food; if assigned to RI, the first response in green occurring after a reinforcer was made available produced food. The DRO pause timer ran only during red and began anew with each onset of red and

Table 1

Sequence of Conditions

Condi-tion	Sessions	Bird 123		Bird 138		Bird 165	
		DRO	pDRO	DRO	pDRO	DRO	pDRO
1	30	20	.5	20	.5	10	.5
2	25	40	.5	40	.5	5	.5
3	28	5	.5	20	.5	40	.5
4	36	10	.5	10	.5	5	.2
5	30	10	.2	5	.5	20	.2
6	30	5	.2	20	.2	20	.5
7	27	20	.2	10	.2	5	.5
8	32	40	.2	40	.2	40	.8
9	30	5	.8	5	.8	40	.2
10	30	10	.5	5	.2	5	.8
11	29	40	.8	10	.8	10	.2
12	30	20	.8	20	.8	20	.8
13	25	10	.8	40	.8	40	.5
14	25	40	.5	40	.5	80	.5
15	31	80	.2	80	.8	80	.8
16	30	80	.5	80	.2	80	.2
17	25	80	.8	80	.5	10	.8

each response in red, while the RI probability gate operated only when the key was green. The design was a 3 x 5 factorial, with five DRO values (5, 10, 20, 40, 80 s) and three probabilities of reinforcer assignment to DRO (.2, .5, .8). Each combination of DRO value and reinforcer probability was maintained throughout a condition. Two conditions were replicated for each bird. Table 1 shows the order of the 17 conditions for each pigeon and the number of sessions for each. Conditions lasted between 25 and 36 sessions as dictated by experimenter convenience.

RESULTS

All data analyses were based on the last five sessions of each condition. The relevant data were the times taken to switch from one component to the other, as these were indicative of temporal control. For each bird average switching time from one component to the other in each of the five sessions never differed by more than 5% from the average over the five sessions combined and showed no monotonic direction of change. Switching time from DRO typically represented a single continuous pause: The pigeons emitted no responses during DRO in over 60% of
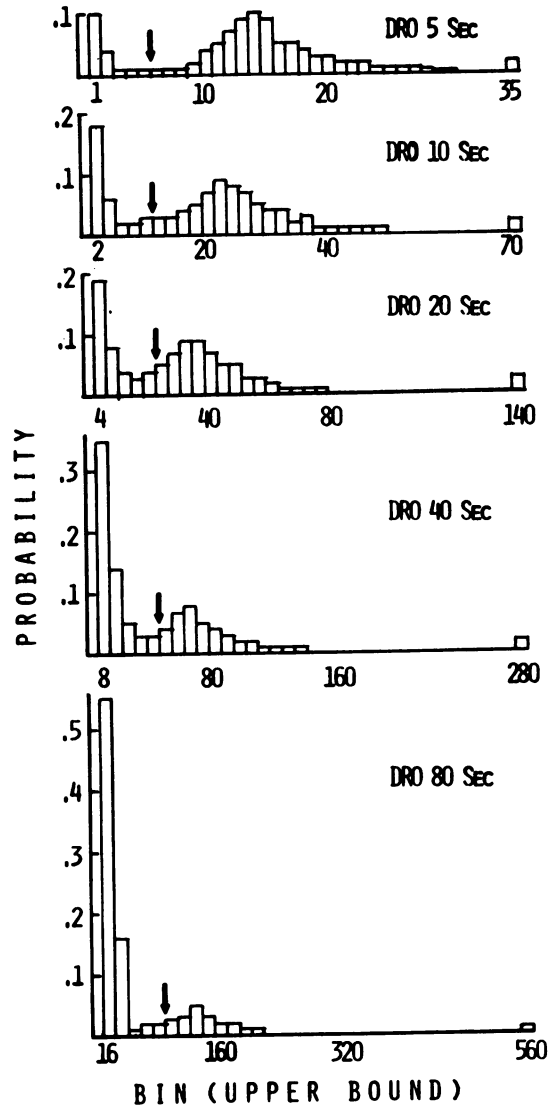

Fig. 1. Relative frequency of switching times from DRO to RI for each DRO value. Bin widths are 1/5 of the pause requirement. Arrows show the location of the DRO requirement.

the sessions and no more than a total of two in the remainder.

