

EFFECTS OF WITHHOLDING THE OPPORTUNITY TO PRESS THE OPERANT LEVER ON THE MAINTENANCE OF SCHEDULE-INDUCED DRINKING IN RATS¹

*EFFECTOS DE RETIRAR LA OPORTUNIDAD DE PRESIONAR LA
PALANCA OPERANTE EN EL MANTENIMIENTO DE LA BEBIDA
INDUCIDA POR PROGRAMA EN RATAS*

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ABSTRACT

Rats developed excessive drinking on a fixed-interval 60-s food reinforcement schedule. In subsequent test sessions, the rats were divided in two groups: in the experimental group, the response lever was retracted; in the control group, the lever was rendered inactive. Food was dispensed at regular one-minute intervals regardless of the animals' behavior (fixed time 60-s schedule). Drinking declined in experimental as opposed to control rats, but this effect proved transitory. A tentative explanation is proposed in terms of the consequences that follow adjunctive behavior. This approach is compared with the view that emphasizes the role of the reinforcer as a discriminative stimulus.

Key words: schedule-induced drinking, lever withdrawal, control by consequences, licking, rats

1. Artículo recibido el 26 de abril de 2004 y aceptado el 7 de junio de 2004.
2. Research and preparation of this manuscript were funded by grants PB98-0010-C02-01 and BSO2002-04322-C02-02 from Ministerio de Educación y Cultura and Ministerio de Ciencia y Tecnología, Spain. Preparation of the manuscript was also aided by financial support from Universidad Nacional de Educación a Distancia. Correspondence should be addressed to Ricardo Pellón, Facultad de Psicología, Universidad Nacional de Educación a Distancia, C/ Juan del Rosal 10, Ciudad Universitaria, 28040-Madrid, Spain. E-mail: rpellon@psi.uned.es. Juan Ardoy is now at Facultad de Ciencias de la Salud, Universidad Rey Juan Carlos, Madrid, Spain.

RESUMEN

Ratas de laboratorio desarrollaron bebida excesiva por su exposición a un programa de intervalo fijo 60 seg de reforzamiento con comida. En posteriores sesiones de prueba, se dividió a las ratas en dos grupos: para el grupo experimental, se retiró la palanca de respuesta; para el grupo control, la palanca se mantuvo pero inactiva. La comida se dispensó a intervalos regulares de un minuto independientemente de la conducta de los animales (un programa de tiempo fijo 60 seg). La bebida disminuyó en las ratas experimentales en comparación con las de control, pero este efecto resultó transitorio. Se propone una explicación tentativa basada en las consecuencias que siguen a la conducta adjuntiva. Esta explicación se compara con la propuesta que resalta el papel del reforzador como estímulo discriminativo.

Palabras clave: bebida inducida por programa, retirada de la palanca de respuestas, control por las consecuencias, lengüetazos, ratas

Falk (1971) proposed that adjunctive behavior occurs on interruption of consummatory activity in an intensely motivated animal, such as a hungry rat that is only able to obtain small amounts of food intermittently. In such circumstances, it is highly likely that a rat will drink in excess if given access to water (Falk, 1961). This type of behavior is difficult to classify as respondent or operant (Wetherington, 1982) and, until now, the existing theoretical interpretations have been unable to make room satisfactorily for all the determinants of adjunctive behavior (Pellón, 1990, 1992).

The way in which adjunctive behavior develops nevertheless indicates that it might be the result of a learning process; an initial hypothesis is that adjunctive behavior is a Pavlovian-type conditioned response. Lashley and Rosellini (1980) have suggested that schedule-induced polydipsia is restricted to time periods involving a low probability of reinforcement, and that its origin is not to be found in the interruption of consummatory behavior *per se*, as suggested by Falk (1971). These authors underscored the importance of associative factors in the development and maintenance of adjunctive drinking, namely, that reinforcement and non-reinforcement signals have a direct influence on schedule-induced polydipsia. This interpretation is compatible with the model proposed by Staddon (1977), in which interim and terminal activities are respectively localized in periods of low and high probability of reinforcement (though the explanatory terms proposed by Staddon are more of a motivational than of an associative nature).

