CONTROL DEL ESTÍMULO EN PROGRAMAS FIJOS Y VARIABLES DEFINIDOS TEMPORALMENTE

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Resumen

Con el objetivo de evaluar el desarrollo del control del estímulo, seis ratas fueron expuestas a un programa de reforzamiento definido temporalmente (T = 60-s, = 0.5) en el que los subciclos t^D y t^Δ se correlacionaron con diferentes estímulos auditivos y probabilidades de reforzamiento de 1 y 0, respectivamente. Para tres ratas el subciclo t^D siempre fue seguido del subciclo t^Δ, mientras que para las ratas restantes ambos subciclos se presentaron de manera aleatoria (p = .5) dentro de la sesión. Al final del experimento, las frecuencias de respuesta de presión de la palanca fueron más altas durante t^D y en presencia del estímulo que señaló dicho subciclo, que durante t^Δ en todas las ratas. Los resultados indican que la disponibilidad limitada de reforzamiento de los programas definidos temporalmente no impide el control del estímulo, así como que dicho control se desarrolla sin patrones conductuales derivados de la regularidad secuencial entre los subciclos. Adicionalmente, los resultados cuestionan el posible desarrollo de una función de reforzador condicionado por parte del estímulo en el subciclo t^Δ.

Palabras clave: discriminación, disponibilidad limitada de reforzamiento, reforzamiento condicionado, agua, ratas.

STIMULUS CONTROL IN FIXED AND VARIABLE TEMPORALLY-DEFINED SCHEDULES

Abstract

In order to evaluate the development of stimulus control, six rats were exposed to a temporally defined reinforcement schedule (T = 60-s, = 0.5) in which t^D and t^Δ were correlated with different auditory stimuli and with reinforcement probabilities of 1 and 0, respectively. For three rats, t^D subcycle always was followed by t^Δ subcycle, while for the remaining rats both subcycles were presented randomly (p = .5) within the session. At the end of the experiment, lever-pressing response frequencies were higher during t^D and in the presence of the stimulus that signaled such subcycle than during t^Δ subcycle for all rats. Results indicate that the limited-hold reinforcement in temporally defined schedules does not necessarily prevent stimulus control, and that such control develops without any behavioral pattern derived from sequential regularity between subcycles. Additionally, results call in to question the possible development of a conditioned reinforcement function by the stimulus in t^Δ subcycle.

Key words: discrimination, limited-hold reinforcement, secondary reinforcement, water, rats.

CONTROLE DO ESTÍMULO EM PROGRAMAS FIXOS E VARIÁVEIS DEFINIDOS TEMPORALMENTE

Resumo

Com o objetivo de avaliar o desenvolvimento do controle do estímulo, seis ratos foram expostos a um programa de reforço definido temporalmente (T = 60-s, T□ = 0,5) no qual os subciclos t^D e $t^Δ$ se correlacionaram com diferentes estímulos auditivos e probabilidades de reforço de 1 e 0, respectivamente. Para três ratos, o subciclo t^D sempre foi seguido do subciclo $t^Δ$, enquanto, para os ratos restantes, ambos os subciclos foram apresentados de maneira aleatória (p = ,5) dentro da sessão. Ao final da experiência, as frequências de resposta de pressão da alavanca foram mais altas durante t^D e em presença do estímulo que sinalizou esse subciclo do que durante $t^Δ$ em todos os ratos. Os resultados indicam que a disponibilidade limitada de reforço dos programas definidos temporalmente não impede o controle do estímulo, da mesma forma que esse controle se desenvolve sem padrões comportamentais derivados da regularidade sequencial entre os subciclos. Além disso, os resultados questionam o possível desenvolvimento de uma função de reforçador condicionado por parte do estímulo no subciclo $t^Δ$.
Palavras-chave: discriminação, disponibilidade limitada de reforço, reforço condicionado, água, ratos.

