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THE EFFECTS OF T(D) DURATION AND PLACEMENT ON OPERANT BEHAVIOR

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The Effects of t^D Duration and Placement on Operant Behavior

by

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ABSTRACT

The Effects of t^D Duration and Placement
on Operant Behavior

by

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Delayed reinforcement has always been described as inferior to immediate reinforcement in its effect upon behavior control. Increases in the temporal separation between the response selected for reinforcement and the reinforcer has been shown to be sufficient to produce decreases in the response rate relative to the condition in which the $R\text{-}S^R$ interval is 0.0 seconds. Reports of decreased behavior control can be found in both the trial-by-trial (Hunter, 1913; _et seq._) and the free-operant literature (Skinner, 1938; _et seq._). Yet, manipulation of the independent variable $R\text{-}S^R$ time has direct systematic effects upon the number of reinforcers which could be presented in an absolute period of time (i.e., reinforcer frequency). In spite of this confounding of reinforcer frequency with $R\text{-}S^R$ interval experimenters have reported their behavior effects as related to the $R\text{-}S^R$ temporal separation, and neglected reinforcer frequency as a contributing variable. If the available reinforcer frequency was held constant, $R\text{-}S^R$

temporal separation could be manipulated and any unique effect could be detected.

The t-system parameters t^D and $t^\blacktriangle$ were modified so that reinforcement for the first response in t^D occurred at the end (rather than immediately) of the prevailing T cycle. Under this experimental arrangement, an early t^D sequence in which t^D precedes $t^\blacktriangle$ and a late t^D sequence in which t^D follows $t^\blacktriangle$ within T became possible. The duration of the early and late t^D was systematically decreased from 30.0 seconds (i.e., t^D = T) to 0.1 seconds. t^D placement and duration constituted the independent variables and their manipulation did not simultaneously affect the available reinforcer frequency which was 1/T.

t^D placement and duration may influence the obtained $R-S^R$ interval between the subject's last response and the reinforcer (i.e., the obtained $R-S^R$). In the early t^D placement, the possible range of obtained $R-S^R$ intervals between the subject's last response and the reinforcer could vary from 0.0 seconds through T seconds. Whereas, in the late t^D placement, the possible range of obtained $R-S^R$ intervals was between the limits of 0.0 and t^D seconds.

The results indicated that early and late t^D placements of comparable duration which have different $R-S^R$ temporal separations had similar overall effects upon response rate, reinforcer frequency, responses per reinforcer, obtained response-reinforcer temporal separation, and response distributions. All of these dependent variables were systematically related to t^D duration. Cumulatively, the results in the present experiment replicated those of prior t-system limited hold research. The results, however, did not support the conventional interpretations of diminished control of behavior by delayed reinforcement.

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INTRODUCTION

In immediate reinforcement procedures a required response is followed immediately by a reinforcer. Delayed reinforcement procedures introduce some temporal separation between the required response and the reinforcer. Delayed reinforcement procedures have generally been considered less effective in maintaining behavior control than have immediate reinforcement procedures.[1] One might conclude from the delay literature that the temporal separation of the reinforced response from the reinforcer controls the conditioned behavior. However, all delay procedures have not only manipulated the temporal separation between the reinforced response and the reinforcer, but by doing so have also altered the maximum number of reinforcers which can be delivered within an absolute time period (i.e., reinforcer frequency), a variable which determines response rate (Catania and Reynolds, 1968; Clark, 1958; Findley, 1958; Wilson, 1954). Therefore, the designs in the delay literature to date do not rule out the possibility that the diminished rate of behavior produced when delay is increased may be the result of a concomitant reduction in reinforcer frequency. If different delays of reinforcement were to be programmed without changing reinforcer frequencies, the the validity of delay as a necessary rather than sufficient independent variable might be tested.

Inconsistencies in behavioral effects produced by different delay designs also might be due to the contribution of reinforcer frequency rather than to temporal separation between the response selected for reinforcement and the reinforcer. Several studies have reported similar levels of behavior in both immediate and delayed reinforcement procedures (Ferster and Hammer, 1965; Neuringer, 1969; Warden and Haas, 1927; Watson, 1917). A few studies have found greater resistence to extinction with delayed reinforcement than with immediate reinforcement training (Amsel and Roussel, 1952; Crum, et al., 1951; Fehrer, 1956; Pubols, 1958). Because reinforcer frequency is seldom measured in these delay designs, one cannot easily determine its influence within the delay literature.

Covariation of reinforcement frequency with delay magnitude has occurred in all "delay" trial-by-trial procedures, because by adding a delay in trial-by-trial procedures time is added to the trial and hence reinforcer frequency must decrease. Theoretical systems (Hull, 1932; Spence, 1947) which were based on the delay research postulated maximal behavior control of those behaviors temporally proximal to reinforcement. The goal-gradient hypothesis is the famous example.[2] However, to conclude from the delay research (see Footnote 1) that it is the temporal separation that produces diminished behavior control is possibly premature because reinforcer frequency always had a reciprocal relationship with the temporal separation.

Delay of reinforcement procedures for free-operant responses have also included a response selected for reinforcement, a temporal separation of the reinforced response from the subsequent reinforcer and covariation of reinforcer frequency with delay. These three elements were incorporated into two variations of delay procedures. Further free-operant response occurrences beyond the reinforced operant may either reset the delay interval (Skinner, 1938; Ferster, 1953; Azzi et al., 1964)[3] or have no effect on its duration (Chung, 1965; Dews, 1969; Pierce et al., 1972; Williams, 1976).[4] However, the reported decrease in response rate given an increase in temporal separation in either method could be caused by the decrease in reinforcer frequency which always occurs in reset procedures and may occur in non-reset procedures. A distinction between reset and non-reset delay procedures can be made with respect to the behavior required for reinforcement. In reset procedures a criterion response must be followed by a period which lacks that response. Non-reset procedures do not stipulate a behavior requirement for the specified time interval which follows the criterion response and terminates with the reinforcer. Thus, "delay" in reset procedures is an independent variable, but a dependent variable in non-reset procedures. In the above free-operant experiments, increased reinforcement delay was accompanied by a decrease in response rate. The results from free operant research not only confirmed and extended the results of earlier trial-by-trial procedures but also have been regarded as showing loss of behavior control due to delay because the operant rates with these delay procedures approached zero. Low response rates obtained in reset and non-reset procedures were interpreted as diminished control, and the loss of control was attributed to increased delay rather than to decreased reinforcer frequency.

In the trial-by-trial and free-operant research reviewed thus far, the generalized conclusion that, "the performance of an instrumental response is poorer the longer the time of delay of reward" (Logan, 1969),[5] remains open to question.[6] This type of summary statement assumes that rate is a direct index of behavior strength (Hull, 1943; Skinner, 1938) and fails to acknowledge reinforcer frequency as a possible determinant of the decreased response rate despite the documented direct relation of reinforcer frequency with response rate. The relation of the obtained behavior with reinforcer frequency cannot be assessed since most of the pertinent delay literature does not disclose the reinforcer frequency.[7] An attempt to regenerate the reinforcement frequencies from either the independent variables or the reported magnitude of the dependent variables cannot be executed.

In those few delay studies[8] in which some behavior was maintained, some reinforcer frequency greater than zero must have also been sustained (Dews, 1960; Ferster, 1953; Perkins, 1947). If both the response and reinforcer distributions are recorded, then an accurate description of the relation or a correlation between these variables can be made. For example, it would be difficult to support the contention that the low rates reported in differential reinforcement of low rate schedules (i.e., DRL) indicate a lack of control especially when the obtained reinforcer frequencies closely approximate the upper limit imposed by the prevailing independent variables (Farmer and Schoenfeld, 1964). In delay research the low rates may not be a reflection of decreased behavior control. If the obtained reinforcer frequency were recorded, then one might find that it approximated the programmed reinforcer frequency. In that case the low response rate could not indicate a lack of control by delayed reinforcement.

In the trial-by-trial and free-operant delay studies mentioned above, an increase in the temporal separation was always confounded by a programmed decrease in the reinforcer frequency; and, behaviorally, an obtained decrement in the rate of conditioned behavior was always perceived as a loss of behavior control by delayed reinforcement. Disruptions in behavior control on delayed reinforcement procedures are consistent with results obtained in immediate reinforcement procedures in which subjects demonstrated transient and variable response rates when continuous reinforcement was changed to some partial reinforcement schedule (Skinner, 1938; Ferster and Skinner, 1957; Gott and Weiss, 1972). Furthermore, experimenters have usually terminated delayed reinforcement procedures given diminished occurrences of conditioned behavior because such a behavior change has been traditionally interpreted as a loss of behavior control by delayed reinforcement (i.e., similar to that generated by extinction). Consequently, the alternative hypothesis that the low rate of conditioned behavior will increase or will be maintained has never been advanced possibly because experiments were prematurely terminated.

Response rate is, in general, directly related to reinforcer frequency in fixed interval schedules (Wilson, 1954; Skinner, 1938), as well as variable interval schedules

(Findley, 1958; Clark, 1958; Catania and Reynolds, 1968) and, has been potentially confounded with R-S^R temporal separation. Hence, one can state from the immediate reinforcement literature that increasing the temporal separation in delay procedures must produce a decrease in response rate (or other measures of control) because reinforcer frequency has been decreased.

In contrast to the relation between response rate and reinforcer frequency in the delayed and immediate reinforcement literature, response rate and reinforcer frequency have shown an inverse relation in certain limited hold t-system research (Schoenfeld and Cole, 1972). A repeating time cycle of defined duration, T, was divided into t^D and $t^\blacktriangle$. The first response in t^D was reinforced immediately, whereas extinction prevailed in $t^\blacktriangle$. When t^D duration was manipulated for a T of fixed duration, T-cycle length set an upper limit on the reinforcer frequency and reinforcer frequency could decrease only when the subject fails to place responses in successive t^Ds. The consistent finding across all t-system studies manipulating t^D with a fixed T was a change from low to high response rates which was accompanied by a decreased the maximum reinforcer frequency (Schoenfeld, Cumming and Hearst, 1956; Schoenfeld and Cumming, 1957; Hearst, 1958; Clark, 1959). On the other hand, when the reinforcer frequency was manipulated by varying T, an increase in response rate was reported (Clark, 1959).

An experimental design is needed which would quantify and separate the effects of reinforcement delay from reinforcer frequency. This would necessitate the following design elements. First, the procedure must include the three experimental events which are common to all delay procedures: 1) a method which selects a response for reinforcement, 2) a temporal separation between the response and the reinforcer, and 3) a subsequent reinforcer. Second, the temporal separation between the response selected for reinforcement and the reinforcer should be systematically varied without a corresponding covariation in reinforcer frequency.

To meet all these criteria, the conventional organization of the t-system parameters was modified in the present experiment. The restriction that the first response in t^D was immediately reinforced was eliminated. Reinforcement for that first response in t^D occurred at the end of the prevailing T cycle. Thus, if reinforcement occurred, it was not only at the same temporal position in all T cycles but also the maximum reinforcer frequency was 1/T (i.e., one reinforcer per unit of time as defined by T) and was independent of t^D manipulations unless t^D = 0, given that the subject places one response in each t^D. T cycle length was held constant as t^D duration was decreased. Since the last response in a T cycle may occur with any temporal separation between 0.0 and T from reinforcement, this type of reinforcement schedule was named "Variable Delay" (Schoenfeld, Cole, Lang and Mankoff, 1973) and the obtained last response-reinforcer temporal separation (i.e., obtained delay) was a dependent variable that had to be measured separately from other dependent variables. Because the reinforcer occurs at the end of the prevailing T cycle, different relations between the required response in t^D and the reinforcer are obtained depending upon the t^D-$t^\blacktriangle$ succession within T cycle. If t^D precedes $t^\blacktriangle$ (i.e., the early t^D placement), decreases in t^D increase the minimum duration between the reinforced response and the reinforcer towards the limit of T seconds. In this operation the minimum temporal separation between the reinforced response and the reinforcer is equal to $t^\blacktriangle$. However, the obtained delay between the subject's last response and the reinforcer (i.e., the obtained R-S^R) could vary from 0.0 seconds to T seconds. This operation is a replication of the basic delay paradigm with a "limited-hold" and without the reset consequence for further responses.

If t^D follows $t^{\blacktriangle}$ (i.e., the late t^D placement), decreases in t^D decrease the maximum response-reinforcer temporal separation between the reinforced response and the reinforcer towards a limit of zero seconds. In this operation the maximum temporal separation between the reinforced response and the reinforcer is equal to t^D. As late t^D duration decreases, the probability increases that the reinforced response will also be the subject's last response. This second operation has no precedent in the literature; nevertheless, one may see that as t^D is decreased, immediate reinforcement (0.0 sec delay) is approached.

Systematic manipulation of the time between the required response and the reinforcer is common to both t^D placements without affecting the defined upper limit for the reinforcement frequency. Hypothetically, the subject's response rate may decrease to 1/T and the obtained reinforcement frequency will be maintained provided that the subject places one response in each successive t^D. Even with high response rates, it is possible for the obtained reinforcement frequency to decrease either when t^D approaches the subject's inter-response time or when no response occurs in t^D. Hearst (1958) and Schoenfeld, Cumming and Hearst (1956) demonstrated that short t^Ds can maintain response rate even with decreases in the frequency of immediate reinforcement. In the reset and non-reset delay procedures the reinforcement frequency was jointly determined first by the experimenter's manipulation of the response-reinforcer temporal separation and second, by the subject's response distribution. In the present design, the independent variable manipulation of t^D placement and duration does not confound response-reinforcer temporal separation with the available reinforcer frequency, but the empirically derived reinforcer distribution is obviously dependent upon the subject's response distribution.

The early and late t^D placements are independent variable manipulations of the response-reinforcer temporal separation. The manipulation of the temporal separation of the reinforced response from the reinforcer should produce decreases in behavior control, as has been reported in the delay literature. In the present experiment one would, therefore, predict that the early and late t^D placements would demonstrate different effects at any single reinforcer frequency as defined by T because those placements program different temporal separations between the response selected for reinforcement and the reinforcer. Delay effects would be indicated by one or more of the following trends in response rate: 1) early t^D placements to have lower response rates relative to late t^D placements because early t^D placements have a greater temporal separation from reinforcement than do late placements; 2) as t^D duration is decreased in the early placement the mean R-S^R temporal separation increases, thus, response rate should decrease; 3) in the late t^D placement, response rate should increase because the mean R-S^R temporal separation decreases as t^D duration is decreased. If reinforcement frequency also decreases because of missed t^Ds as t^D duration decreases, then further reductions in response rate would be predicted from studies by Skinner (1938), Findley (1958), Wilson (1954), Clark (1958), Reynolds (1961), Reynolds and Catania (1968), but the opposite prediction would be made from results reported by Schoenfeld, Cumming and Hearst (1956). If equivalent effects are obtained from both t^D placements, as one might expect from the "limited-hold" t-system literature (Schoenfeld and Cole, 1972), then the changes displayed by the dependent variables may be attributed to t^D duration. In that case, response rate would be inversely related to t^D duration regardless of t^D placement. Thus, the duration of the early and late t^D placements was systematically manipulated without changing the constant upper limit for the reinforcement frequency. The purpose of the present experiment was to provide a schedule framework within which one may evaluate the effects of response-reinforcer temporal separation independently of the effects of changes in reinforcer frequency.

METHOD

Subjects

The subjects were eight female experimentally naive White Carneau pigeons approximately four years old at the beginning of the experiment. Water and grit were continuously available throughout the experiment in the subjects' home cage. For 30 days the subjects were weighed and given free-access to food. Mean free-feeding weights were calculated, and then each pigeon was reduced to 80% of its free-feeding weight. For the remainder of the experiment, subjects were weighed before and after experimental sessions and were fed the difference between their post-session weight and their 80% weight after each session.

Apparatus

One standard Lehigh Valley pigeon chamber (BRS/LVE Panel Model 141-16) was used in this experiment. The house light (#1829 miniature lamp) and key light were on during experimental sessions and off at all other times. Although the chamber had three translucent plastic pecking keys, only the center key was used. A static mass of 16-g was required to operate the switch behind the key. The experimental session and the reinforcement schedules were programmed by BRS digital logic devices. Data were recorded by Sodeco impulse and print-out counters.

Procedure

Five days after the subjects reached 80% of their free-feeding weight, the operant level of key pecking was measured in two 30 minute sessions. In the third experimental session, hopper approach and key pecking were shaped. For the remainder of the experiment, reinforcement was 2.75 sec of free access to mixed grain (popcorn, Canadian peas, Austrian peas, wheat milo and vetch). Subjects were allowed 100 responses under a regular reinforcement schedule in the third session.

In all subsequent experimental sessions, food presentations were defined with modified t-system schedule variables (Schoenfeld & Cole, 1972). A repeating time cycle, T, was divided into two alternating time periods, t^D and $t^{\blacktriangle}$. t^D was that portion of T in which the first response was eligible for reinforcement. Responses in $t^{\blacktriangle}$ had no scheduled consequence. Variable delay (VD) schedules were used in which the first response in t^D was reinforced at the end of the prevailing T cycle. In the first session following regular reinforcement, subjects were exposed to a VD 5-sec reinforcement schedule with $T=t^D=5$-sec for 60 reinforcer presentations. T and t^D were increased by 5-sec durations on each subsequent experimental day until $T=t^D=30$-sec was obtained. Subjects were exposed to VD 30-sec for 30 sessions, the last ten of which were analyzed and presented in results.

Subjects were matched in four pairs according to overall rate and visual examination of the form of the temporal response distribution through the T cycle obtained under VD 30-sec. One bird from each pair was assigned to either an early t^D or late t^D condition. In the early t^D conditions, t^D preceded $t^\blacktriangle$ in the T cycle. As t^D decreased, the minimum "delay" between the reinforced response and the reinforcer was equal to $t^\blacktriangle$ and approached T as the maximum delay. In the late t^D condition, t^D followed $t^\blacktriangle$ in the T cycle. As t^D decreased, the minimum possible delay between the reinforced response and the reinforcer approached 0.0-sec ("immediate" reinforcement) and the maximum delay was t^D. The early t^D durations were 30.0, 25.0, 23.0, 20.0, 15.0, 10.0, 5.0, 2.5, 1.5, 0.5, 0.2, and 0.1 seconds. The late t^D durations were 30.0, 20.0, 15.0, 10.0, 5.0, 2.5, 1.5, 0.5, 0.2, and 0.1 seconds. T was maintained at 30-sec throughout the experiment.

Subjects were exposed to each t^D (with the exception of the initial 30 second t^D) for a block of 15 experimental sessions. The last ten sessions on each t^D constituted the data presented in the results. Sodeco impulse counters accumulated total responses, total post-reinforcement-pause, responses in t^D, reinforcers presented and the temporal distribution of responses in 15 successive 2-sec bins. Sodeco print-out counters recorded each post-reinforcement-pause and each elapsed duration between the last response prior to reinforcement and reinforcer presentation (i.e., the obtained response-reinforcer interval).

After the subject had been placed in the experimental chamber, the programming equipment was started by E and, simultaneously, the house and key lights were illuminated. All schedule variables were in force at the occurrence of the first response which started the session and the prevailing independent variable determined its consequence. The first key peck also initiated the session counter which terminated the session when 60 T cycles had been accumulated.

RESULTS

The early and late t^D placements manipulated the possible range of temporal separations between the response selected for reinforcement and the reinforcer. Generally, the effects produced by the early t^D placement were equivalent to those produced by the late t^D placement. The overall direction of change on the dependent variables was determined by t^D duration regardless of its location within the T cycle.

Percent baseline response rate divides the average response rate at a given t^D by the average response rate

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Insert Figures 1-8 about here.

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at baseline (t^D = 30 seconds). In both early (Figures 1-4) and late (Figures 5-8) t^D placements, as the duration of t^D decreased percent baseline response rate increased. All the subjects (save 455L) demonstrated positive growth functions in percent baseline response rate between t^D = 2.5 seconds and t^D = 0.2 seconds. Because different response-reinforcer temporal separations (i.e., the early and late t^D placement) produced similar effects on response rate, one must attribute this congruence to t^D duration which was systematically manipulated across the same range of t^D durations in both placements. There was no indication that long R-S^R temporal separations (i.e., the early t^D placement) produced lesser control than short R-S^R temporal separations (i.e., the late t^D placement). Finally, a two-way analysis of variance demonstrated a significant main effect on absolute response rate by t^D duration ($F = 23.83$; $df = 9,54$; $p<0.0001$) but not by t^D placement ($F = 2.25$; $df = 1,6$; $p = 0.18$) nor the t^D placement-duration interaction ($F = 1.3$; $df = 9,54$; $p = 0.26$). This statistical analysis is consistent with the present conclusion that t^D duration was the only major determinant of reliable differential effects.

Figure 9 shows the mean percent baseline response rate for the four subjects in the early t^D (open circles) and late t^D (filled circles) placements. The average number of responses per session for the early (open circles) and for the late (filled circles) t^D placements are presented in Figure 10. Comparison of Figures 9 and

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Insert Figures 9-10 about here.

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10 reveals that the percent baseline response rate transformation and the total responses per session both demonstrate the same function shapes and inverse relation with t^D duration.

Decreases in t^D duration decreased the reinforcer frequency as measured by the number of reinforcers received per session. By comparing Figures 1-8 against Figures 11-18, one can see that the response rate increased as reinforcer frequency decreased as a result of the

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Insert Figures 11-18 about here.

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subject's failure to sample each t^D. At all t^D durations and placements, given one response per t^D, reinforcer frequency would have remained at 1/T. In fact, subjects maintained 90% of their baseline reinforcer frequency for the first four t^D durations and two subjects (455L and 156L) maintained this performance until $t^D = 0.5$ seconds. The shape of the reinforcer frequency functions displayed differential effects between the t^D placements. This differential effect can be clearly seen in Figure 19 by the separation between the mean number of reinforcers

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Insert Figure 19 about here.

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per session functions for the early and late t^D placements. Decreases in the duration of the early t^D produced a gradually declining linear function, whereas decreases in the duration of the late t^D produced a positively accelerated function. Even though the independent variables were chosen so that the programmed reinforcer frequency could remain constant, the actual reinforcer frequency decreased. Given the increase in percent baseline response rate and the decrease in reinforcement frequency, the positive growth curves for responses per reinforcer (R/S^R) with decreased t^D duration were predictable.

Insert Figures 20-27 about here.

Figure 28 revealed minimal separation between the mean R/S^R function for the early and late t^D placements.

Insert Figure 28 about here.

There was a differential effect of early and late t^D placement in that the average R/S^R value at the shortest late t^D was 216.87 R/S^R, in contrast to, 120.53 R/S^R for the shortest early t^D (see Figure 28). Control of R/S^R was demonstrated by both t^D placements, and the differential in the final values of these functions cannot support a comparison of control versus no control as encountered in the delayed reinforcement literature. Table 1 shows the correlation of R/S^R, reinforcer frequency and response per session for each subject across the t^D durations.

The average obtained $R\text{-}S^R$ interval decreased as t^D decreased, as shown in Figures 29-36. These figures show the effect of the maximum programmed $R\text{-}S^R$ temporal separation for the early t^D and of the minimum $R\text{-}S^R$ temporal separation for the late t^D between the response selected for reinforcement and the reinforcer on the obtained $R\text{-}S^R$ delay. The open symbols were significantly

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Insert Figures 29-36 about here.

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different ($p<0.05$) from the mean obtained $R\text{-}S^R$ time at $t^D = 0.1$ second. This t-test comparison of each individual sample against a chosen value was necessary because decreased variability around the mean obtained $R\text{-}S^R$ as t^D decreased precluded an analysis of variance. The present statistical analysis showed that one finds differences in the obtained $R\text{-}S^R$ distribution when the obtained $R\text{-}S^R$ for each t^D is compared against the final obtained $R\text{-}S^R$ at $t^D = 0.1$ second. A Kruskal-Wallis analysis of the mean obtained $R\text{-}S^R$ times within the early t^D placement ($H=20.18$; $df= 11$; $p=0.043$) and the late t^D placement

($H=31.27$; $df=9$; $p<0.001$) were both significant.

The early and late t^D placements allowed for the possible development of different magnitude of obtained R-S^R intervals. In the early t^D group an obtained R-S^R time could be any value between 0.0 second and T seconds for all t^D durations. In the late t^D placement the obtained R-S^R interval range was limited between 0.0 and t^D seconds. The overall direction of change as t^D duration decreased was towards a 0.0 second obtained R-S^R in both groups. The mean obtained R-S^R is plotted in Figure 37 for both t^D placements. The visual difference between the shape

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Insert Figure 37 about here.

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of the early and late t^D mean obtained R-S^R functions was not reflected in the other dependent variables, especially not in rate (see Figures 1-10). Obtained R-S^R was, however, negatively correlated with response rate with the exception of subjects 152E and 161L (see Table 1).

The effects of decreased t^D duration on the cumulative percent response distribution and the obtained R-S^R frequency distribution can be seen in Figures 38-45. There were no obvious visual differences for these dependent variables when one compares the early t^D placement birds (Figs. 38-41) against the late t^D placement birds (Figs. 42-45).

In Figures 38-45 "bins" refers to the fifteen temporally

Insert Figures 38-45 about here.

successive two-second classes comprising T into which responses and obtained $R-S^R$ were distributed. The cumulative percent response distribution was computed by dividing the average number of responses emitted up to a bin in T by the average total number of responses. The gradual increase in this variable is due to its cumulative percentage derivation and not to the gradual increase in response rate which is known as deviations of the third order (Skinner, 1938; Cumming and Schoenfeld, 1958). The obtained $R-S^R$ percent frequency distribution divides the observed response-reinforcer frequency within a specified $R-S^R$ bin by the total number of $R-S^R$ occurrences at a t^D duration. The cumulative percent response distribution demonstrated curvature at above t^D = 5.0 seconds which changed to a linear trend as both the early and late t^D further decreased in duration. The effect of shortening t^D on percent obtained 0.0-2.0 second $R-S^R$ of the total number of obtained $R-S^R$s is highlighted in Figures 46-54. The overall direction of

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Insert Figures 46-54 about here.

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change for both the cumulative percent response distribution and the obtained $R-S^R$ frequency distribution were comparable in the early and late t^D placements. One may conclude that t^D duration was the determining variable for both these measures because the same trends developed in both t^D placements as t^D duration decreased. Comparison of Figures 1-4 with 46-49 for the early t^D group reveals that each subject demonstrated a similar curve shape on both of these variables as a function of t^D duration.

Figures 55a and 55b plot mean responses per session as a function of mean obtained reinforcers per session. Figures 56a and 56b plot mean responses per session as a function of mean obtained $R-S^R$. Figures 57a and 57b plot mean obtained reinforcer per session as a function of mean obtained $R-S^R$. The "a" and "b" refer to the early and late t^D placements, respectively. These figures are replots of the dependent variables as functions of each other. The graphs were drawn to facilitate the comparison of findings in the subsequent discussion. The order of

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Insert Figures 55-57 about here.

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the data points, in some cases, may not correspond to the order generated by the sequence of t^D reductions as was true in Figures 1-54.

DISCUSSION

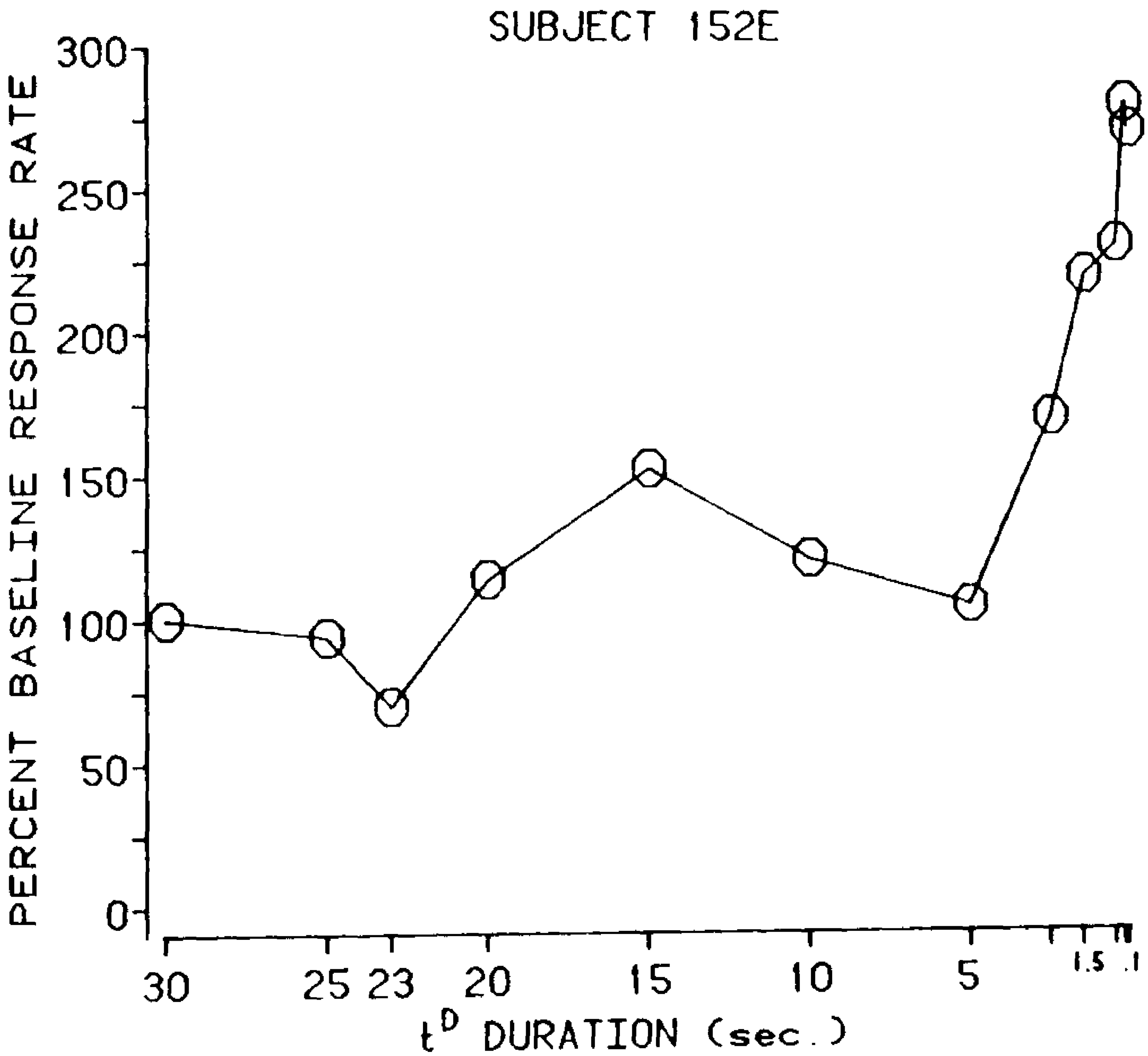
Delayed reinforcement procedures have manipulated the temporal separation between the reinforced response and the reinforcer and have attributed all behavior effects to this independent variable even though reinforcement frequency was confounded with the manipulation of delay (see Footnotes 1, 3 and 4). The level of behavior which was maintained by delayed reinforcement was always compared against that level maintained by immediate reinforcement or, at the other end of the continuum, extinction. The delay literature has generally reported that an increase in the temporal separation between the response selected for reinforcement and the reinforcer produced a decrease in response rate which was accompanied by a decreased reinforcer frequency and an increased obtained delay between the last response and the reinforcer (Sizemore and Lattal, 1978; Williams, 1976).

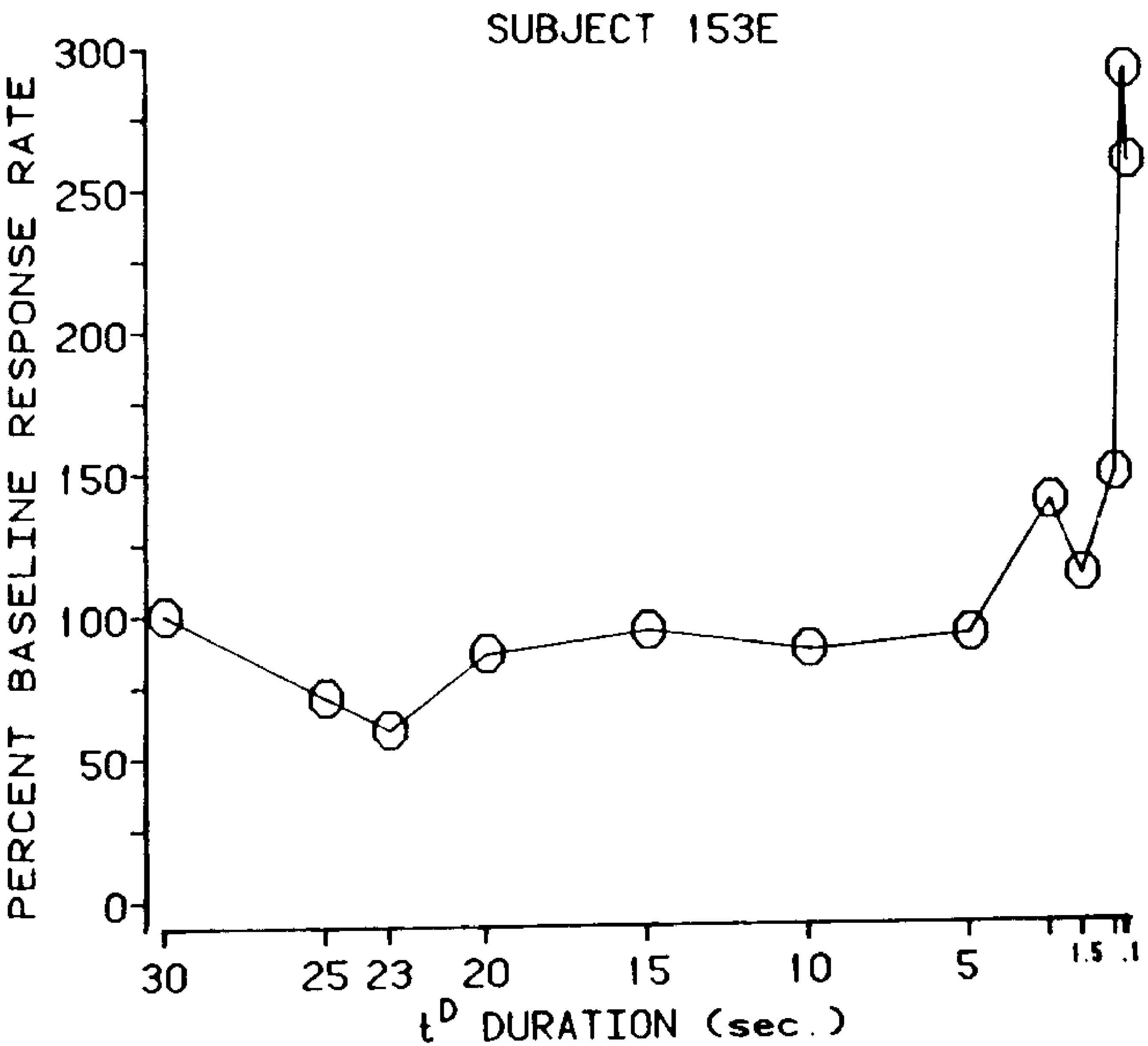
The independent variables in the present design provided for ranges of response-reinforcer temporal separations to occur which did not necessarily influence the availability of the programmed reinforcers. The present free-operant experiment had no reset requirement and differed from previous delay research in that it defined a period of time in which the first response was required for reinforcement to be presented at the end of the prevailing T-cycle. This procedure offered two independent variables for manipulation of R-S^R temporal separation -- i.e., t^D placement and duration. These independent variables were chosen because differential effects on the obtained delay were expected as a function of t^D duration and placement.