Schedule-induced polydipsia, however, is not always emitted immediately after food. In studies where water is not available in post-pellet periods, animals tend to drink the same amount during the parts of the inter-food interval in which water is available (Flory & O'Boyle, 1972; Gilbert, 1974). Furthermo-

re, polydipsia has been successfully induced with water available under fixed ratio schedules (Falk, 1966a), which means that, in addition to having to press a lever to obtain food, the animal must also do so to obtain water.

Another line of interpretation is to consider adjunctive behavior as a case of operant behavior. Clark (1962) proposed that schedule-induced polydipsia might be superstitious behavior maintained by adventitious food reinforcement. However, animals do not drink to obtain food, because drinking normally occurs *after*, rather than before, the delivery of the reinforcer. Furthermore, polydipsic drinking can develop under FR schedules of food reinforcement (Burks, 1970), in which a relationship between drinking and food presentation is difficult to establish.

Nevertheless, a good body of evidence indicates functional similarities between adjunctive and operant behaviors, in particular with respect to their susceptibility to environmental consequences. Pellón and Blackman (1987) reported that drinking induced by a fixed time (FT) 1-min schedule could be punished by lick-contingent, signaled or unsignaled, 10-s delays to food presentation. Polydipsic drinking has also been punished by lick-dependent electric shocks (Bond, Blackman & Scruton, 1973). Finally, adjunctive drinking can be increased or decreased according to whether the licks are followed by additional presentations of food or by its withdrawal (Reberg, 1980).

The degree of schedule-induced polydipsia also depends on motivational variables related to the reinforcer (Pellón, 1992; Reid & Staddon, 1990). Increases in the level of food deprivation are normally accompanied by increases in the amount of adjunctive drinking (Falk, 1969). There is a bitonic relationship between the rate of polydipsic drinking and the frequency of food presentation (Falk, 1966b; Flory, 1971). The amount of adjunctive drinking also varies with changes in the magnitude of the food reinforcer (Flory, 1971; Robinson & Flory, 1989) or the nature of the food presented (Poling, Krafft, Chapman & Lyon, 1980). However, schedule-induced polydipsia clearly depends neither upon the animals' level of thirst (Roper & Posadas-Andrews, 1981), nor upon water being artificially administered to them before the experimental session (Porter, McDonough & Young, 1982; Porter, Young & Moeschl, 1978).

Adjunctive behavior seems therefore to depend in great measure upon the motivational characteristics that define the food reinforcer, the degree of adjunctive behavior being determined by the manipulation of access to food. But these data do not directly evidence the mechanisms responsible for the acquisition and maintenance of adjunctive behavior; rather, they are indicators of similarities between adjunctive and operant behavior. Therefore it remains to ascertain whether, in the case of adjunctive behavior, environmental consequences play a role akin to that which they are known to play in operant behavior. Showing that the degree of adjunctive behavior depends in part on its environmental consequences would be a further step towards conceptua-

lizing adjunctive behavior as a case of operant behavior (see Pellón, Flores, & Blackman, 1998).

The experiment described below is an exploratory study of the role played in the maintenance of schedule-induced polydipsia by events that follow such behavior. Animals were exposed to a fixed interval (FI) 60-s food reinforcement schedule and developed stable sequential patterns of adjunctive drinking and operant lever pressing. The response lever was then withdrawn and the schedule changed to an FT 60-s schedule. If adjunctive drinking is controlled by prior presentation of the reinforcer, then no significant change would be expected in the level of schedule-induced polydipsia. If, on the other hand, the actions that follow behavior partly determine the amount of adjunctive drinking, then changes in the level of schedule-induced polydipsia ought to appear. In such a case, denying subjects the chance of pressing the lever with the introduction of the FT schedule should affect adjunctive drinking, in spite of the fact that reinforcer presentations remain periodic. Control animals with the response lever present but inactive were included to evaluate if a change from an FI to an FT schedule was sufficient in itself to produce changes in the amount of adjunctive drinking.