In contrast with traditional fixed- and variable-interval reinforcement schedules, in which the response requirement for the production of the reinforcer could be satisfied at any time once the stipulated period by the schedule had elapsed (Ferster & Skinner, 1957), in temporally-defined schedules a limited-hold period for reinforcer delivery is specified. In the corresponding terminology, the limited-hold period for reinforcement is called t^D subcycle, while that in which responses have no consequences is called $t^Δ$ subcycle. When different exteroceptive stimuli are added to each one of these subcycles, the first response in t^D subcycle produces the delivery of the reinforcer and turns off the exteroceptive stimulus, while in $t^Δ$ the stimulus remains on independently of emitted responses. If no responses are emitted during t^D, the scheduled reinforcer for that particular cycle is withheld and the stimulus remains on until the beginning of $t^Δ$ (see Schoenfeld & Cole, 1972).

Several experiments have found that simple discrimination is not developed under temporally-defined schedules (Ribes & Torres, 1996; Ribes & Torres, 1997; Ribes, Torres, Barrera & Mayoral, 1997; Ribes, Torres & Piña, 1999; Ribes, Torres & Mayoral, 2000a; 2000b; 2002). In those studies rats were exposed to temporally-defined schedules in which different exteroceptive stimuli were added to t^D and $t^Δ$ subcycles, which in turn were respectively correlated with exclusive (i.e., 1 and 0) or complementary (e.g., .75 y .25) reinforcement probabilities. In general, authors observed that independently of the physical dimension of stimuli those correlated with the lowest reinforcement probability controlled a higher response frequency than the ones correlated with the highest probability. Such an absence of stimulus control was attributed to the differences between scheduled and obtained reinforcers due to non responding in the t^D subcycle of various T cycles within

sessions, as well as to the absence of a response pattern in the presence of the correlated stimulus due to its cancelation by the first response emitted in its presence. Both of them were collateral effects of the limited-hold reinforcement that characterizes temporally-defined schedules.

Regarding the previously described studies, Sosa (2011) pointed out a possible confusion in the measurement of stimulus control. Specifically, he noted that such control was estimated on the basis of total responses emitted during t^D subcycle, that is to say, including responses in both presence and absence of the correlated stimulus and, correspondingly, response frequencies not necessarily were a good index of the control exerted by the stimulus added to t^D. He also remarked that, at best, the calculus must be limited to the interval between the onset and the offset of the stimulus. Regarding responses emitted in the presence of the stimulus correlated with the lowest reinforcement probability, the same author suggested that their frequencies could be a byproduct of the regular alternation of t^D and $t^Δ$ subcycles, therefore fostering a scalloped response pattern similar to that produced by traditional fixed-interval schedules (Ferster & Skinner, 1957).

Previous experiments using temporally-defined schedules and rats as experimental subjects support the previous interpretation. Serrano, Moreno, Camacho, Aguilar and Carpio (2006), for example, observed higher response frequencies at the first 3-s long subinterval of the t^D subcycle than at any other subinterval of the T cycle when either auditory or visual and auditory stimuli were added to t^D and $t^Δ$ subcycles, respectively. When the added stimuli in both subcycles were visual, authors observed lower response frequencies during t^D that during $t^Δ$ as well as a scalloped response pattern along $t^Δ$. A similar response pattern was reported by Mateos and Flores (2009) when a

3-s long interval was imposed between t^Δ and t^D subcycles. However, for rats exposed to a 30-s long inter-subcycles interval response frequencies were higher during t^D that during t^Δ and, additionally, responding was near zero along both t^Δ and the inter-subcycles interval. Consequently, Mateos and Flores suggest that in experiments by Ribes and Torres (1996; 1997) and by Ribes et al. (1997; 1999; 2000a; 2000b; 2002) response frequencies in the presence of the stimulus added to the t^Δ subcycle could were due to the development of a conditioned reinforcement function by virtue of pairings of such stimulus and the primary reinforcement produced in the t^D subcycle.