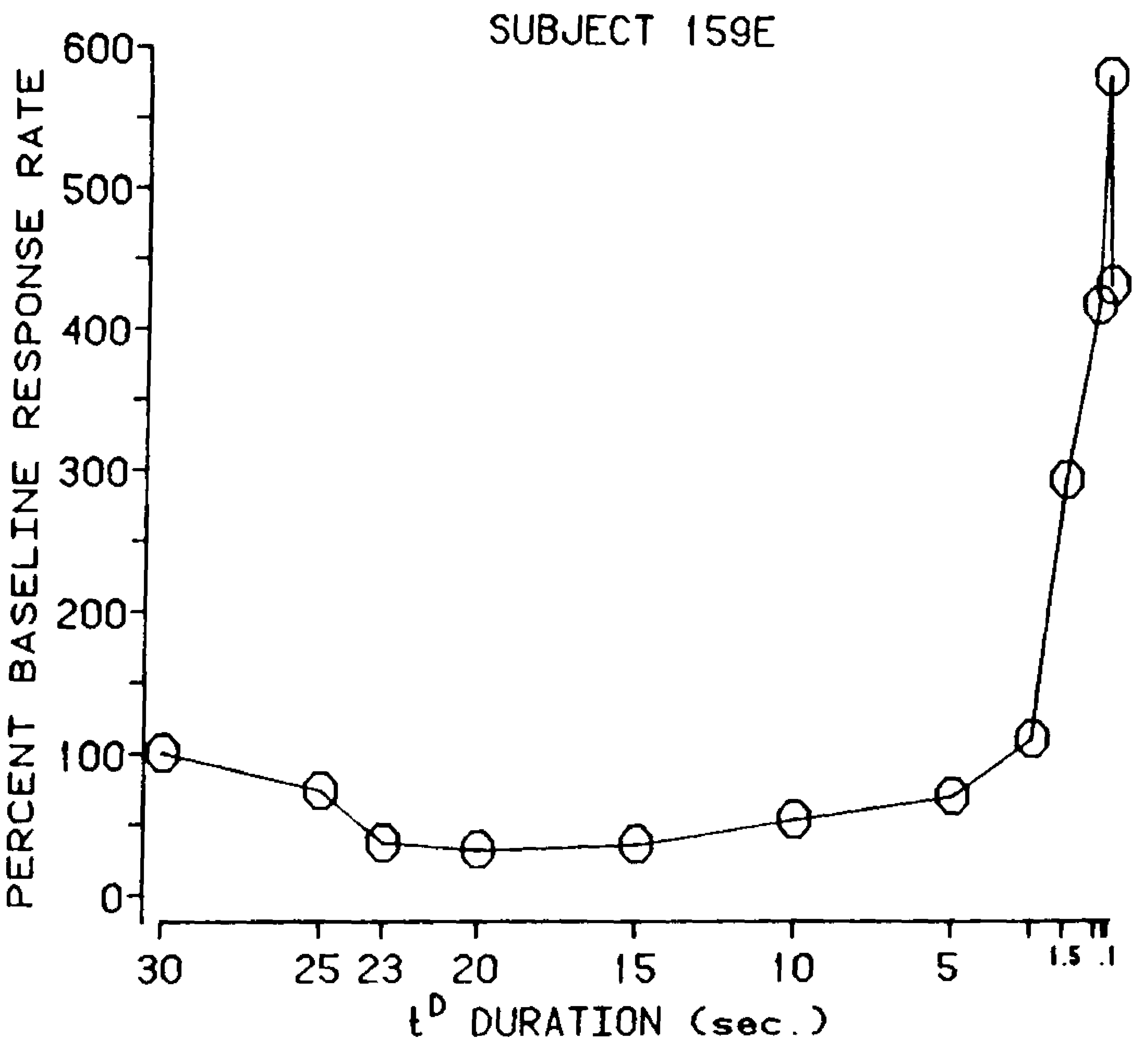
If R-S^R temporal separation is a potent control variable (see Footnotes 1, 3 and 4) and has a reciprocal relation with response rate, as one is led to expect from the delay literature, then one would expect the proximity of t^D placement to the reinforcer and decreases in early t^D duration to be directly related to response rate. On the other hand, the decrease in late t^D duration approaches immediate reinforcement as a limit. Using immediate reinforcement for the first response in t^D, Hearst (1958), Clark (1959), Cumming and Schoenfeld (1957) have shown that as t^D duration decreased response rate increased and reinforcer frequency decreased. In the present experiment, response rate was inversely related to t^D duration regardless of its placement. The shapes of the response rate, responses per reinforcer and reinforcer frequency functions for the early and late t^D placements were similar to each other and to those previously reported in the t-system literature involving t^D manipulations with immediate reinforcement. Any differences between the data functions for the early and late t^D placements did not influence the overall direction and progress of those functions.

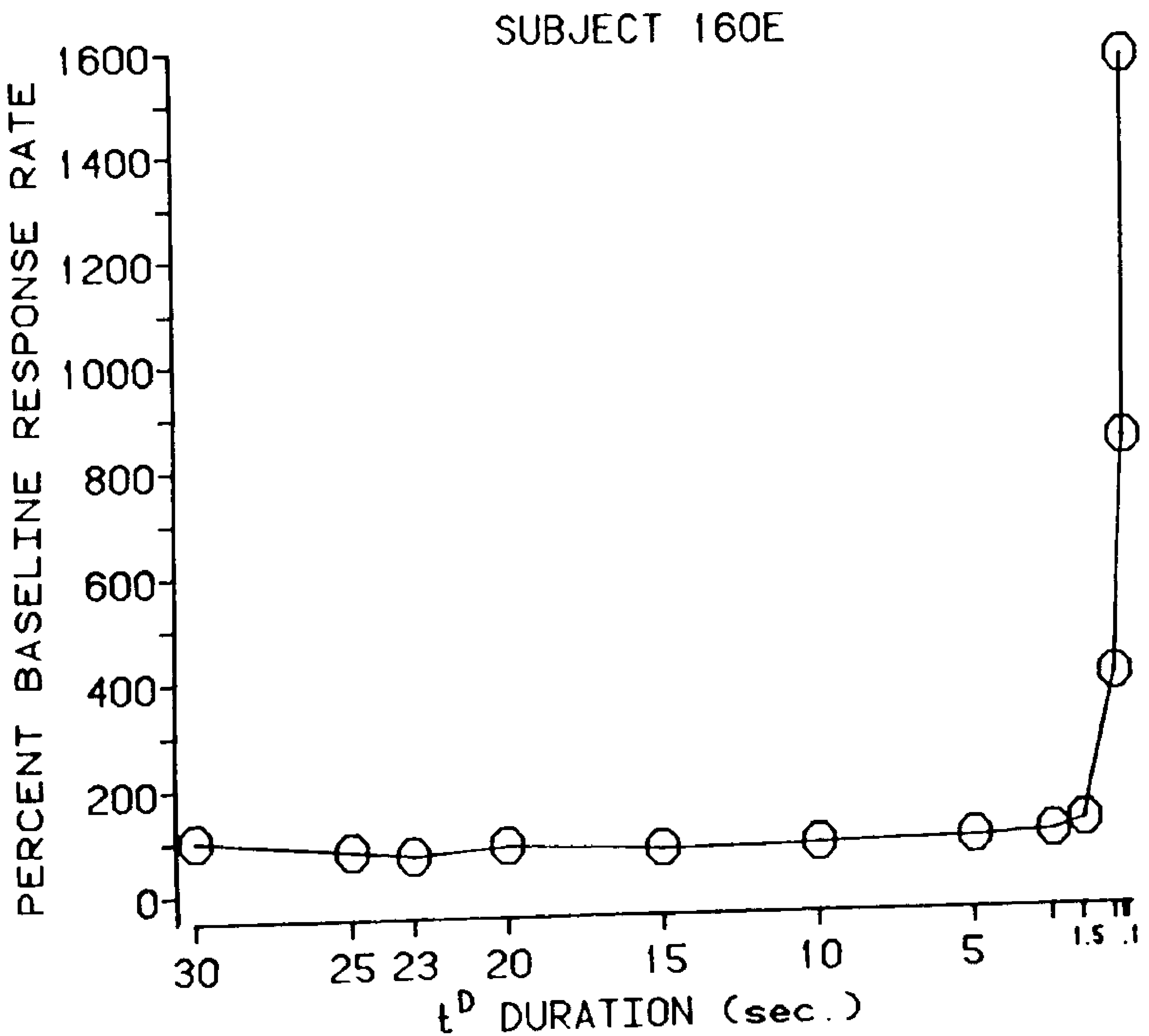
Figure 55 replicated the inverse relation between response rate and reinforcer frequency as reported in the prior t-system research which manipulated t^D. Figure 56 replicated the inverse relation of response rate with obtained $R\text{-}S^R$ as reported in the delay literature (Williams, 1976; Sizemore & Lattal, 1978). However, Figure 57 demonstrated that the shortest obtained $R\text{-}S^R$ values occurred with the lowest reinforcer frequencies and the longest $R\text{-}S^R$ values occurred with the highest reinforcer frequencies. This finding is in direct contrast with the delay literature which had consistently reported the longest $R\text{-}S^R$ intervals at the lowest reinforcer frequencies. In the present schedule context where temporal separations between the reinforced response and the reinforcer were manipulated, and where delays between the last response and the reinforcer were obtained, these delays did not alter the development of behavioral effects of decreasing t^D found with immediate reinforcement procedures. The findings reported herein, which could not be predicted from the delay literature, may be placed in the same behavioral domain with typical delayed reinforcement findings only when the schedule variables which define that dcmain have been more fully investigated.

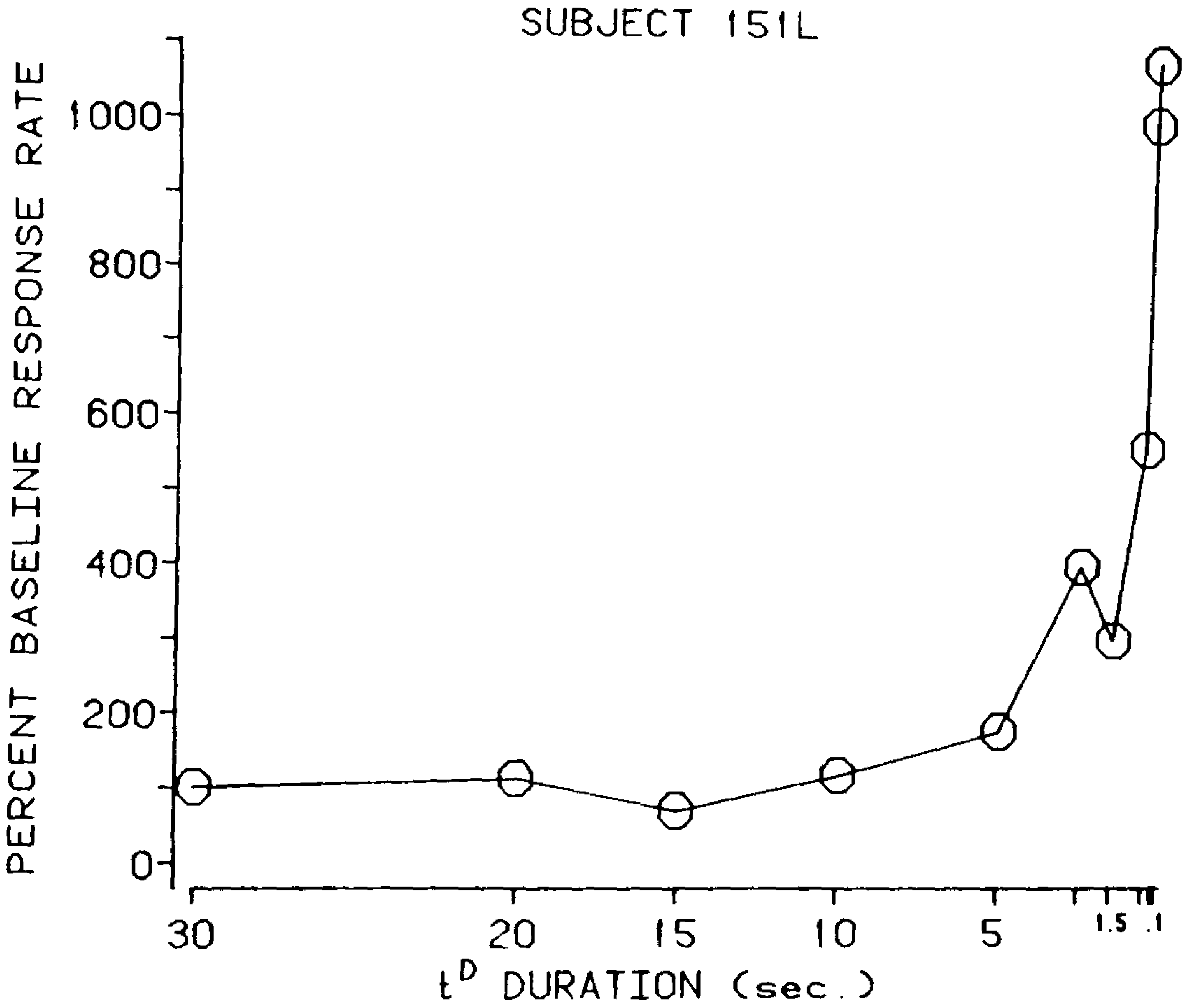
Figures 1-8. Percent of baseline response rate as a function of t^D duration for each subject. The values for the plotted points are presented in Table 2 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

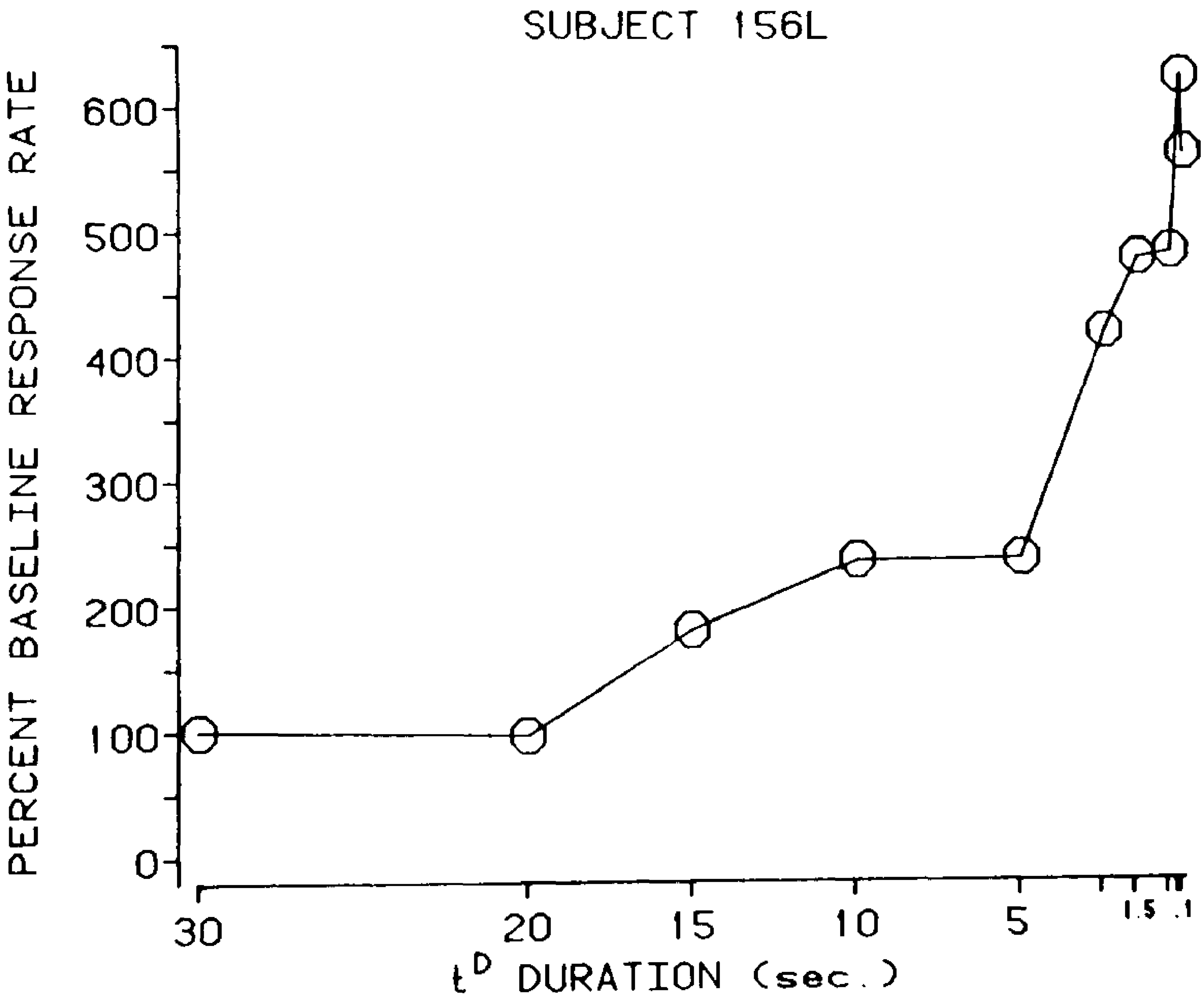

SUBJECT 152E
PERCENT BASELINE RESPONSE RATE
300
250
200
150
100
50
0
30
25 23
20
15
10
5
1.5 .1
t^D DURATION (sec.)

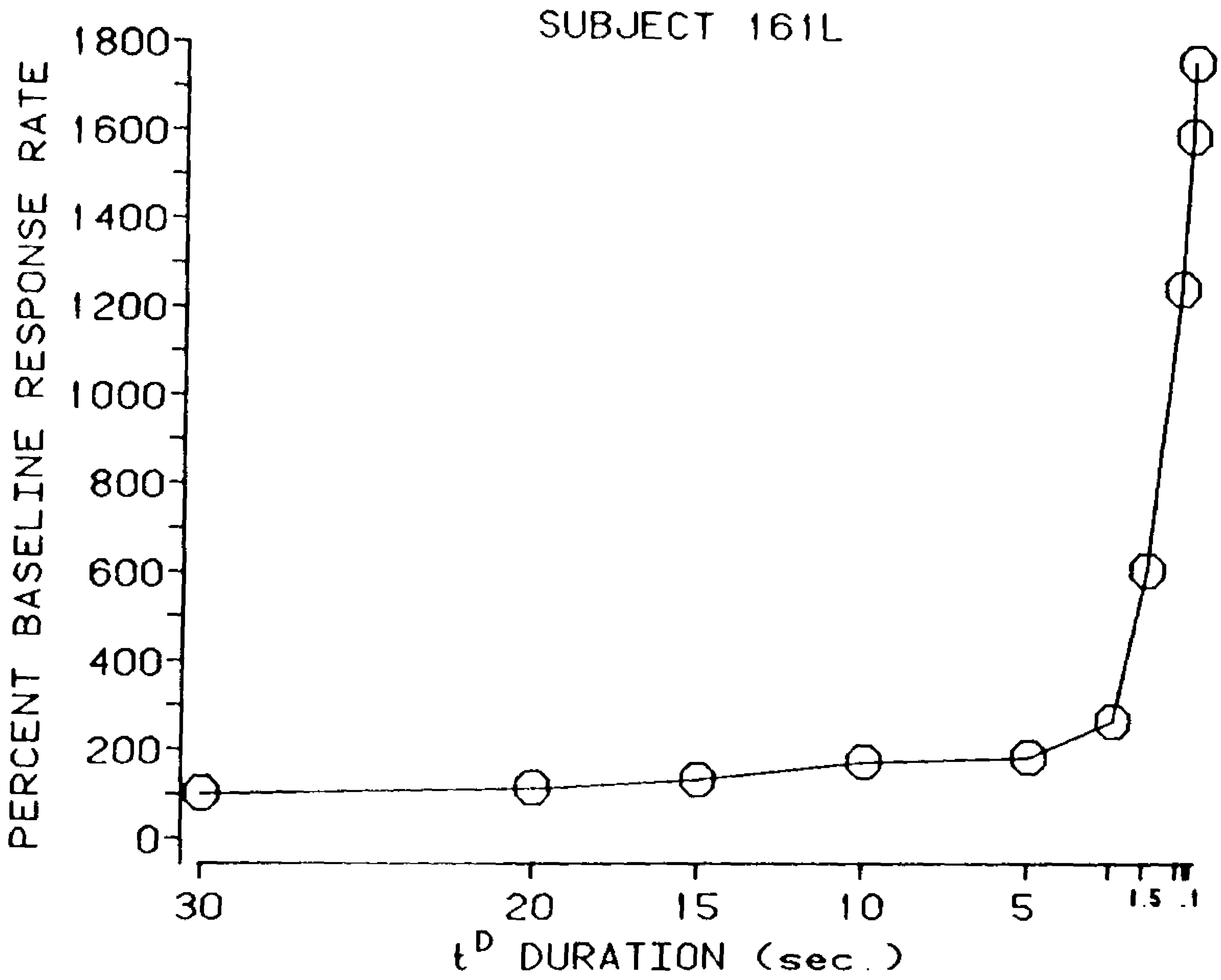

SUBJECT 153E
PERCENT BASELINE RESPONSE RATE
300
250
200
150
100
50
0
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 159E
PERCENT BASELINE RESPONSE RATE
0
100
200
300
400
500
600
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 160E
PERCENT BASELINE RESPONSE RATE
0
200
400
600
800
1000
1200
1400
1600
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 151L
PERCENT BASELINE RESPONSE RATE
0
200
400
600
800
1000
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 156L
PERCENT BASELINE RESPONSE RATE
0
100
200
300
400
500
600
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 161L
PERCENT BASELINE RESPONSE RATE
1800
1600
1400
1200
1000
800
600
400
200
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

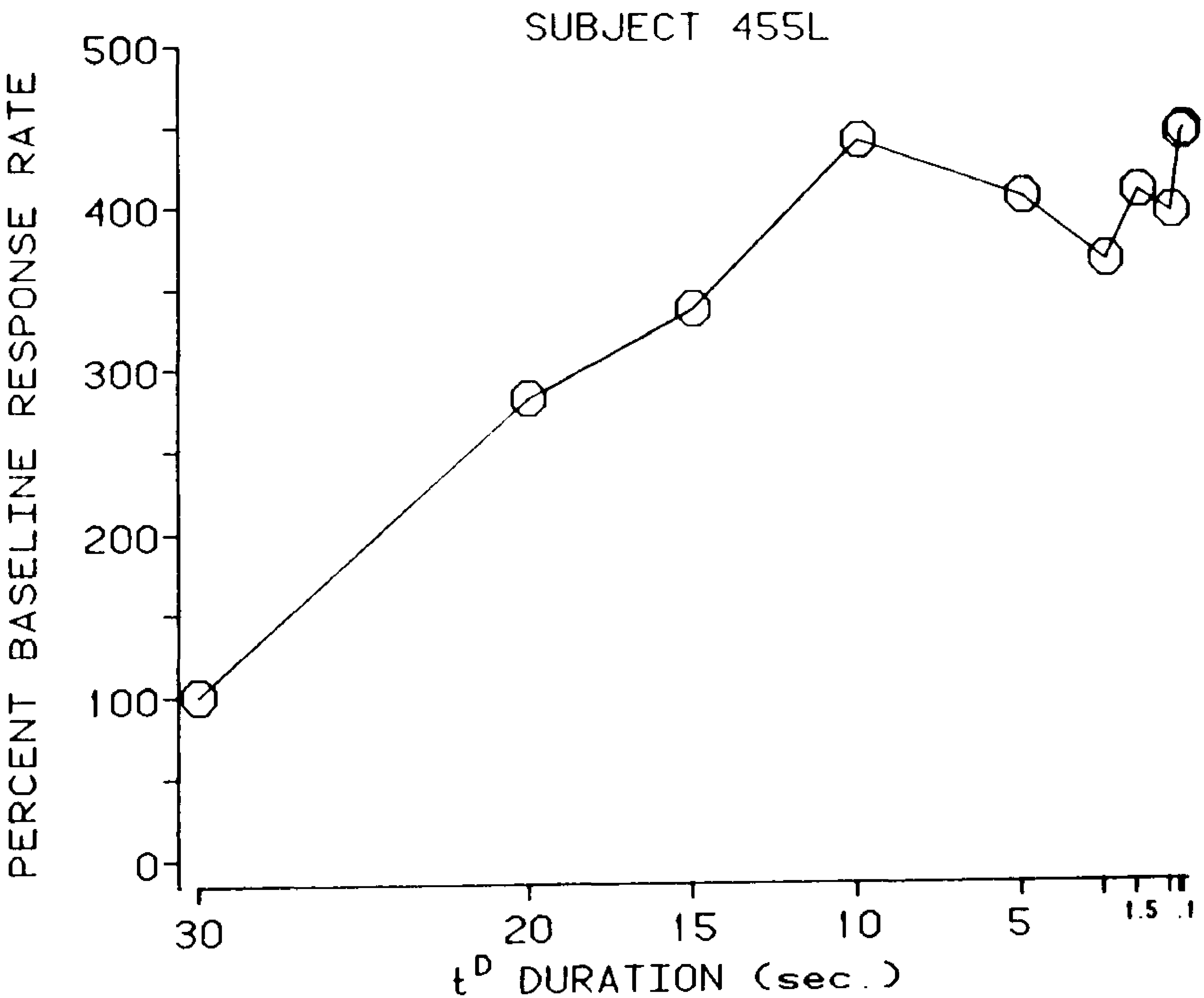

SUBJECT 455L
PERCENT BASELINE RESPONSE RATE
500
400
300
200
100
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

Figure 9. Mean percent of baseline response rate as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 2 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

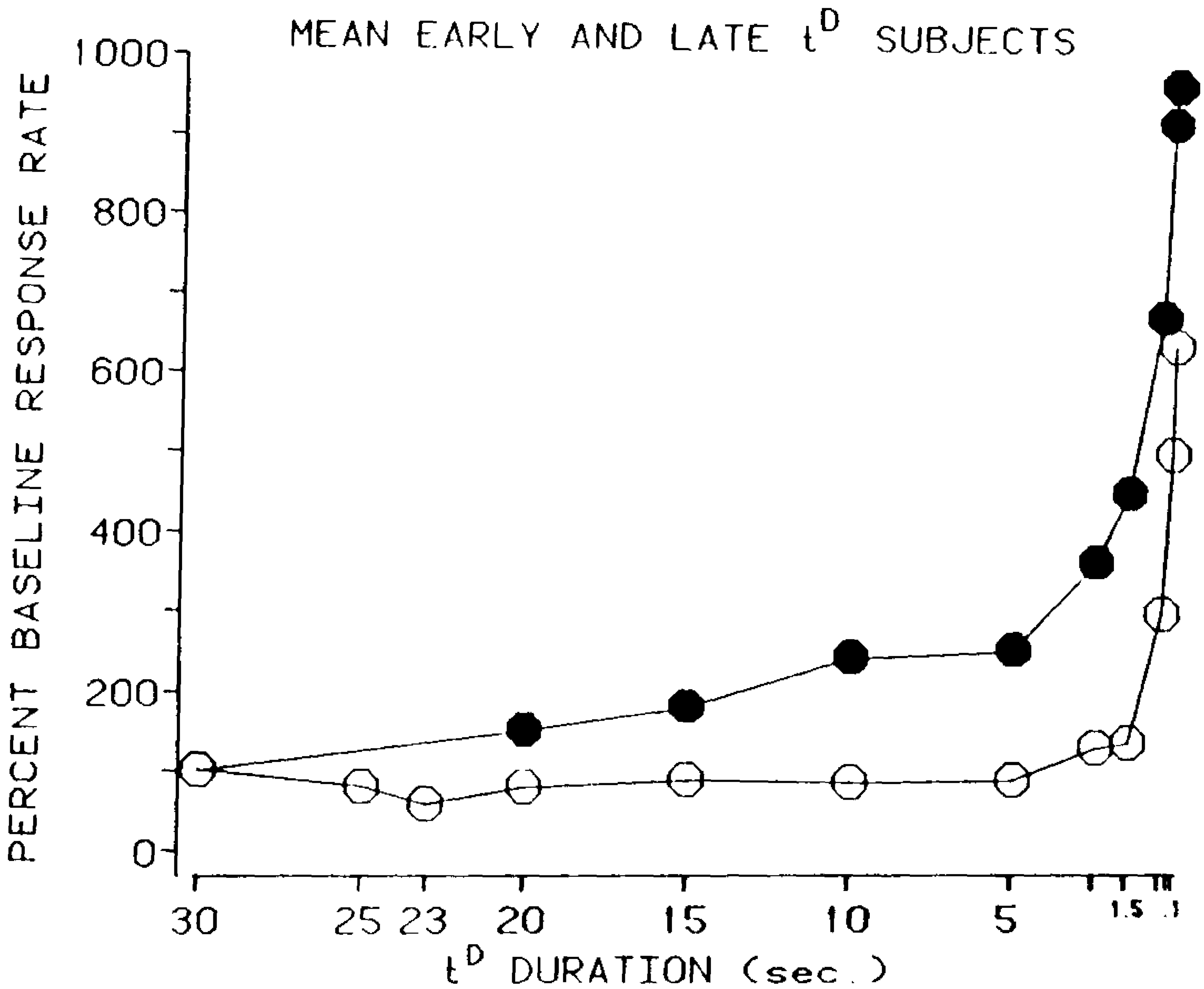
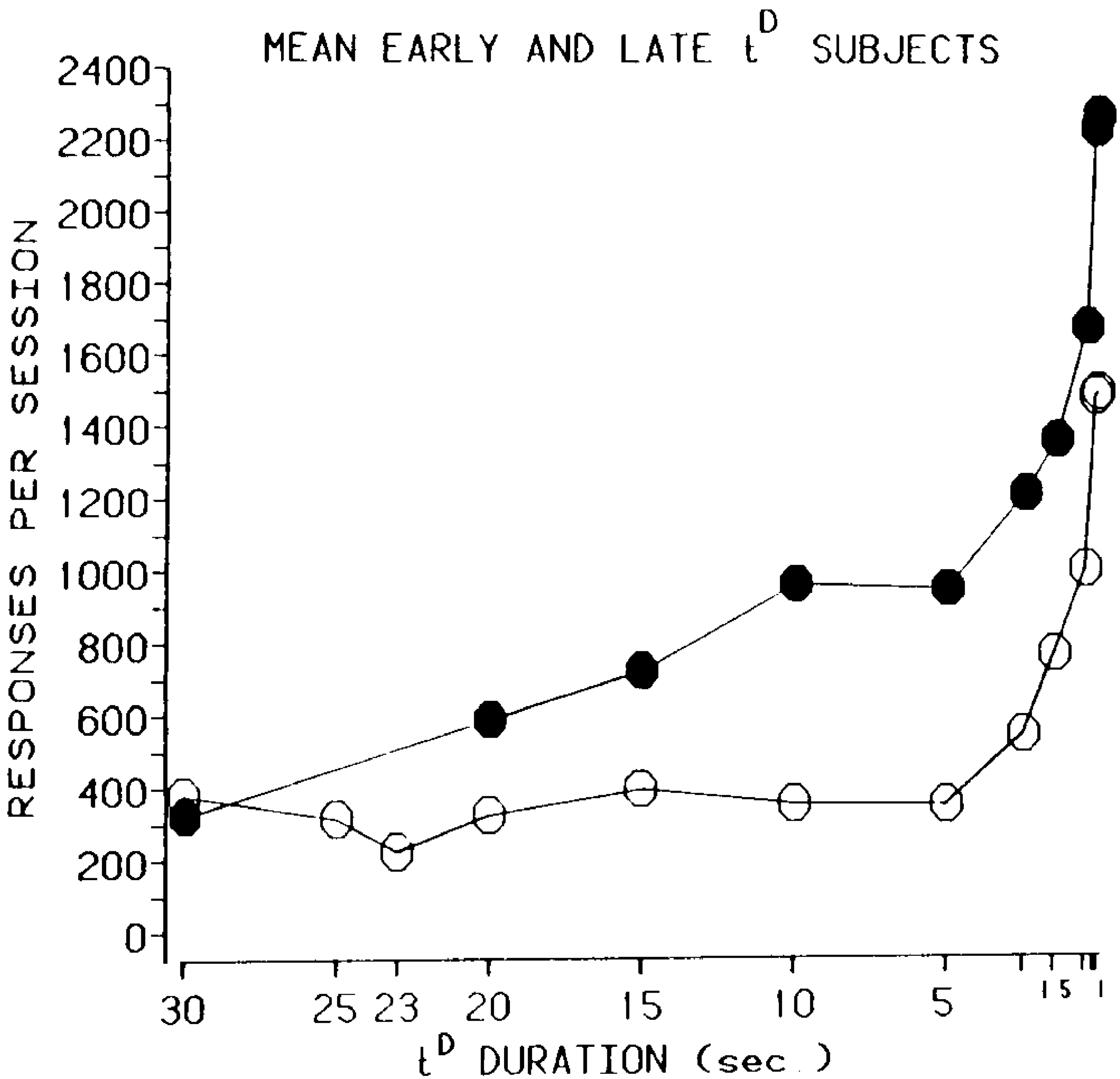
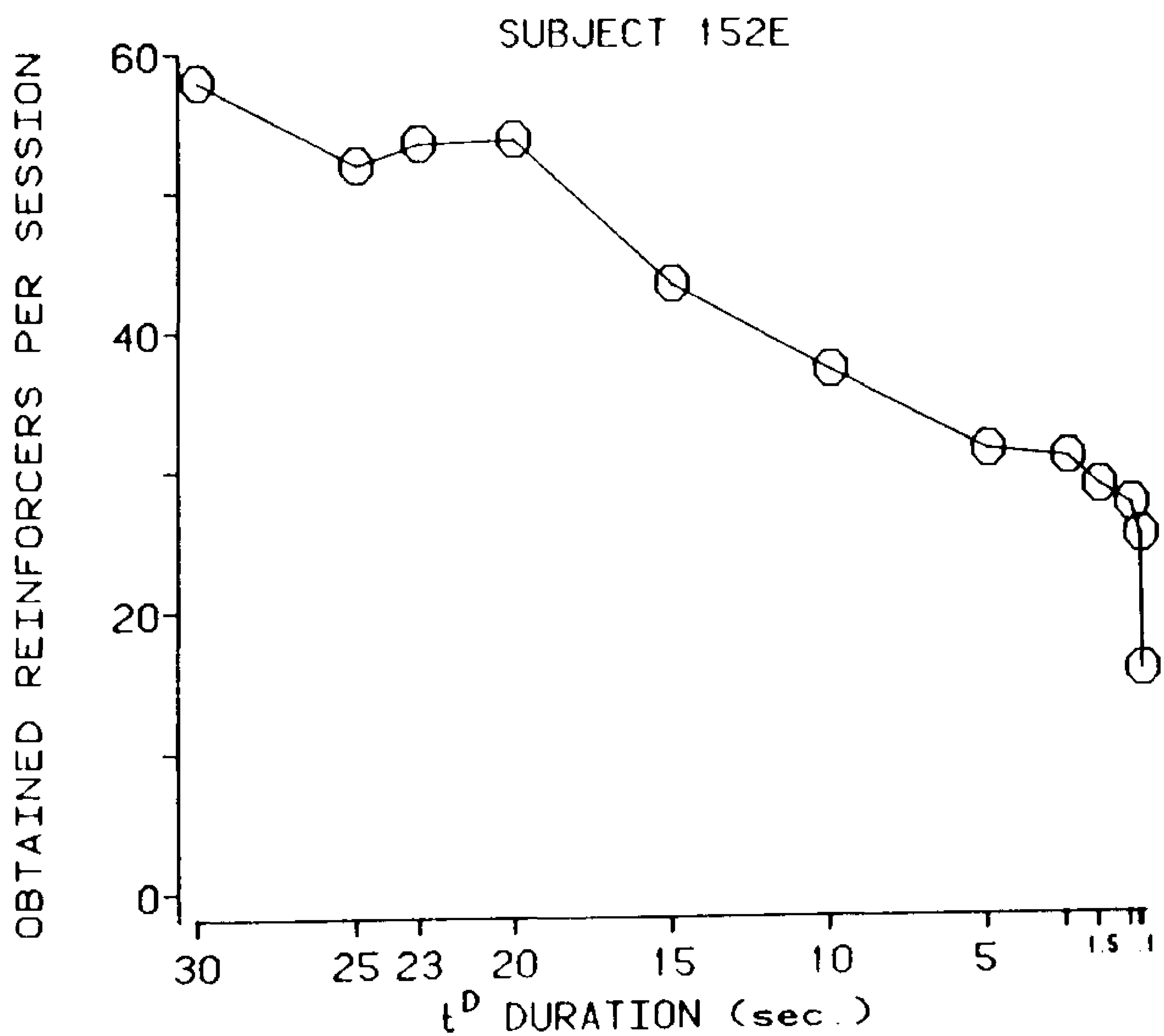

MEAN EARLY AND LATE t^D SUBJECTS
PERCENT BASELINE RESPONSE RATE
1000
800
600
400
200
0
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