Figure 1 shows the distribution of times taken to switch from the DRO to the RI component for each DRO value. Distributions were combined for the three birds, because the individual data were similar. Comparisons of the probability distributions for the individual birds with those of Figure 1 showed that the average difference over the 35 bins for each DRO value was 0.00 with a standard
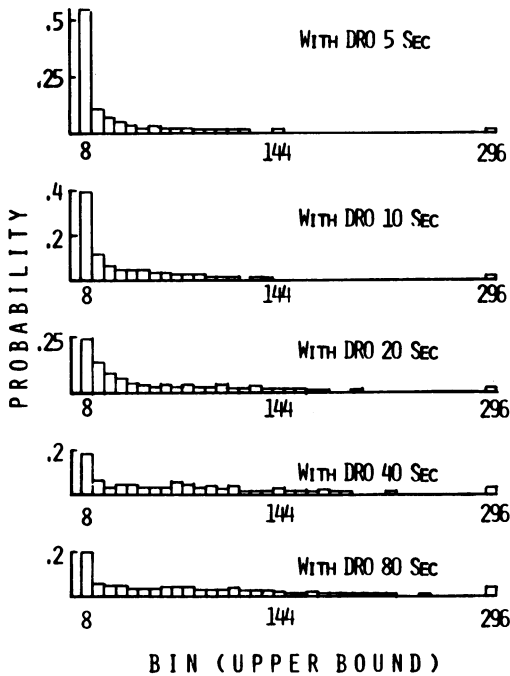
Fig. 2. Relative frequency of switching times from RI to DRO for each DRO value. Bin widths are 8 s.
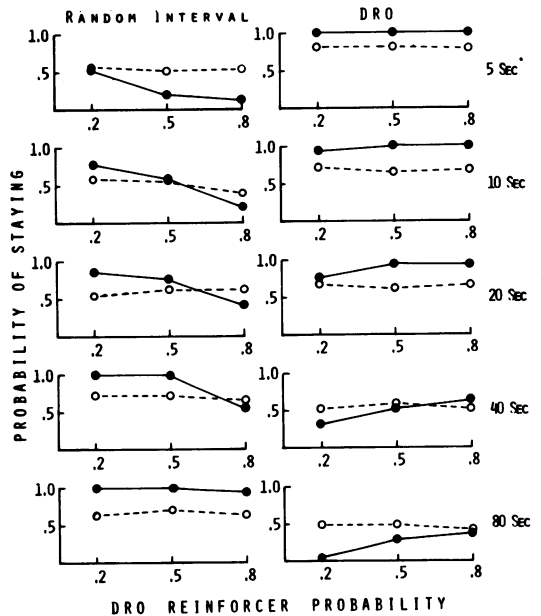

Fig. 3. Probability of staying for first 40% of DRO period and first 16 s of RI. Data are shown separately for switches following component entry following reinforcement and session start (filled circles) and following a switch from the other component (unfilled circles). The DRO schedule for each pair of graphs appears on the right.

deviation between 0.001 and 0.01. A chi-square test of goodness of fit showed that the distributions for the individuals never differed significantly ($p > .10$) from the grouped distributions. All of the distributions were bimodal with one peak at the shortest switching times and a second at a value larger than the DRO requirement. Figure 2 shows the switching times from RI to DRO. Bimodality was less evident; instead, the switching probabilities declined in successive bins. Both Figures 1 and 2 reveal some outliers separated from the remainder of the distribution by a series of bins having no entries.

How a component was initiated influenced the time taken to switch out. Figure 3 shows the probability of staying in RI for the first 16 s and the probability of staying in DRO for the first 40% of the DRO time requirement, depending on whether component entry had been subject-determined (the pigeon had switched from the other component) or determined by the probability gate operating at the start of a session and after reinforcer delivery. If entry was determined by the gate, the likelihood of staying depended both on DRO