If in the experiments conducted by Serrano et al. (2006) and in that conducted by Matos and Flores (2009) the absence of stimulus control was due to collateral response patterns produced by t^D and t^Δ regular alternation, the same possibility applies to the performances that suggested stimulus control by signals added to the t^D subcycle. For example, it is well known that under differential low-rate reinforcement schedules the efficacy of responding is usually correlated with the development of collateral response patterns within inter-reinforcement interval (e.g., Hodos, Ross & Brady, 1962; Laties, Weiss, Clark & Reynolds, 1965; Willson & Keller, 1953). If this is the case, such patterns prevent the estimation of limited-hold reinforcement effects upon stimulus control development. Avoiding the development of collateral behavioral patterns would require not only eliminating the temporal contiguity between the ending of t^Δ and the beginning of t^D, but also their regular alternation. In this sense, the objective of the present experiment was to compare the effects of regular *versus* random alternation of t^D and t^Δ subcycles upon responding along them and the percentage of obtained water deliveries.

METHOD

Subjects

Six male Wistar rats, approximately 3-months-old, were used. All rats were experimentally naive and maintained under a water deprivation schedule with free access to food (Purina Rodent Lab Chow 5001 ®) in their home-cages. After each experimental session the rats had free access to water during 30 min. Home-cages were located in a controlled temperature, 12:12 light/dark schedule room.

Apparatus

Four operant test chambers (ENV-008) manufactured by Med Associates Inc. ® were used. Front and back walls of each chamber were made of aluminum while side walls were made of Plexiglas. Centered in the front wall of each chamber, 2 cm above the steel rods floor, a water dispenser (ENV-202M-S) was mounted. Dispensers provided a 0.01 cc of water per activation. Individual response levers (ENV-112CM) were mounted 6 cm above the floor and 0.5 cm from the left-side wall of each chamber. All levers were operated by a force of 0.25 N. Two sonalert speakers were located 17 cm above the floor and 0.5 cm from the left and right side walls, respectively. The left-hand speaker (ENV-223AM) emitted a 2900 Hz tone per activation, while the right-hand speaker emitted a 4500 Hz tone per activation. Operant chambers were individually housed in sound-attenuating cubicles (ENV-022MD-27), each one containing a fan that provided ventilation as well as white-noise. Experimental events were controlled by a desktop computer (HP Compac Pro 6305) provided with an interface (SG-6510DA) and specialized software (SOF-735).

Procedure

Initially, lever-pressing responding was shaped by successive approximations for all rats. After the shaping period, lever-pressing responses were reinforced according to a continuous reinforcement schedule until rats received 60 drops of water or after one hour had elapsed, whichever occurred first. After that, two groups of three rats each were randomly formed. Rats labeled R1, R2, and R3 formed the Variable Group, while rats labeled R4, R5, and R6 formed the Constant Group.

A 60-s long temporally-defined schedule was used for all rats. Both t^D and t^Δ subcycles were 30-s long and were correlated with 1 and 0 reinforcement probabilities, respectively. The t^D subcycle was signaled by the 2900 Hz tone and the t^Δ subcycle was signaled by the 4500 Hz tone. For rats from the Constant Group the t^D subcycle was always followed by the t^Δ subcycle, at the end of which a new t^D subcycle always began. For rats from the Variable Group, both subcycles were randomly presented within an experimental session according to a 0.5 probability. In other words, for rats in the Variable Group experimental sessions could begin with either subcycle which could be followed with either a new t^D subcycle or a new t^Δ subcycle. For both groups of rats, the first response during the t^D subcycle produced the activation of the water dispenser for 3 s as well as the tone offset. When no responses were emitted during the t^D subcycle the tone remained on until the end of the subcycle and the scheduled reinforcer for that particular cycle was omitted. During the t^Δ subcycle emitted responses had no consequences. Each one of the 20 sessions of the experiment comprised 30 T cycles.