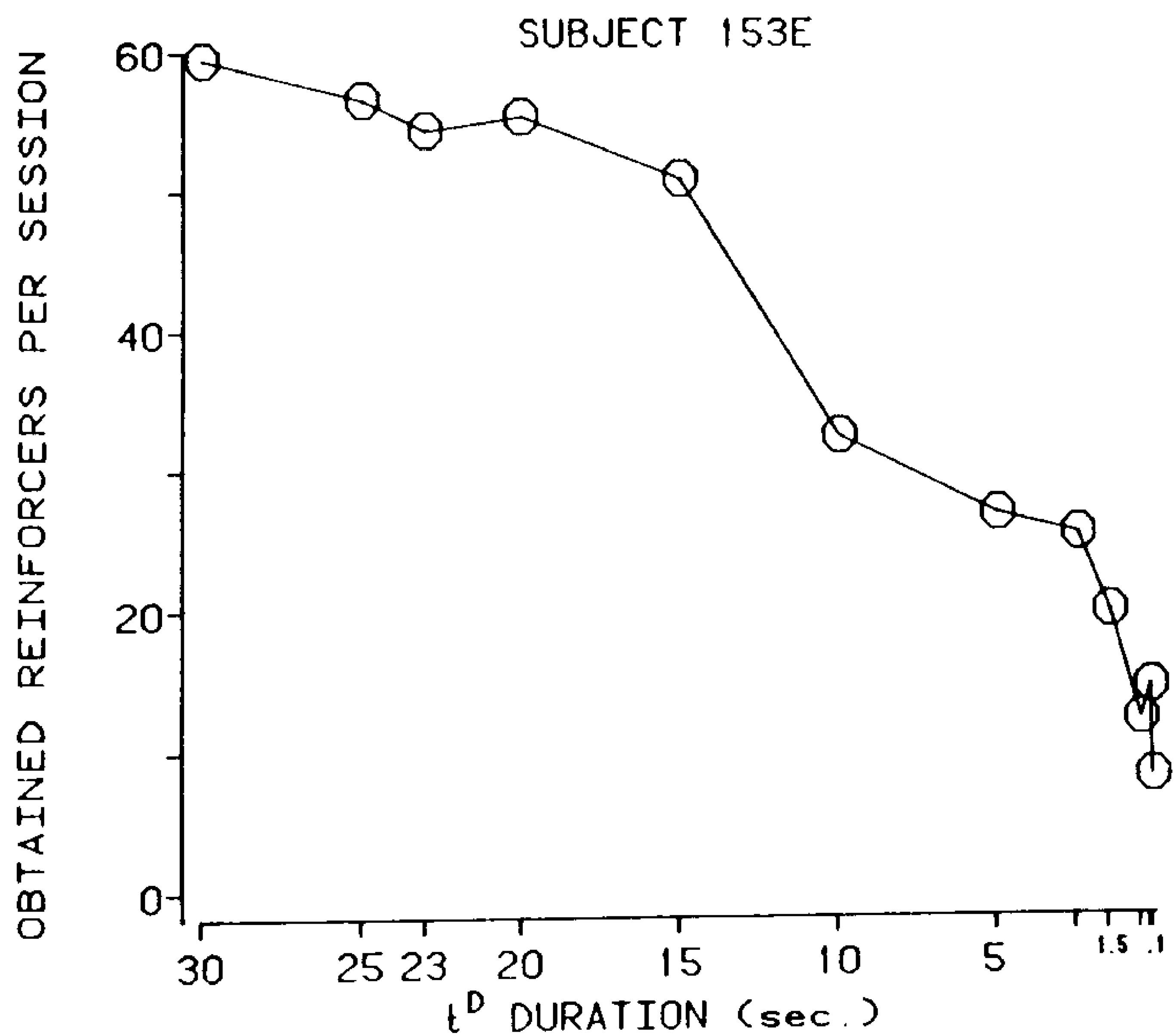
Figure 10. Mean responses per session as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 3 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

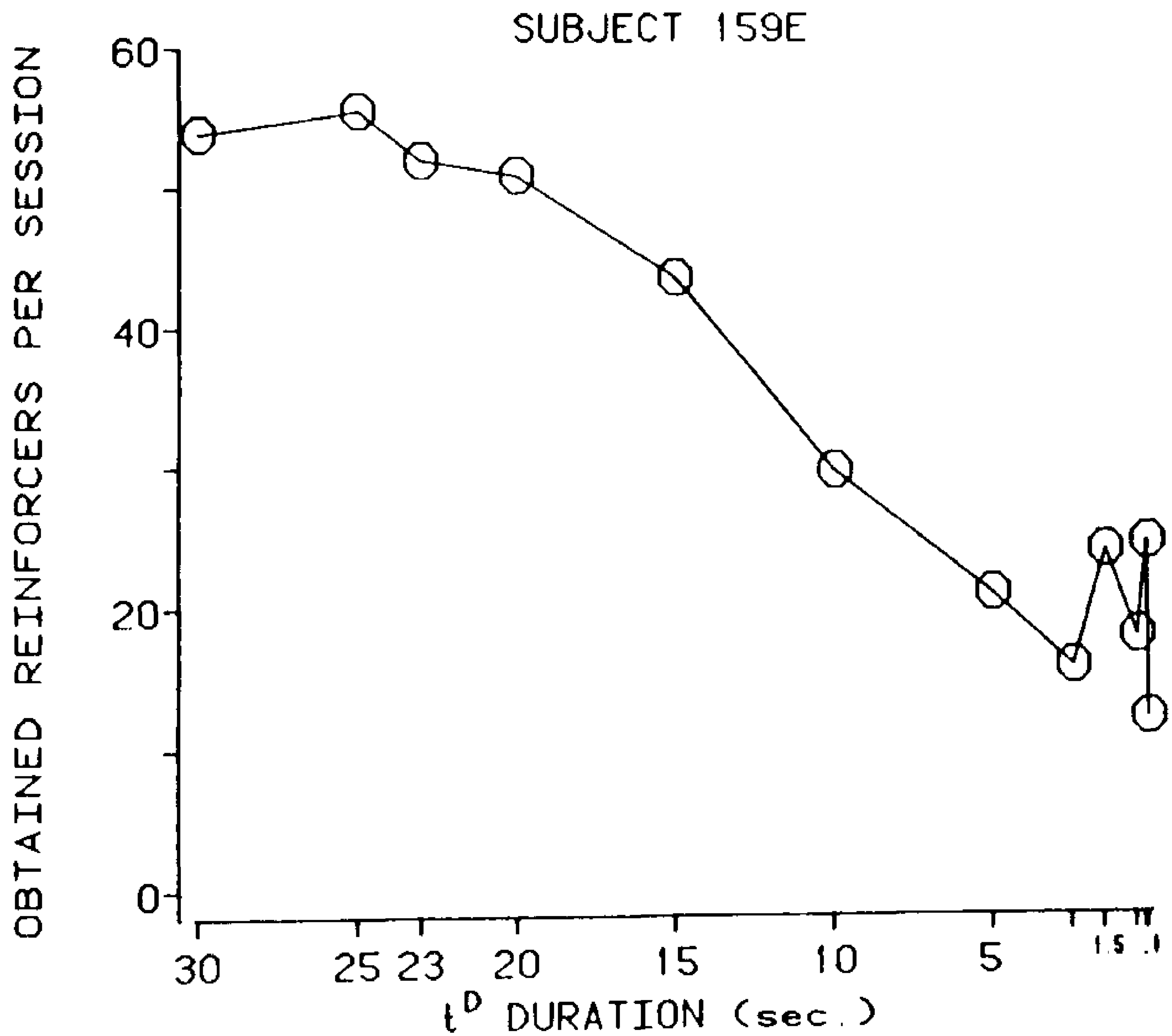

MEAN EARLY AND LATE t^D SUBJECTS
RESPONSES PER SESSION
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
30
25 23
20
15
10
5
1.5
1
t^D DURATION (sec.)

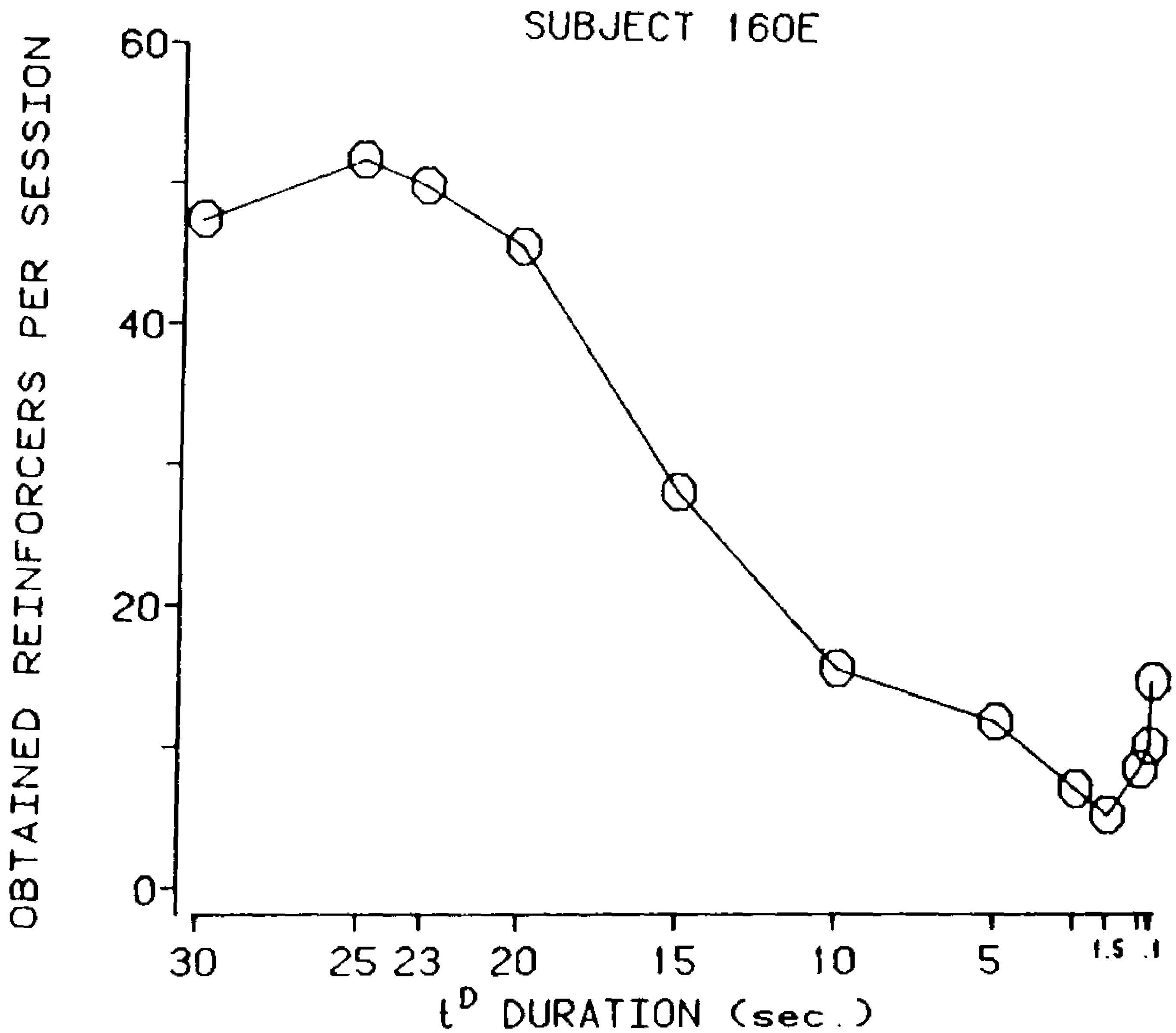
Figures 11-18. Reinforcers per session as a function of t^D duration for each subject. The points plotted are means computed from the last ten sessions of exposure to each t^D duration. The plotted means and their standard errors are presented in Table 4 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

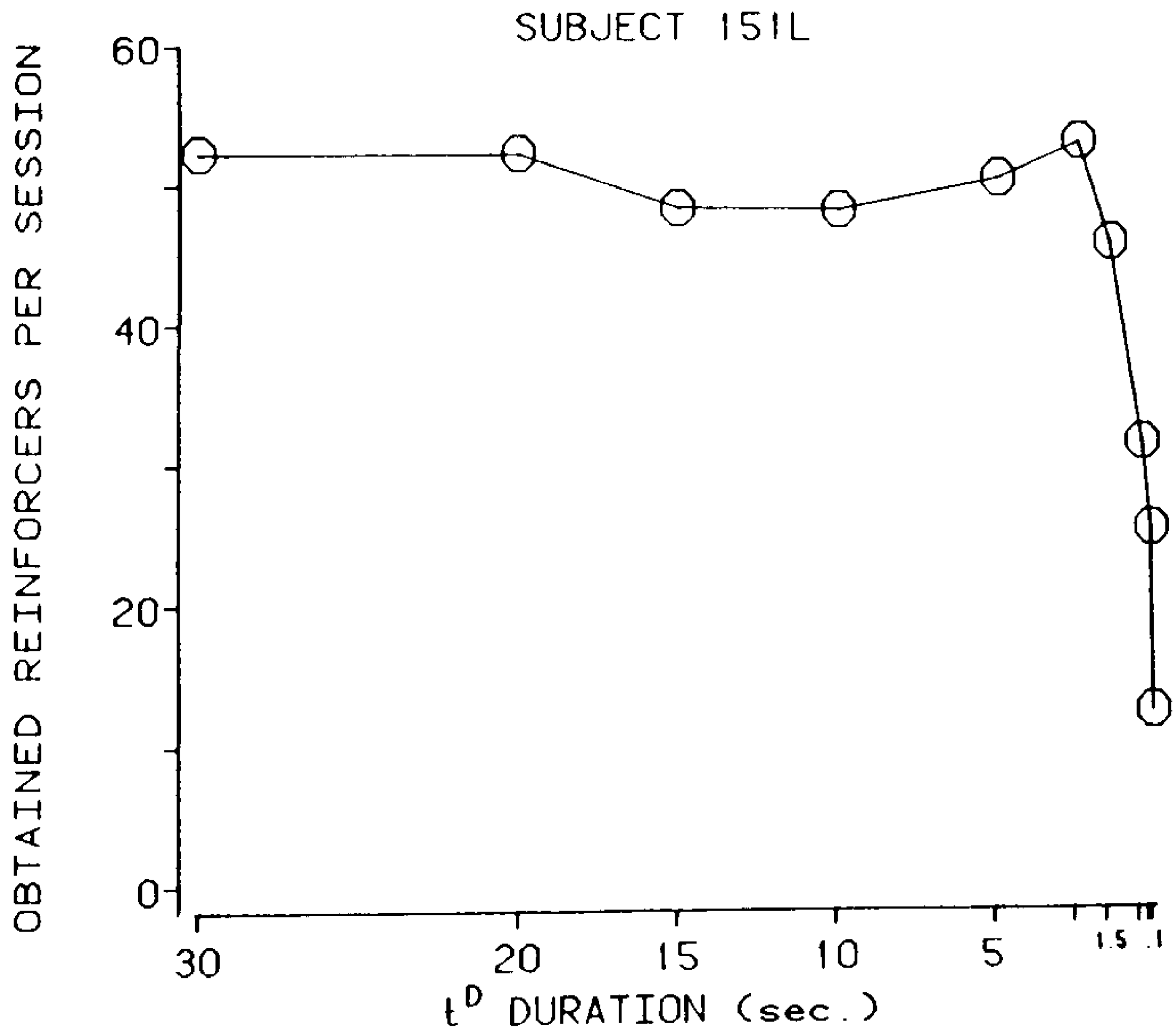


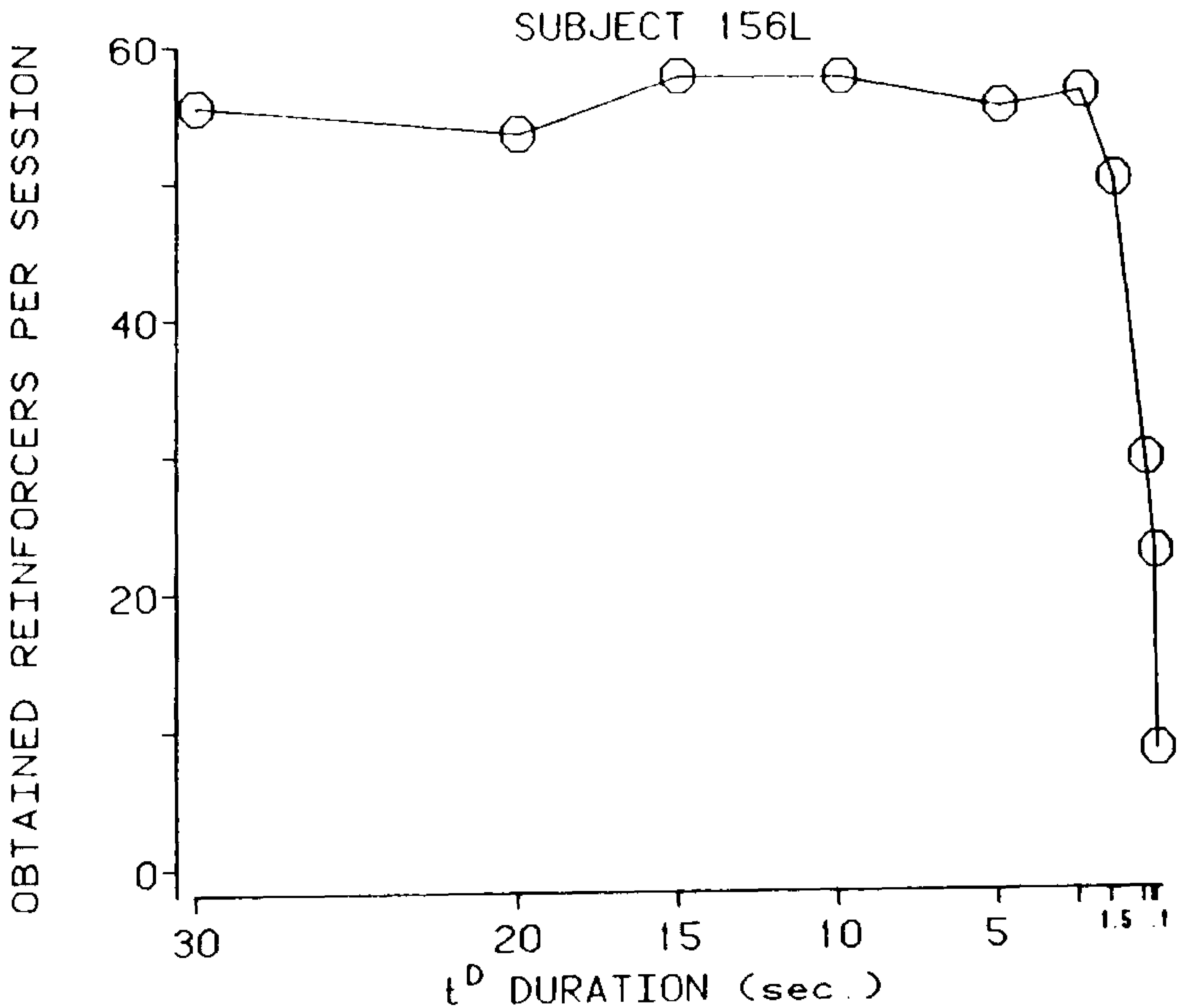
SUBJECT 152E
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

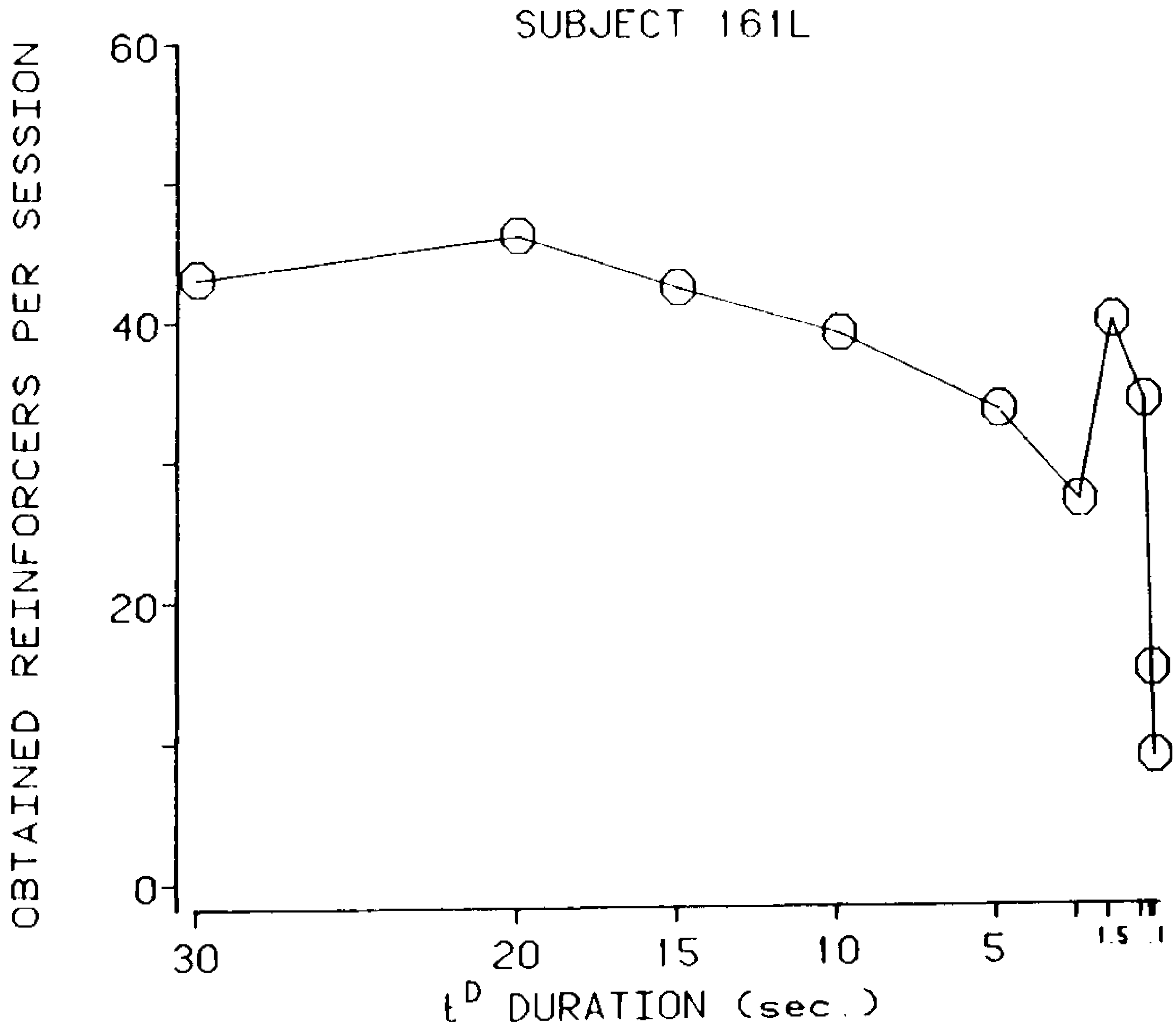

SUBJECT 153E
OBTAINED REINFORCERS PER SESSION
0
20
40
60
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

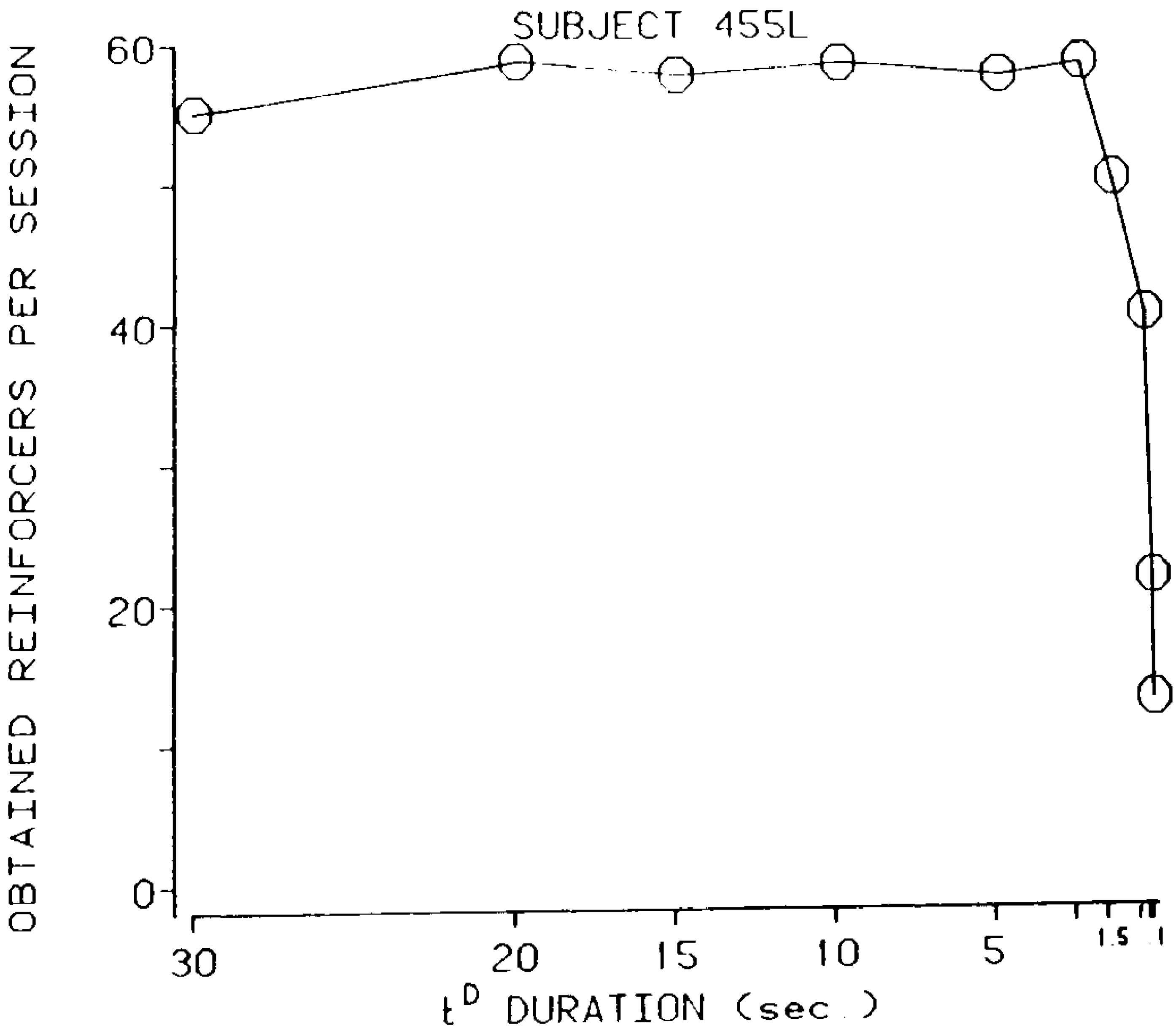

SUBJECT 159E
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
25
23
20
15
10
5
t^D DURATION (sec.)


SUBJECT 160E
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 151L
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

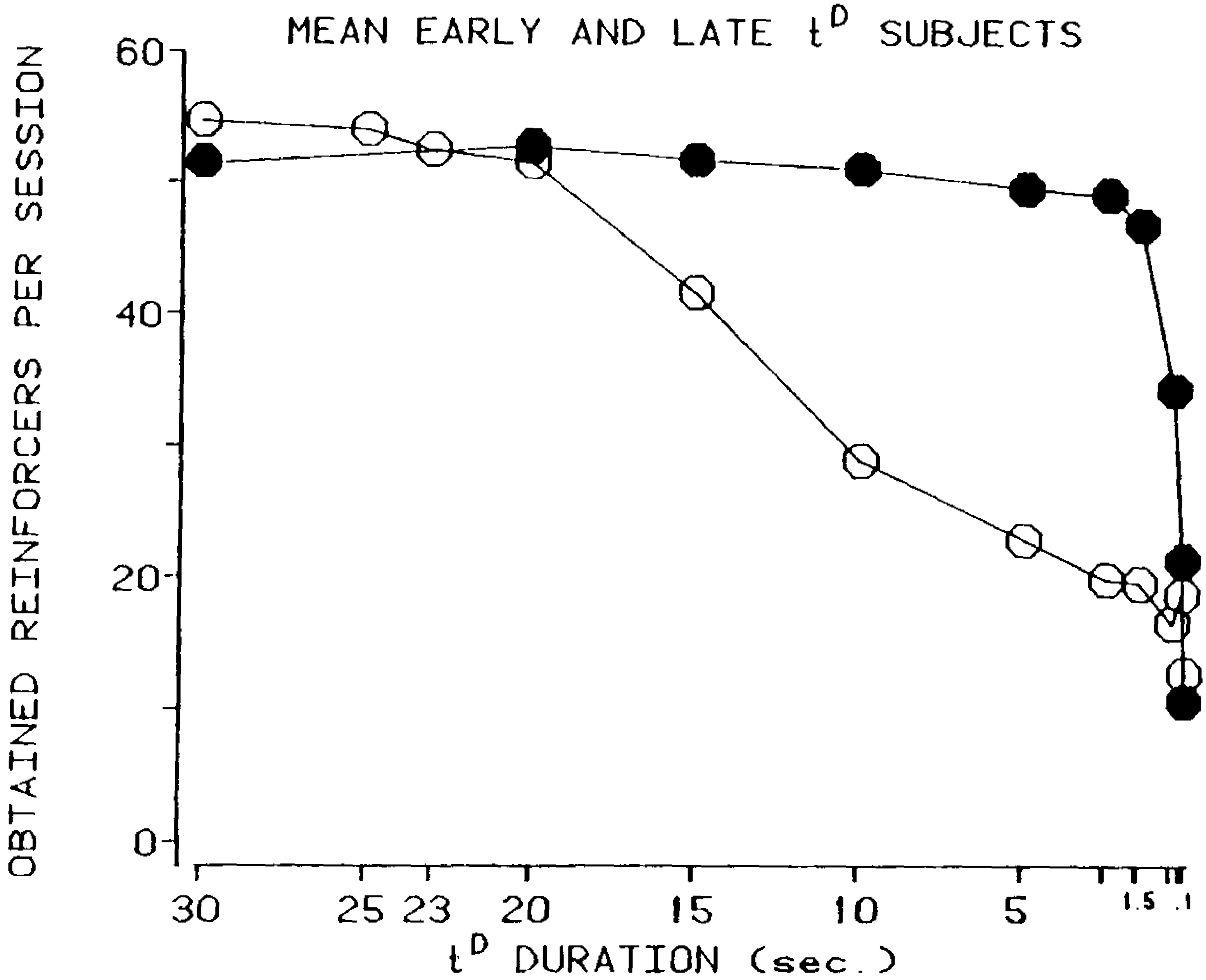

SUBJECT 156L
OBTAINED REINFORCERS PER SESSION
0
20
40
60
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 161L
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
20
15
10
5
1.5
1
t^D DURATION (sec.)

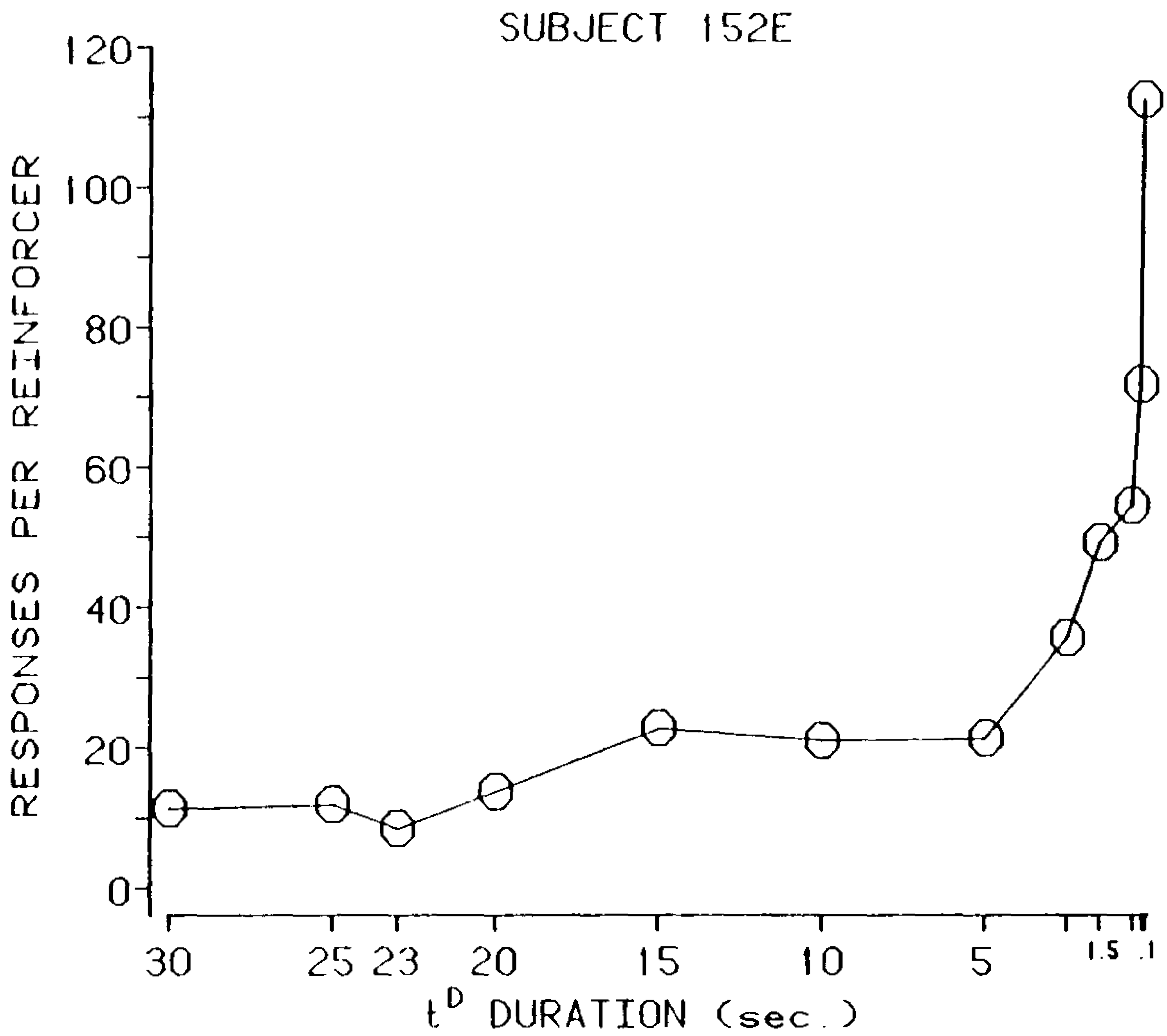


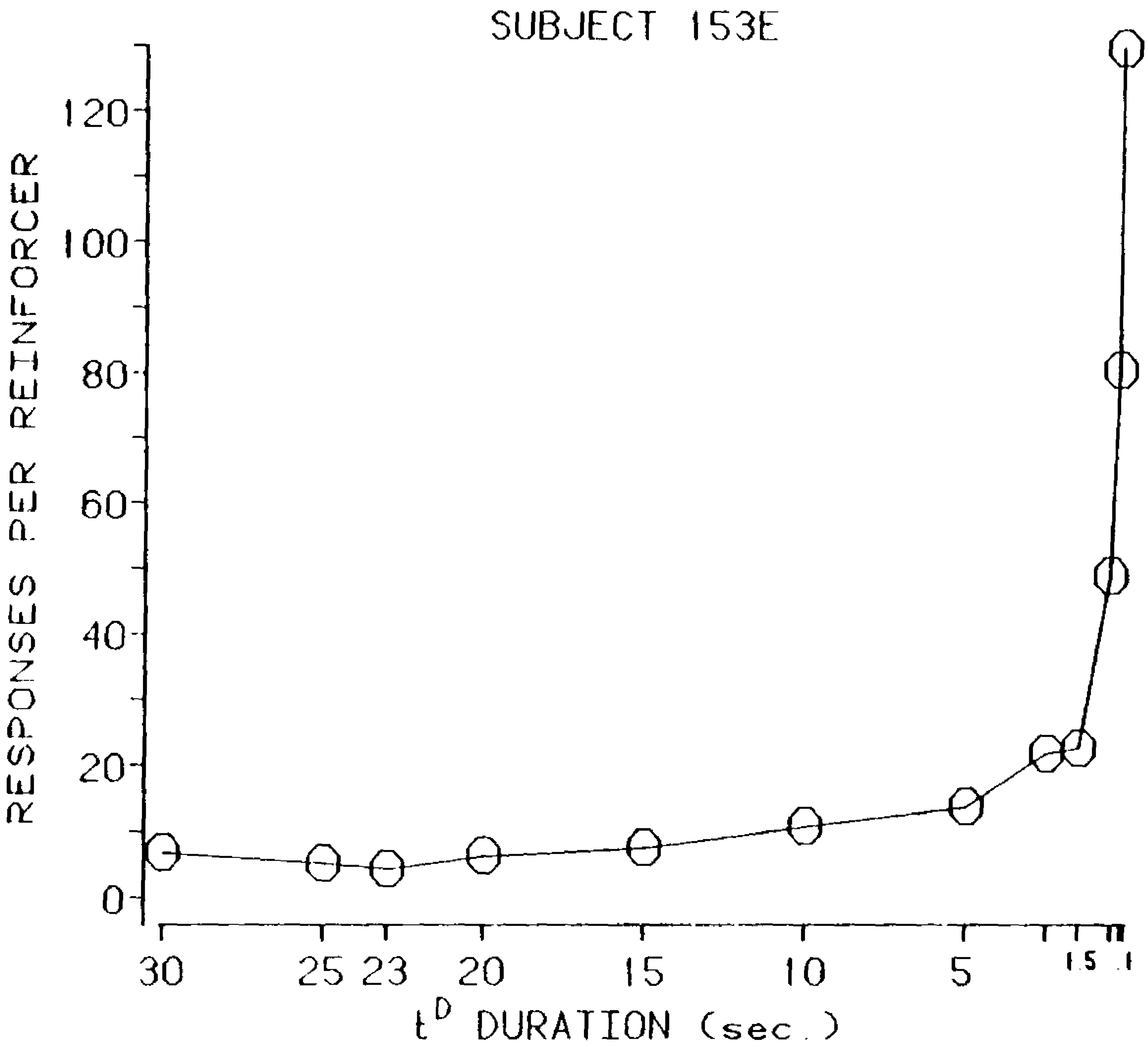
SUBJECT 455L
60
40
20
0
OBTAINED REINFORCERS PER SESSION
30
20
15
10
5
1.5
1
t^D DURATION (sec.)

