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EFFECTS OF CONTINGENT AND NON-CONTINGENT SIGNALS DURING DELAY INTERVAL ON RESPONSE ACQUISITION BY RATS

EL EFECTO DE SEÑALES CONTINGENTES Y NO CONTINGENTES DURANTE EL INTERVALO DE DEMORA SOBRE LA ADQUISICIÓN DE LA RESPUESTA EN RATAS

MARCO ANTONIO PULIDO, LETICIA LÓPEZ
AND NURIA LANZAGORTA[1]
LABORATORIO DE CONDICIONAMIENTO OPERANTE
UNIVERSIDAD INTERCONTINENTAL, MÉXICO

ABSTRACT

Research on delay of reinforcement effects under temporally defined schedules of reinforcement suggests delay effects are diluted under short cycle durations. This conclusion is tentative because attempts to replicate the seminal study conducted by Weil (1984) differed from the original study in a number of ways. The present study attempted a more direct replication of Weil`s study and also to extended the original manipulation to encompass two different signaled delay of reinforcement procedures. Thirty-six naive rats were exposed to a repetitive time cycle of 32-s. The cycle was divided into two portions, t^d

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and t delta. A response during t^d produced food at the end of the cycle; responses emitted during t delta had no programmed consequences. For some experimental groups t^d was signaled by a response-produced signal; in other groups a non-contingent signal occurred during t^d ; in still other experimental groups t^d was unsignaled. The placement of t^d was varied to produce two different response-reinforcer temporal relations; t^d duration was also varied to assess the generality of the results. Response rates were considerably lower when t^d was at the beginning of the cycle than when the opportunity to respond was at its end. Non-contingent signals produced low rates of responding; in contrast response produced signals were associated with high response rates. In general the results show that delay of reinforcement has detrimental effects on response acquisition even under short reinforcement cycles. Both non-contingent and contingent signals have facilitative effects on the response acquisition process, but the former favors low rates of responding and the later favors high response rates.

Key Words: Delay of reinforcement, contingent and non-contingent signals, rats, response acquisition, temporally defined schedules

RESUMEN

La investigación en demora de reforzamiento basada en programas definidos temporalmente, sugiere que cuando los ciclos son cortos los efectos de la demora se diluyen. Este hallazgo aun no puede considerarse definitivo dado que aun no se han llevado a cabo replicaciones directas del estudio seminal de Weil (1984). El propósito del presente estudio fue el de intentar una replicación directa del procedimiento de Weil, simultáneamente se pretendió extender la manipulación original para incorporar procedimientos de demora señalada. Treinta y seis ratas ingenuas fueron expuestas a diferentes ciclos de tiempo repetitivo de 32-s. Los ciclos se dividieron en dos porciones, t^d y t delta; la primera respuesta emitida durante t^d producía alimento al finalizar el ciclo, las respuestas durante t delta no tenían consecuencias programadas. Se varió la colocación de t^d dentro del ciclo (al principio o al final) para exponer a los sujetos a distintas condiciones de separación temporal entre la respuesta y el reforzador. Con la finalidad de evaluar la generalidad de los resultados se varió la duración de t^d (4-s u 8-s). Para algunos grupos experimentales la primera respuesta durante t^d producía una señal auditiva; para otros grupos la señal ocurría durante t^d independientemente de la respuesta del sujeto; por último en otros grupos no se presentó señal alguna durante t^d. Los resultados mostraron que la demora del reforzador tiene efectos decrementales evidentes sobre la tasa de respuesta aun en ciclos de reforzamiento cortos. Los resultados también mostraron que tanto las señales no contingentes como contingentes tienen efectos facilitares sobre la adquisición de la respuesta, sin embargo las primeras suelen producir tasas de respuesta bajas y las segundas tasas de respuesta altas.

Palabras clave: Demora de reforzamiento, señales contingentes y no contingentes, ratas, adquisición de la respuesta de palanqueo, programas definidos temporalmente.

A number of studies suggest delayed reinforcers are less effective in maintaining control over behavior than reinforcers that immediately follow the response (Skinner, 1938; Hull, 1943). Response acquisition criteria are typically met faster by subjects exposed to immediate reinforcement procedures than by those exposed to delayed reinforcement (Hunter, 1913; Wolfe, 1934). Studies in concurrent schedule behavior have shown that switching to delayed reinforcement occurred less often as response-reinforcer separation increased (Schull, Spear & Bryson, 1981). Delayed punishment has been found to be less effective than immediate punishment (Baron, Kaufman & Fazzini, 1969). Reviews focusing on delay of reinforcement consistently suggest that delay decreases reinforcement value across an important number of experimental procedures and animal species (Renner, 1964; Tarpy & Sawabini, 1974).