value and probability of reinforcer assignment. The smaller the DRO value or the more reinforcer assignments to DRO, the more likely the bird would stay in DRO or switch to it from RI. The probability of staying in DRO 5 s or switching to it from RI was high, whereas that of staying in DRO 80 s or switching to it from RI was low. The intermediate DRO values showed the interaction of the two sources of control. If, however, the component had been entered by a switch from the other schedule, the effects of both DRO value and reinforcer probability were weakened. The reason was that the birds often pecked the switching key several times in quick succession, thereby rapidly switching between components and producing a series of very short switching times from both RI and DRO. Many of the switching times contained in the first bins of Figures 1 and 2 that emanated from switch-initiated components were less than 0.5 s. Instead of reflecting temporal control, therefore, early switches stemmed either from immediate choice of the other component

or from response bursts on the switching key. Such switches were responsible for the segment of the distributions of Figure 1 characterized by the first mode and have little to do with timing.

A second group of untimed switches were the very long ones appearing as outliers in Figures 1 and 2. There were no switch durations between 35 and 104 s with DRO 5 s, none between 60 and 147 s with DRO 10 s, none between 89 and 233 s with DRO 20 s, none between 145 and 412 s with DRO 40 s, and none between 241 and 483 s with DRO 80 s. The series of bins with no entries suggested that these very long switching times represented something other than timing. Over 80% of these occurred following a burst of switching-key responses, and they would seem to reflect some sort of extinction effect arising from repeated switching.

The lower bound of the distribution that represented timing was taken as the value between the first two segments of the distributions shown in Figure 1 that had the lowest switching probability. These points suggested where the first part of the distribution ended and the second began. They were 2 s with DRO 5 s, 4 s with DRO 10 s, 9 s with DRO 20 s, 19 s with DRO 40 s, and 39 s with DRO 80 s. The distributions beginning at these lower limits and excluding the outliers tended towards symmetricality with peaks at points considerably larger than the DRO values.

The left column of Figure 4 shows the mean time taken to switch out of DRO for each time value for each probability of reinforcer assignment when the full switching distributions were considered. Regularities are not easily discerned. However, when only the timing distributions were considered (right column of Figure 4), each DRO value had constant effects independent of the probability of reinforcer assignment, and mean switching time was determined by DRO value alone.

In order to determine whether restricting times in the way done for DRO would impress order on these data as it had for DRO, the RI distributions of Figure 2 were also treated as having three components. A trough between the presumed first two parts was found at
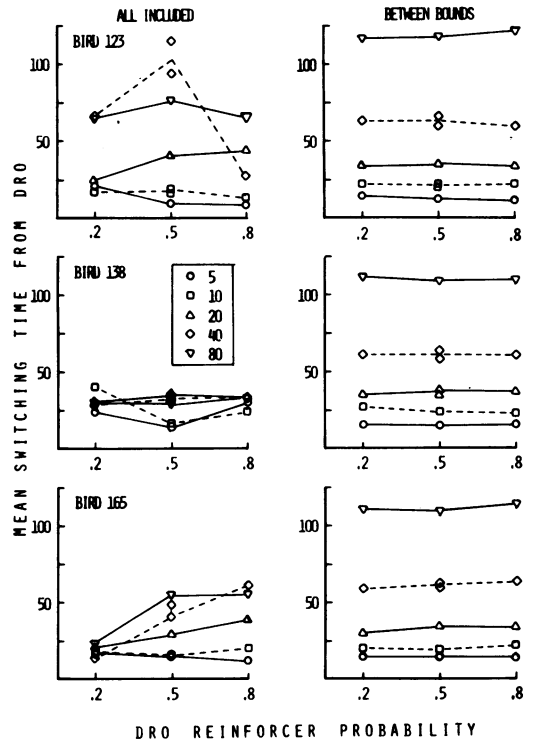

Fig. 4.   Mean switching time from DRO for each DRO value and each probability of reinforcer assignment. Left column is based on all pauses; right column is based on those in the timing distribution.

14 s, and the outliers were excluded. Figure 5 shows the mean time taken to switch from RI to DRO for the full distributions, and for the segments of those distributions that excluded all times below 14 s and those qualifying as outliers. For both the full and the restricted distributions the means were affected by both DRO value and reinforcer probability.