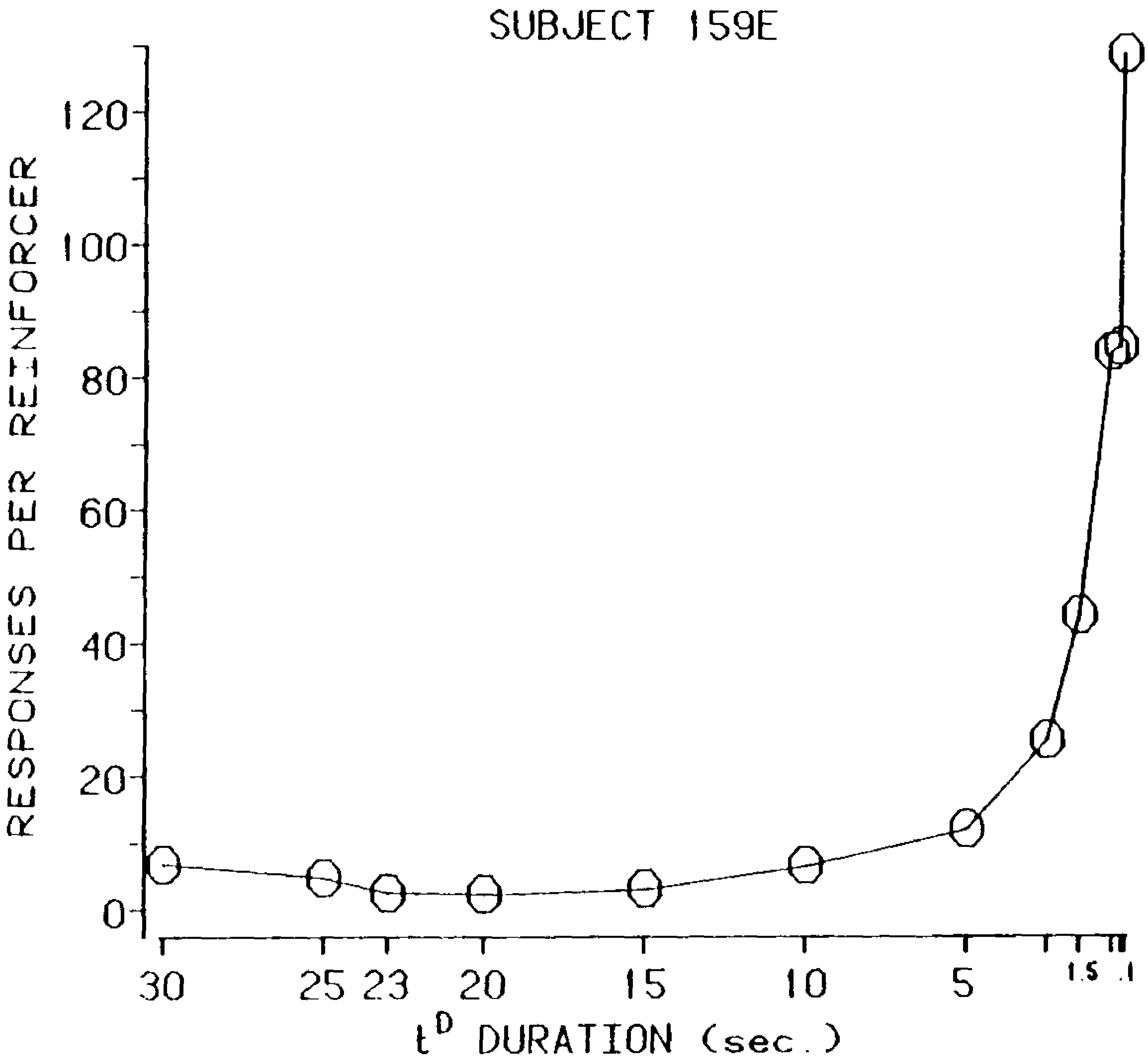
Figure 19. Mean obtained reinforcers per session as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 4 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

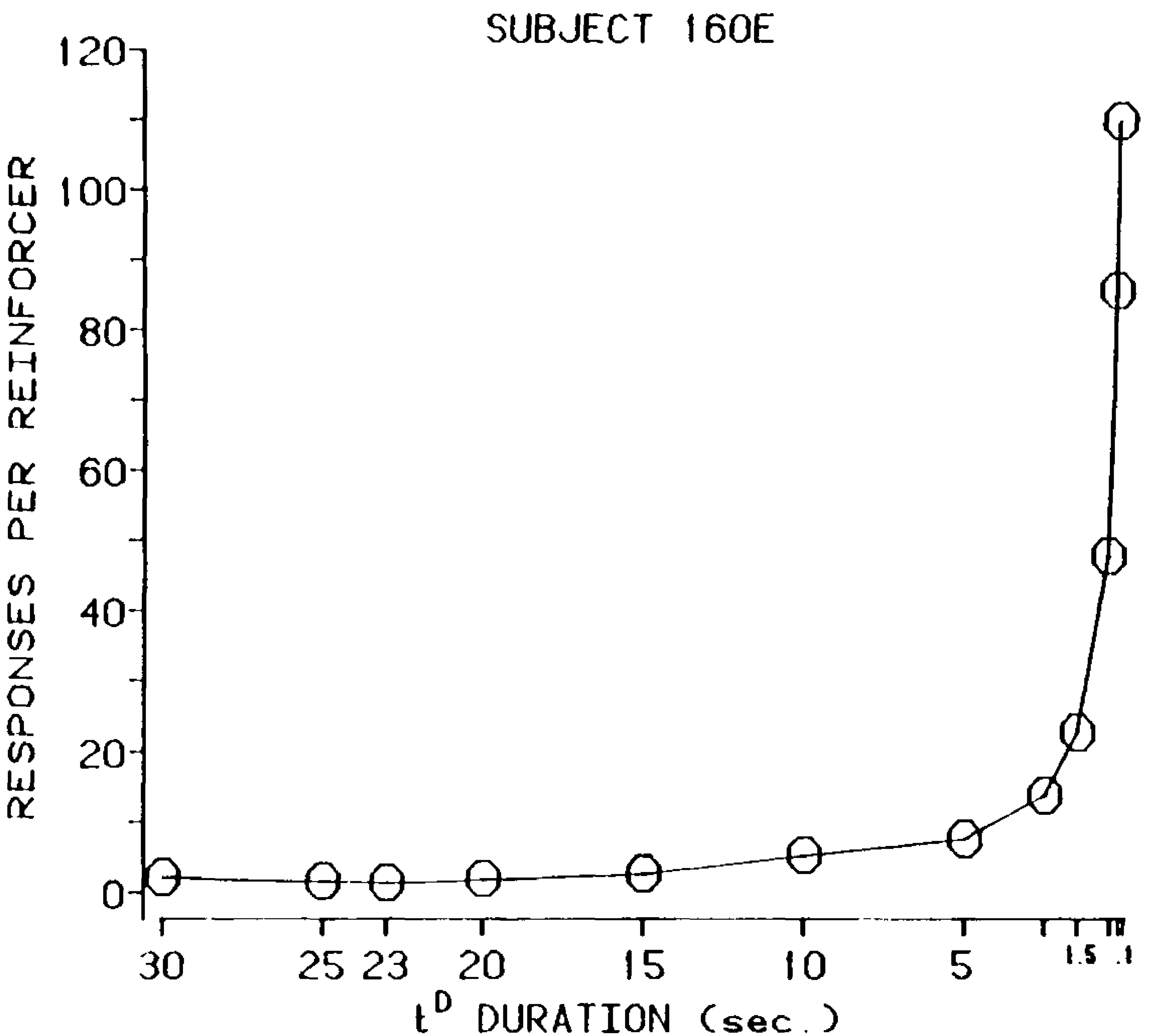

MEAN EARLY AND LATE t^D SUBJECTS
OBTAINED REINFORCERS PER SESSION
60
40
20
0
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

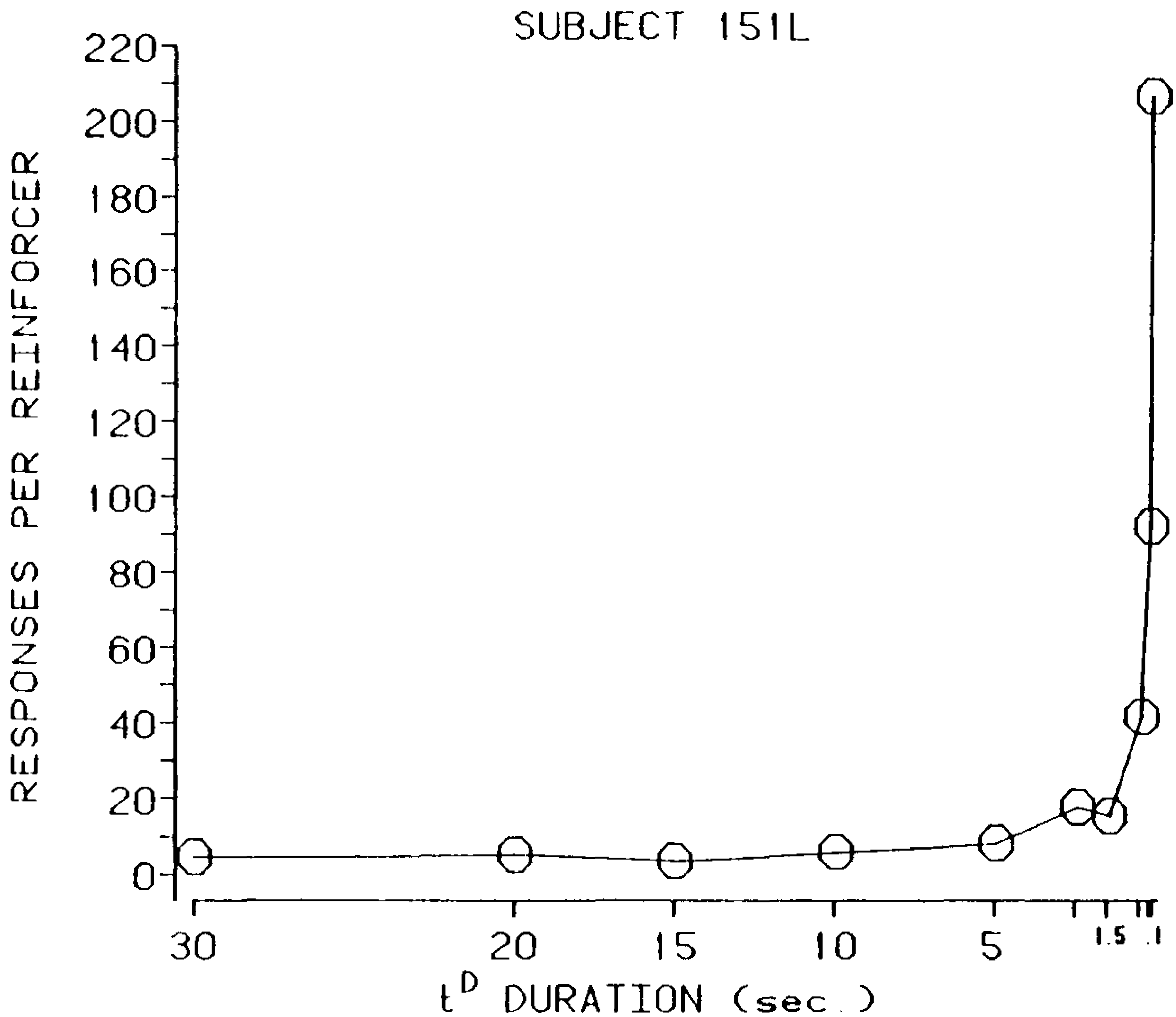
Figures 20-27. Responses per reinforcer as a function of t^D duration for each subject. The points plotted are means computed from the last ten sessions of exposure to each t^D duration. The plotted means and their standard errors are presented in Table 5 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

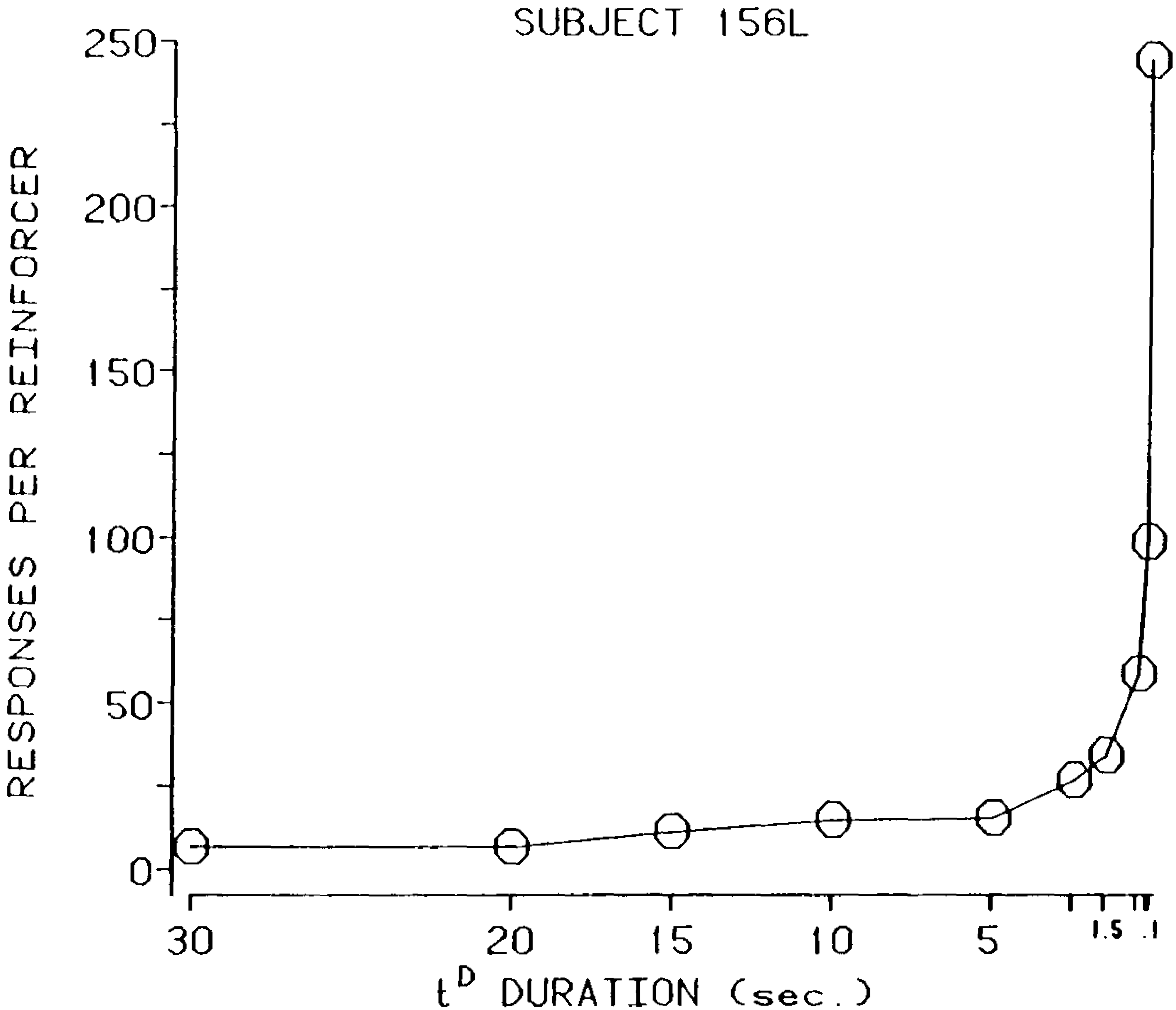

SUBJECT 152E
RESPONSES PER REINFORCER
0
20
40
60
80
100
120
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 153E
RESPONSES PER REINFORCER
0
20
40
60
80
100
120
30
25
23
20
15
10
5
t^D DURATION (sec.)

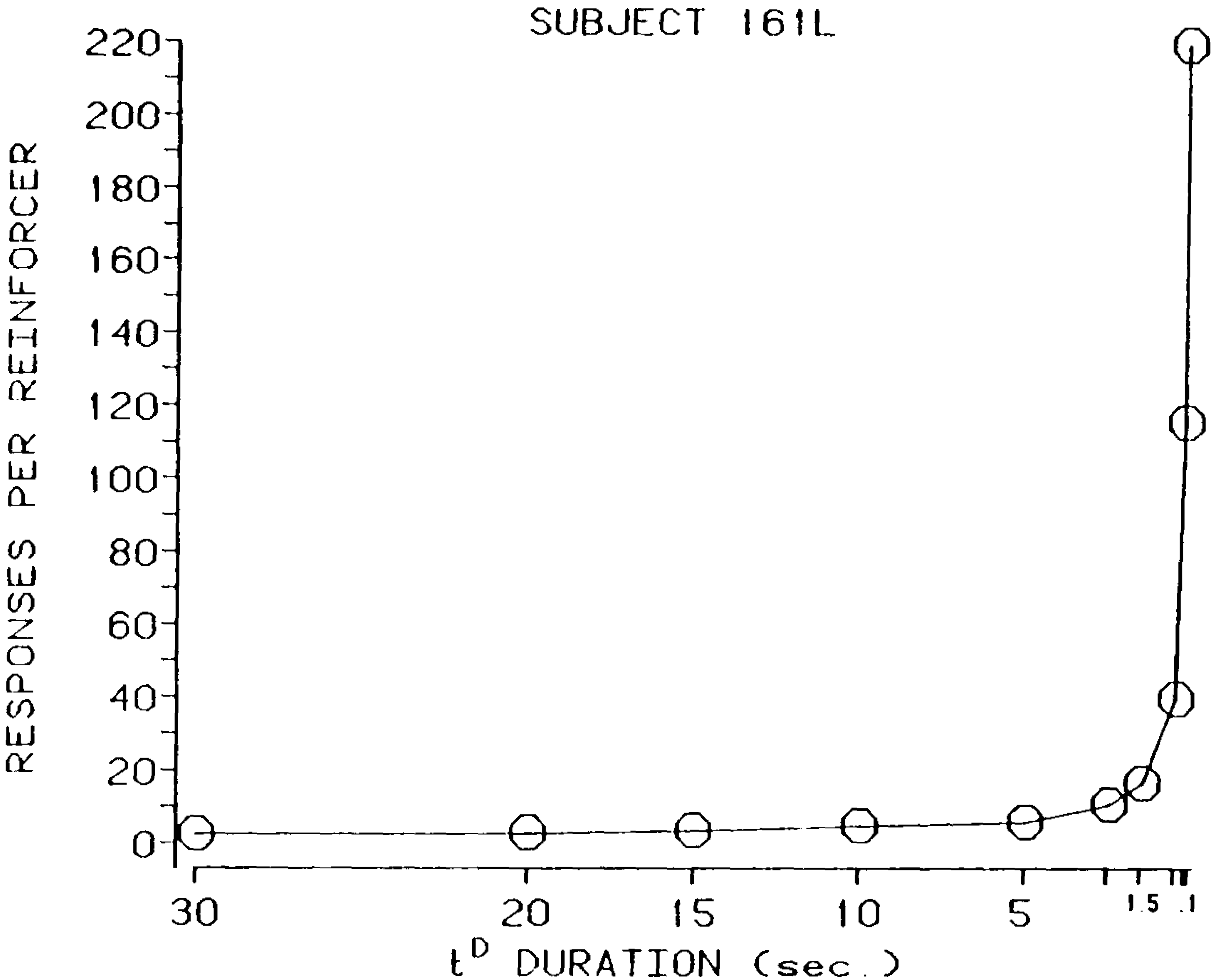

SUBJECT 159E
RESPONSES PER REINFORCER
0
20
40
60
80
100
120
30
25
23
20
15
10
5
1.5
.1
tD DURATION (sec.)

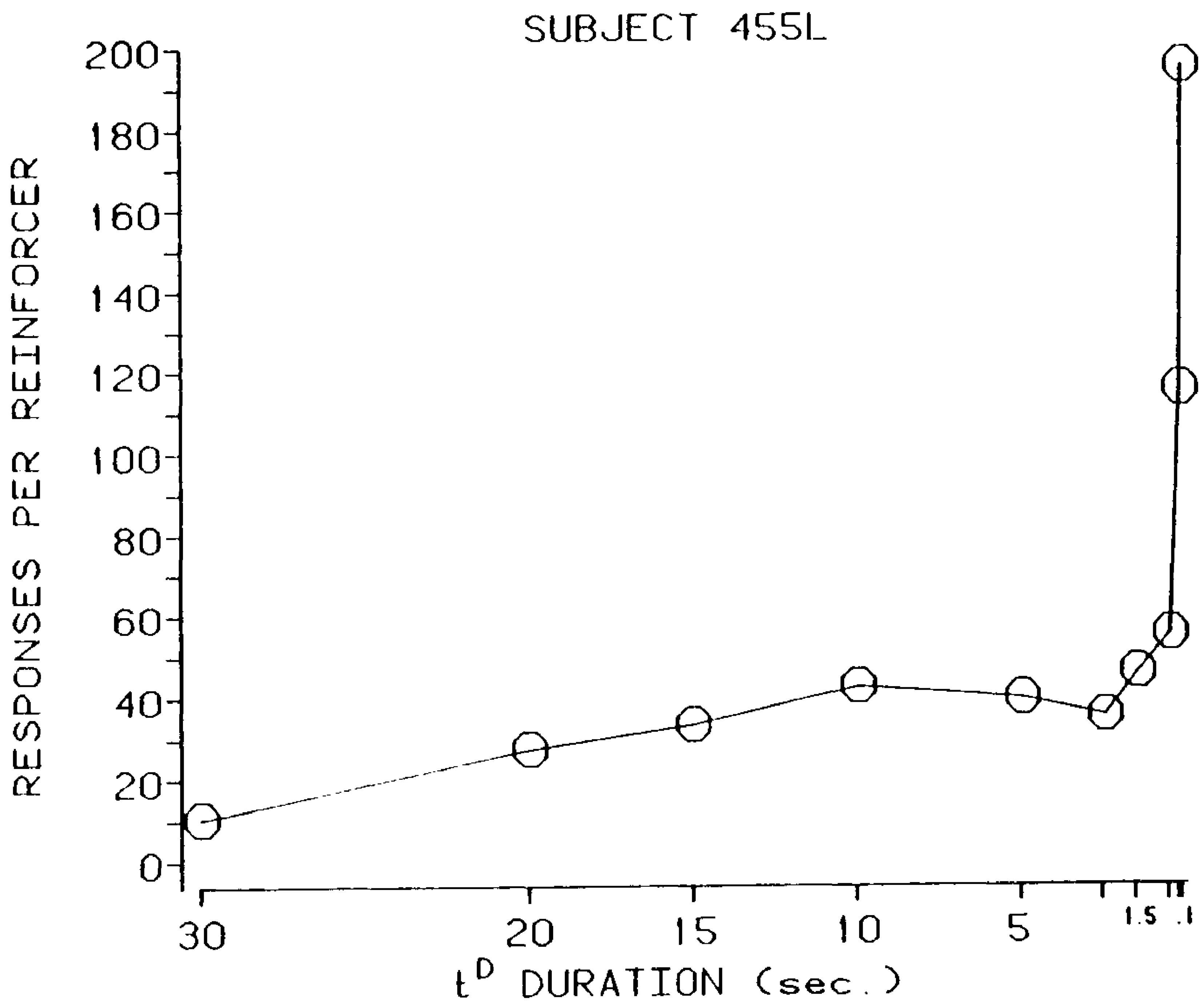

SUBJECT 160E
RESPONSES PER REINFORCER
120
100
80
60
40
20
0
30
25
23
20
15
10
5
1.5
.1
tD DURATION (sec.)


SUBJECT 151L
RESPONSES PER REINFORCER
220
200
180
160
140
120
100
80
60
40
20
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)



SUBJECT 156L
RESPONSES PER REINFORCER
250
200
150
100
50
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

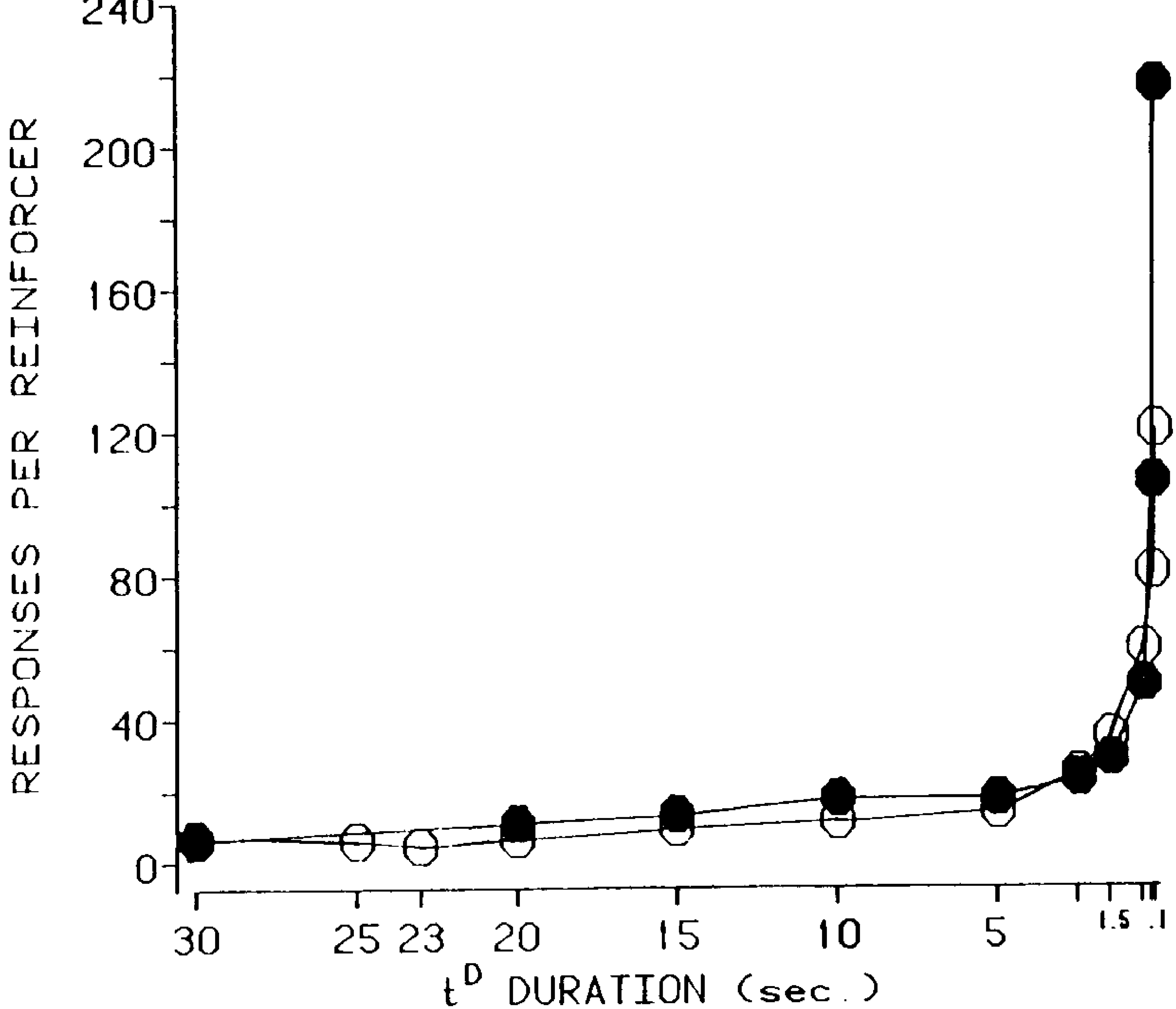

SUBJECT 161L
RESPONSES PER REINFORCER
220
200
180
160
140
120
100
80
60
40
20
0
30
20
15
10
5
1 .5
.1
t^D DURATION (sec.)



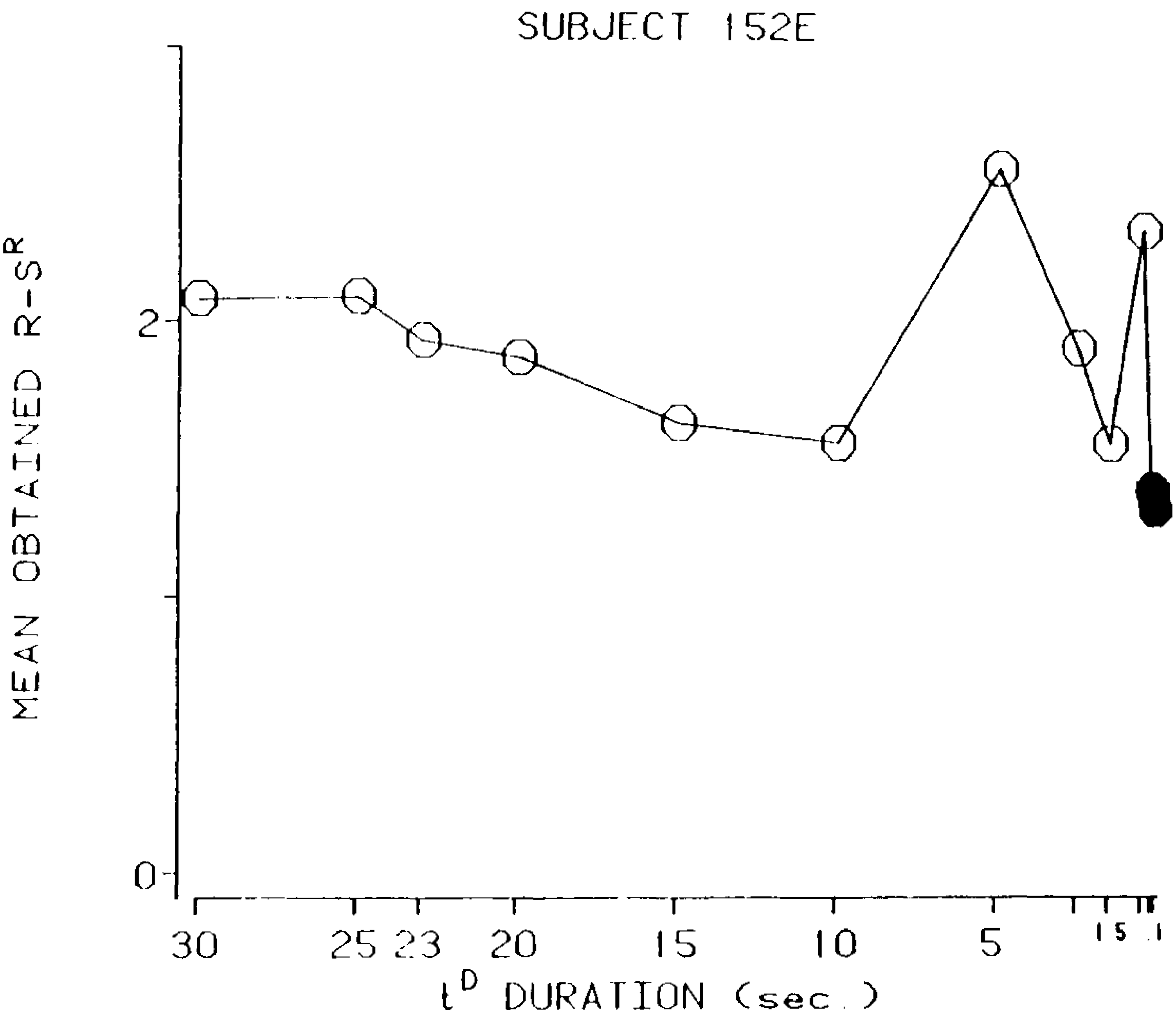
SUBJECT 455L
RESPONSES PER REINFORCER
200
180
160
140
120
100
80
60
40
20
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

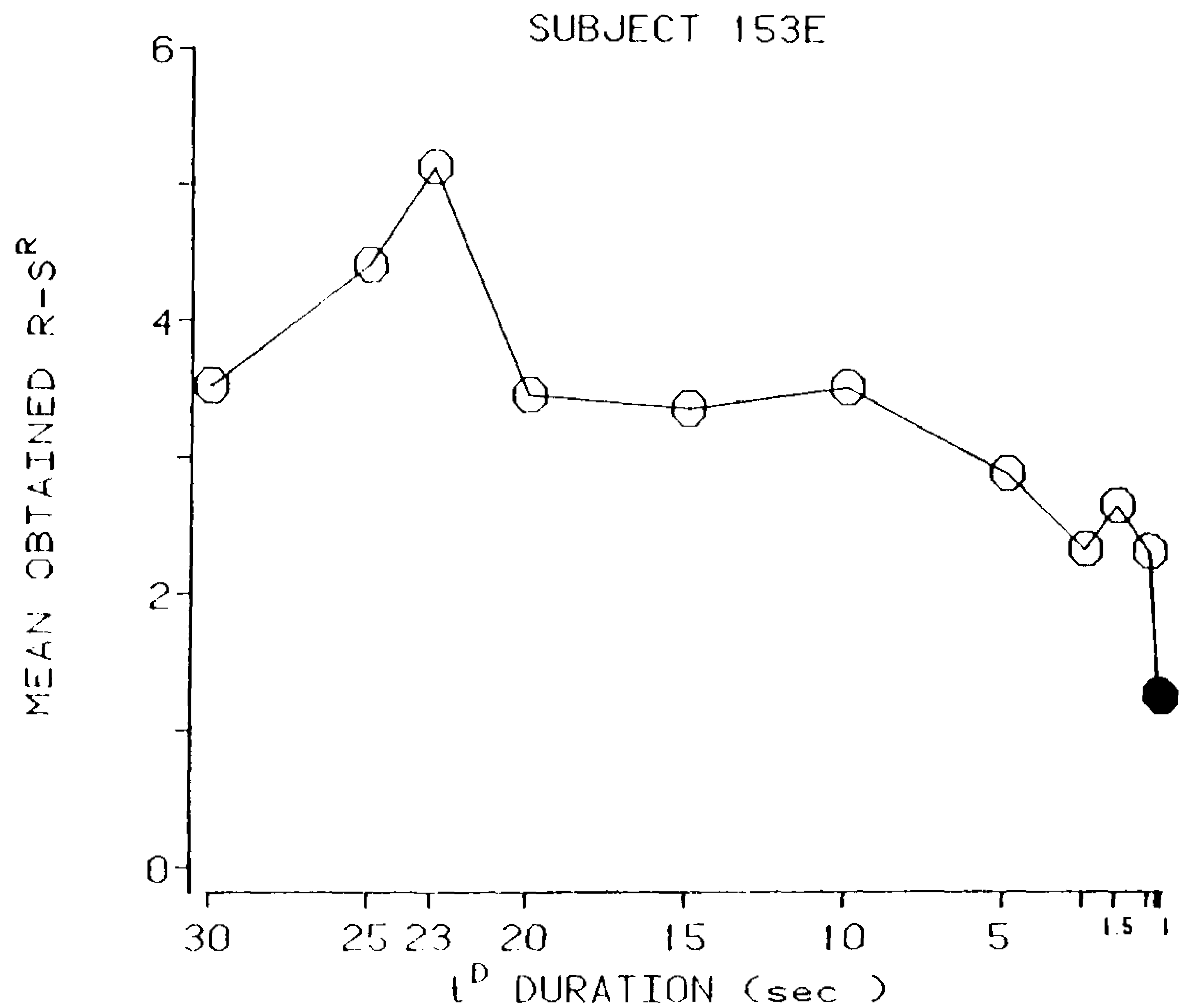
Figure 28. Mean responses per reinforcer as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 5 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