The previous review suggests that delay of reinforcement is one of the most important parameters of operant behavior. In this light, delay of reinforcement studies that fail to reproduce the most typical findings necessarily attract attention (as any review on taste aversion conditioning will reveal). One study on delay of reinforcement that failed to produce a delay gradient and that thus far has received little attention was conducted by Weil (1984). In most delay of reinforcement studies, delay duration covaries with interreinforcer interval duration (and thus concomitantly with programmed reinforcement rate). As reinforcement rate is an important determinant of response rate (Herrnstein, 1970), Weil searched for a procedure that would allow him to manipulate the temporal separation between the target response and reinforcement delivery without simultaneously changing programmed reinforcement rate. Eventually Weil settled for a procedure involving temporally defined schedules of reinforcement (Schoenfeld & Cole, 1972). In this procedure two different time windows (t^d and t delta) alternate within a 30-s repetitive cycle of fixed duration (T). The first response emitted during t^d will produce food at the end of the cycle; responses emitted during t delta have no programmed consequences. Weil`s study may be conceptualized as a factorial design with two independent variables, t^d placement and t^d duration. Weil reasoned that by changing the position of t^d within the cycle he could vary response- reinforcer temporal contiguity without varying programmed reinforcer rate (one reinforcer every 30-s). In some conditions t^d was located at the beginning of the cycle (early t^d placement) and thus response-reinforcer interval was relatively long; in other conditions t^d was placed at the end of the cycle (late t^d condition) and thus response-reinforcer interval was relatively short. In addition to changing t^d placement Weil suggested that by varying t^d duration he could also produce different response-reinforcer temporal relations. For instance short t^d durations in the late t^d placement condition could produce very short reinforcement delays, in contrast short t^d durations in the early t^d condition could produce reinforcement delays nearing 30-s.

Weil found rates of key-pecking by pigeons were very similar in both the early and the late t^d conditions. The only systematic result from the study was that very high response rates appeared in those conditions where t^d duration equaled one second (or less).

At least two different studies have tried to replicate Weil`s findings using response acquisition as dependent variable. In one replication Bruner, Pulido & Escobar (1999) exposed experimentally naïve rats to 60-s temporally defined schedules where t^d was located at either the beginning or the end of the reinforcement cycle and t^d duration was varied form 8-s to 56-s. Results showed response rates increased faster and reached higher levels in the late t^d placement conditions. With the exception of the 56-s t^d duration condition, all response rates produced by those subjects exposed to early t^d placement conditions were homogeneously low (and in the shorter t^d duration groups, responses were almost nonexistent in the last ten experimental sessions).

This first replication led Bruner et al to hypothesize that Weil`s procedure lacked the appropriate parametric extensions and that a comparison between T cycles of different duration would reveal that the effects of t^d placement appear when T is fixed at values that exceed 30-s. In order to assess this possibility Bruner, Pulido & Escobar (2000) exposed naïve rats to temporally defined schedules of reinforcement of either 32-s, 64-s or 128-s. The second study by Bruner et al also differed from the first one because instead of anchoring t^d to the beginning or the end of the reinforcement cycle and then varying its duration, t^d was fixed at 8-s and presented at different positions during the interreinforcer interval. As expected by the authors t^d placement had no effect on response rate in the 32-s cycle conditions. In contrast, clear delay gradients appeared when t^d placement was varied in the 64-s and 128-s conditions.

Taken together the studies conducted by Bruner et al suggest effects of delayed reinforcement may be diluted when the delay interval is programmed using short temporally defined schedules. However no definite conclusions may be drawn because the previously referred studies are not direct replications of Weil`s procedure. For instance, in the 1999 study by Bruner et al, interreinforcer interval duration was much longer than that employed by Weil. In the second study by Bruner et al the 32-s cycle condition is similar to that employed by Weil, but t^d placement was freely moved around the interreinforcer interval (instead of anchoring t^d at the beginning or at the end of the reinforcement cycle). Thus one purpose of the present study was to closely replicate

Weil`s procedure by exposing naïve rats to 32-s temporally defined schedules where t^d was anchored to either the beginning or the end of the cycle.

Delay of reinforcement procedures have been classified as either signaled or unsignaled (Lattal, 1987) depending on the presence (or absence) of discriminative stimuli during the different components of the schedule. To date no attempt has been made to assess the effects of signal presentation during t^d on response acquisition by naïve rats exposed to temporally defined schedules of reinforcement. Thus a second purpose of the present study was to assess the effects of signaled and unsignaled t^d`s on response acquisition by rats.

METHOD

Subjects

Thirty-six naive male Wistar Lewis rats were used as subjects. All subjects were approximately five months old at the beginning of the study. Each subject's weight was registered on five consecutive days under free-feeding conditions to determine *ad libitum* body weight; food was then restricted until all subjects reached 80% of their free-feeding weight. Subjects were kept at their prescribed body weights through out the experiment by means of supplementary feeding following each experimental session. Subjects were kept on the Laboratory *vivarium* under constant temperature conditions and a twelve-hour light-dark cycle (lights on a 7:00 a.m.). All experimental subjects were kept in individual cages with free access to water.