Further analyses agreed in showing the viability of separating the timing distributions from the full distributions of Figure 1 and the irrelevance of performing comparable subdivisions of the distributions of Figure 2. These analyses were based on the probability of staying in DRO or RI for the first segment of the restricted distributions. (These analyses were identical to those of Figure 3, except that now the first bin was the first of the restricted distribution.) One new effect was that now the probability of staying was independent of whether the component had been entered via a switch or via the probability gate operating
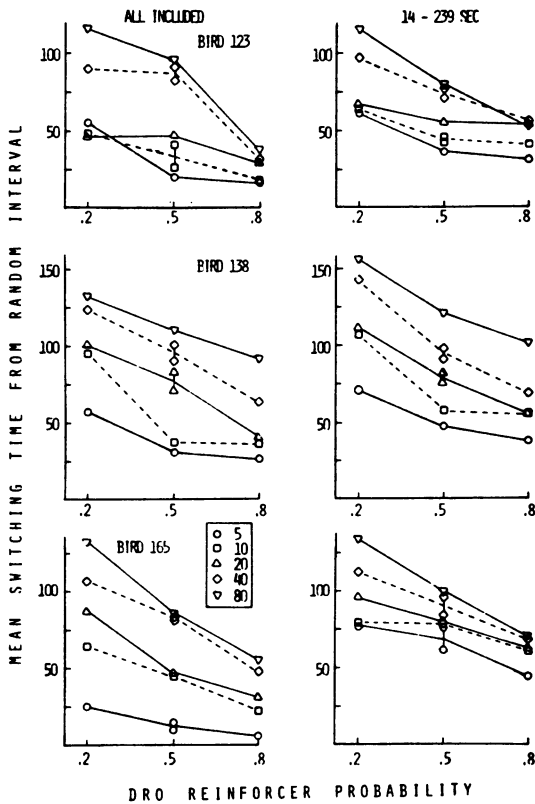
Fig. 5.   Mean switching time from RI for each DRO value and each probability of reinforcer assignment. Left column shows all switches; right column excludes those shorter than 14 s and longer than 239 s.

after food delivery or session onset. A second was that the probability of staying in DRO was unaffected by reinforcer probability, even though the likelihood of staying in RI continued to vary with both DRO value and reinforcer probability. These various data showed that when switching times stemming from immediate choice of the other component and from outliers both were eliminated, DRO switching times depended only on DRO value. All of the analyses converge in showing that the timing distribution was determined only by the duration requirement imposed by the DRO schedule, whereas switching from RI depended on reinforcer probability, the value of the accompanying DRO, and presumably on the RI value as well.

Figure 6 shows the relation between DRO switching time and reinforced pause duration for the timing distributions of each bird's 17
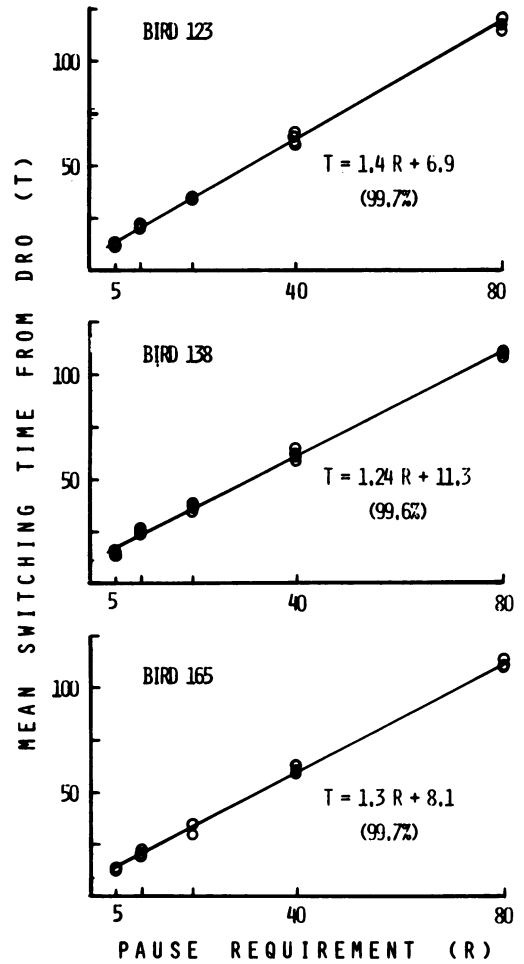

Fig. 6.   Pause timing. The straight lines are the best-fitting linear functions (equations shown). Percent variance accounted for appears in parentheses.

conditions. For all three pigeons, the data were described accurately by linear functions. In no instance did a power or logarithmic function account for as much of the variance as did the linear function. When the data for the individual birds were combined, 99% of the variance was accounted for by the linear function, $T = 1.31\ R + 8.7$. The individual as well as the grouped data show substantial linear overestimation of the reinforced pause.