RESULTS

Figure 1 shows response frequencies during t^D and t^Δ subcycles, as well as the percentage of produced water deliveries in each experimental session. It is observed that for the three rats from the Variable Group and rats R4 and R6 from the Constant Group, response frequencies were higher during the t^D subcycle than during the t^Δ subcycle in most of the sessions. For the remaining rat, R5, the same effect was only observed in the last four sessions of the experiment. In the remaining sessions response frequencies in both subcycles were practically equivalent for the same rat. Figure 1 also shows that, with the exception of rats R1 and R5, water deliveries for most rats in both groups were close to 100% from the third and sixth sessions. For rat R1 water deliveries were erratic along the experiment, but were between 70% and 100% along the last 10 sessions. For rat R5 water deliveries were close to 20% in the first five sessions, near 40% in the following seven sessions, around 65% from the 14th to the16th session, and between 80% and 100% in the last four sessions of the experiment.
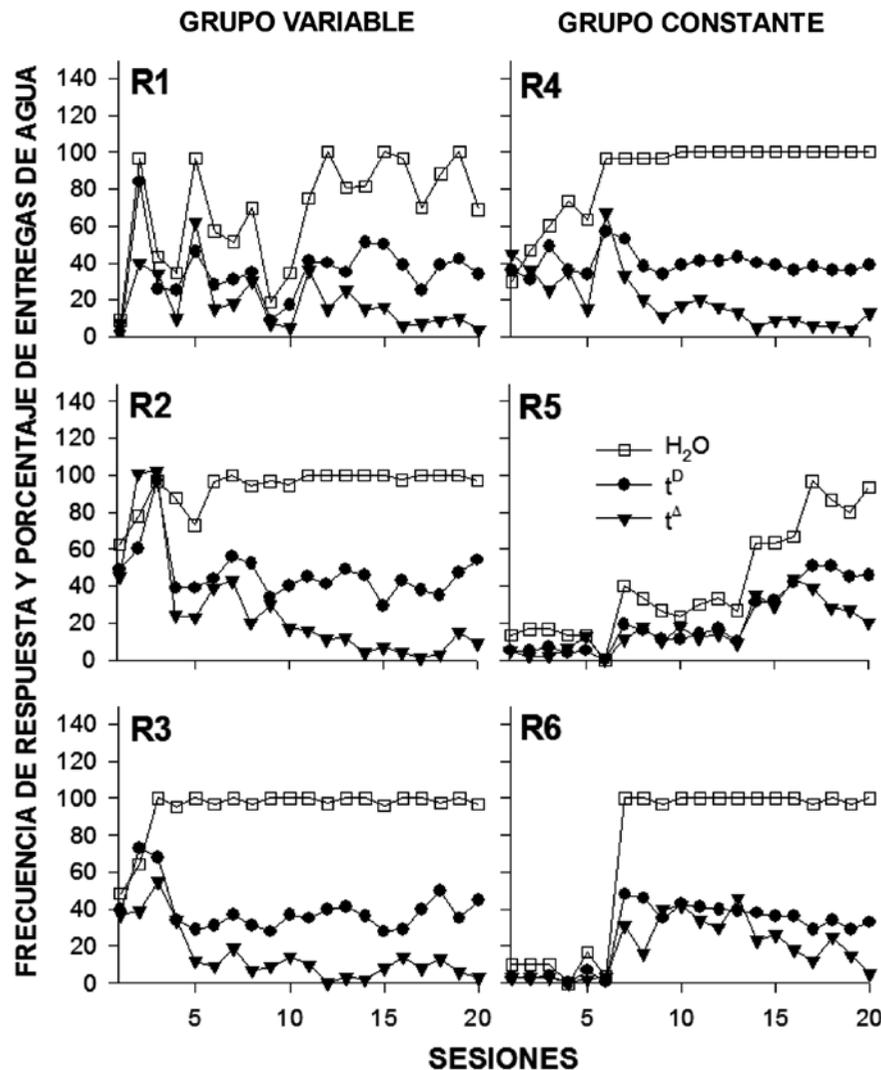

Figure 1. Lever-pressing response frequencies during the tD (black circles) and tΔ (black triangles) subcycles and the percentage of water deliveries (white squares) per session for rats from the Variable Group (left) and rats from the Constant Group (right).