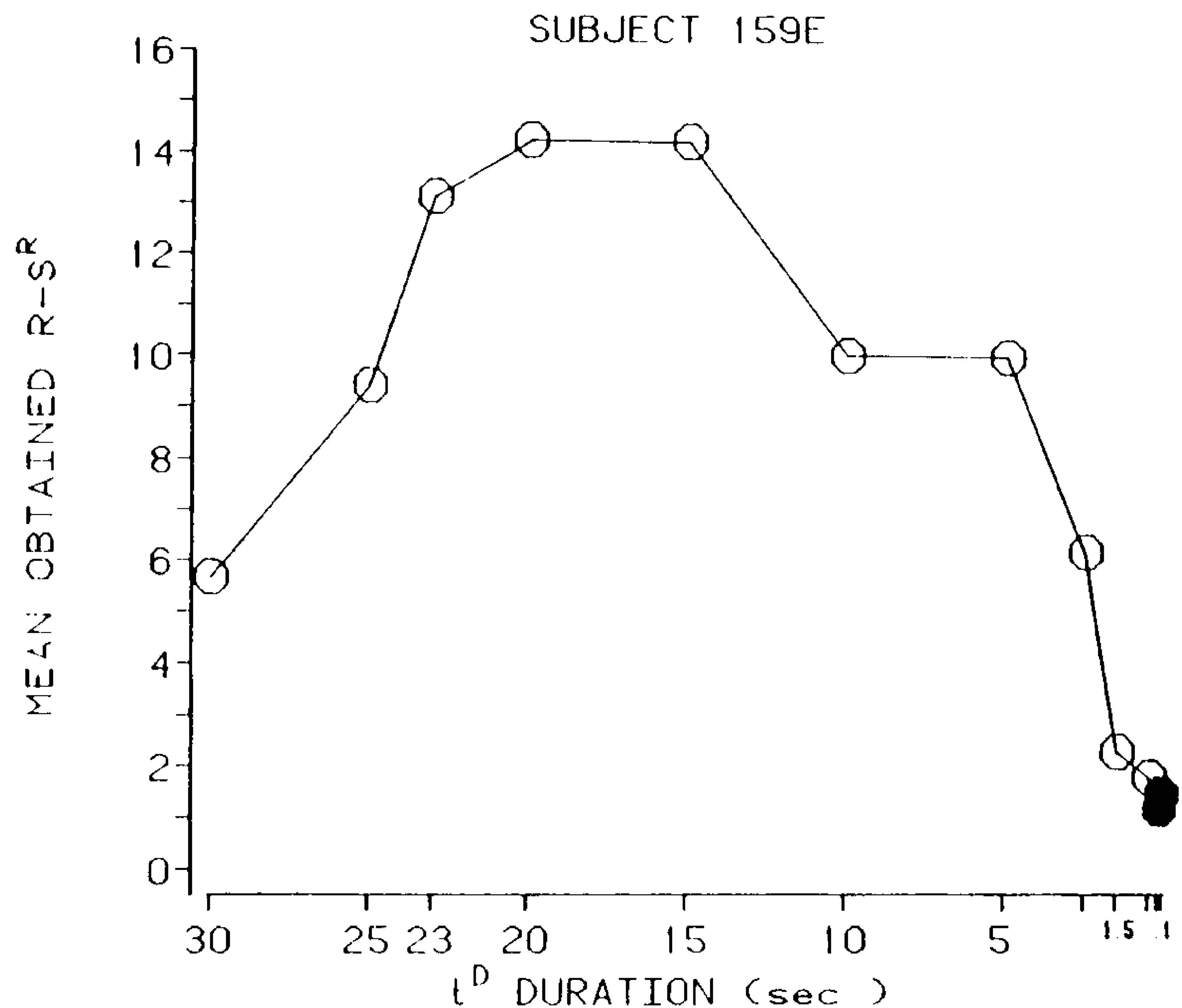
MEAN EARLY AND LATE t^D SUBJECTS

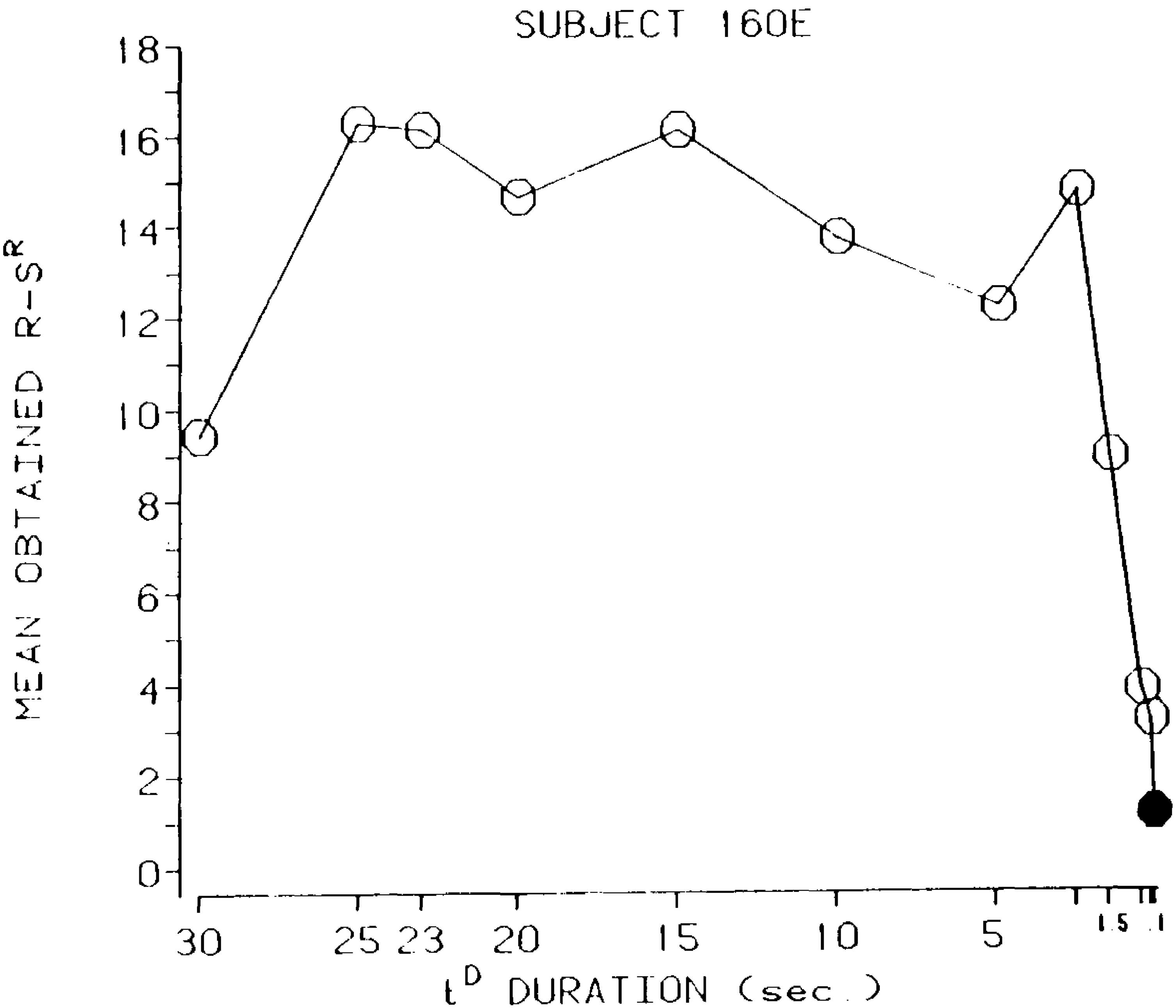


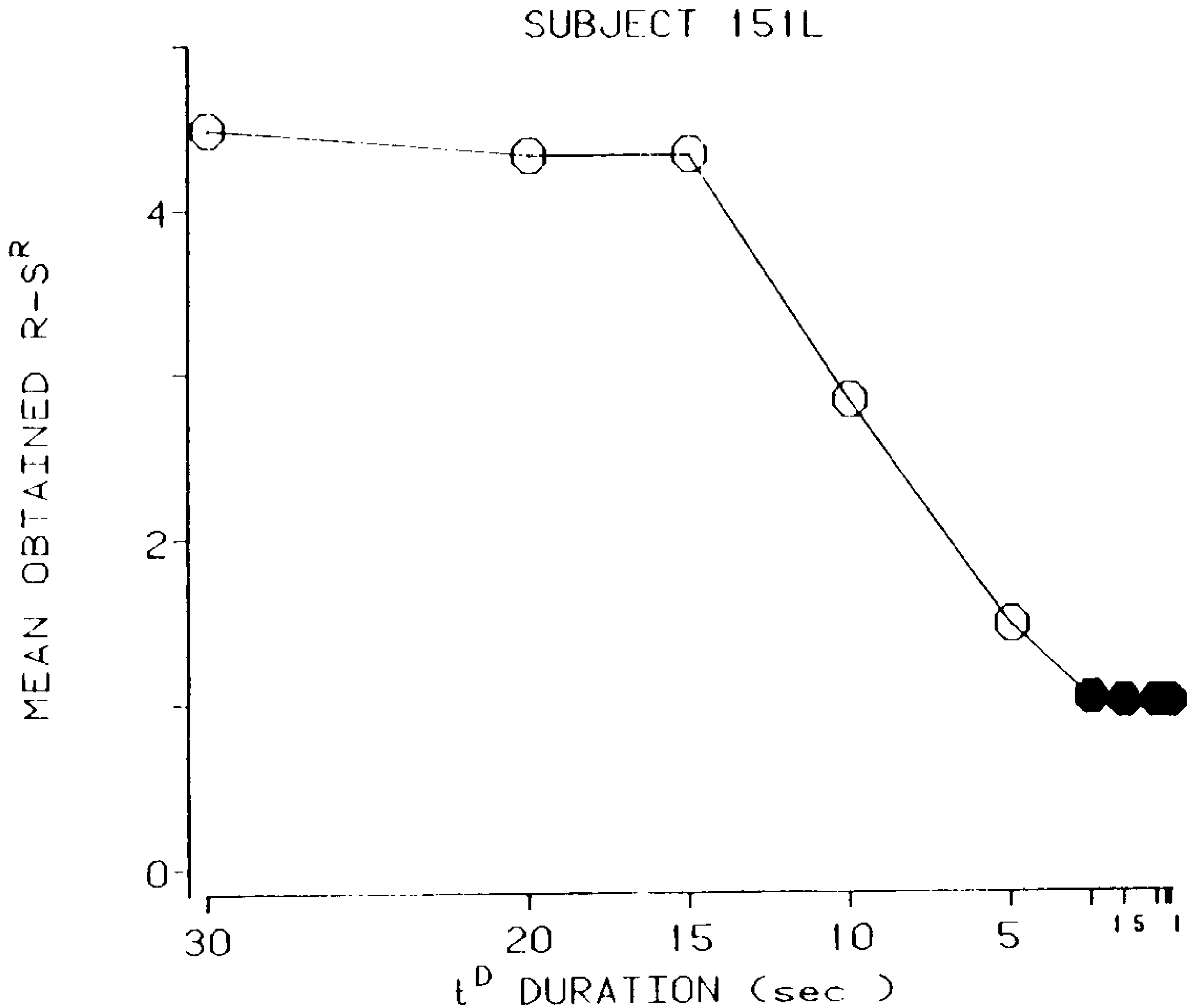
Figures 29-36. Obtained $R-S^R$ in seconds as function of t^D duration for each subject. The points plotted are means computed from the last ten sessions of exposure to each t^D duration. The plotted means and their standard errors are presented in Table 6 (see Appendix). The open symbols are significantly different by t-test ($p<0.05$) from the obtained mean $R-S^R$ at $t^D=0.1$ seconds. The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

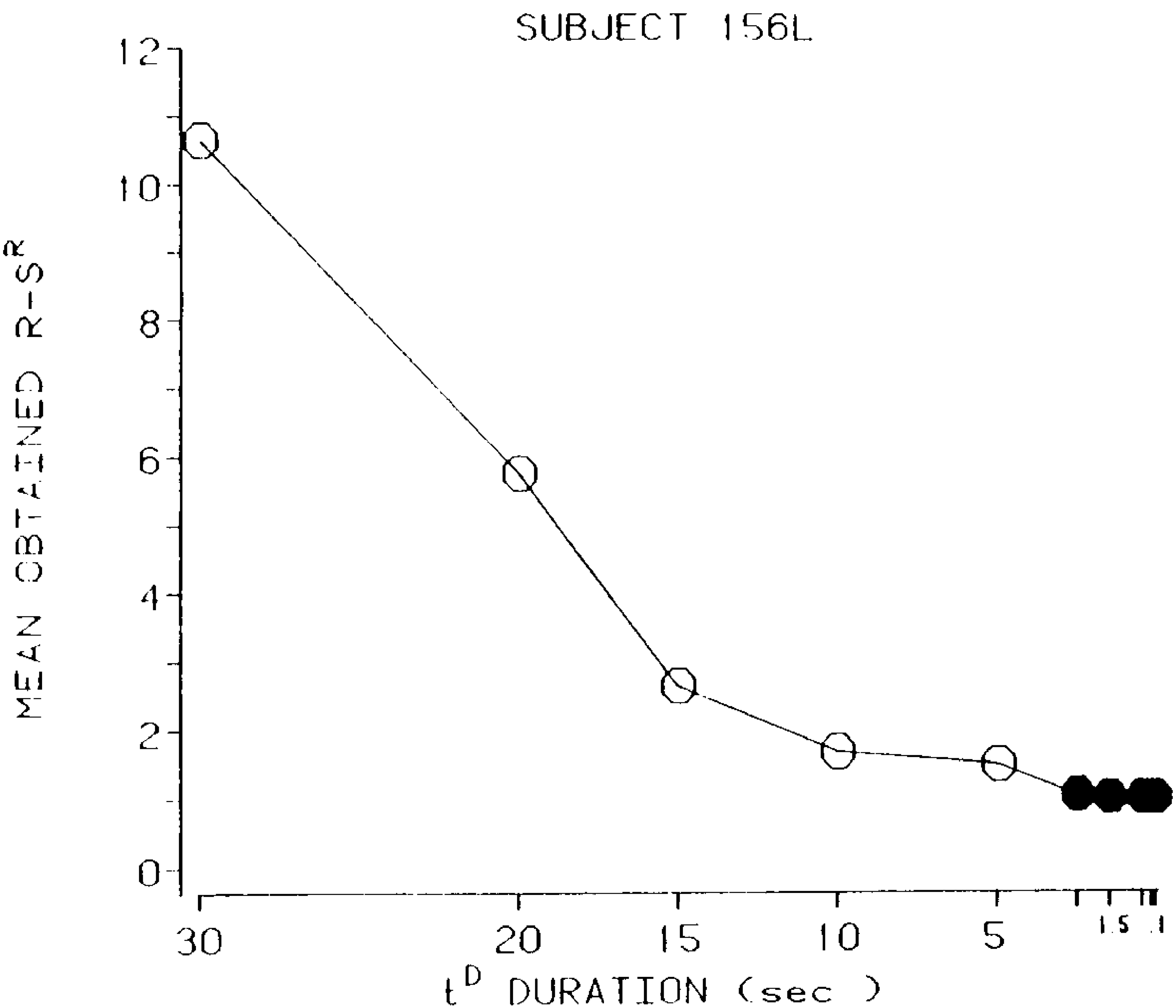

SUBJECT 152E
MEAN OBTAINED R-S^R
2
0
30
25
23
20
15
10
5
t^D DURATION (sec.)

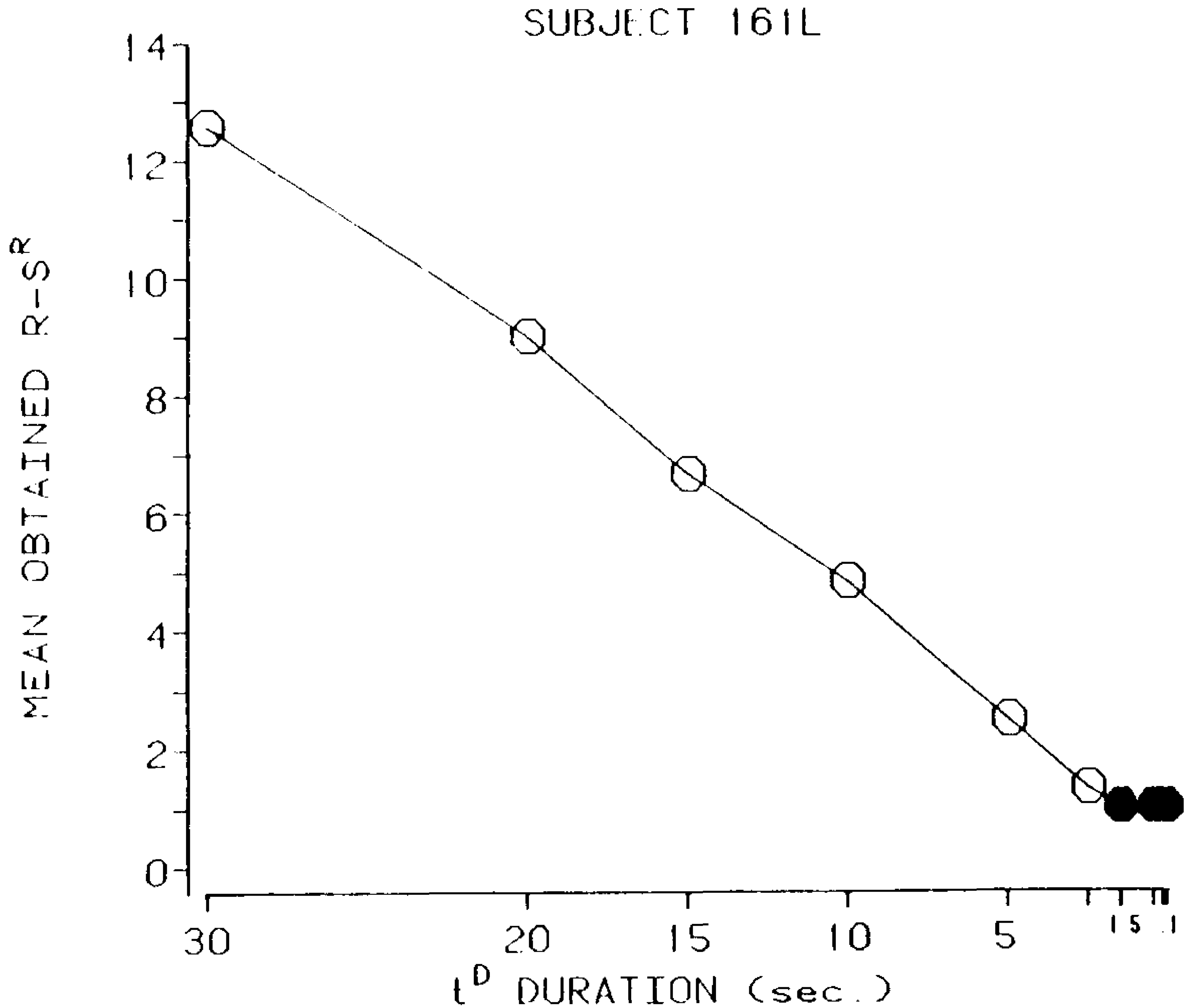

SUBJECT 153E
MEAN OBTAINED R-S^R
6
4
2
0
30
25 23
20
15
10
5
1.5
1
t^D DURATION (sec)


SUBJECT 159E
MEAN OBTAINED R-S^R
16
14
12
10
8
6
4
2
0
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec)


SUBJECT 160E
MEAN OBTAINED R-S^R
0
2
4
6
8
10
12
14
16
18
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 151L
MEAN OBTAINED R-S R
4
2
0
30
20
15
10
5
1.5
1
t D DURATION (sec)


SUBJECT 156L
MEAN OBTAINED R-S^R
12
10
8
6
4
2
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec)


SUBJECT 161L
MEAN OBTAINED R-S^R
14
12
10
8
6
4
2
0
30
20
15
10
5
t^D DURATION (sec.)

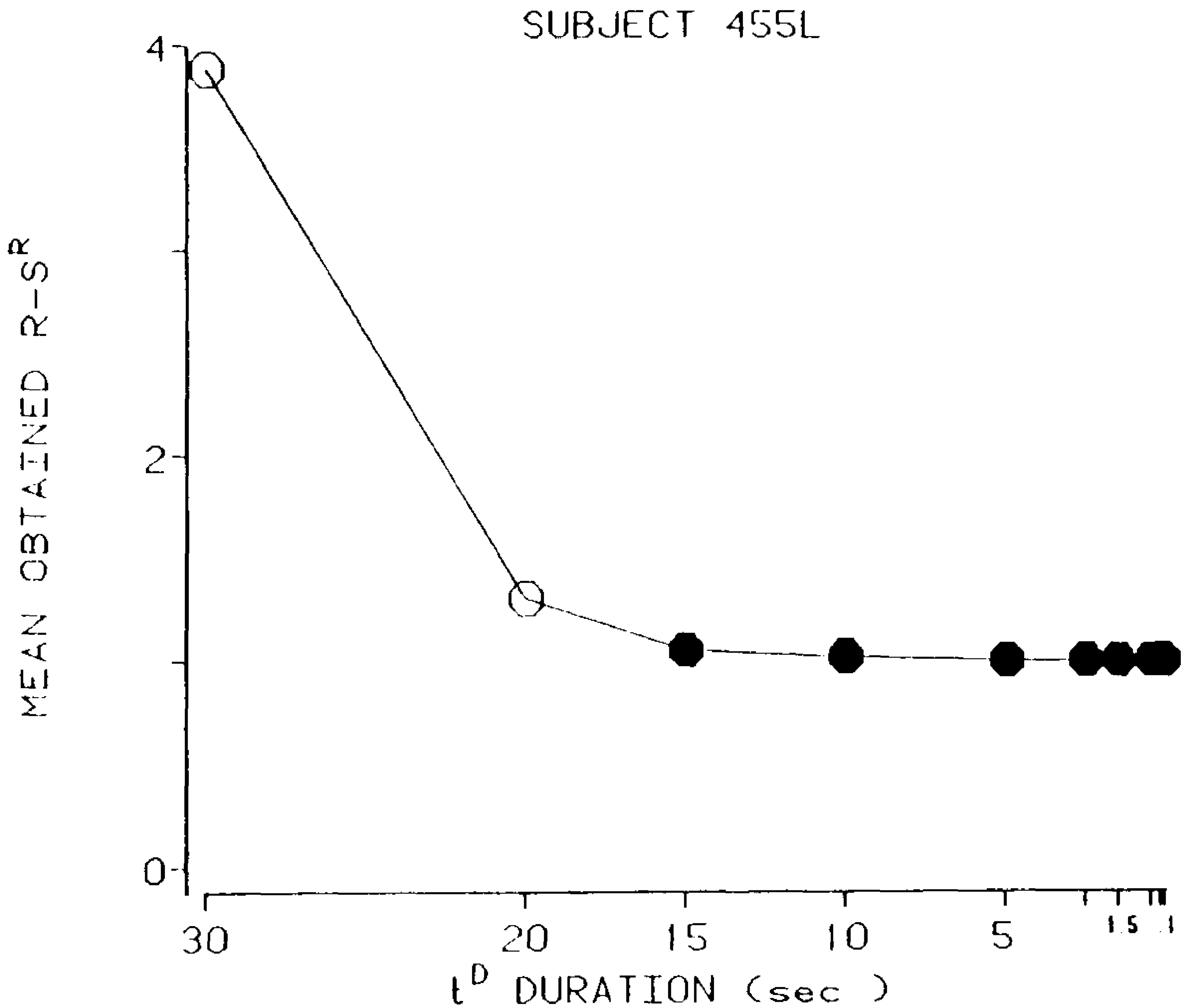
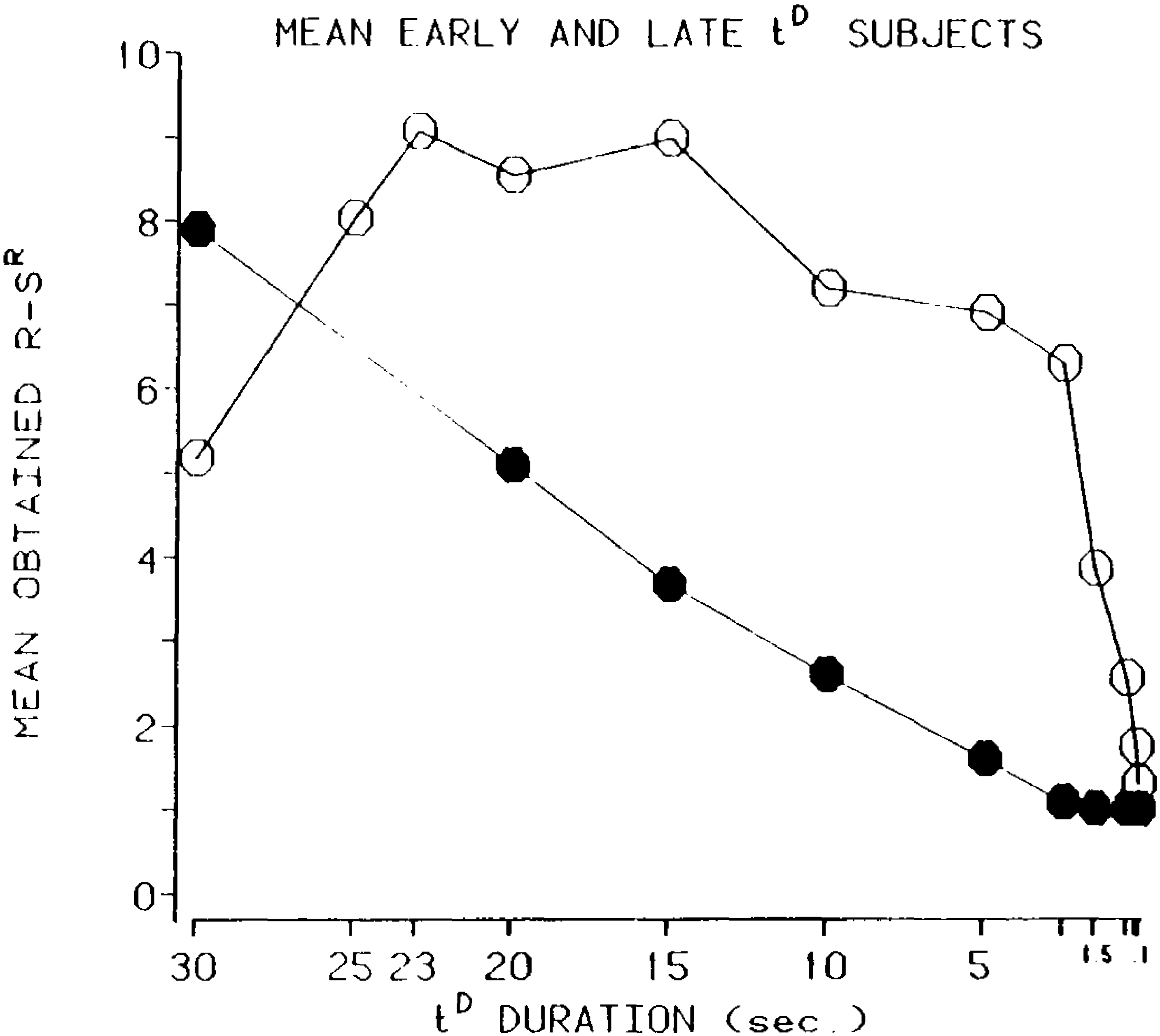
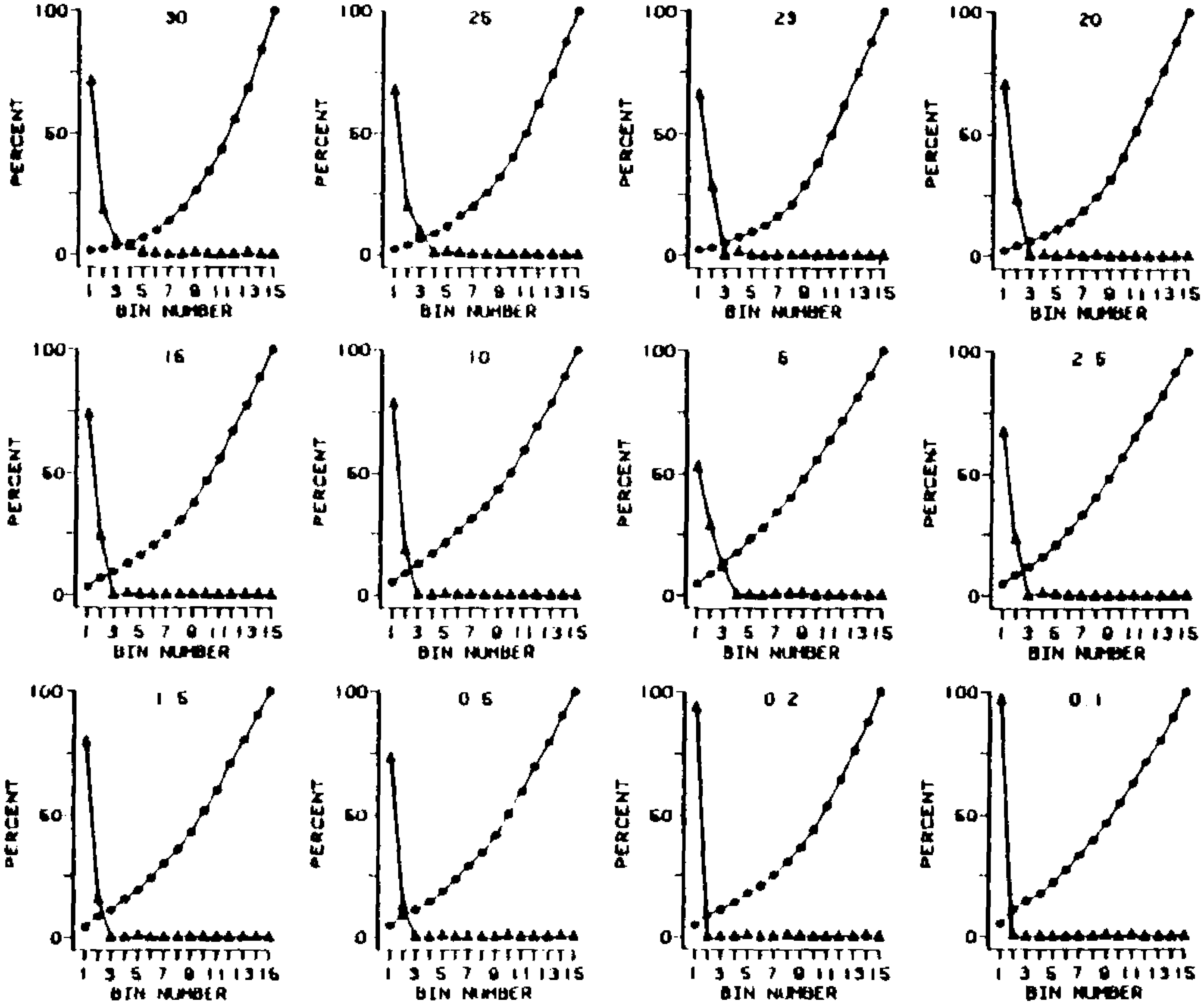

SUBJECT 455L
MEAN OBTAINED R-S^R
4
2
0
30
20
15
10
5
t^D DURATION (sec)

Figure 37. Mean obtained $R-S^R$ in seconds as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 6 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

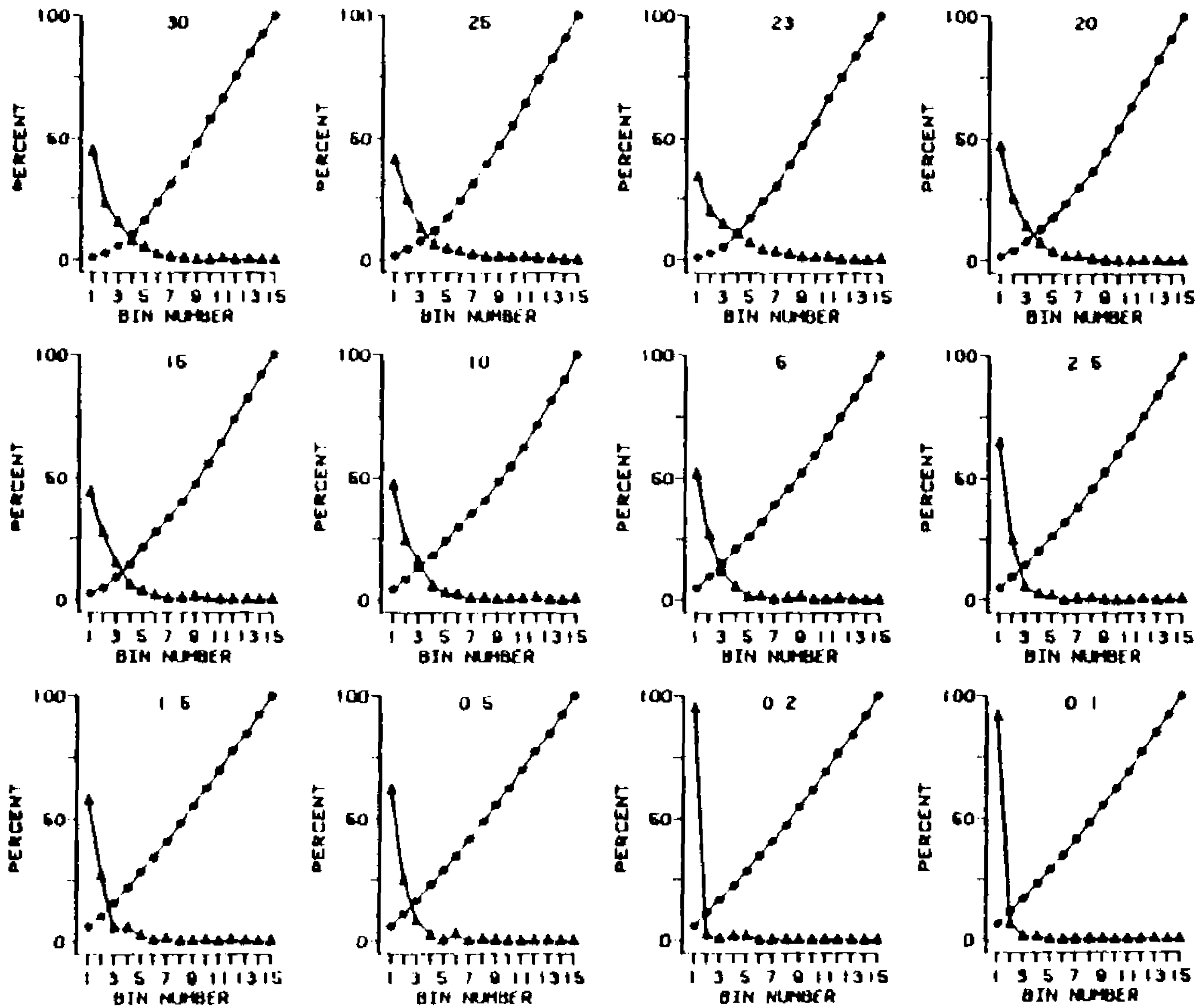

MEAN EARLY AND LATE t^D SUBJECTS
MEAN OBTAINED $R-S^R$
10
8
6
4
2
0
30
25 23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

Figures 38-45. Individual cumulative percent response distribution (filled circles) through T and the obtained frequency distribution of $R-S^R$ (filled triangles) for each t^D duration. The first bin contains the percent of total responses which accumulated during the first two seconds of each T-cycle. On the other hand, bin one was defined as all obtained $R-S^R$ which were between 0.0-2.0 seconds, bin two was all obtained $R-S^R$ which were between 2.0-4.0 seconds and soon up to bin fifteen which was all obtained $R-S^R$ greater than 28.0 seconds.