Apparatus

Sessions were conducted in a custom-built rodent operant conditioning chamber made of transparent Plexiglas. The space in which the subjects were studied measured 18.5 cm in height by 23.5 cm length by 23.5 cm depth. A stainless steel lever made of a 3 cm bar topped by a 2 cm in diameter metal disk was placed on the front wall of the chamber. The lever was placed 5.5 cm above the floor and 11 cm apart from each wall. The lever required a force of at least 24 grams for depression. A 2 cm depression of the lever produced an audible click and was counted as a response. A 5 cm in diameter metal plate, located two cm below and to the right of the lever, was used as a pellet receptacle. A BRS-LVE, PDH-020 pellet dispenser delivered 4 .25 mg pellets in each emission. Pellets were produced by means of remolding pulverized Purina Nutri Cubes. Two 1.1 W, 28 Vdc pilot lights with a glass translucent cover were used to illuminate the experimental chamber. One light was located inside the box seven cm above the food receptacle. The second light was placed outside the chamber glued directly on the center of its Plexiglas ceiling. A sonalert, which delivered a 87.62 dB auditory signal was attached to the external front wall of the experimental chamber, 5 cm to the left of the lever. The conditioning chamber was housed inside a sound-attenuating larger wooden box equipped with a ventilating fan. Experimental events were programmed and recorded using an IBM compatible 386 microcomputer equipped with an industrial automation card (Advantech PC-Labcard 725) coupled to a relay rack.

Procedure

During the first session, with the lever absent from the chamber, each rat was exposed to a magazine training procedure. Magazine training consisted of thirty consecutive response-independent food deliveries using a FT-30-s schedule. All experimental subjects consumed the food in the tray after just one exposure to the schedule. On the second session (and on thirty additional consecutive sessions) the lever was inside the experimental chamber and all subjects were exposed to a 32-s temporally defined schedule of reinforcement (Schoenfeld & Cole, 1972). The schedule consisted of a repetitive time cycle of fixed duration (T). Two different components alternated within the reinforcement cycle (t^d and t delta). A response emitted during t^d produced reinforcement at the end of the 32-s cycle; responses during t delta were recorded but had no programmed consequences. This experiment can be conceptualized as a between subjects factorial design with three factors: 1) t^d placement (at the beginning of the cycle or at the end of the cycle). 2) t^d duration (4 s or 8 s). 3) Signal conditions (no signal, non-contingent signal, and contingent signal). t^d placement was varied in order to produce at least two response-reinforcer temporal relations. When t^d was placed at the beginning of the cycle, reinforcement was temporally separated from the consequated response; the opposite occurred when t^d was placed at the end of the cycle. Because responses could occur during t delta, (or after one response had occurred during t^d) the experimental procedure used in the study may be characterized as a variable delay of reinforcement procedure (Lattal, 1987; Schoenfeld, Cole, Lang & Mankoff, 1973). In Weil`s seminal study t^d duration was varied across a vast number of different values. Because previous studies suggest that t^d duration is relatively insensitive to response-reinforcer temporal relations, in the present study only two different t^d durations (4-s and 8-s) were used.

In signaled experimental conditions an audible tone and a change in illumination occurred during t^d (the pilot light located on the front wall was extinguished and the pilot light located on the ceiling of the chamber was turned on) occurred during t^d. Contingent signals were produced by the first response produced during t^d and lasted until the end of t^d (and thus may be considerably shorter than t^d duration). Non-contingent signals were presented automatically by the program throughout t^d (thus the signal began precisely at the onset of t^d and was turned off at the end of t^d). In unsignaled experimental conditions no programmed exteroceptive stimuli (other than reinforcement delivery and the audible clicks made by depressing the lever) occurred during the reinforcement cycle. Figure 1 shows a schematic representation of the experimental procedures.

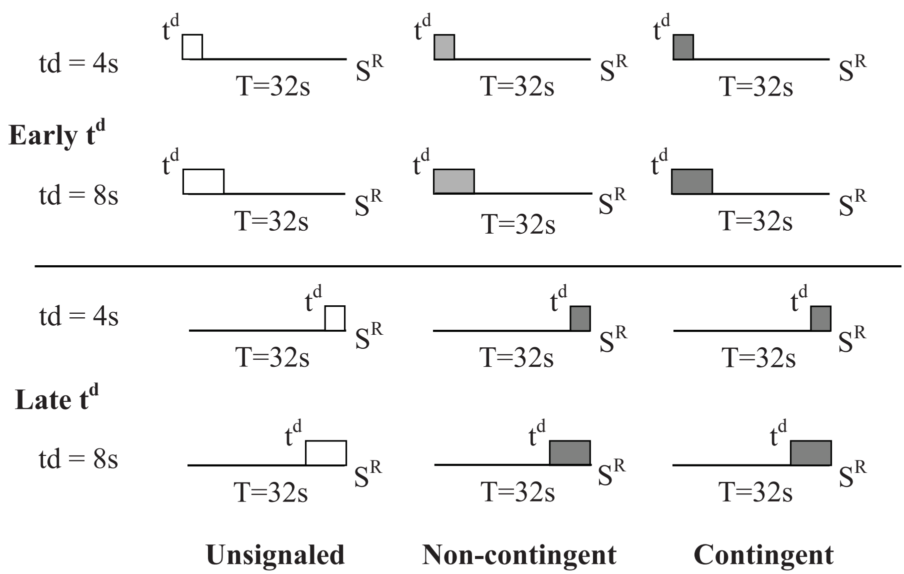

Figure 1. Schematic representation of the experimental procedure

Three animals were assigned to each experimental condition. Sessions were conducted six days per week at approximately the same time each day. Each session lasted one hour or the time necessary to obtain thirty reinforcers, whichever occurred first.