Figure 7 shows the standard deviation of DRO switching times plotted against mean switching time. Once again, linear fits were always better than power fits. The function, $SD = 0.38\ T + 0.43$, accounted for 93% of the grouped data, indicating that the standard de-
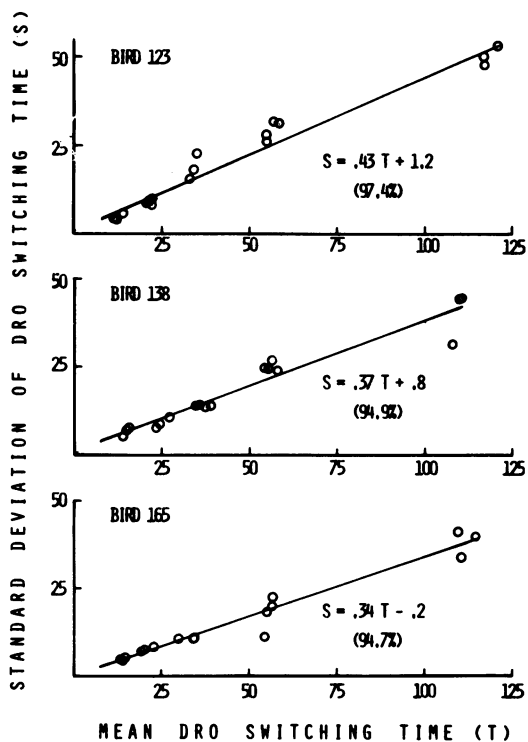
Fig. 7. Standard deviation of switching times for each mean switching time. The straight lines are the best-fitting linear functions (equations shown). Percent variance accounted for appears in parentheses.

viation approximated a constant proportion of the mean, with an average intercept appropriately close to 0. These results show that the coefficient of variation of timed switches was constant at about 0.38 over the range of means from 12 to 123 s, and they imply that Weber's law described sensitivity to pause duration.

DISCUSSION

The data are relevant to two separate issues in the analysis of behavior in temporal differentiation procedures. The first is the relation between emitted and reinforced durations of behavior patterns; the second is the nature of sensitivity to differences in duration. The present procedure was the first to separate timing from responding in temporal differentiation, and so it was able to display both of these characteristics of pure temporal control unconfounded by the need for a response after the interval elapsed. The results showed a linear relation between emitted and reinforced duration, and they supported Weber's law.

Previous studies of temporal differentiation reported a fractional-exponent power relation between the durations emitted by animals and the durations that were reinforced. This has proven to be theoretically uninterpretable, because if scaling obeys a power function having an exponent of any value, the data should display linearity (Gibbon, 1981). Power data (to be more accurate, data described by a power function whose exponent differs from 1.0) can be explained only by a scaling process that could not possibly obtain. As a result, some theorists (e.g., Platt, 1979) have argued that temporal differentiation is not an appropriate technique for studying the relation between physical and psychological duration. However, the present study of temporal differentiation revealed that temporal control was in fact best described by a linear function, and these data, therefore, are theoretically tractable. The precise form of the linear function indicated overestimation of the duration of the standard.

Actually, however, the results may not be as novel as they seem. In many of the previous experiments, the power-function exponents often were close to 1.0. This means that a linear function would have done equally well, and that the results indeed might have shown overestimation if the best-fitting linear function were applied. The use of power functions probably represented the influence of Stevens' (1975) psychophysical power law. When the exponent of a power function is close to 1.0, a linear function with a small intercept probably will fit the data just as well, so emphasis on the power law is dictated by theory rather than by data. Stevens' account of duration-magnitude estimation by humans shows a power function with an exponent of 1.1. These data, too, probably would show a good linear fit and overestimation. In short, the conclusion that response timing involves linear overestimation is not as much at variance with previous data as might be supposed.