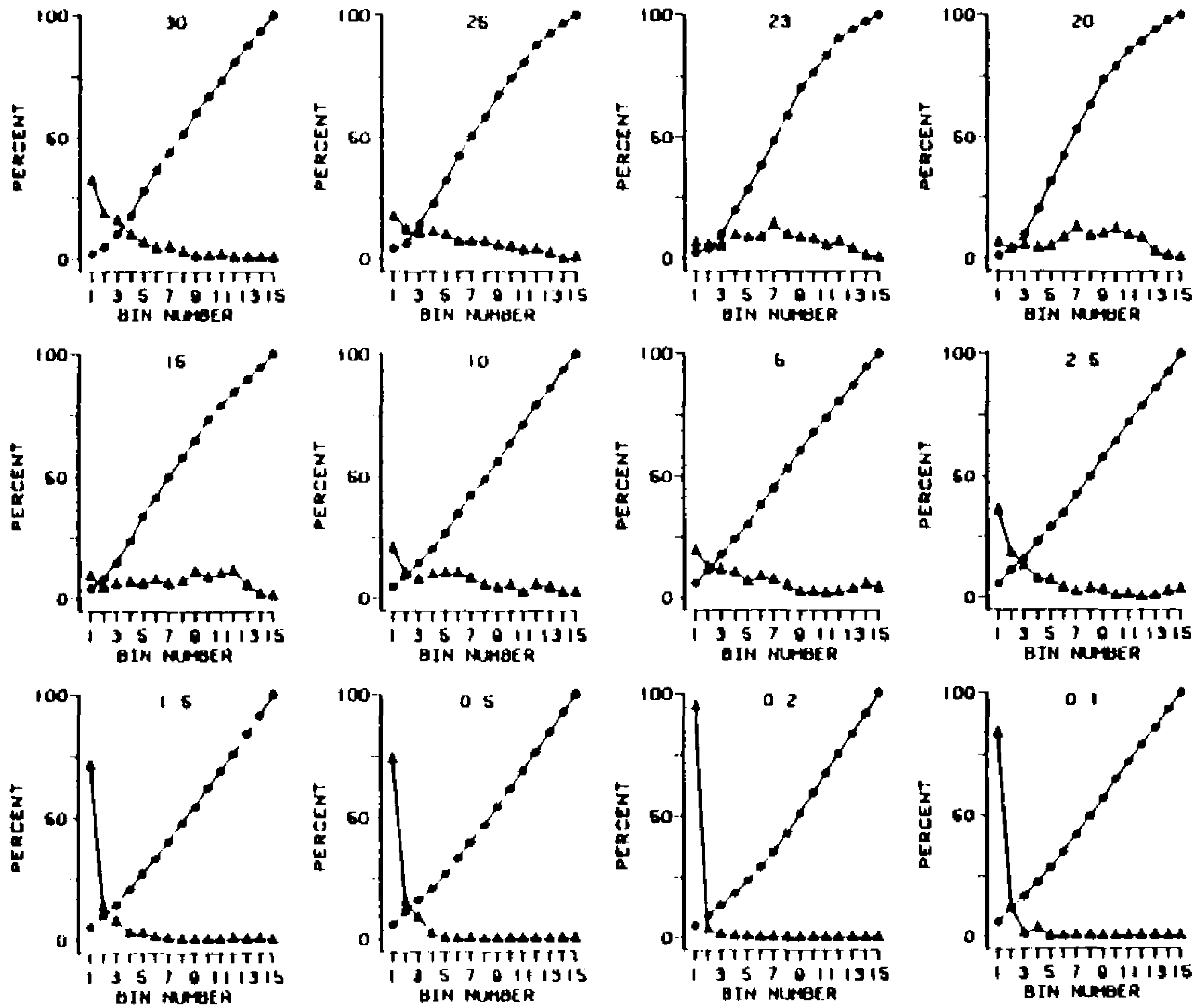
152 E



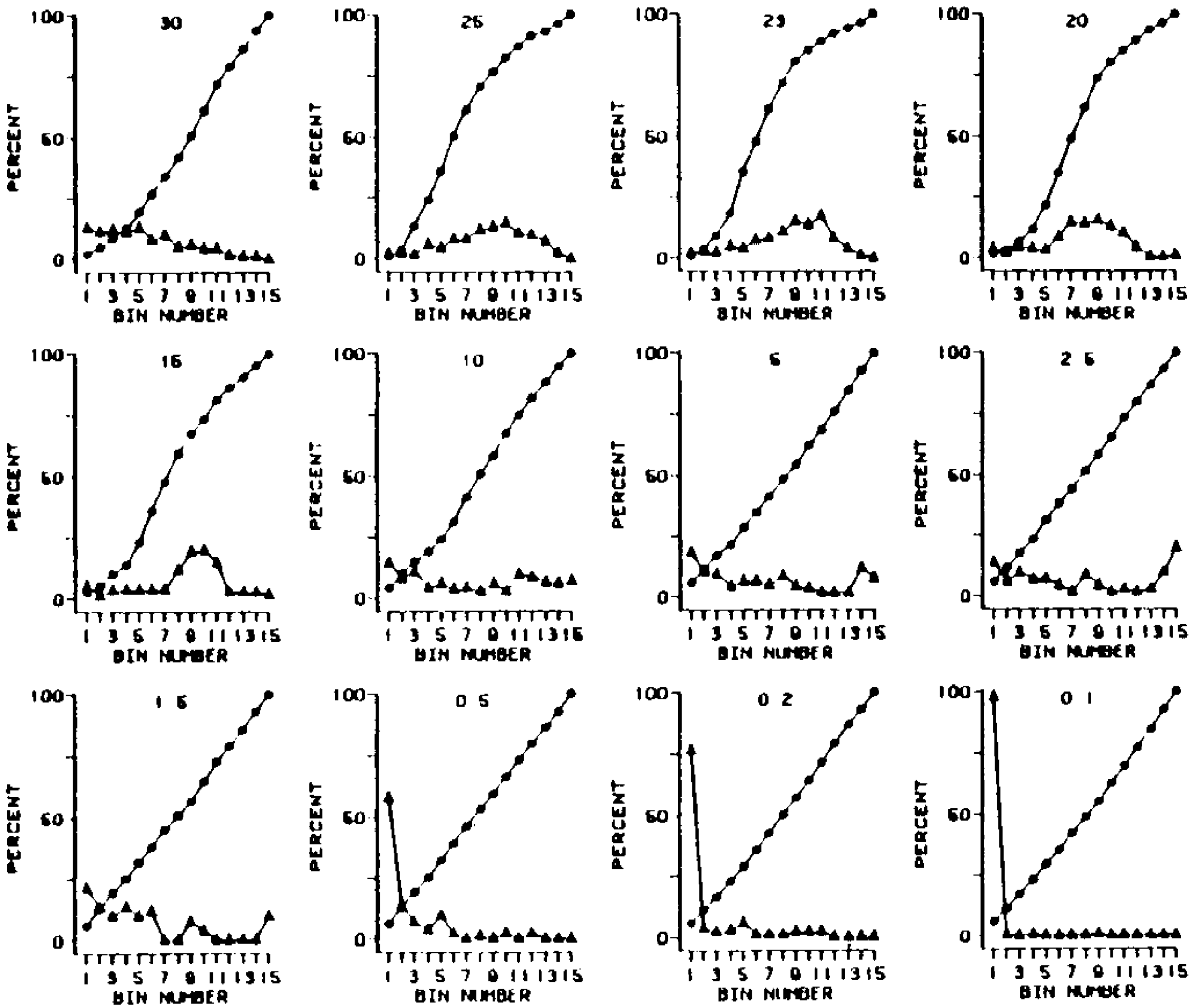
153 E



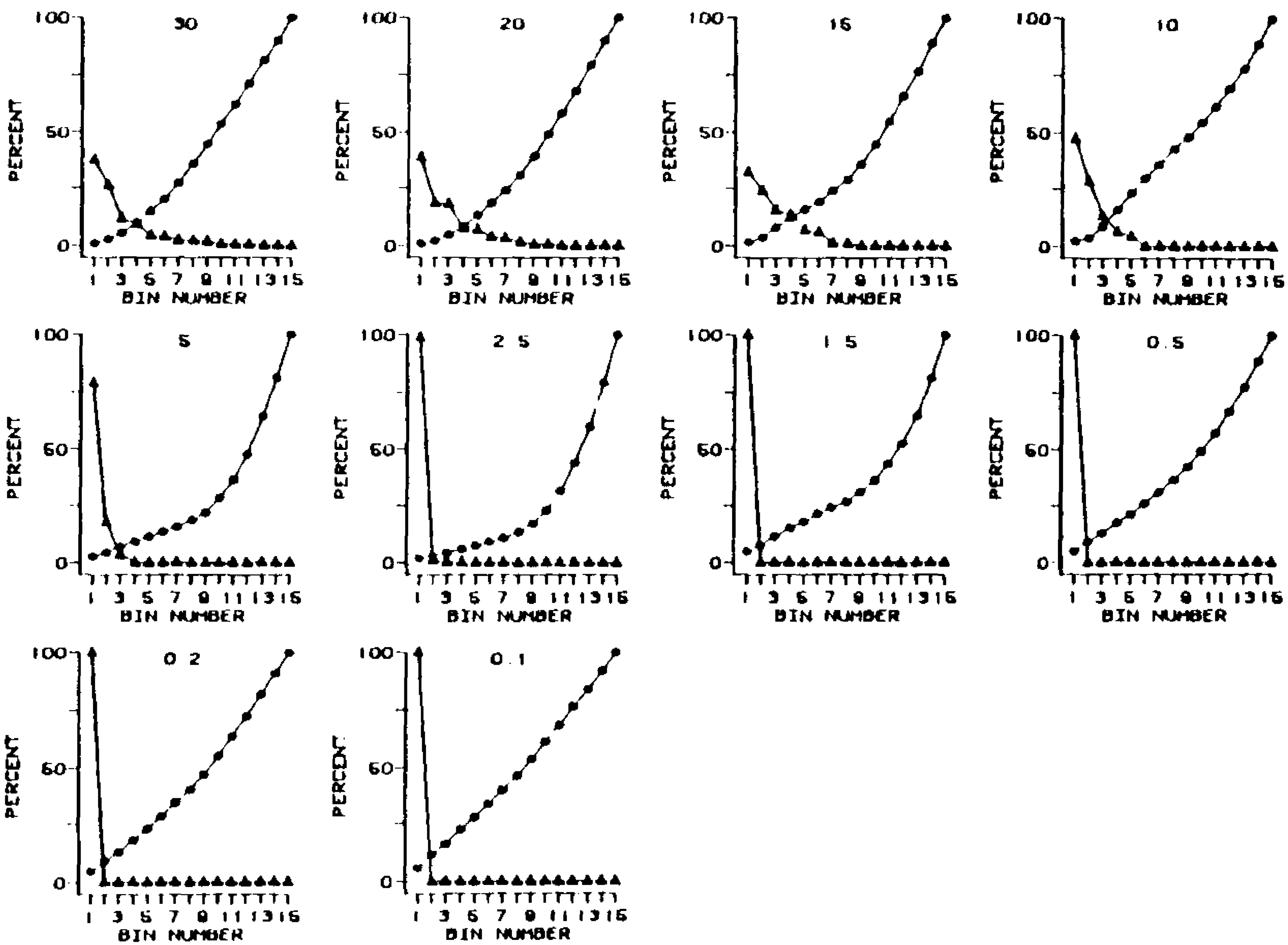
159 E



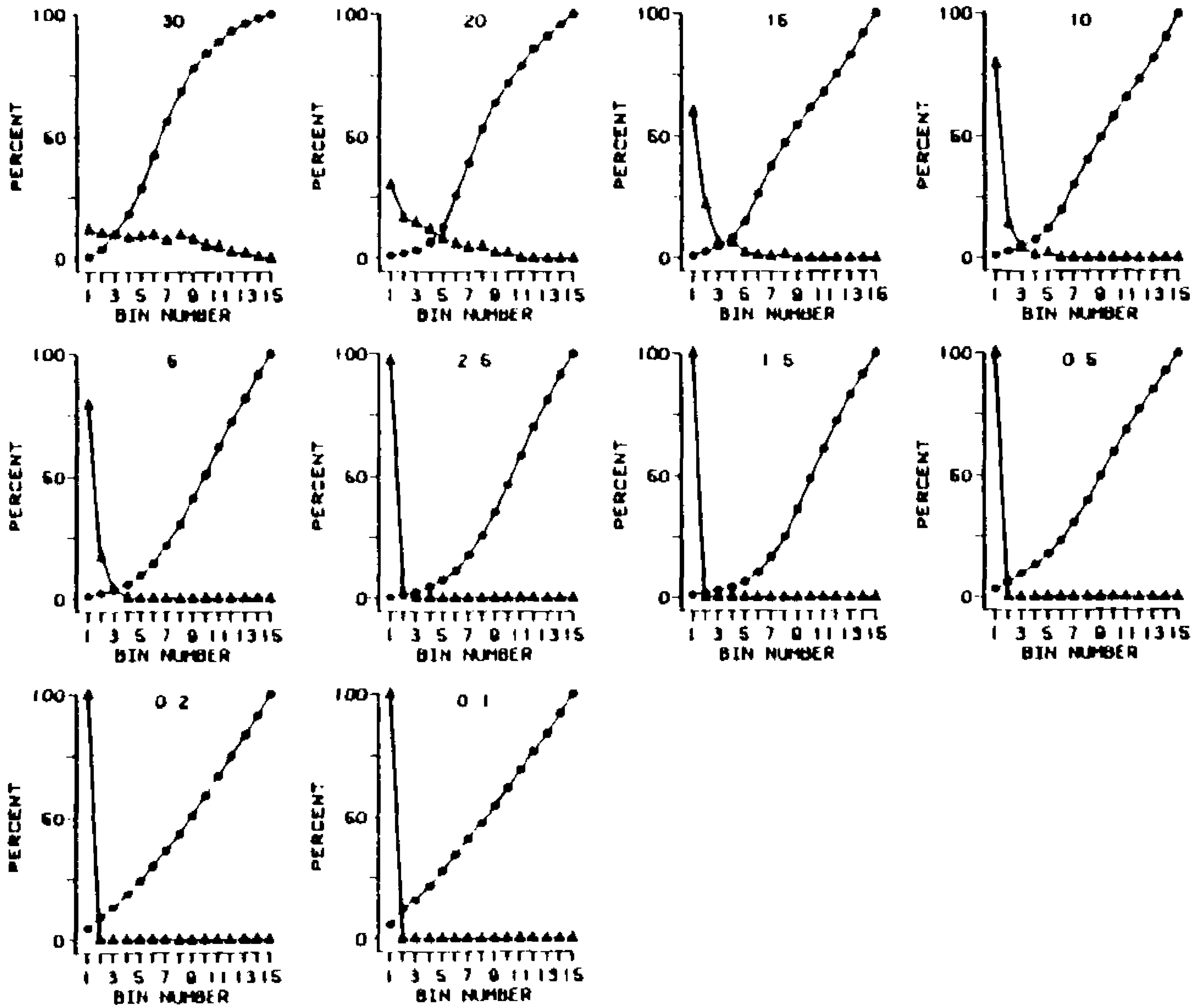
160E



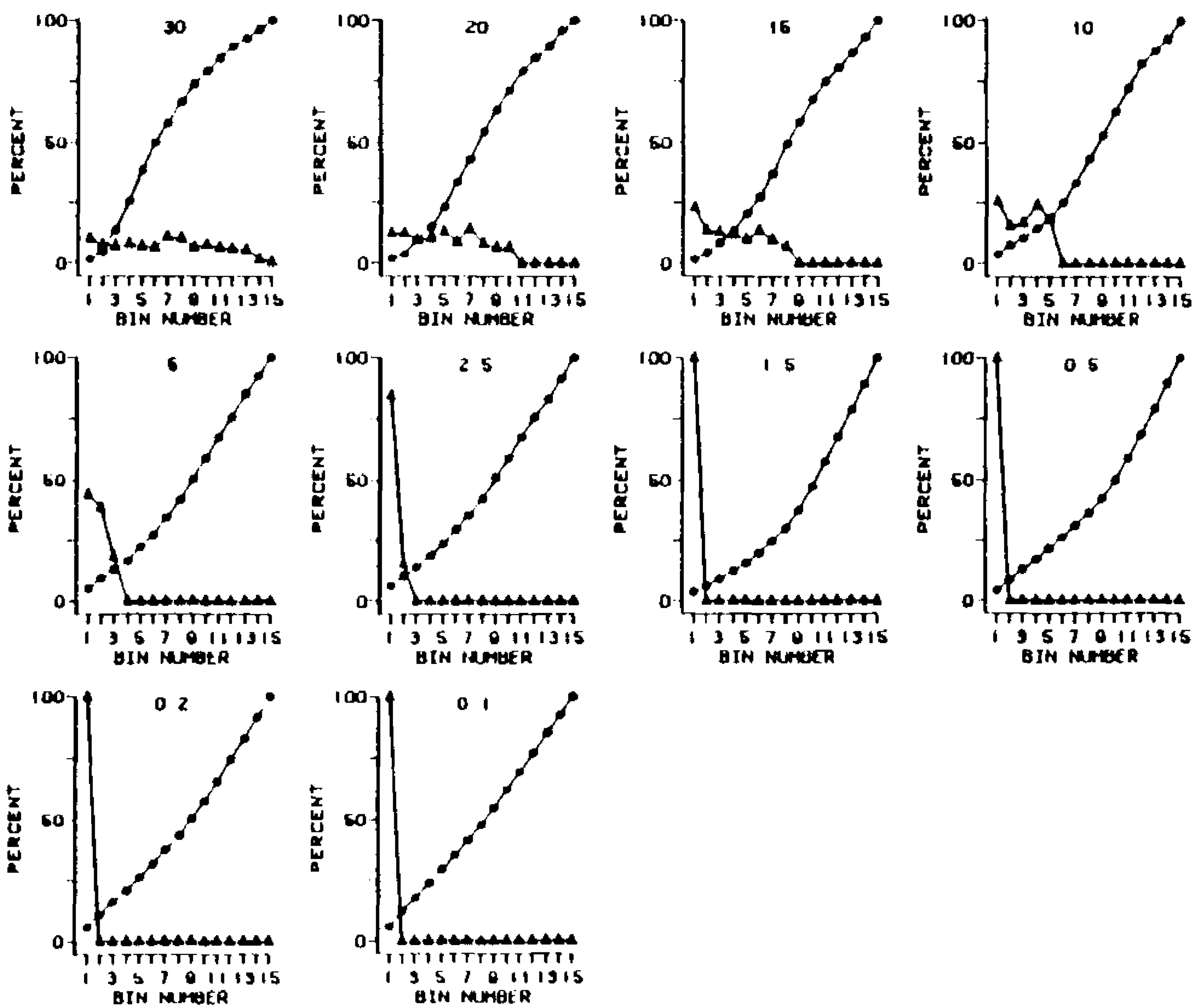
151L



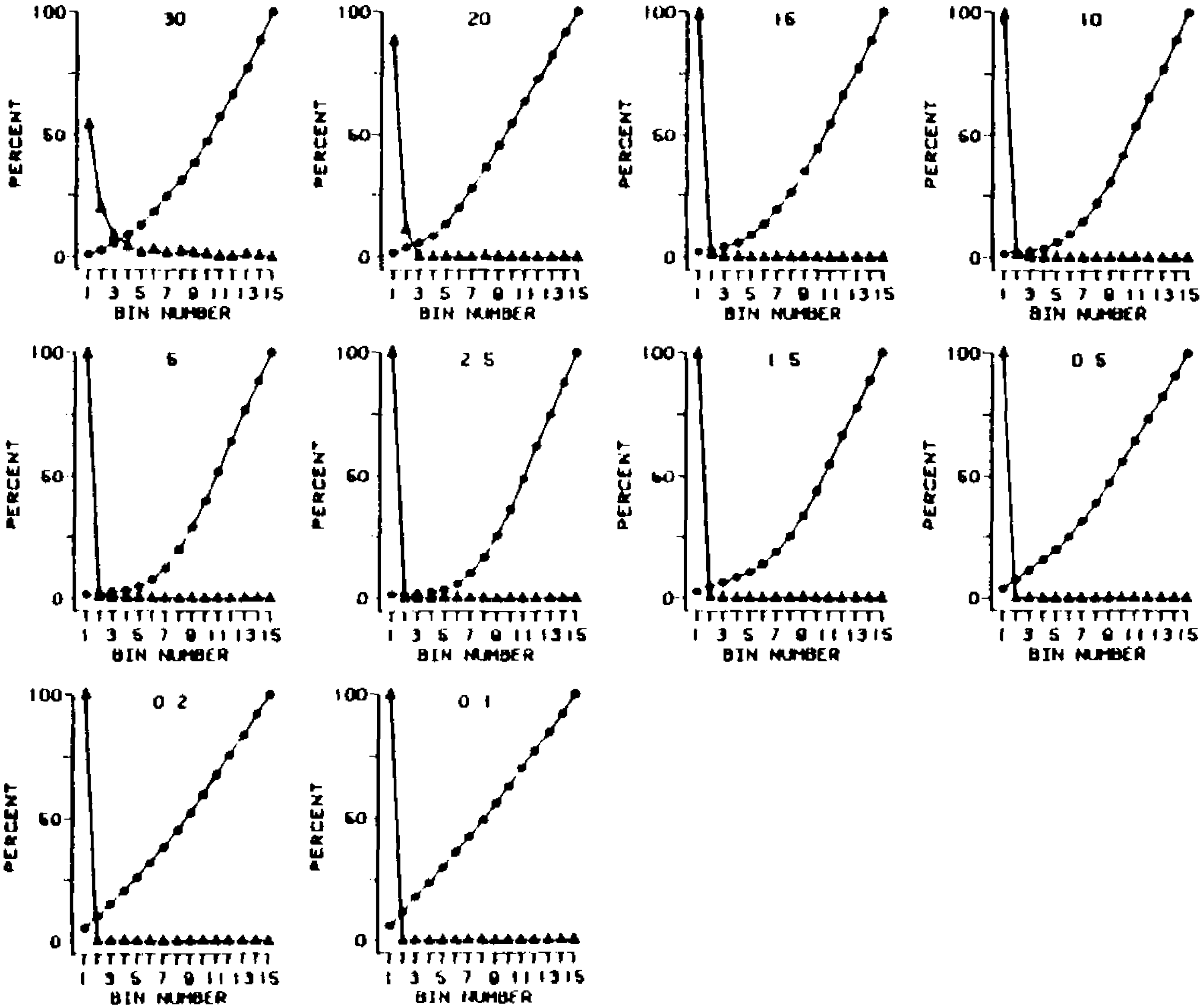
156L



161L

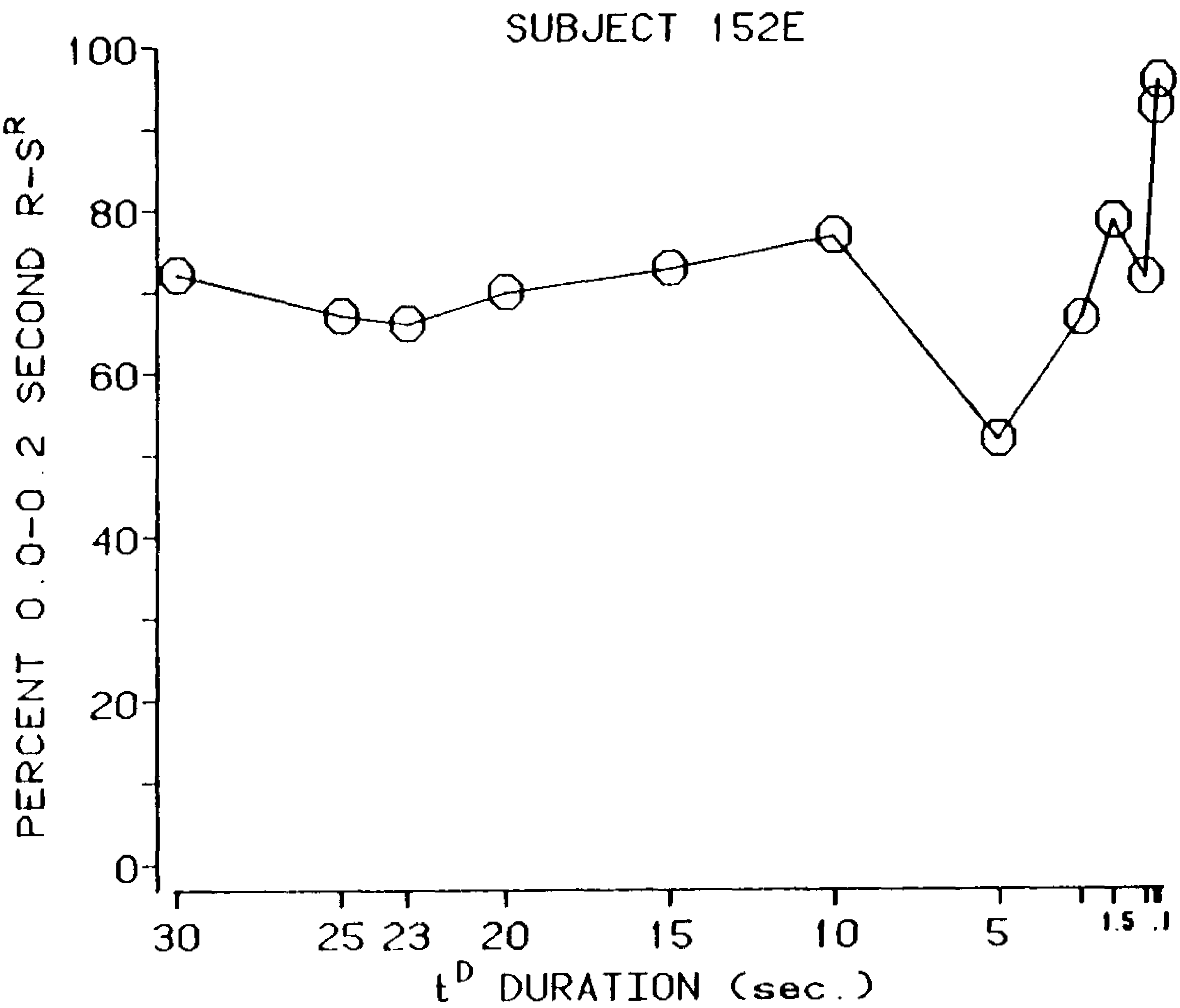


455L

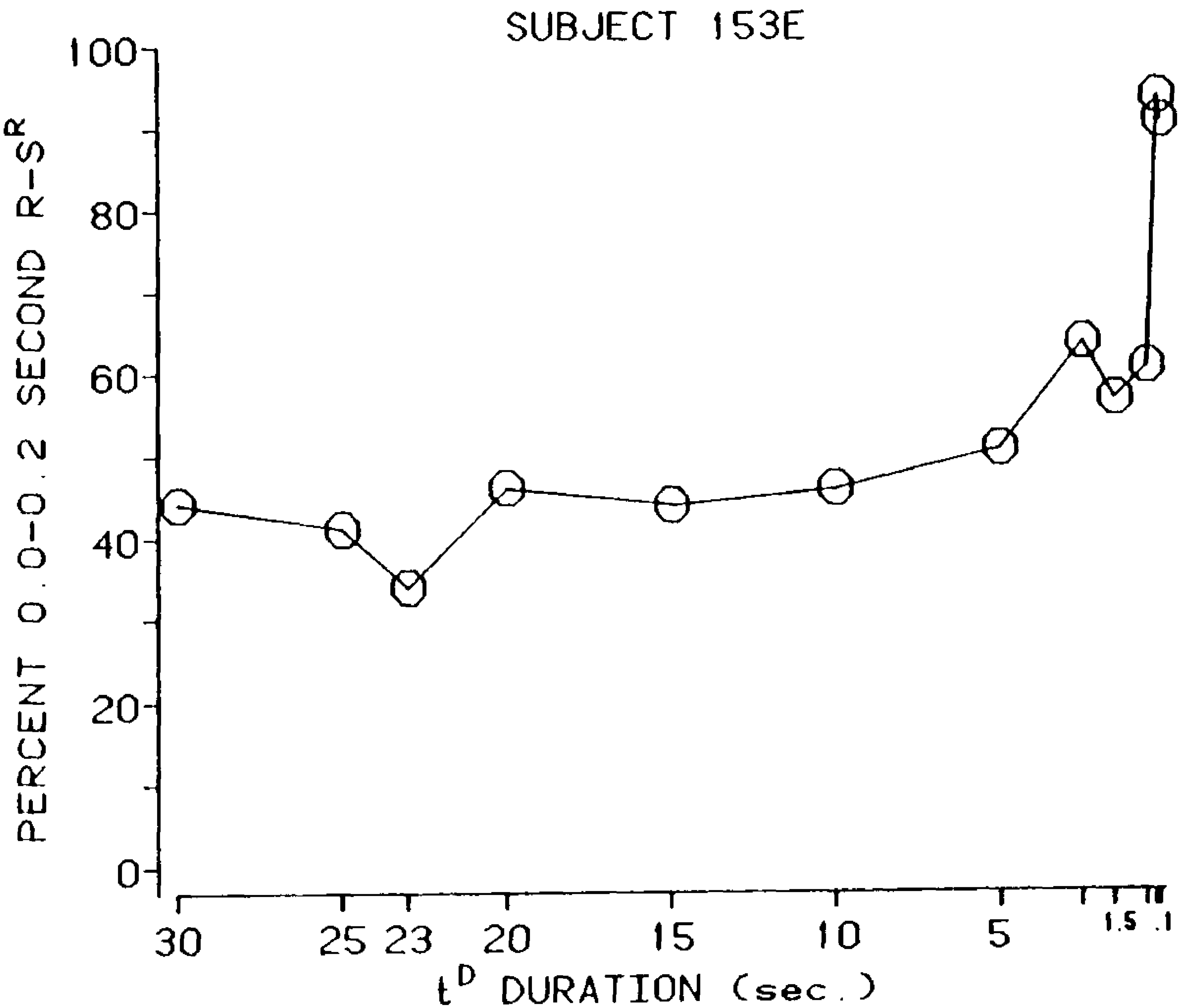


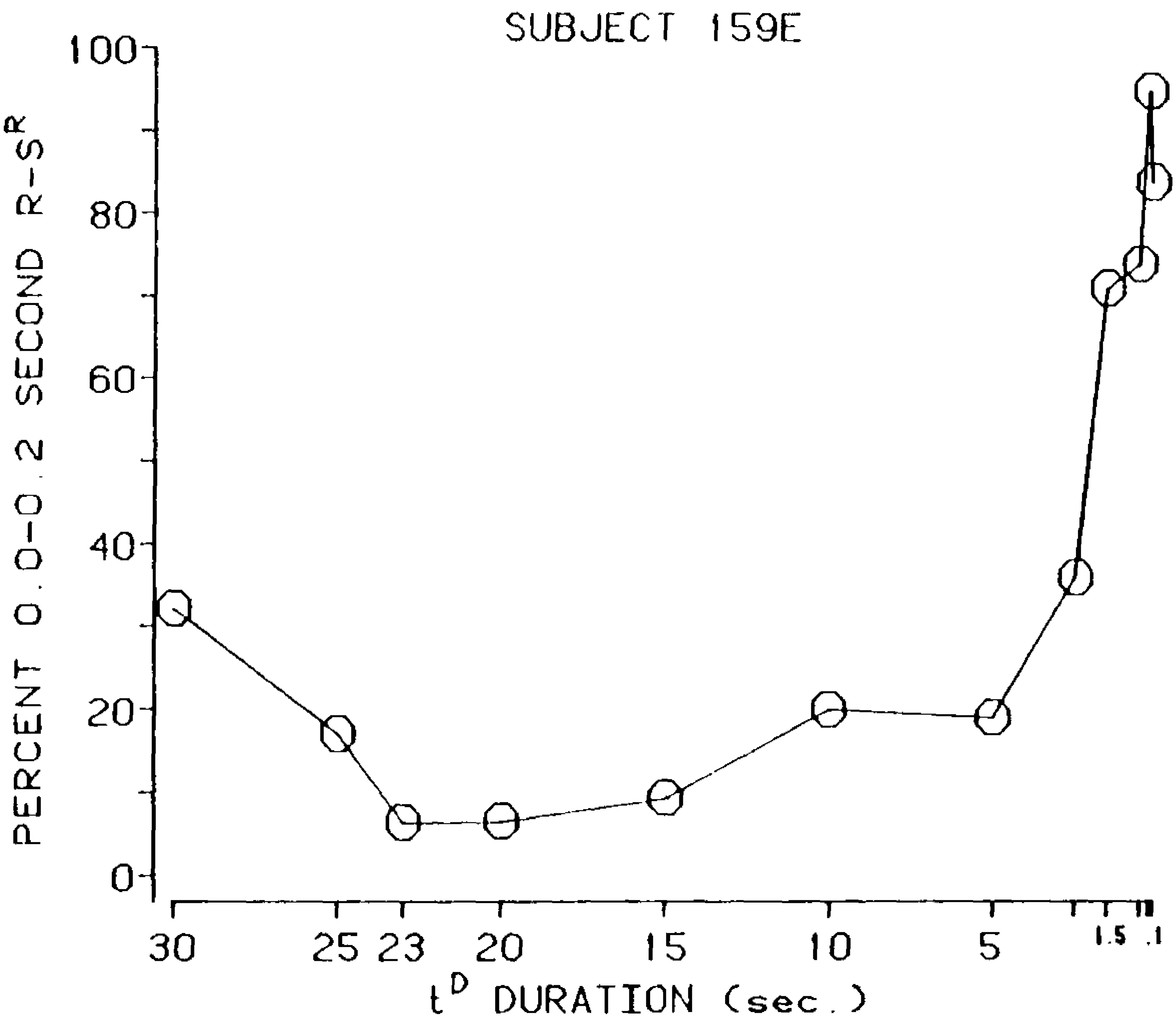
30
20
16
10
5
2 5
1 5
0 5
0 2
0 1
PERCENT
100
60
0
1 3 5 7 9 11 13 15
BIN NUMBER