Figure 2 shows the proportion of responses in the presence and absence of the stimulus during the t^D subcycle and in the presence of the stimulus in the t^Δ subcycle. It is observed that for the three rats from the Variable Group and for rat R4 from the Constant Group, the proportion of responses in the presence of the stimulus during t^D progressively increased along experimental sessions, concomitantly to decreases in the response proportion in the absence of the stimulus during such subcycle and the proportion of responses in the presence of the stimulus in the t^Δ subcycle. For rats from the Constant Group, it is observed that in the first half of the experiment the proportion of responses in the absence of the stimulus during the t^D subcycle is higher than the proportion of responses in the t^Δ subcycle, while no systematic differences are observed between both response proportions at the second half of the experiment. The same

absence of systematic differences between both response proportions is also observed for rat R4 from the Constant Group; however, for this rat the proportion of responses was consistently higher in the presence of the stimulus during the t^Δ subcycle than in the absence of the stimulus during the t^D subcycle at the initial experimental sessions. A similar response proportion distribution is observed for the remaining rats from the Constant Group along most of the sessions. Additionally, Figure 2 shows that for rat R6 the proportion of responses in the presence of the stimulus during the t^D subcycle was higher than the proportion of responses in the presence of the stimulus during the t^Δ subcycle along the last seven experimental sessions, while for rat R5 the same effect was observed only in the last experimental session.
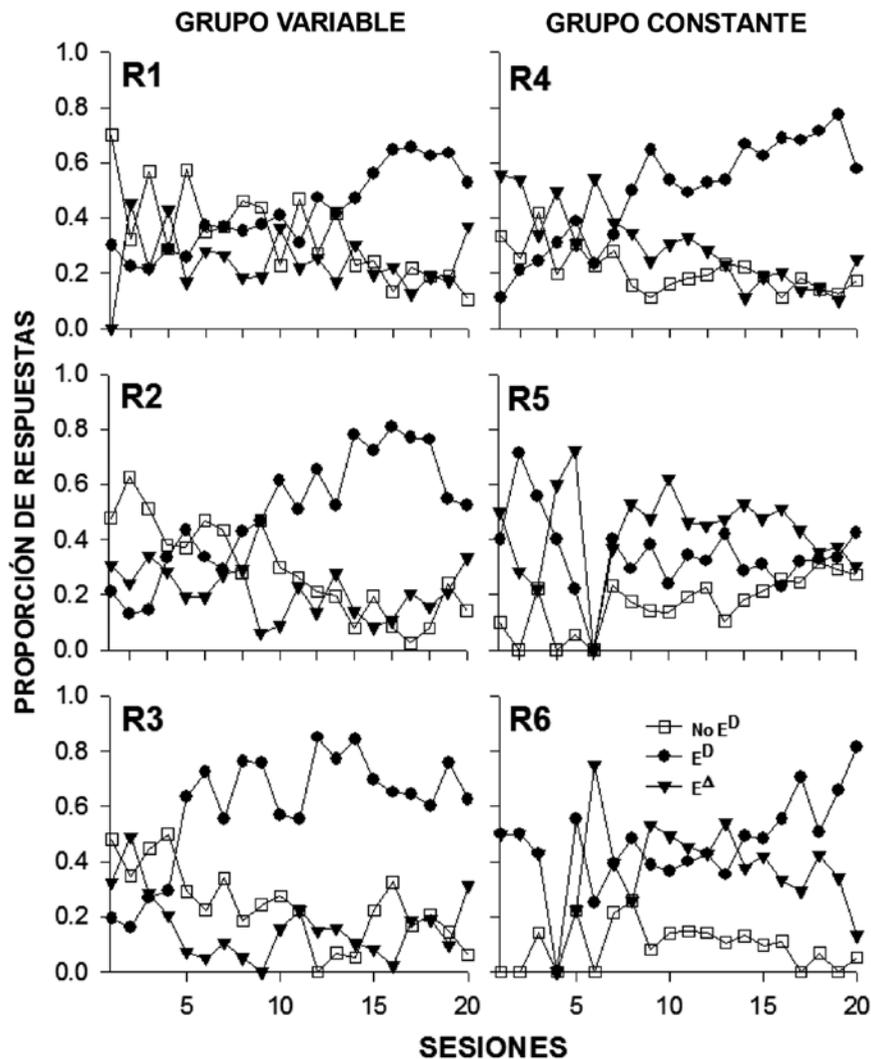
Figure 2. Proportion of lever-pressing responses in the presence of the stimulus during the tD subcycle (black circles), during the post-reinforcement remaining of the tD subcycle (white squares) and during the t∆ subcycle (black triangles) per session for rats from the Variable Group (left) and rats from the Constant Group (right).