RESULTS

Figure 2 shows responses emitted per minute for all three animals in each experimental condition. Response rate is shown as a function of exposure to the different reinforcement schedules used in the study. To facilitate data presentation, late t^d conditions are located on the lower part of the figure and early t^d conditions are located on the upper part of the figure. The left column shows unsignaled experimental conditions; the middle column shows non-contingent signal conditions; the right column shows response-produced signal conditions.

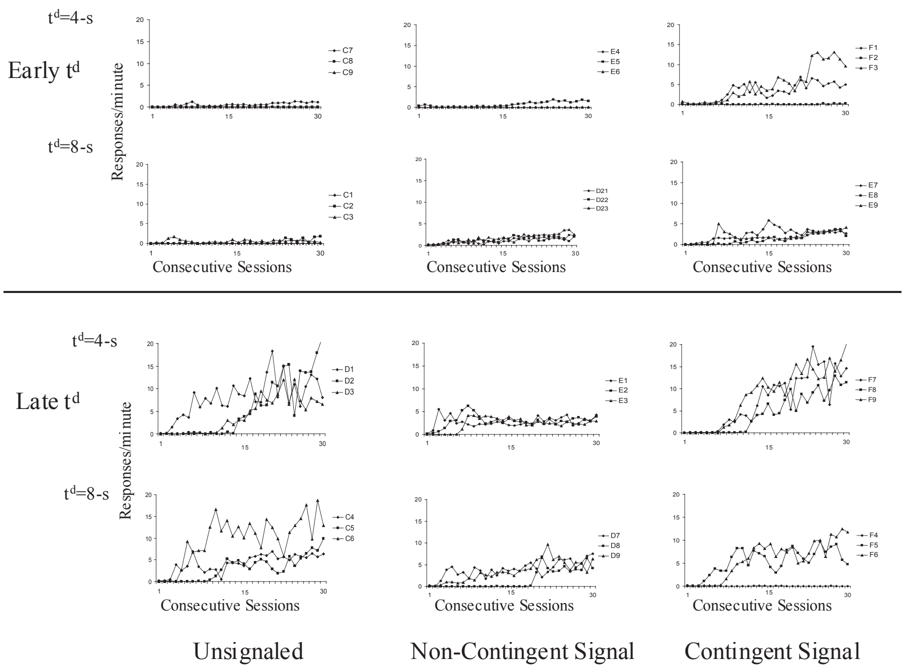

Figure 2. Response rate per minute for each subject on each experimental session for all experimental conditions.

Higher response rates occurred in late t^d conditions than in early t^d conditions. This difference is more apparent in unsignaled experimental conditions and less noticeable when t^d was signaled by a contingent signal. Also response rates increased more abruptly in late t^d than in the early t^d groups. Response rates produced by both t^d values look similar in late t^d placement groups. In contrast response rates appear slightly more consistent with the long t^d duration under early t^d placement conditions (this effect is more apparent in signaled conditions).

Unsignaled and contingent-signal conditions produced higher response rates than non-contingent signal conditions under the late t^d placement procedure. Under early t^d placement conditions, low response rates appear on both unsignaled and non-contingent signal conditions (relative to response rates produced by the contingent-signal presentation procedure).

Figures 3A, 3B and 3C show, respectively, the evolution of local response distribution for all subjects in each experimental condition in the unsignaled, non contingent signal and contingent signal conditions. Graphs show the average response rate per minute emitted on each one of four 8-s sub-intervals of the reinforcement cycle, for the first, intermediate and last five sessions. Early t^d placement conditions (for both t^d =4-s and t^d =8-s) are located on the upper part of each figure. Each column shows different days of exposure to the experimental conditions.