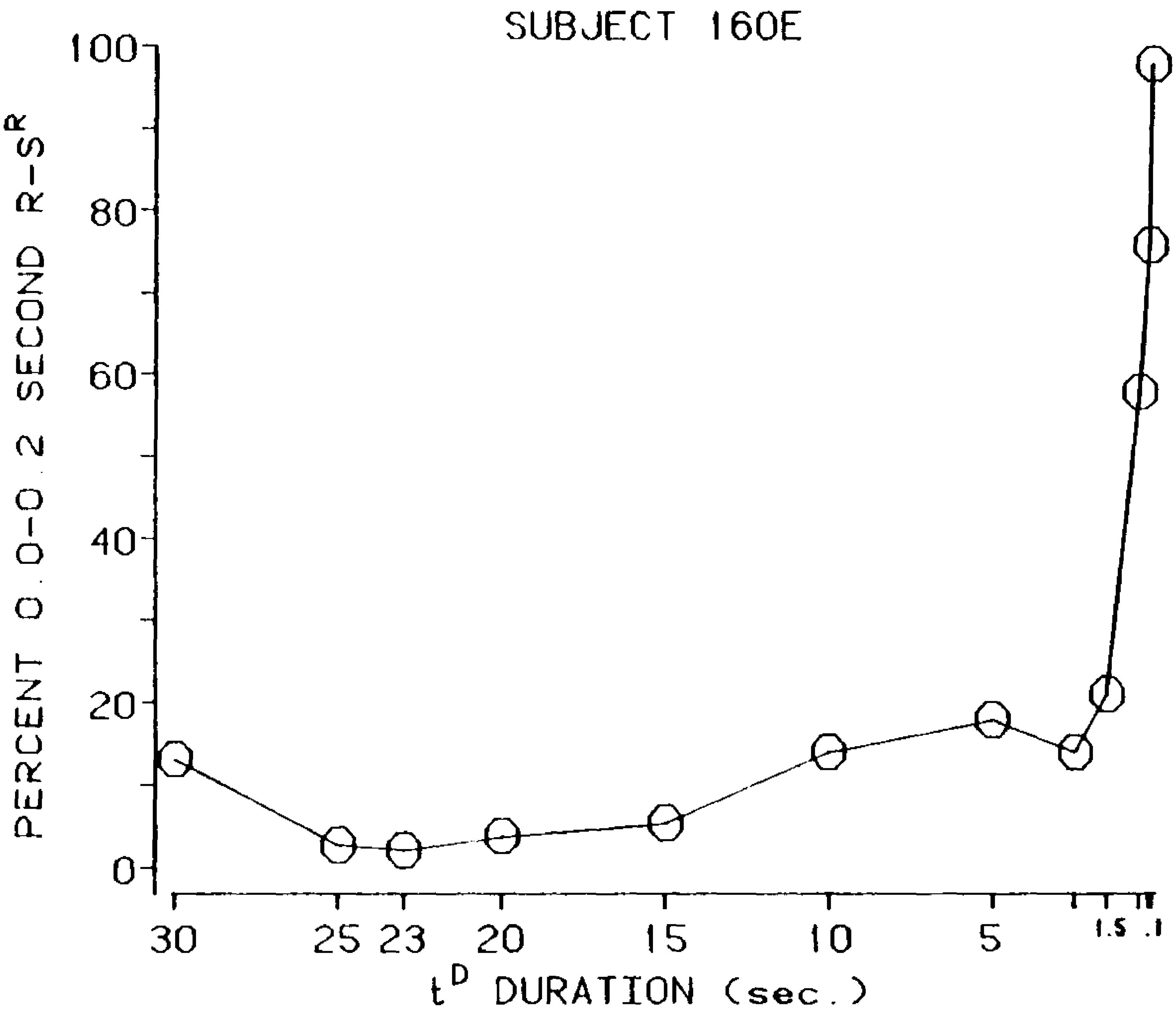
Figures 46-53. Percent of total 0.0-2.0 seconds $R\text{-}S^R$ as a function of t^D duration for each subject. The values for the points plotted are presented in Table 7 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

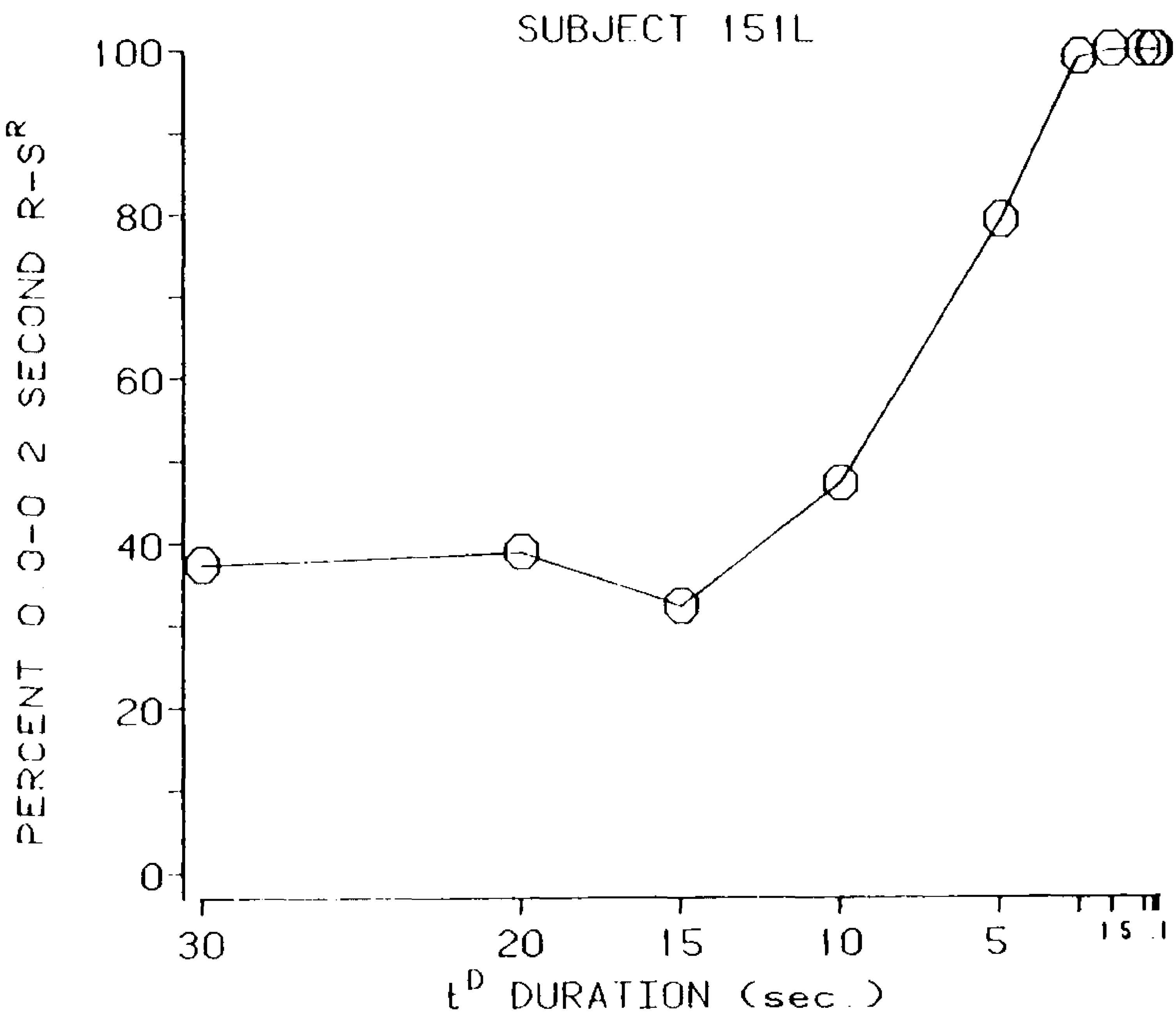


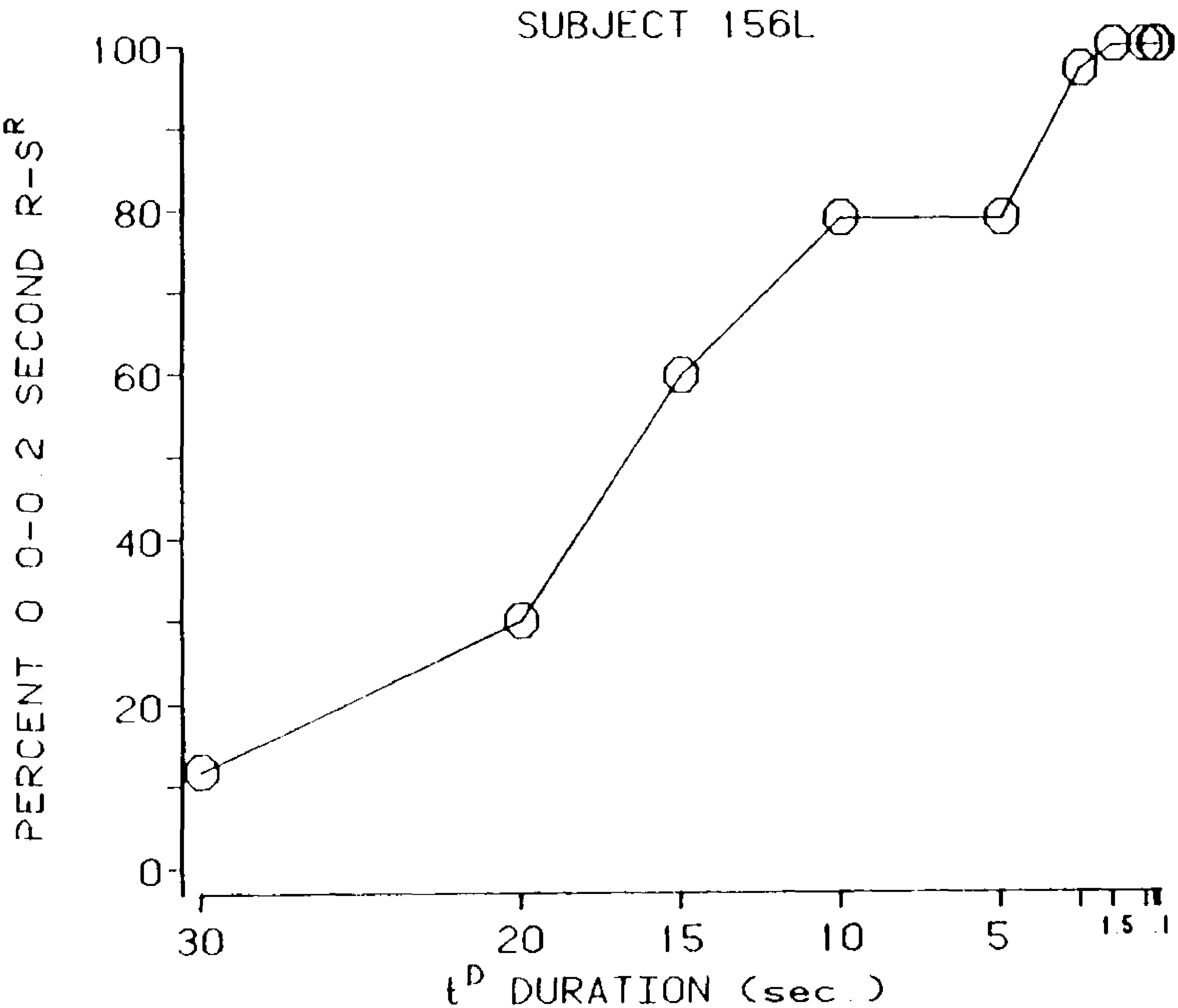
SUBJECT 152E
100
80
60
40
20
0
PERCENT 0.0-0.2 SECOND R-S^R
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)

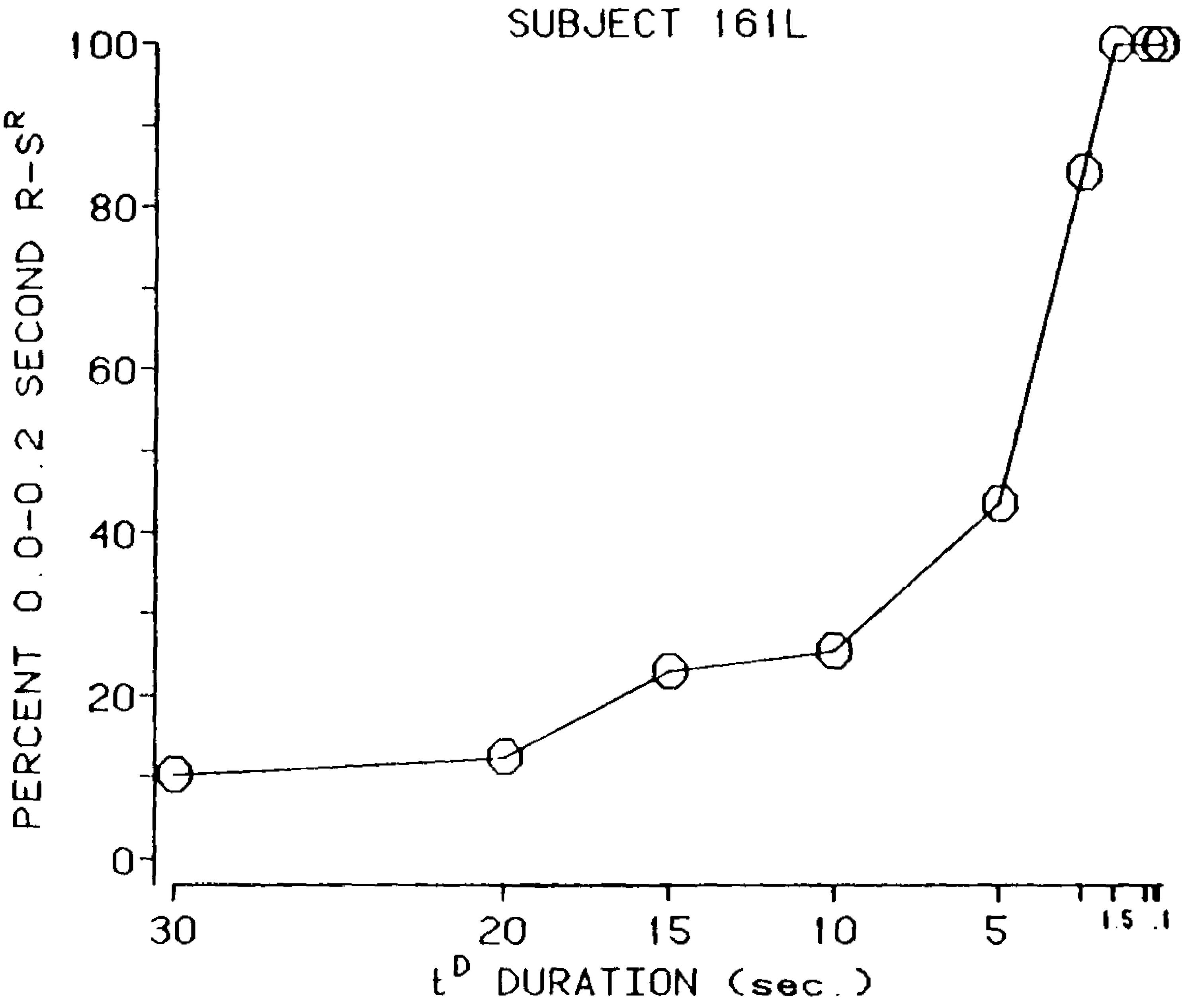

SUBJECT 153E
PERCENT 0.0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 159E
PERCENT 0.0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 160E
PERCENT 0.0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
25
23
20
15
10
5
1.5
.1
t^D DURATION (sec.)


SUBJECT 151L
PERCENT 0 0-0 2 SECOND R-S^R
100
80
60
40
20
0
30
20
15
10
5
t^D DURATION (sec.)


SUBJECT 156L
PERCENT O 0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)



SUBJECT 161L
PERCENT 0.0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
20
15
10
5
1.5 .1
t^D DURATION (sec.)

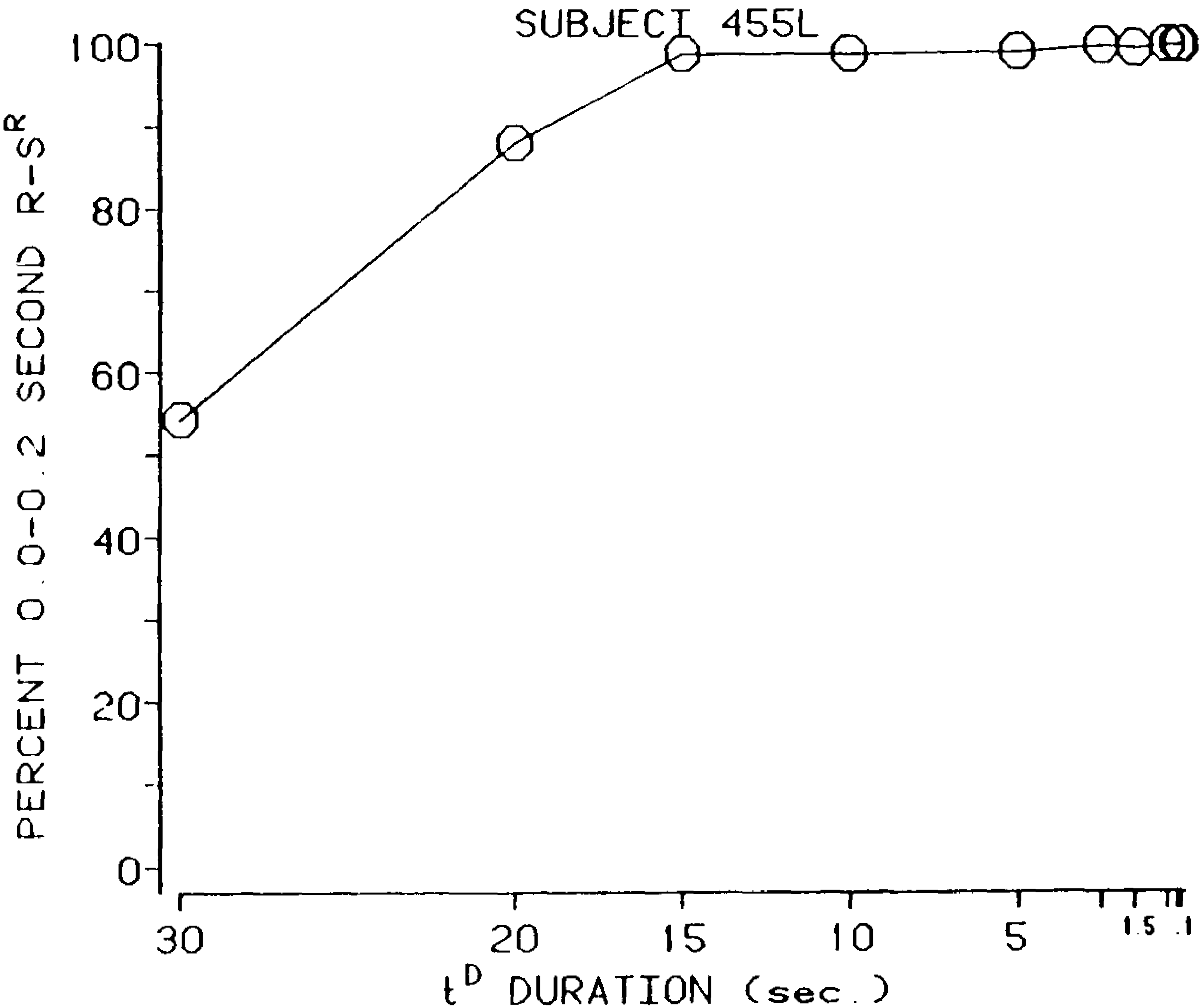
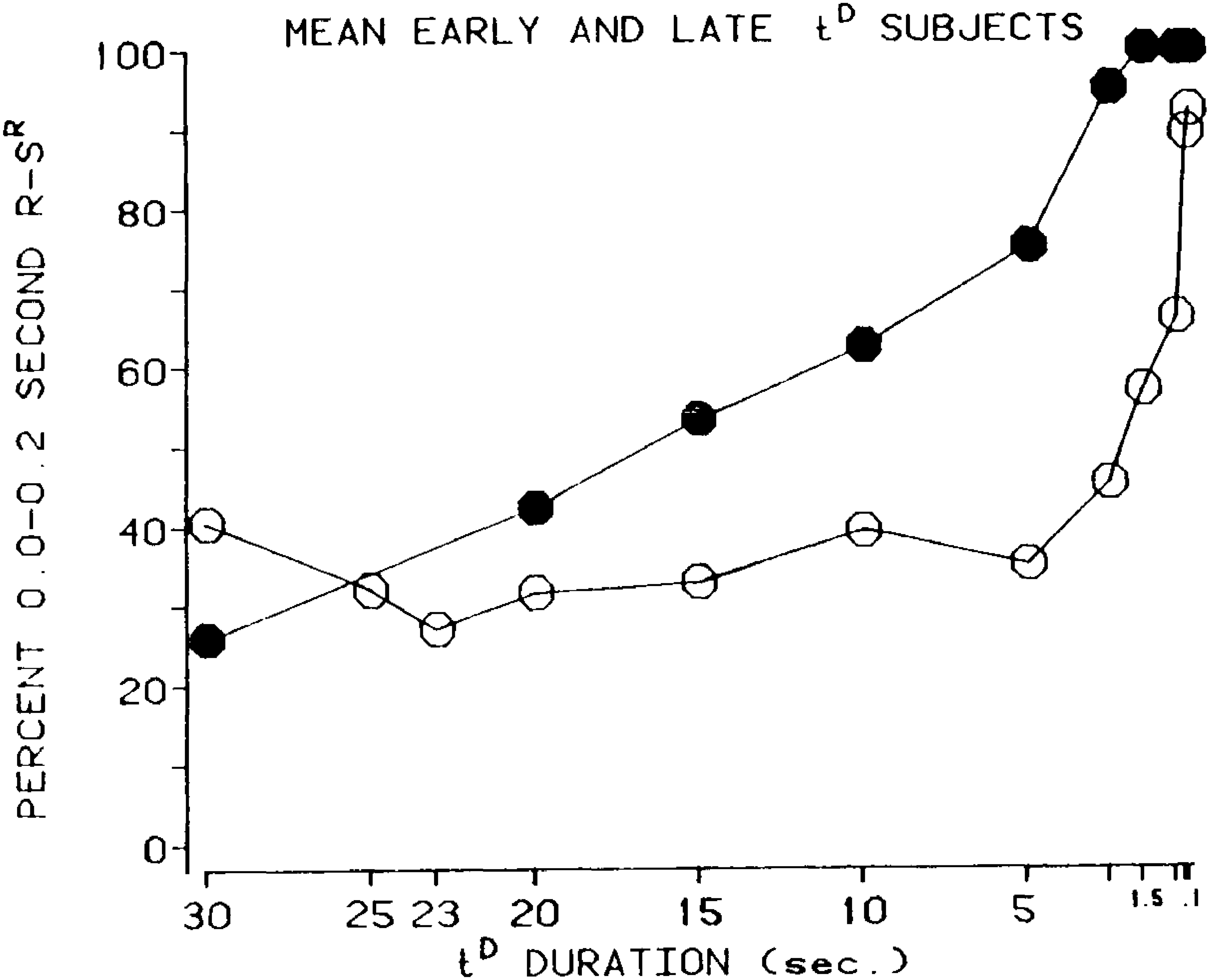
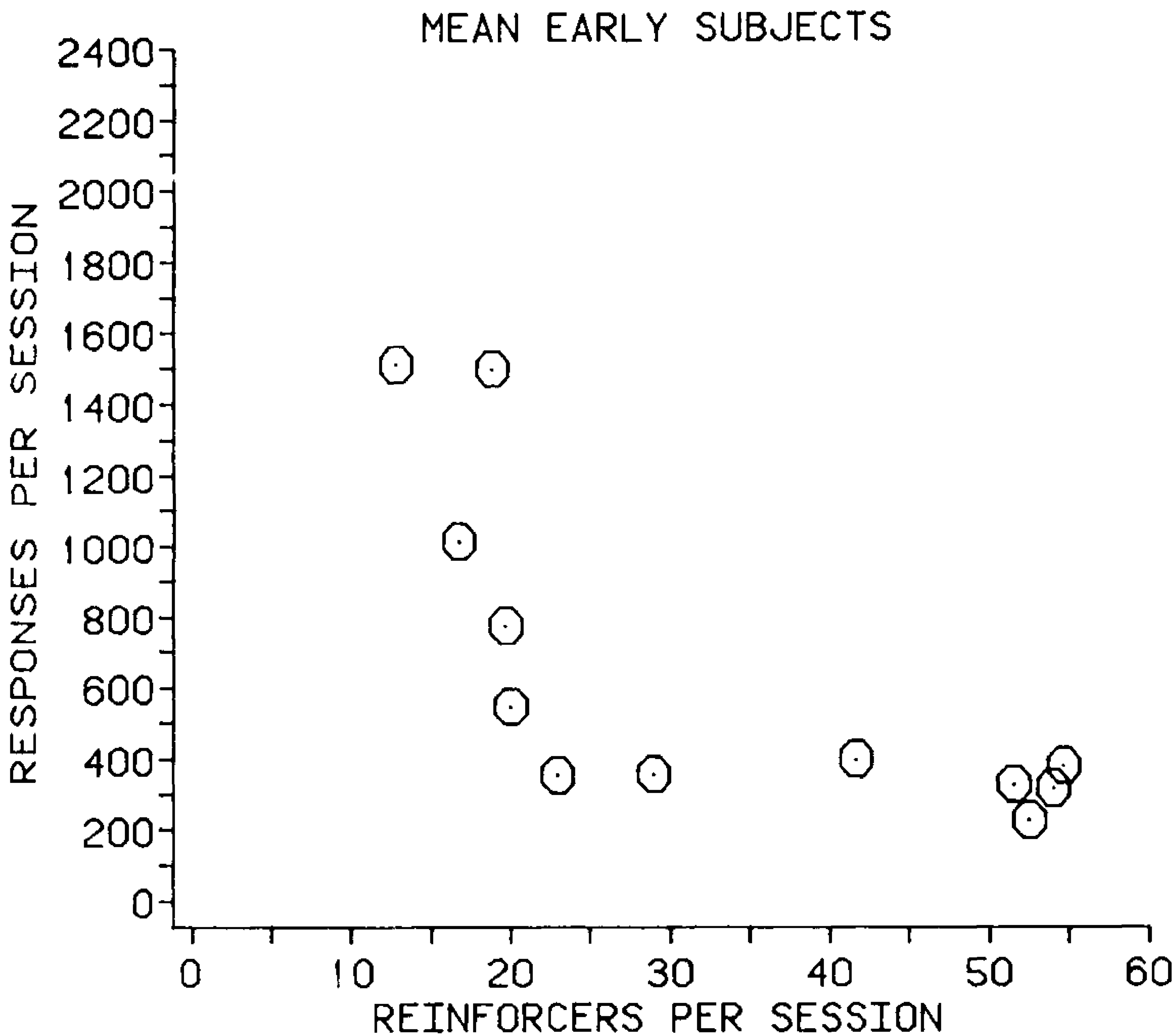
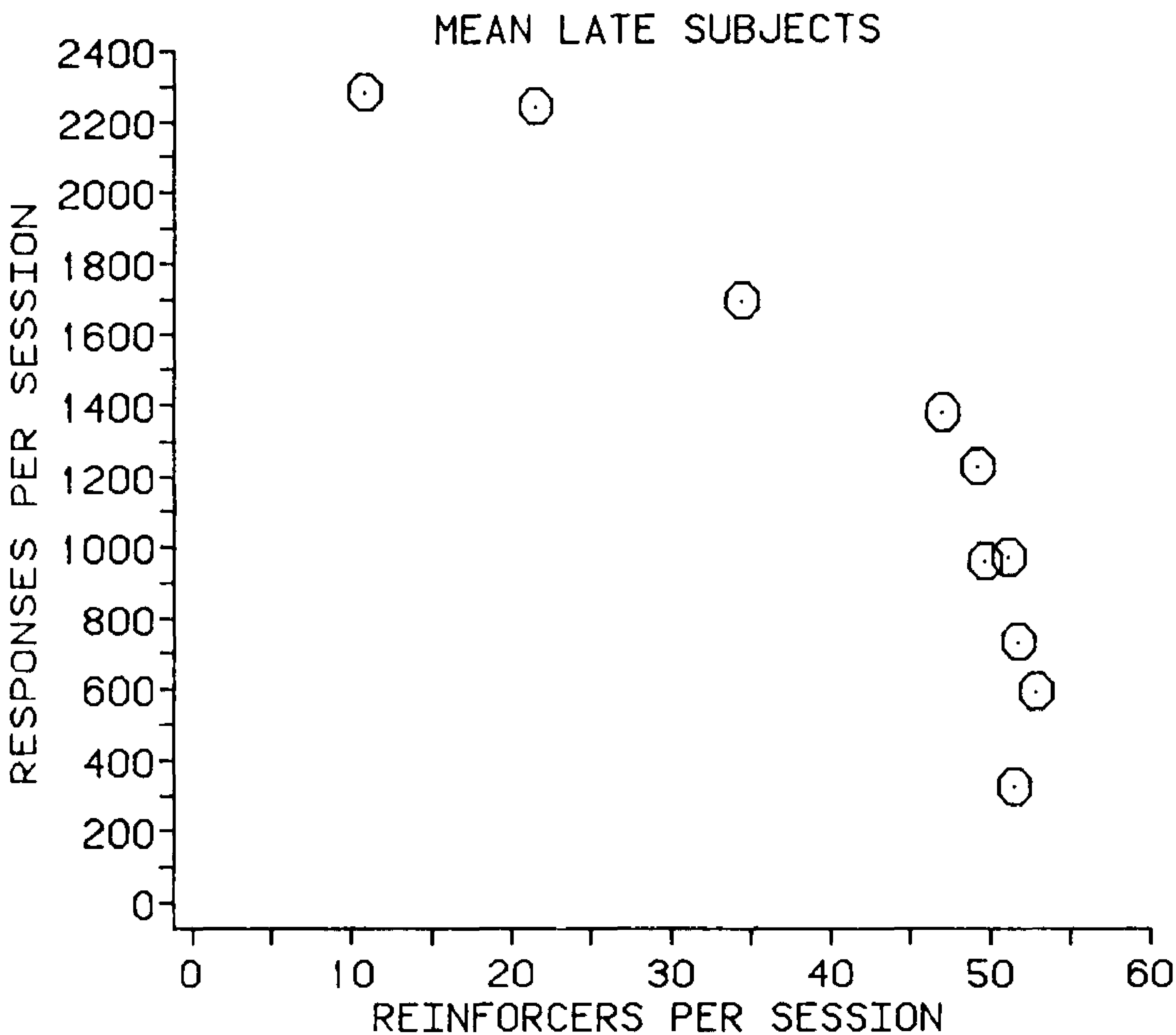

SUBJECT 455L
PERCENT 0.0-0.2 SECOND R-S^R
100
80
60
40
20
0
30
20
15
10
5
1.5
.1
t^D DURATION (sec.)

Figure 54. Mean percent of total 0.0-2.0 as a function of t^D duration for the early (open circles) and late (filled circles) t^D placements. The points plotted are means computed from the four subjects in each t^D placement group. The plotted means and their standard errors are presented in Table 7 (see Appendix). The x-axis is labeled from 30.0 seconds to 0.1 second because this order reflects the systematic decreases in t^D duration to which the subjects were exposed.

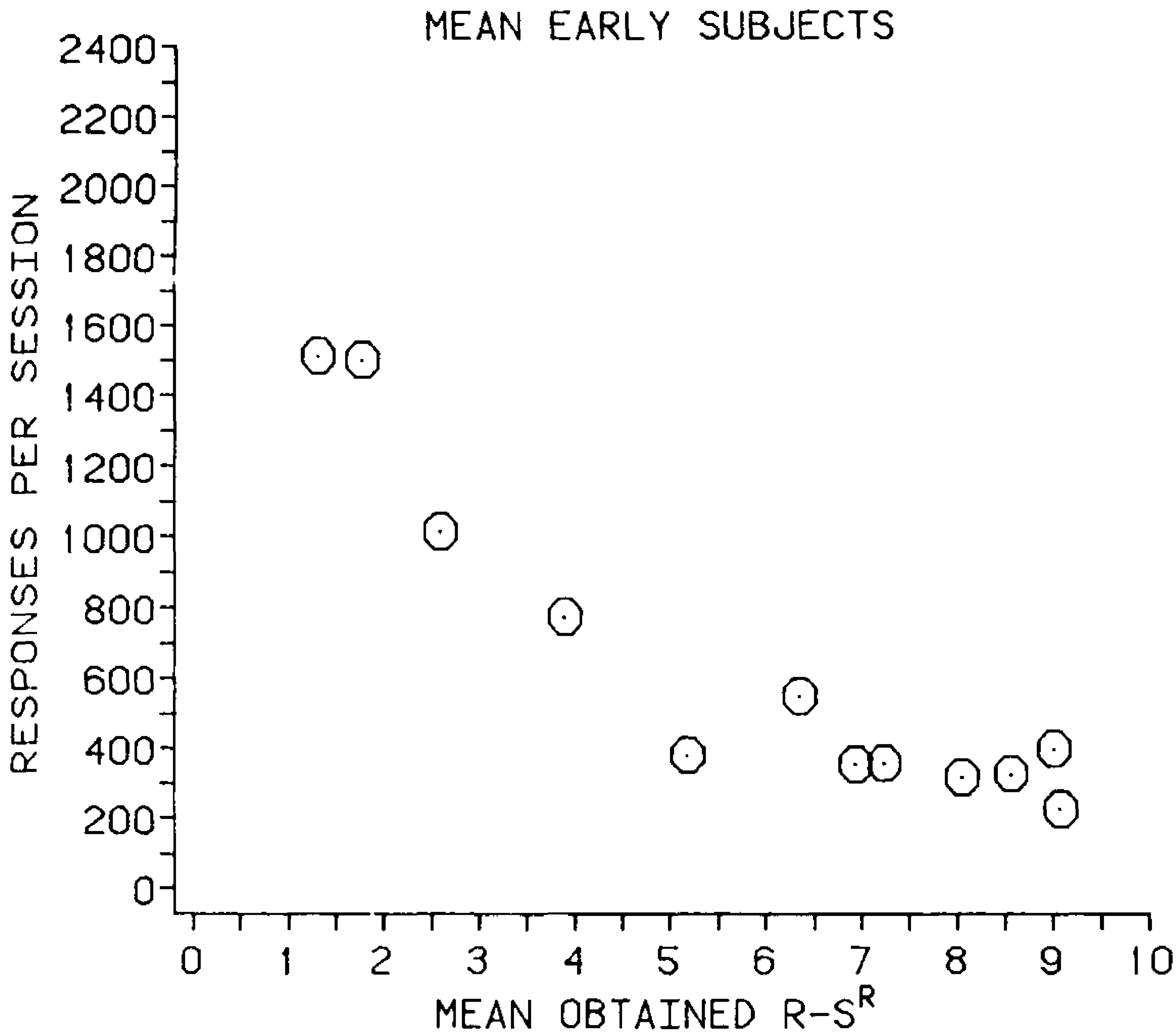

MEAN EARLY AND LATE t^D SUBJECTS
PERCENT 0.0-0.2 SECOND $R-S^R$
100
80
60
40
20
0
30
25 23
20
15
10
5
1.5 .1
t^D DURATION (sec.)

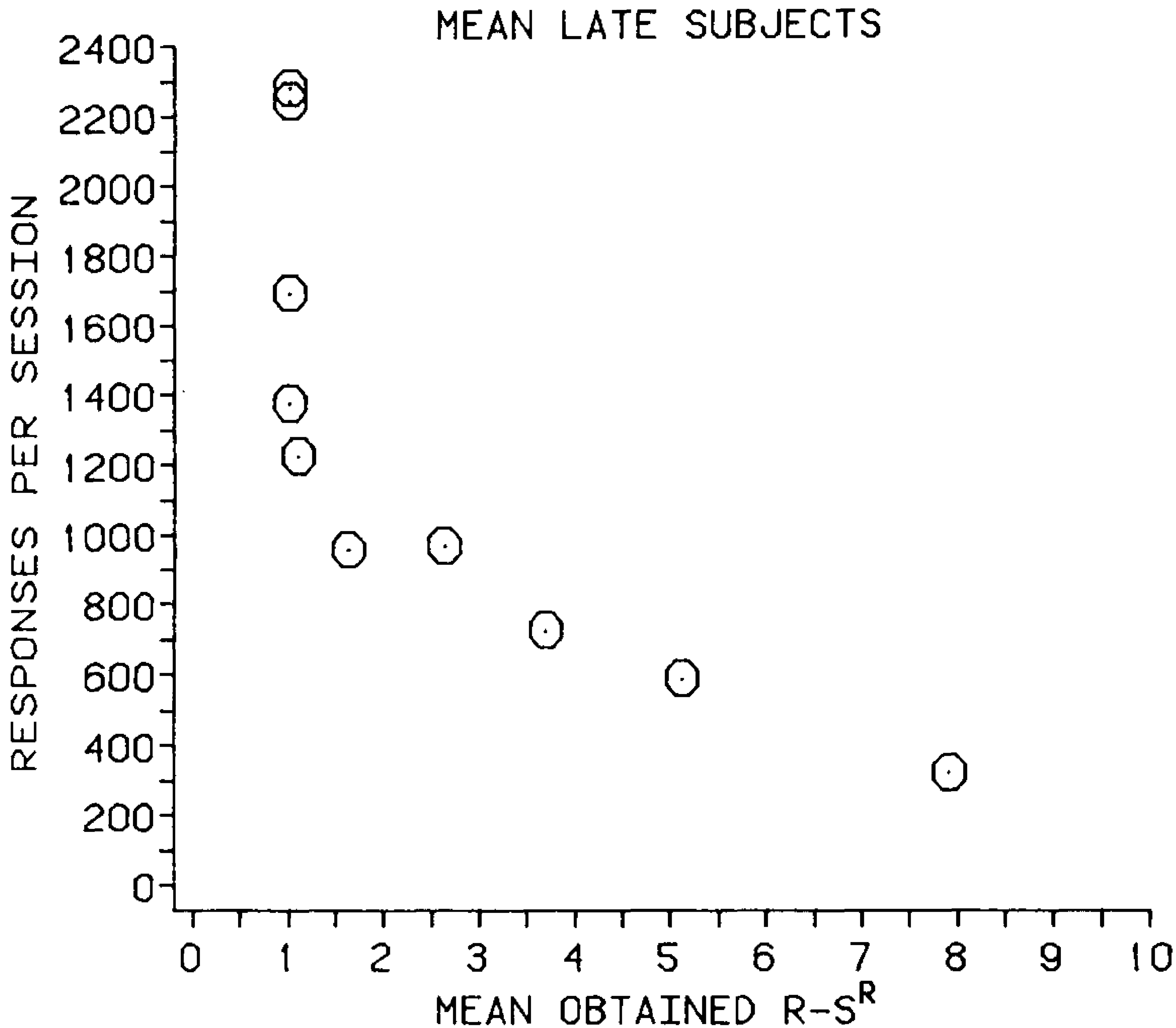
Figures 55a & b. Mean responses per session as a function of mean reinforcers per session. At each t^D duration the calculated group mean responses per session and the group mean reinforcers per session become the coordinates of the plotted data points.