The results that most clearly support a power-function account are those of temporal differentiation experiments with pigeons.

These data yield exponents between 0.35 and 0.8, and the fits are better than those provided by linear functions. The present experiment showed that linear overestimation also occurs with pigeons, but that observation of this relation requires the separation of timing from response processes. The present data, then, would seem to resolve the theoretical dilemma provoked by previous reports of fractional exponents in temporal differentiation.

A remaining question is why the linear function relating pause duration to the standard implies overestimation on the order of 30% together with a sizable intercept. Perhaps the data do not signify mismatching of switching time and DRO value at all, but instead indicate that the pigeons paused until elapsed time exceeded the functional duration of the standard by a constant proportion. The particular contingencies of reinforcement certainly would favor such a pattern. It is suggestive in this regard that Church et al. (1976) found that rats responded differentially to comparison and standard stimulus durations when the former exceeded the latter by a factor of 1.32. The correspondence with the present coefficient of 1.31 for the grouped data may be fortuitous, but it may also imply that this same property was being tapped by the present procedure. The proportionality constant may depend on the discrimination of differences together with such specifics of the reinforcement contingencies as whether timing involves only a lower bound (the present case) or has upper bounds that restrict the range of reinforced durations. The substantial intercept perhaps reflects such factors as latency to begin timing, the time required to execute the switching response, and the latency to initiate a switch from a DRO to an RI schedule. If so, the intercept probably is the product of particular experimental arrangements and so would not be invariant. Whether in fact the pigeons would stay in DRO for more than 8 s on average with a DRO 0-s requirement (as the intercept implies) is a question that can be answered only experimentally.

The constancy of DRO switching time across the different probabilities of reinforcer assignment shows that the frequency of rein-

forcer delivery in the other component of the concurrent schedule was relevant to the frequency of immediate choices of components but not to DRO switching time once that alternative was chosen. It suggests that the characteristics of DRO timing would not be affected by using a different RI schedule although choice would be influenced. On the other hand, the data show that RI switching time depended on both the DRO value and probability of reinforcement, and it probably was affected by the parameter value of the RI schedule itself.

The second important feature of the data with respect to temporal control relates to sensitivity (discriminability of various durations). Previous research on temporal differentiation schedules showed that Weber's law did not describe the results; instead, relative sensitivity decreased with longer time intervals. Now, however, when timing was isolated from responding, animals showed the linear relation between standard deviation and mean switching time (constant coefficient of variation) supportive of Weber's law. These data resolve the troublesome issue of the apparently unique absence of constant sensitivity (failure of Weber's law) in temporal differentiation. They show that pure response timing indeed reveals constant sensitivity, and that here, as in temporal discrimination, Weber's law holds.

In the present procedure, switching time from DRO was determined by the temporal parameter of the DRO schedule. The use of switching time to measure temporal control also occurs in differentiation versions of the bisection procedure, but in those cases it is presumed to measure the functional midpoint of two or more durations rather than when any particular interval has elapsed. The basic differences between the current and the bisection procedures are that now the clocks timing the relevant intervals operated only when the pigeon was in the component, the schedules did not prevail in a fixed sequence, and one component had variable times to reinforcer availability. A comprehensive account of behavior in this general paradigm still is not available; the present results show that it can measure control by the duration of one com-

ponent rather than only providing a technique for getting animals to report their subjective midpoint. Integration of the various data that can stem from the paradigm entails explanation of why each earlier experiment yielded data corresponding to a different power-mean exponent and why the present result—either from RI or DRO—cannot be described by any exponent at all. The problem, like that of the mismatch between reinforced and emitted duration in previous studies of differentiation, may relate to misconceptions about the controlling duration in both differentiation and discrimination procedures.

There is an apparently growing belief that temporal differentiation is not an appropriate procedure for studying timing (cf. Platt, 1979). This opinion may stem from the apparent anomolies appearing in the differentiation literature, including the fractional-exponent power function and the failure to support Weber's law. Yet, as the present study implies, appropriate recognition of what is involved in differentiation not only resolves these anomolies, but also leads to data that agree closely with the conclusions of formal analyses and are among the most orderly of any in the timing literature.

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