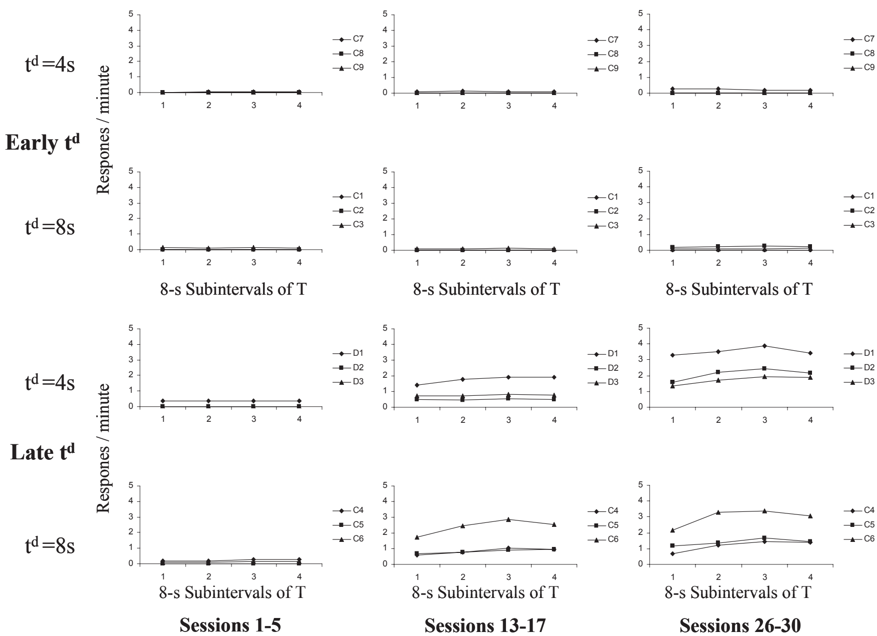

Figure 3A. Mean response rate per minute in consecutive 8-s bins of the reinforcement cycle for the first, intermediate and last five sessions. Mean response rate is shown for each subject and for the different experimental conditions of the unsignaled delay group.

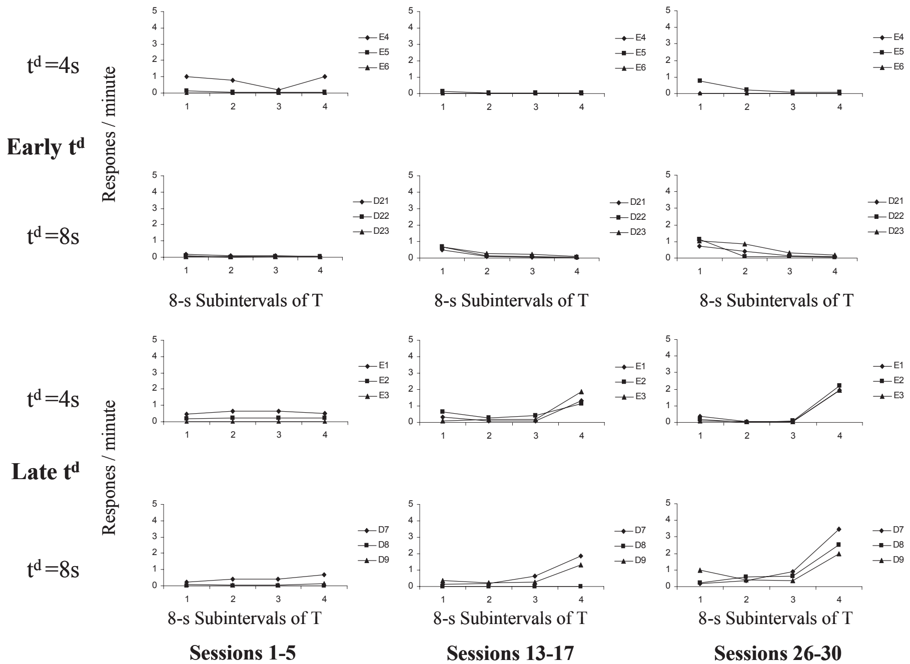

Figure 3B. Mean response rate per minute in consecutive 8-s bins of the reinforcement cycle for the first, intermediate and last five sessions. Mean response rate is shown for each subject and for the different experimental conditions of the non-contingent signal group.

Response distribution patterns in most experimental conditions appear to change as exposure to the reinforcement schedule increases. Change in response distribution is more apparent in signaled conditions with late t^d placement and less noticeable in unsignaled conditions and early t^d placement groups. In unsignaled t^d conditions (Figure 3A) change in local response rate is only apparent in late t^d placement groups; response rates appear very low on the first sessions and then gradually increase. The final late t^d placement patterns suggest (at least for five subjects) that a brief post-reinforcement pause may occur, followed by a gradual increase in response rate that reaches its maximum height in the second and third 8-s subintervals (the authors acknowledge that response patterns during the cycle may only be inferred as no data from cumulative recorders is available).