MEAN EARLY SUBJECTS
RESPONSES PER SESSION
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
REINFORCERS PER SESSION

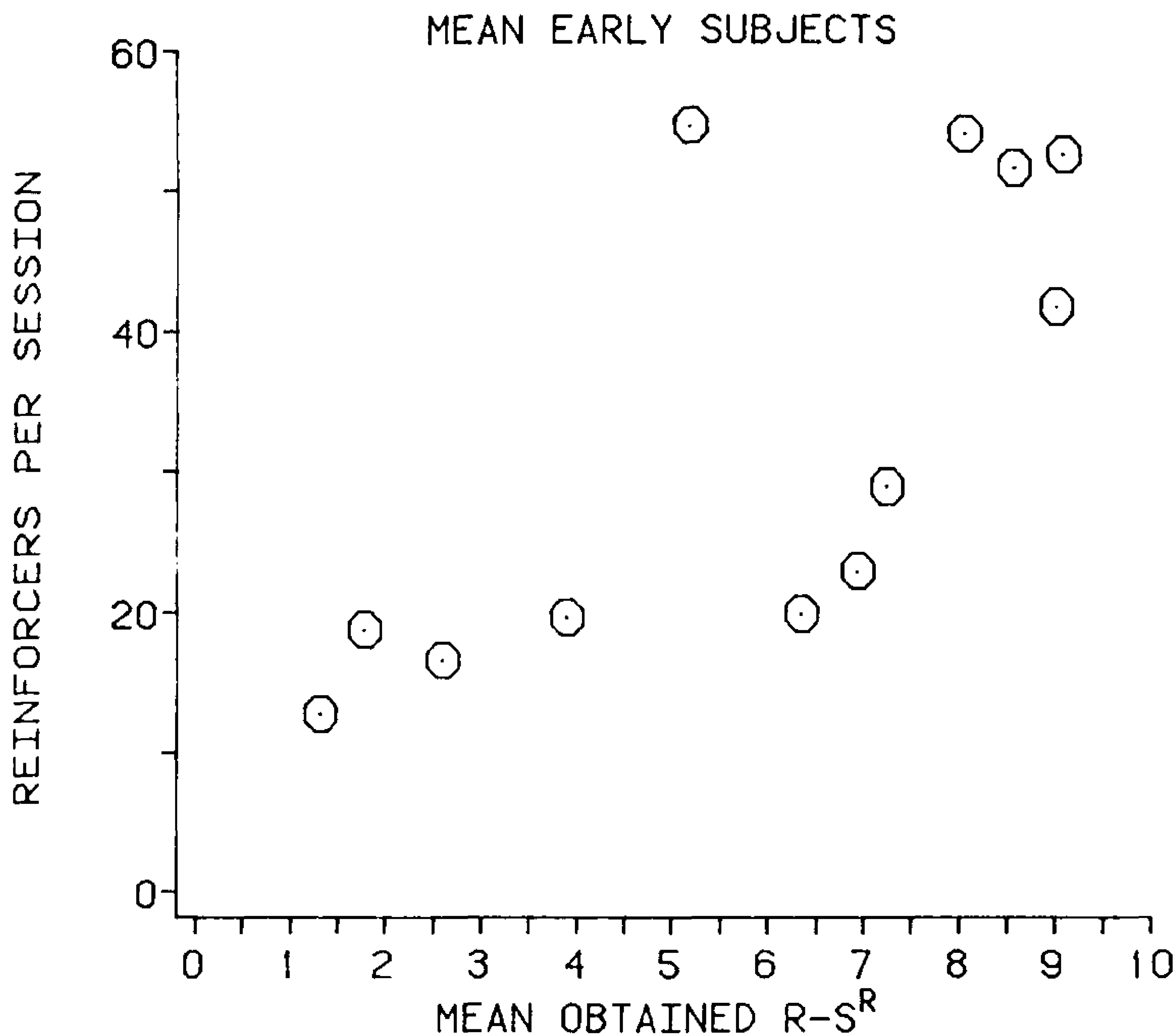

MEAN LATE SUBJECTS
RESPONSES PER SESSION
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
0
10
20
30
40
50
60
REINFORCERS PER SESSION

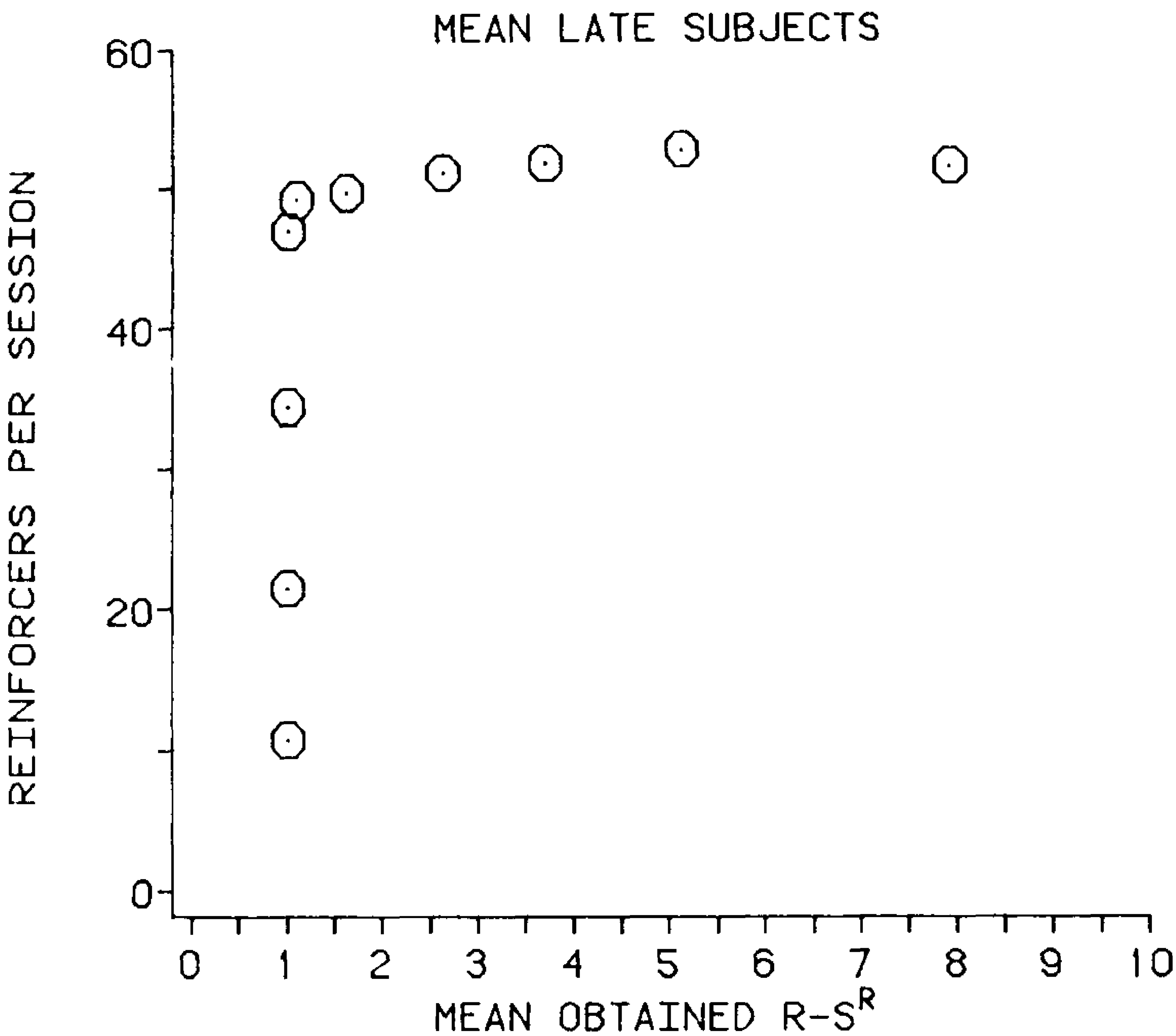
Figures 56a & b. Mean responses per session as a function of mean obtained R-S^R. At each t^D duration the calculated group mean responses per session and the group mean obtained R-S^R become the coordinates of the plotted data points.


MEAN EARLY SUBJECTS
RESPONSES PER SESSION
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
MEAN OBTAINED R-S^R


MEAN LATE SUBJECTS
RESPONSES PER SESSION
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
MEAN OBTAINED R-S^R

Figures 57a & b. Mean reinforcers per session as a function of mean obtained R-S^R. At each t^D duration the calculated group mean reinforcers per session and the group mean obtained R-S^R become the coordinates of the plotted data points.


MEAN EARLY SUBJECTS
REINFORCERS PER SESSION
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
MEAN OBTAINED R-S^R


MEAN LATE SUBJECTS
REINFORCERS PER SESSION
0
20
40
60
0 1 2 3 4 5 6 7 8 9 10
MEAN OBTAINED R-S^R

FOOTNOTES

[1]See Azzi et al., 1964; Chung, 1965; Clements, 1928; DeCamp, 1920; Dews, 1960, 1969; Ferster, 1953; Grice, 1948; Hamiliton, 1929; Harker, 1956; Hull, 1934; Hunter, 1913; Logan, 1952; Perin, 1943a, 1943b; Perkins, 1947; Pierce et al., 1972; Sams and Tolman, 1925; Seward and Weldon, 1953; Skinner, 1938; Spence, 1932; Warden and Diamond, 1931; Williams, 1976; Wolfe, 1934; Yoshioka, 1929.

[2]Hull (1932), for example, stated, "The mechanism which in the present paper will be mainly depended upon as an explanatory and integrating principle is that the goal reaction gets conditioned most strongly to the stimuli preceding it, and the other reactions of the behavior sequence get conditioned to their stimuli progressively weaker as they are more remote (in time or space) from the goal reaction (Hull, 1932, pp. 25-26)." However, Watson (1917) and Warden and Haas (1927) demonstrated control with long reinforcement delays. Watson (1917) required subjects to solve a sawdust digging problem, and Warden and Haas (1927) required subjects to complete a maze prior to entry into a goal compartment. Once in the goal compartment, subjects were either delayed up to 30 seconds (Watson, 1917) or 5 minutes (Warden and Haas, 1927) or given immediate access to the goal. An inverted funnel with air holes allowed for constant olfactory stimulation but denied food access to the delay subjects in both experiments. The performances of the delayed and immediate goal groups were equivalent.

The demonstrated equivalence of delayed and immediate reinforcement was rationalized theoretically with gradients of primary and secondary reinforcement (Hull, 1943; Wolfe, 1934; Perin, 1943; Spence, 1947; Perkins, 1947; Kimble, 1961; Lawrence and Hommel, 1961). The demonstrated behavioral control was attributed to the additional experimental stimulus manipulations which counteracted the effects of reinforcement delay. Secondary reinforcement theories and gradient-type interpretations of data are based on the presumption that delay does in fact produce lesser behavior control; therefore, the reasoning proceeds, any evidence of control must be attributed to the additional stimulus and response variables. An alternative hypothesis, which avoids this assumption, is that no change in behavior occurred because the controlling variables were not manipulated -- i.e., as in the Warden and Haas (1927), and Watson (1917) experiments where the frequency of the stimuli associated with reinforcement was not altered.

[3]In the first free-operant delay procedure with a reset requirement, Skinner (1938) found that acquisition of a free-operant occurred with delays up to 4.0 seconds. However, in periodic reconditioning the response rate in a five minute interval was inversely related to the delay magnitude, when delays of either 2, 4, 6 or 8 seconds were added to the fixed interval. Ferster (1953) conditioned pigeons under variable interval 60 seconds and then an additional 60 second blackout period was imposed between the completion of the variable interval and the occurrence of reinforcement. Response rates in the variable interval decreased "to a value near zero" with the added blackout. Azzi et al. (1964) exposed rats successively to reinforcement delays of 1.0, 3.0, 5.0, 7.5, 10.0, 15.0, and 20.0 seconds. Response rates decreased and post-reinforcement-pause increased as reinforcement delay increased. Focusing on Skinner (1938), one may note that given a subject that responds once per 2, 4, 6 or 8 seconds, reinforcement frequency would be limited to a maximum frequency of 30, 15, 10 or 7.5 reinforcers per minute, respectively. Similar calculations between the delay and maximum possible reinforcer frequency for all other free-operant delay research since Skinner's can be made.

[4]In other non-reset free-operant procedures (Dews, 1960, 1969; Chung, 1965; Pierce et al., 1972) reoccurrences of the operant have no effect on the duration of the temporal separation, nor on the reinforcement frequency as imposed by that temporal separation. In a two-keyed concurrent schedule of reinforcement (Chung, 1965), relative response rate was inversely related to delay on the delay key. The addition of a 1.0 second reinforcement delay at the completion of a fixed interval 180 second reduced response rates by one-half (Dews, 1969). A 75% decrease in response rate occurred when a three second delay was introduced in a variable interval two minute reinforcement schedule (Williams, 1976). Pierce et al. (1972) conditioned pigeons under variable interval 60 seconds. At that point fixed delays of 10.0, 30.0, or 100.0 seconds were added to the variable interval 60 seconds across successive experimental sessions. Response rate in the variable interval was inversely related to the length of the fixed delay. In a second experiment (Pierce et al., 1972), a variable interval 60 second requirement was followed by a subsequent fixed delay or fixed interval reinforcement schedule. Operant response

rate in the fixed delay was lower than operant rate in the fixed delay was lower than operant rate in the fixed interval. Schoenfeld, Cole, Lang and Mankoff (1973) studied variable delay schedules which operationally define maximum and minimum temporal limits for the separation between the reinforced response and the reinforcer. They found that response rate decreased as the maximum limit was increased. Sizemore and Lattal (1978) compared tandem variable interval-fixed time (VI FT) schedules against VI and VI FI with equivalent mean interreinforcement time (ISRT). A response contingent interval timer was initiated by the first response after expiration of the VI in the tandem VI FT schedule defined as the additional "nominal delay" imposed in between the reinforced response and the reinforcer. Their results evidence a direct relationship between the response-reinforcer "obtained delay" (the dependent variable) with the independent "nominal delay" (the independent variable). Therefore, the response-reinforcer temporal separation, defined either as a dependent or independent variable, was inversely related to operant rate. Sizemore and Lattal (1978) concluded that, "The effects of an unsignalled delay of reinforcement arranged by tandem VI FI schedules were similar to those reported using other delay-of-reinforcement procedures, i.e., the tandem-schedules procedures of the present study, procedures with unsignalled delay and a DRO schedule during the delay interval, and procedures with signalled delay of reinforcement all resulted in systematic decreases in responding with increasing delays..." (p. 173). Delayed punishment has been found less effective than immediate punishment (Baron, Kaufman and Fazzini, 1969).

[5]Similar material can be found in general discussions of delayed reinforcement by Bolles (1975), Kimble (1961), Rachlin (1970), and Reynolds (1968).

[6]It is interesting to note that extinction measures rather than those of acquisition and learning demonstrated reinforcement equivalence or superiority for pretraining with delayed reinforcement over pretraining with immediate reinforcement (Amsel and Roussel, 1952; Crum, et al., 1951; Fehrer, 1956; Pubols, 1958). Other researchers have obtained inconclusive results (Logan, 1960; Renner, 1963).

[7]Possibly, investigators assumed that delay was the only independent variable manipulated. Some reinforcement frequency results can be found in the delayed reinforcement literature (Sizemore and Lattal, 1978; Williams, 1976). Nonetheless, the intent of these experiments was to show that reinforcer frequency was constant among the different conditions, thus, any decrements in response rate could be attributed to the delay manipulation.

[8]Examination of Perkins' (1947) results revealed an increase in percent correct responses for all the delay groups in a T-maze choice response procedure as well as from 50% (i.e., chance) to 60% correct responses for the 120 second delay group over 20 experimental days. Similarly, in a free-operant procedure Ferster (1953) indicated that in pilot delay studies, operant rate was recovered following initial depression "over longer [experimental exposure] periods." (see Ferster, 1953, Fig. 4), and that responding was maintained "with short delays which were gradually increased."

APPENDIX

TABLE 1.....................................111

TABLE 2.....................................113

TABLE 3.....................................115

TABLE 4.....................................118

TABLE 5.....................................121

TABLE 6.....................................124

TABLE 7.....................................127

TABLE 1

Correlations between responses per session, reinforcers per session, responses per reinforcer, and obtain R-S^R. The critical value of the correlation coefficient at the $p = 0.05$ significance level is 0.576, df = 10.

Early t^D Placement.

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	R-S^R
	1.00	-0.845	-0.864	0.327
		1.00	0.919	-0.527
152E			1.00	-0.531
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	R-S^R
	1.00	-0.736	-0.755	0.849
		1.00	0.919	-0.887
153E			1.00	-0.812
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	R-S^R
	1.00	-0.611	-0.706	0.653
		1.00	0.918	-0.876
159E			1.00	-0.823
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	R-S^R
	1.00	-0.336	-0.497	0.519
		1.00	0.961	-0.815
160E			1.00	-0.896
				1.00

TABLE 1 (continued)

Correlations between responses per session, reinforcers per session, responses per reinforcer, and obtain $R\text{-}S^R$. The critical value of the correlation coefficient at the $p = 0.05$ significance level is 0.632, df = 8.

Late t^D Placement.

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	$R\text{-}S^R$
	1.00	-0.929	-0.935	0.535
		1.00	0.902	-0.682
151L			1.00	-0.482
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	$R\text{-}S^R$
	1.00	-0.768	-0.919	0.355
		1.00	0.689	-0.706
156L			1.00	-0.366
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	$R\text{-}S^R$
	1.00	-0.835	-0.896	0.641
		1.00	0.886	-0.626
161L			1.00	-0.456
				1.00

	Reinforcers Per Session	Responses Per Session	Responses Per Reinforcer	$R\text{-}S^R$
	1.00	-0.430	-0.937	0.192
		1.00	0.559	-0.907
455L			1.00	-0.348
				1.00

TABLE 2

Percent of baseline response rate as a function of t^D duration.

Early t^D	152E	153E	159E	160E	Mean	Standard Error Of The Mean
30	100	100	100	100	100	0.00
25	94	71	74	79	79.5	5.11
23	70	60	37	68	58.75	7.56
20	114	87	32	85	79.5	17.16
15	153	95	36	75	89.75	24.38
10	121	88	54	81	86.0	13.78
5.0	105	94	71	87	89.25	7.12
2.5	171	141	112	95	129.75	16.71
1.5	221	115	298	115	137.5	57.98
0.5	232	151	424	397	301.0	65.58
0.2	281	294	586	852	503.25	135.91
0.1	272	262	438	1585	639.25	317.82

TABLE 2 (Continued)

Total responses per session as a function of t^D duration.

Late t^D	151L	156L	161L	455L	Mean	Standard Error Of The Mean
30	100	100	100	100	100	0.00
20	113	97	112	283	151.25	44.07
15	70	182	133	339	181.0	57.44
10	118	238	176	443	243.75	70.79
5.0	178	240	186	409	253.25	53.71
2.5	401	423	268	370	365.5	34.27
1.5	303	482	614	413	453.0	65.1
0.5	560	488	1259	400	676.75	196.8
0.2	997	628	1606	449	920.0	255.5
0.1	1078	566	1773	451	967.0	301.25

TABLE 3

Individual subject means and standard errors are presented. Group means and standard errors were computed from the four early and four late t^D subjects.

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D=30.0	Mean	650.7	400.8	359.6	102.7	378.00
	Standard Error	34.72	30.51	46.11	7.2	112.18
t^D=25.0	Mean	617.0	287.6	267.2	81.1	313.23
	Standard Error	60.23	17.64	35.29	5.98	111.41
t^D=23.0	Mean	453.7	238.8	132.9	69.9	223.83
	Standard Error	15.31	24.36	5.09	2.87	84.18
t^D=20.0	Mean	743.9	351.2	116.1	88.0	324.80
	Standard Error	38.42	20.09	5.68	7.16	151.65
t^D=15.0	Mean	993.9	381.2	130.7	77.1	395.73
	Standard Error	26.58	16.20	11.02	3.71	210.12
t^D=10.0	Mean	787.4	354.4	194.6	83.7	355.03
	Standard Error	48.98	17.66	24.10	3.51	154.46
t^D= 5.0	Mean	680.0	376.2	254.4	89.8	350.08
	Standard Error	36.45	8.64	12.79	5.21	124.65
t^D= 2.5	Mean	1110.6	568.1	404.8	98.1	545.43
	Standard Error	86.52	19.72	71.77	9.27	212.09

TABLE 3 (continued)

Early Placement:		152E	153E	159E	160E	Mean Early Group
$t^D = 1.5$	Mean	1436.7	460.6	1072.9	118.7	772.23
	Standard Error	48.34	20.04	36.47	11.51	296.67
$t^D = 0.5$	Mean	1512.7	606.3	1525.7	407.9	1013.15
	Standard Error	61.46	45.40	69.02	37.37	294.97
$t^D = 0.2$	Mean	1828.8	1180.1	2107.8	875.7	1498.08
	Standard Error	96.93	62.18	52.65	52.23	284.24
$t^D = 0.1$	Mean	1771.7	1052.7	1577.3	1628.5	1507.55
	Standard Error	95.15	53.95	80.81	95.26	157.10

Late Placement:		151L	156L	161L	455L	Mean Late Group
$t^D = 30.0$	Mean	238.2	363.5	109.0	568.2	319.73
	Standard Error	28.45	45.87	13.78	74.57	97.77
$t^D = 20.0$	Mean	269.8	352.0	122.2	1610.8	588.65
	Standard Error	36.34	15.16	9.73	59.69	344.02
$t^D = 15.0$	Mean	167.4	662.4	145.1	1930.3	726.3
	Standard Error	14.26	61.18	11.15	127.13	418.71

TABLE 3 (continued)

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=10.0	Mean	282.5	866.4	192.4	2518.2	964.88
	Standard Error	20.31	29.08	8.39	61.35	538.89
t^D= 5.0	Mean	425.1	874.9	203.4	2321.2	956.15
	Standard Error	42.20	56.69	8.97	75.12	475.97
t^D= 2.5	Mean	955.2	1539.3	292.1	2104.8	1222.88
	Standard Error	57.97	75.92	14.86	73.57	388.89
t^D= 1.5	Mean	722.3	1753.3	669.3	2349.2	1373.53
	Standard Error	40.12	81.33	21.57	69.47	409.9
t^D= 0.5	Mean	1333.0	1776.7	1372.5	2276.6	1689.7
	Standard Error	38.12	65.05	44.35	26.35	219.82
t^D= 0.2	Mean	2375.3	2284.9	1751.5	2553.8	2241.28
	Standard Error	90.23	43.47	29.44	65.18	172.5
t^D= 0.1	Mean	2567.9	2059.3	1932.9	2563.0	2280.78
	Standard Error	51.94	171.42	47.33	47.21	166.37

TABLE 4

Reinforcers per session as a function of t^D duration. Individual subjects means and standard errors are presented. Group means and standard errors were computed from the four early and four late t^D subjects.

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D=30.0	Mean	57.9	59.4	53.9	47.4	54.65
	Standard Error	0.64	0.27	1.66	2.05	2.68
t^D=25.0	Mean	52.0	56.6	55.6	51.7	53.98
	Standard Error	1.07	1.00	0.85	1.33	1.25
t^D=23.0	Mean	53.6	54.4	52.0	49.9	52.48
	Standard Error	1.02	1.28	0.77	1.51	0.99
t^D=20.0	Mean	53.9	55.5	50.9	45.7	51.5
	Standard Error	0.67	0.69	1.27	1.55	2.16
t^D=15.0	Mean	43.5	51.0	43.7	28.2	41.6
	Standard Error	0.96	1.35	2.03	1.01	4.8
t^D=10.0	Mean	37.4	32.6	29.9	15.7	28.9
	Standard Error	0.56	0.69	1.83	1.04	4.67
t^D= 5.0	Mean	31.6	27.1	21.1	11.9	22.93
	Standard Error	0.70	1.10	1.38	0.69	4.26
t^D= 2.5	Mean	31.0	25.7	15.9	7.1	19.93
	Standard Error	0.73	0.62	2.80	0.97	5.30

TABLE 4 (continued)

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D= 1.5	Mean	29.1	20.1	24.2	5.2	19.65
	Standard Error	0.48	1.26	1.20	1.15	5.16
t^D= 0.5	Mean	27.6	12.3	18.1	8.5	16.63
	Standard Error	0.95	1.36	1.92	0.96	4.16
t^D= 0.2	Mean	25.4	14.6	24.8	10.2	18.75
	Standard Error	1.63	1.56	1.50	1.31	3.78
t^D= 0.1	Mean	15.7	8.1	12.2	14.8	12.7
	Standard Error	2.18	1.20	1.60	1.21	1.70

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=30.0	Mean	52.3	55.5	43.0	55.1	51.48
	Standard Error	1.61	1.49	2.79	1.22	2.91
t^D=20.0	Mean	52.4	53.6	46.2	58.9	52.78
	Standard Error	1.42	1.25	1.21	0.18	2.61
t^D=15.0	Mean	48.5	57.8	42.5	57.9	51.68
	Standard Error	1.56	0.70	1.54	0.48	3.77

TABLE 4 (continued)

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=10.0	Mean	48.4	57.8	39.3	58.8	51.08
	Standard Error	1.16	0.70	0.91	0.34	4.57
t^D= 5.0	Mean	50.7	55.8	33.9	58.0	49.6
	Standard Error	1.31	0.73	0.75	0.39	5.45
t^D= 2.5	Mean	53.3	56.9	27.4	59.0	49.15
	Standard Error	1.43	0.75	1.29	0.33	7.34
t^D= 1.5	Mean	46.1	50.5	40.4	50.7	46.93
	Standard Error	1.93	2.16	2.19	2.32	2.42
t^D= 0.5	Mean	31.8	29.9	34.6	41.0	34.33
	Standard Error	3.11	1.10	0.93	1.20	2.43
t^D= 0.2	Mean	25.6	23.0	15.1	22.0	21.43
	Standard Error	1.67	3.02	1.04	1.11	2.24
t^D= 0.1	Mean	12.4	8.4	8.8	13.1	10.68
	Standard Error	1.19	0.79	0.57	1.03	1.21

TABLE 5

Responses per reinforcer as a function of t^D duration. Individual subject means and standard errors are presented. Group means and standard errors were computed from the four early and four late t^D subjects.

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D=30.0	Mean	11.26	6.74	6.67	2.16	6.70
	Standard Error	0.63	0.51	0.68	0.11	1.85
t^D=25.0	Mean	11.86	5.08	4.80	1.57	5.83
	Standard Error	0.91	0.27	0.59	0.15	2.16
t^D=23.0	Mean	8.46	4.39	2.55	1.40	4.20
	Standard Error	0.28	0.38	0.09	0.08	1.55
t^D=20.0	Mean	13.77	6.32	2.28	1.93	6.08
	Standard Error	0.63	0.32	0.10	0.21	2.76
t^D=15.0	Mean	22.85	7.47	2.98	2.73	9.01
	Standard Error	0.80	0.37	0.17	0.12	4.74
t^D=10.0	Mean	21.05	10.78	6.50	5.33	10.94
	Standard Error	1.11	0.49	0.55	0.29	3.58
t^D= 5.0	Mean	21.50	13.88	12.05	7.55	13.75
	Standard Error	0.97	0.53	0.56	0.66	2.91
t^D= 2.5	Mean	35.83	22.10	25.46	13.82	24.3
	Standard Error	2.31	0.99	2.18	3.00	4.55

TABLE 5 (continued)

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D= 1.5	Mean	49.37	22.91	44.33	22.83	34.86
	Standard Error	1.49	1.58	2.51	3.62	7.00
t^D= 0.5	Mean	54.81	49.29	84.29	47.98	59.09
	Standard Error	2.92	3.76	7.34	8.50	8.53
t^D= 0.2	Mean	72.0	88.83	84.99	85.85	80.92
	Standard Error	6.42	11.40	4.57	11.52	3.17
t^D= 0.1	Mean	112.85	129.96	129.28	110.03	120.53
	Standard Error	16.93	20.56	13.00	11.68	5.28

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=30.0	Mean	4.55	6.55	2.53	10.31	5.99
	Standard Error	0.42	0.70	0.21	1.17	1.66
t^D=20.0	Mean	5.15	6.56	2.64	27.34	10.42
	Standard Error	0.56	0.22	0.15	1.08	5.7
t^D=15.0	Mean	3.45	11.46	3.41	33.33	12.91
	Standard Error	0.24	1.01	0.20	2.30	7.06

TABLE 5 (continued)

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=10.0	Mean	5.84	14.99	4.90	42.82	17.41
	Standard Error	0.38	0.53	0.25	0.88	8.86
t^D= 5.0	Mean	8.38	15.68	6.00	40.02	17.52
	Standard Error	0.73	0.87	0.36	1.31	7.78
t^D= 2.5	Mean	17.92	27.05	10.66	35.67	22.83
	Standard Error	0.76	1.31	0.90	1.30	5.44
t^D= 1.5	Mean	15.67	34.72	16.56	46.33	28.32
	Standard Error	0.89	0.60	0.53	2.44	7.44
t^D= 0.5	Mean	41.92	59.42	39.66	55.53	49.13
	Standard Error	3.11	2.10	0.98	1.82	4.90
t^D= 0.2	Mean	92.78	99.33	116.00	116.08	106.05
	Standard Error	6.21	5.69	8.55	7.49	5.92
t^D= 0.1	Mean	207.08	245.15	219.64	195.64	216.88
	Standard Error	16.13	23.70	17.68	18.66	10.62

TABLE 6

Obtained R-S^R in seconds as a function of t^D duration. Individual subject means and standard errors are presented. Group means and standard errors were computed from the four early and four late t^D subjects.

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D=30.0	Mean	2.08	3.52	5.65	9.42	5.17
	Standard Error	0.11	0.14	0.24	0.30	1.60
t^D=25.0	Mean	2.09	4.41	9.40	16.26	8.04
	Standard Error	0.10	0.21	0.28	0.27	3.14
t^D=23.0	Mean	1.93	5.12	13.1	16.12	9.07
	Standard Error	0.09	0.21	0.30	0.26	3.32
t^D=20.0	Mean	1.87	3.45	14.22	14.65	8.55
	Standard Error	0.08	0.15	0.29	0.26	3.42
t^D=15.0	Mean	1.63	3.36	14.88	16.14	9.00
	Standard Error	0.08	0.14	0.37	0.37	3.79
t^D=10.0	Mean	1.56	3.52	10.02	13.77	7.22
	Standard Error	0.06	0.23	0.46	0.70	2.84
t^D= 5.0	Mean	2.56	2.90	9.99	12.28	6.93
	Standard Error	0.13	0.18	0.59	0.90	2.47
t^D= 2.5	Mean	1.91	2.34	6.20	14.83	6.32
	Standard Error	0.08	0.20	0.56	1.30	3.00

TABLE 6 (continued)

Early Placement:		152E	153E	159E	160E	Mean Early Group
t^D= 1.5	Mean	1.56	2.66	2.28	9.00	3.88
	Standard Error	0.07	0.22	0.19	1.20	1.72
t^D= 0.5	Mean	2.34	2.32	1.78	3.87	2.58
	Standard Error	0.20	0.21	0.11	0.54	0.45
t^D= 0.2	Mean	1.39	1.26	1.16	3.21	1.76
	Standard Error	0.14	0.10	0.04	0.49	0.49
t^D= 0.1	Mean	1.32	1.25	1.47	1.16	1.30
	Standard Error	0.17	0.10	0.11	0.11	0.07

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=30.0	Mean	4.48	10.64	12.58	3.88	7.90
	Standard Error	0.20	0.29	0.37	0.22	2.18
t^D=20.0	Mean	4.32	5.76	9.01	1.30	5.10
	Standard Error	0.17	0.21	0.25	0.05	1.60
t^D=15.0	Mean	4.33	2.64	6.68	1.05	3.68
	Standard Error	0.15	0.12	0.22	0.03	1.20

TABLE 6 (continued)

Late Placement:		151L	156L	161L	455L	Mean Late Group
t^D=10.0	Mean	2.84	1.67	4.89	1.02	2.61
	Standard Error	0.10	0.06	0.15	0.12	0.85
t^D= 5.0	Mean	1.47	1.49	2.48	1.00	1.61
	Standard Error	0.04	0.04	0.08	0.03	0.31
t^D= 2.5	Mean	1.02	1.04	1.31	1.00	1.09
	Standard Error	0.01	0.01	0.04	0.00	1.09
t^D= 1.5	Mean	1.00	1.00	1.00	1.00	1.00
	Standard Error	0.00	0.00	0.00	0.00	0.00
t^D= 0.5	Mean	1.00	1.00	1.00	1.00	1.00
	Standard Error	0.00	0.00	0.00	0.00	0.00
t^D= 0.2	Mean	1.00	1.00	1.00	1.00	1.00
	Standard Error	0.00	0.00	0.00	0.00	0.00
t^D= 0.1	Mean	1.00	1.00	1.00	1.00	1.00
	Standard Error	0.00	0.00	0.00	0.00	0.00

TABLE 7

Percent of total 0.0 - 2.0 second R-S^R as a function of t^D duration.

Early t^D	152E	153E	159E	160E	Mean	Standard Error Of The Mean
30	72	44	32	13	40.25	12.36
25	67	41	17	2.6	31.9	10.93
23	66	34	6.5	2.0	27.13	14.76
20	70	46	6.5	3.8	31.58	16.03
15	73	44	9.3	5.3	32.9	15.94
10	77	46	20	14	39.25	14.37
5.0	52	51	19	18	35.00	9.53
2.5	67	64	36	14	45.25	12.54
1.5	79	57	71	21	57.00	12.83
0.5	72	61	74	58	66.25	3.97
0.2	93	94	95	76	89.5	4.52
0.1	96	91	84	98	92.25	3.12

TABLE 7 (Continued)

Late t^D	151L	156L	161L	455L	Mean	Standard Error Of the Mean
30	37.2	11.8	10.2	54.2	28.35	10.61
20	38.9	29.9	12.5	87.9	42.3	16.16
15	32.2	59.8	23.0	98.8	53.45	17.02
10	47.2	78.9	25.4	98.8	62.6	16.32
5.0	79.2	79.0	43.6	99.0	75.2	11.53
2.5	99.0	97.0	84.3	99.8	95.0	3.62
1.5	100	100	100	100	100	0.00
0.5	100	100	100	100	100	0.00
0.2	100	100	100	100	100	0.00
0.1	100	100	100	100	100	0.00

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