DISCUSSION

As in the experiments conducted by Serrano et al. (2006) and Mateos and Flores (2009), the results of the present experiment support the idea that neither the potential reinforcer loss, nor the absence of a response pattern in the presence of the stimulus during the t^D subcycle by its cancellation by virtue of the first response emitted in its presence, impede stimulus control development. Specifically, in the present experiment it was observed that response frequencies were higher during the t^D subcycle than during the t^Δ subcycle for four of the six rats independently of the experimental condition. While for these rats the percentages of water deliveries were close to 100% from the fifth or the sixth experimental session, for rats in which the percentage of water deliveries were severely low (R5) or erratic (R1) along most of experimental sessions, response frequencies during both subcycles were practically equivalent or higher during the t^D subcycle than during the t^Δ subcycle, respectively.

Various aspects could be highlighted about the results of the present experiment. First, it is noteworthy that, with the exception of rat R5, the differentiation of responding transcended what Sosa (2011) called subcycle control, that is to say, that the differences in response frequencies during t^Δ and t^D subcycles independently of the presence or absence of the stimulus added to the latter subcycle. With the exception already noted, it was observed that towards the end of the experiment, the proportion of responses was higher in the presence of the stimulus during the t^D subcycle than in the presence of the stimulus during the t^Δ subcycle for all rats. Second, it must be noted that, while for rats from the Constant Group the proportion of responses was mostly higher in the presence of the stimulus during t^Δ than during the post-reinforcement remaining of the t^D subcycle, for rats from the Variable Group the proportion of responses was initially higher in the post-reinforcement period of the t^D subcycle than in the presence of the stimulus during t^Δ subcycle and, towards the end of the experiment, no systematic differences between both response proportions were observed.

The fact that towards the end of the present experiment the proportion of responses has been higher in the presence of the discriminative stimulus than in the presence of the stimulus presented along the t^Δ subcycle for most rats complements previous commentaries on the collateral effects of limited-hold reinforcement. Specifically, it indicates that the absence of a response pattern in the presence of the stimulus during the t^D subcycle -due to the stimulus offset by the first response emitted in its presence- does not impede stimulus

control development. The fact that initial response frequencies during the post-reinforcement period of the t^D subcycle were higher than response frequencies in the presence of the stimulus during the t^Δ subcycle for rats from the Variable Group indicates that such a condition enhanced the differentiation of responding between stimuli presented during t^D and t^Δ subcycles rather than obstruct it. Given that under two-choice matching-to-sample procedures the onset of sample stimuli in a particular key promotes the control of that key location over responding (e.g., Lionello & Urcuioli, 1998; Lionello-DeNolf & Urcuioli, 2000), it is possible that the regular alternation between t^D and t^Δ subcycles could develop a similar collateral control that, by virtue of it, functional irrelevance regarding stimuli, responses and reinforcement, retards stimulus control development. The fact that the proportion of responses was higher in the presence of the stimulus during the t^Δ subcycle than during the post-reinforcement remaining of the t^D subcycle for rats from the Constant Group supports this idea. At the same time, however, this result cast doubts over the statement by Mateos and Flores (2009) regarding the lack of stimulus control in the experiments conducted by Ribes and Torres (1996; 1997) and by Ribes et al. (1997; 1999; 2000a; 2000b; 2002) due to a conditioned reinforcer function by the stimulus presented along the t^Δ subcycle.