Figure 3B shows that response rates remain homogeneously low as time of exposure to the schedule increases; in contrast response distribu-

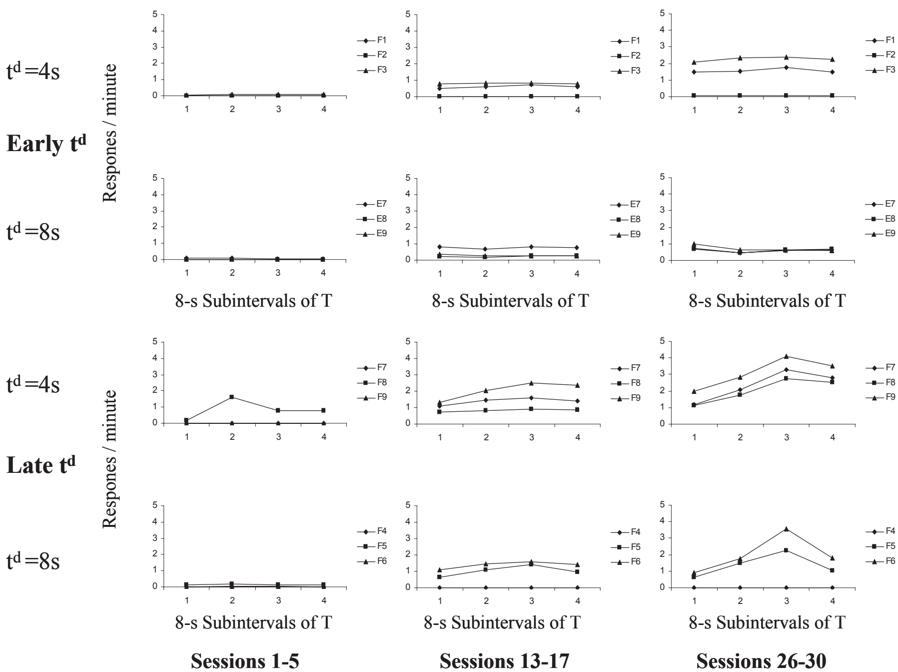

Figure 3C. Mean response rate per minute in consecutive 8-s bins of the reinforcement cycle for the first, intermediate and last five sessions. Mean response rate is shown for each subject and for the different experimental conditions of the contingent signal group.

tion changes dramatically as the experimental sessions progress. Both the intermediate and final five sessions show response distribution during the signal peaks notably (except on early t^d placement with a 4-s t^d where only E5 responds during the signal). Responding during the signal occurs early in the study (as nine out of eleven subjects who showed the discrimination on the last five sessions were already lever-pressing during the signal in the intermediate sessions).

Response patterns in figure 3C changed in different ways in early and late t^d conditions. In early t^d placement conditions response rates for most subjects appear to increase with longer exposure to the schedule (this effect is more apparent for subjects F1 and F3 in the t^d = 4-s condition). Although response rates increased in early t^d placement conditions response patterns remained relatively flat throughout the experiment; in contrast, in late t^d placement conditions both response rates and response patterns changed as exposure to the schedules increased. Response rates increased monotonically as exposure to the schedules also increased. In the intermediate sessions response patterns were rather flat and a slight post-reinforcement pause may be inferred from the data. However in the last five sessions response rates increased sharply during the unsignaled component of the cycle, and then decreased sharply during the signaled component.

In general, Figures 3A, 3B and 3C showed that those subjects exposed to signaled delay of reinforcement procedures distribute behavior in a less uniform fashion than subjects in unsignaled conditions do. In order to further assess response efficiency in the different experimental conditions, Table 1 shows the mean number of reinforcers obtained by all subjects in the first and the last five sessions of the study. The upper part of the Table shows early t^d conditions and the bottom of the table shows late t^d conditions. The data in the first column correspond to unsignaled delay of reinforcement conditions and the last two columns show data corresponding to signaled delay of reinforcement groups.

Table 1. Mean number of reinforcers earned on the first and last five sessions for all subjects and all experimental conditions.

t^d Placement and Duration	Condition								
	Unsignaled			Non-Contingent Signal			Contingent Signal		
	Rat	First 5	Last 5	Rat	First 5	Last 5	Rat	First 5	Last 5
Early t^d=4-s	C7	1	10.4	E4	0.4	0.4	F1	0.2	30
	C8	0	0	E5	7.8	30	F2	0	1.8
	C9	0.2	0	E6	0.4	0	F3	3.4	30
Early t^d=8-s	C1	0.8	0	D21	8.8	30	E7	4.4	30
	C2	0.4	14.4	D22	3.8	28.8	E8	0	27.8
	C3	10.4	7.8	D23	3.6	30	E9	0.6	30
Late t^d=4-s	D1	9.2	30	E1	8.8	30	F7	0.8	30
	D2	0.2	30	E2	7.6	30	F8	0.2	30
	D3	0	29.6	E3	0	30	F9	0.2	30
Late t^d=8-s	C4	13.8	30	D7	19.2	30	F4	0.2	0.2
	C5	0.2	30	D8	0	30	F5	9.8	30
	C6	6.6	30	D9	15	30	F6	1	30

Table 1 shows most subjects obtained more reinforcers during the last five experimental sessions (with the exception of four subjects in the early t^d

condition, C8, C9, E4 and E6; and one subject in the late td condition, F4). In general, Table 1 shows subjects on late t^d conditions obtained a larger number of reinforcers than subjects did in the early t^d conditions. This difference is more noticeable on unsignaled t^d conditions and with the short t^d value. Long and short t^d values produce very similar results on the late t^d conditions (both on the first and the last five sessions). In early t^d conditions animals obtained more reinforcers with the long t^d value (this difference is more apparent in unsignaled and non-contingent signal conditions). In late t^d conditions unsignaled and signaled delays produce a similar number of reinforcers. In early t^d conditions, signaled groups appear to produce a greater number of reinforcers than unsignaled ones.