METHOD

Subjects

Twelve experimentally naive male Wistar albino rats of approximately 90 days of age were used (supplied by IFFA-CREDO, Lyon, France). The animals were individually housed and placed in a laboratory animal facility, automatically kept at a constant ambient temperature (22°) and humidity (55%) with a twelve-hour light/dark cycle (with lights on between 8:00 and 20:00 hours).

Animals were gradually reduced to 80% of their free-feeding weights. They were weighed daily at the beginning of each experimental session; supplementary food was supplied to them thirty minutes after the end of the session. Water was freely available in all animals' home cages.

Apparatus

The experiment was conducted in six operant conditioning chambers (Letica LI-836, Barcelona, Spain) that were controlled by an ACORN computer programmed in SPIDER. The boxes were enclosed in soundproofed housing, with the ventilation fan providing masking noise (60 dB).

Each chamber consisted of a grid-type floor, two walls made of opaque acrylic material, a roof and left wall made of transparent Plexiglass, and a

main wall composed of interchangeable aluminium modules. The food tray, to which 45-mg food pellets (Bio-Serv) were funneled by an automatic dispenser, was located in the center of the front panel, 3.7 cm above the floor. A retractable lever was located on each side of the food tray, 4.8 cm from the food tray and 4.7 cm above the floor. The right lever was left in retracted position throughout the experiment, so that only the left lever was operative, requiring a force of approximately 0.15 N. A pair of lights of 3-watt power output were located above the levers, 15 cm off the floor, and were on during the session. A 3.2 x 3.9 cm aperture in the lower right-hand side of the right wall, 20 cm from the left wall and 7 cm from the floor, provided an outlet for the water spout. This spout was connected to an electronic sensor which, when activated by the animal's tongue, counted each contact as one lick.

Procedure

The animals first underwent magazine training. Approximately 20 food pellets were supplied; the rats were placed inside the chambers and were left to eat during 10 min. The following session served to train lever pressing, each lever press being reinforced with a food pellet until 30 reinforcers had been obtained or 30 min had elapsed (whichever came first). In the next two sessions the reinforcement schedule was changed to an FI 15-s and then to an FI 30-s schedule, in this order; the sessions ended when 30 reinforcers had been obtained or after 30 min had elapsed.

The experiment proper began the following day. Water bottles were installed in the chambers, as described above, and the food reinforcement schedule was changed to an FI 60-s. The sessions terminated 60 s after the thirtieth reinforcer or 35 min after the start of the session, whichever came first. During each session, the following were measured for each rat: session duration; number of reinforcers obtained; number of lever presses; number of licks to the water spout; and amount of water consumed. These measures in turn allowed to compute the rate of lever pressing (number of lever presses divided by duration of the session) and the rate of licking (number of licks divided by duration of the session).

Training continued for 39 sessions to ensure that lick- and lever-pressing rates were stable. Once drinking and lever pressing showed no systematic session-to-session variation, the subjects were divided among an experimental group and a control group. Subjects were allocated to the groups randomly, taking into account their licks-per-minute data for the last five sessions. Rats were matched in pairs by licking rate, and each animal in a pair allocated to a group by the toss of a coin. Session 40 (hereafter referred to as *Pre-test*) was identical to the preceding sessions, but additionally, lever presses and licks were recorded in each of the 30 inter-reinforcer intervals.

The last phase of the experiment comprised two test sessions (hereafter referred to as *Test 1* and *Test 2*). In the experimental group, the lever remained retracted and the food was presented at regular 1-min intervals (FT 60-s), regardless of the rat's behavior. The rats in the control group had access to the lever, but manipulating it had no scheduled consequences; an FT 60-s schedule was in order, as in the experimental group. The data were recorded as in the Pre-test session.