The interpretation that the lack of stimulus control under temporally-defined schedules due to the development of a conditioned reinforcer function by the stimulus presented along the t^Δ subcycle, depends on the similarity between the stimulus conditions under such kind of schedules and some of the procedures by which the development of a conditioned reinforcing value by an arbitrary stimulus is assessed. Sosa (2014) recently has reviewed those kinds of procedures and their corresponding critiques regarding the demonstration of the conditioned reinforcement value by arbitrary stimuli. From our perspective, and omitting such critiques, the most pertinent comparison procedure seems to be chained schedules of reinforcement (Ferster & Skinner, 1957). , As it is well known, in this kind of schedules the delivery of the reinforcer takes place once response requirements specified by two or more simple schedules have been satisfied. In general, under chained schedules, the sooner the delivery of the primary reinforcer, the greater the frequency of the response along each link of the chain, being the maintenance of responding and the corresponding performance patterns between links, an index of the

conditioned reinforcement value (e.g., Kelleher & Fry, 1962).

In that vein, the conditions to which rats R4, R5, and R6 of the present experiment were exposed can be described -at least partially- as a variable time (VT)-fixed-time (FT)-continuous reinforcement (CRF) chained schedule, whose links correspond with the post-reinforcement period of the t^Δ subcycle, the t^Δ subcycle, and the period of the t^D subcycle in which the auditory stimulus was on. If this analogy is accepted, it must be noted that only for two of the three rats from the Constant Group -rats R4 and R6- response proportions along VT, FT and CRF "links" progressively increased as mentioned earlier and, additionally, that such increment was only observed in the experimental sessions in which response frequencies were higher during t^D than during t^Δ, that is to say, those sessions in which, according with the metrics by Ribes and Torres (1996; 1997) and Ribes et al. (1997; 1999; 2000a; 2000b; 2002), stimulus control was observed.

Only for rat R5 responding during t^D and t^Δ subcycles showed no notable differences along 16 of the 20 sessions of the experiment. In this respect, it must be noted that for this rat the percentage of water deliveries was lower than 50% along such sessions; a situation similar to those in the experiments conducted by Ribes and Torres (1996; 1997) and by Ribes et al. (1997; 1999; 2000a; 2000b; 2002) due to the high percentage of "lost" water deliveries. In fact, such dependent variable questions by itself the idea that the lack of stimulus control in the above mentioned experiments could be explained on the basis of the conditioned reinforcement concept. Specifically, if as it is assumed, the conditioned reinforcer function by an arbitrary stimulus depends on a classical conditioning mechanism (Dinsmoor, 2001), the question that arises is how the stimulus correlated with the FT link could develop a conditioned reinforcer function if the proportion of pairings between the stimulus and water deliveries was lower than 0.5 in most sessions (Rescorla, 1967).

In the above context, it is noteworthy that neither in the experiments by Ribes and Torres (1996; 1997) and by Ribes et al. (1997; 1999; 2000a; 2000b; 2002), nor in the case of the rat R5 of this study, the stimulus during the t^Δ subcycle developed an inhibitory function for responding. Further studies should address this problem. At the moment it is likely that the absence of the sub-cycle control and stimulus control observed for rat R5 in most sessions of the present experiment was related to the use of pure tones -as in the experiment by Ribes et al. (2002) in which absence of stimulus control was reported- rather than a pure tone and white noise -as in the study by Serrano et al. (2006), in which stimulus control was attributed to intra- and interdimensional differences between stimuli during t^D and t^Δ subcycles.

In any case, the results of the experiment described here, on the one hand, confirm that collateral effects of limited-hold reinforcement do not prevent stimulus control and, on the other hand, when stimulus control has been observed, such control is not attributable to the regular alternation between t^D and t^Δ subcycles. Further experiments should determine if, as in the experiments conducted by Lionello and Urcuioli (1998) and Lionello - Denolf and Urcuioli (2000), the "multipletemporal placement training" implemented in the present experiment enhances or not the transfer of simple discrimination to new stimulus instances.

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