The comparison of non-contingent and contingent signals effects in the present study is not straightforward because reinforcement always follows a response produced signal, and may or may not follow a non-contingent one. In order to assess the correlation between signal occurrence and reinforcement delivery, Table 2 shows the reinforcer-signal ratio for the non-contingent signal conditions in the last five experimental sessions. In the Table the rows show the different experimental conditions and the columns show the number of reinforcers (as the numerator) and the number of signals (as the denominator) for each subject on the last five sessions. The last two columns show the average reinforcer-signal ratio and the standard deviation of the last five sessions for each subject.

Table 2. Reinforcement-signal ratio on the last five sessions for subjects exposed to the non-contingent signal condition.

t^d Placement and Duration	Reinforcer/signal ratio, last five sessions							
	Rat	26	27	28	29	30	X	SD
Early t^d =4-s	E4	1/120	0/120	0/120	1/120	0/120	.003	.004
	E5	27/120	30/97	30/107	30/110	30/94	.281	.036
	E6	0/120	0/120	0/120	0/120	0/120	0	0
Early td=8-s	D21	30/84	30/84	30/120	30/56	30/50	.419	.143
	D22	30/60	30/58	30/61	30/109	30/51	.474	.117
	D23	30/81	30/67	30/58	30/76	30/64	.439	.058
Late td=4-s	E1	30/41	30/42	30/37	30/35	30/33	.822	.082
	E2	30/33	30/34	30/30	30/33	30/34	.918	.055
	E3	30/36	30/37	30/36	30/36	30/33	.843	.037
Late td=8-s	D7	30/36	30/38	30/37	30/39	30/31	.833	.078
	D8	30/34	30/38	30/33	30/35	30/41	.833	.072
	D9	30/41	30/38	30/37	30/43	30/36	.772	.056

Table 2 shows that reinforcer-signal ratio was much higher in late t^d placement condition than in the early t^d placement conditions. Reinforcer-signal ratios were very similar for both t^d durations in the late t^d placement condition. In contrast, for early t^d conditions 8-s t^d duration showed a considerably higher reinforcer-signal ratio than the shorter t^d value.

In order to further assess the effects of the independent variables manipulated in the present study, a three-way ANOVA (t^d duration x t^d placement x signal condition) was conducted. Response rates from each subject on the last five experimental sessions were used as dependent variable. Main effects from all independent variables reached statistical significance (t^d duration $F(1/168)= 7.41$, $p<.01$); (t^d placement $F(1/168)=173.965$, $p<.001$); (signal condition $F(2/168)=30.85$, $p<.001$). Interaction between t^d placement and t^d duration attained significance ($F(1/56)= 5.64$, $p<.05$); interaction between signal condition and t^d placement attained significance ($F(2/84)= 20.93$, $p<.001$); interaction between signal condition and t^d duration also attained significance ($F(2/84)=19.39$, $p<.001$). Interaction between the three independent variable also reached statistical significance ($F(2/168)=3.16$, $p<.05$). The statistical analysis suggests lower response rates occurred on the early t^d placement than on the late t^d placement ($X=2.05 < X=7.91$). Response rates on the last five days were higher with a short t^d value than with the long t^d value ($X=5.59>X=4.38$). A Newman-Keuls test (with a .05 significance level) revealed that response rates were significantly lower in the non-contingent signal condition than in both the unsignaled and the contingent signal conditions (which in turn did not differed significantly amongst themselves) ($X=2.706<X=5.3<X=6.94$). Response rates produced by unsignaled and contingent signal conditions in the late t^d placement group produced very similar response rates. This finding could probably be attributed to goal-seeking behavior produced by the signal (the animal approaches the food tray when the signal occurs). In order to assess this possibility the average response rates of both conditions produced in the first 24-s of the cycle for the last five sessions were compared. Difference between the two means did not attain significance ($t(10)=.072$, $p>.05$).

DISCUSSION.

In general the results of the study suggest response rates reach higher levels, in fewer sessions when t^d is located at the end of the reinforcement cycle than when it is placed at its beginning. Similarly, more reinforcers were produced by those subjects exposed to late t^d placement conditions than by those subjects assigned to early t^d placement groups. In general local response rates produced by subjects exposed to early t^d placement groups appear relatively flat (when compared to those produced under late placement conditions). Thus local response rates suggest stimulus control over behavior is stronger when response-reinforcer interval is brief. Response rates appear higher in the late t^d placement conditions regardless of t^d duration or signal condition.

Taken together these results are similar to those produced by Bruner, Pulido & Escobar (1999) with 60-s T cycles and different from those produced by Weil (1984) and Bruner, Pulido & Escobar (2000) with shorter cycles. The results suggest that the idea that long delays of reinforcement are necessary to produce a delay gradient in temporally defined schedules of reinforcement is probably wrong (as had been inferred from the previously existing data). However the argument made by the results of this study would be stronger if cycles exceeding 32-s, and shorter than 32-s had been used.

If the different results produced by the previous studies can not be reconciled in terms of parametric variations in cycle duration then, how can they be accounted for? Pulido & López (2005) have suggested the Weil`s atypical finding could probably be attributed to carryover effects produced by inadequate experimental design selection and lax stability criteria. Weil exposed the subjects in his study to at least 24 different experimental conditions and each condition was in effect for exactly fifteen sessions. Obviously this procedure lacks a common baseline of departure for all experimental condition and thus each preceding condition becomes an extraneous variable in the study. Carryover effects produced by the lack of a common baseline could have been diluted if the experimental subjects had been allowed to remain in each experimental condition for a considerable amount of time. As the stability criterion was fixed at 15 sessions, performance on each new schedule may not have had enough time to filter out carryover effects from a previous condition (Baron & Leinenweber, 1995; Ono & Iwabuchi, 1997; Pulido & López, 2005). Thus the presence of carryover effects in Weil´s experiment could probably explain why most studies that have used a between subjects design have failed to reproduce the atypical results reported by the former author. An account of Weil´s atypical findings in terms of carry over effects does not provide any clue as to why Bruner, Pulido & Escobar (2000) failed to produce a delay gradient in 32-s cycles using a between subjects design. One tentative explanation for the atypical result produced by Bruner et al has to do with the temporal separation between the two t^d placements used in their study. In the present study early and late t^d placement conditions were separated by at least 16-s, in contrast temporal separation between t^d placements in Bruner et al study was a mere 8-s. Future studies may help determine if a minimum temporal separation between t^d conditions is necessary to produce a delay gradient in temporally defined schedules of delayed reinforcement.

Signal effects found in the early t^d placement conditions are consistent with a number of empirical findings and theoretical developments. Richards (1981) and Lattal (1984) have produced evidence that suggests that the presentation of response produced exteroceptive stimuli during delay interval is associated with higher response rates than comparable unsignaled conditions. Recent reviews of the effect of signals in delayed reinforcement procedures are in general agreement with this idea (Pulido, Lanzagorta, Morán Reyes & Rubi, 2004). In the present study early t^d placement conditions were associated with higher response rates when a response produced signal occurred during t^d, in contrast response rates in unsignaled and non-contingent signal conditions were very low. In agreement with the previously discussed literature, low response rates in unsignaled delay conditions were an expected result (as were high response rates in response-produced signal conditions). Lattal (1984) has produced data that suggest that the correlation between signal occurrence and reinforcement delivery is crucial in order to produce the typical response enhancement effect reported by signaled delay procedures. Table 2 suggests signal-reinforcer correlation was not perfect in non-contingent signal conditions (correlations were particularly poor in the early t^d placement groups) and thus low response rates were the expected finding. Local response rates reported in this study suggest an alternative explanation for the low response rates found in non-contingent signal conditions. As figure 3B suggests response rates increase sharply for most subjects in the presence of the cue. This finding suggests the cues may function as discriminative stimuli that signal the precise moment when lever-pressing will produce food at the end of the interval. As t^d placement may be discriminated by subjects exposed to non-contingent signal conditions, continuous interreinforcer interval "probing behavior" is not likely to develop. Thus, low response rates in non-contingent signal conditions does represent efficient cue discrimination by the experimental subjects (instead of evidence of poor response acquisition). Table 1 suggests this last hypothesis may be considered seriously as the number of reinforcers earned in both contingent and non-contingent signal conditions was very similar.

Signal effects in late t^d placement conditions are very similar to those found in the early t^d placement groups. Response rates were higher in the contingent signal condition groups and comparatively lower in the non-contingent signal groups. In contrast to signaled conditions, unsignaled ones produced very different results in the two different t^d placement conditions assessed in this study. Instead of finding very low rates of responding in unsignaled late t^d placement groups, response rates were very high (reaching response rate levels comparable to those produced by contingent signal conditions). Initially these results were attributed to competing goal seeking behavior occurring in signaled conditions. However a comparison of local response rates prior to signal occurrence showed response rates in both unsignaled and contingent signal conditions were very similar even before the onset of the signal. Data produced by Lattal & Ziegler (1982) has shown that very brief delays to reinforcement my increase, rather than decrease, response rates. In the present study, responses could produce food during the last seconds of the reinforcement cycle, and thus it is possible that a number of lever-presses may have occurred in very close proximity to reinforcement delivery. Future studies that closely monitor response emission during the last seconds of late t^d placement conditions could provide more information regarding the present issue.

It may be argued that the present study fails to fully assess the effects of temporally defined schedules of reinforcement on operant behavior because a number of subjects failed to respond through out the experiment (or emitted a very small number of responses). Perhaps future replications of the present study, using steady state performance as a dependent variable, could provide more information about the effects of delay of reinforcement in temporally defined schedules.

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