RESULTS

Figure 1 shows the acquisition curves for lever pressing (upper panel) and for drinking (lower panel) in both groups, expressed in terms of response

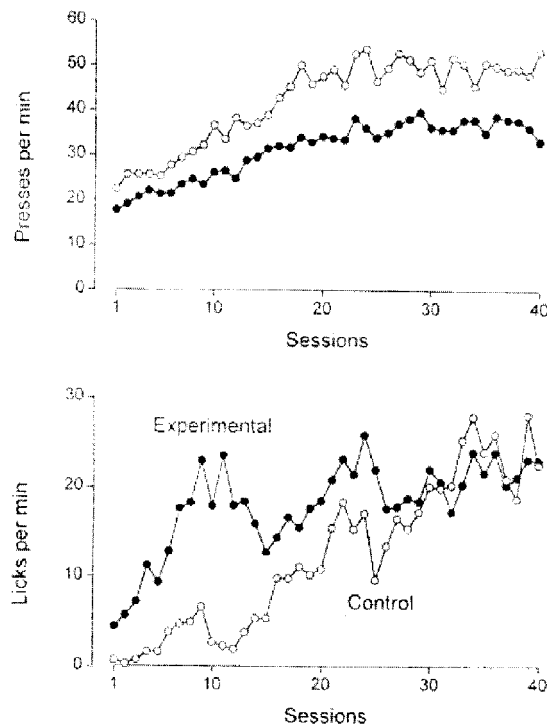


Figure 1. Mean rate of lever pressing and mean rate of licking in the experimental and control groups (black and white circles, respectively) over the 40 training sessions.

rate. During training, animals in the two groups developed a high rate of lever pressing and a high rate of licking, indicating that the FI 60-s schedule was effective in maintaining reliable patterns of operant and adjunctive behavior. Given that the distribution of subjects among groups was based only on the rate of licking in the last training sessions, some differences can be observed in Figure 1 for the two groups. For instance, at every stage of the experiment the rats assigned to the control group pressed the lever more than did those in the experimental group, though at no time were these differences statistically significant [$F(1, 10) = 2.59, p = 0.14$]. There was no apparent difference between the groups in terms of licks per minute [$F(1, 10) = 0.82, p = 0.39$], but the group \times session interaction was significant [$F(39, 390) = 2.03, p < 0.01$]. The experimental rats acquired schedule-induced drinking before the controls, yet final levels of licks per minute were identical for the two groups.

Figure 2 shows the average licking rate for the experimental and control groups on Pre-test and tests 1 and 2. During the first test session, licks per minute declined in the experimental group with respect to its Pre-test level (black bars in Figure 2). No such decline was apparent in the control group (white bars). In the second test session, licking rate increased in both groups, the experimental group remaining at a lower level than the control group. In no case did the results proved statistically significant, however [$F(1, 5) = 0.79, p = 0.42$, and $F(1, 5) = 0.23, p = 0.65$, for the Pre-test vs. Test 1 comparison in the experimental and control groups, respectively; $F(1, 5) = 0.22, p = 0.66$, and $F(1, 5) = 2.96, p = 0.15$, for the Pre-test vs. Test 2 comparison in the experimental and control groups, respectively].

Figure 3 shows the rate of licking for each of the 30 inter-reinforcer intervals contained in the Pre-test, Test 1 and Test 2 sessions. The graphs on the left co-

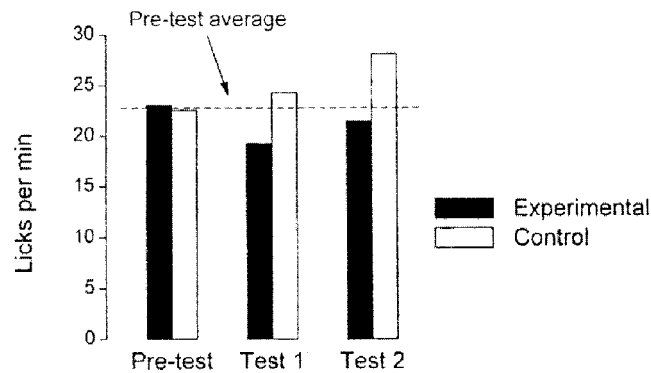


Figure 2. Mean licking rate for the experimental and control groups (black and white bars, respectively) for the Pre-test, Test 1 and Test 2 sessions.

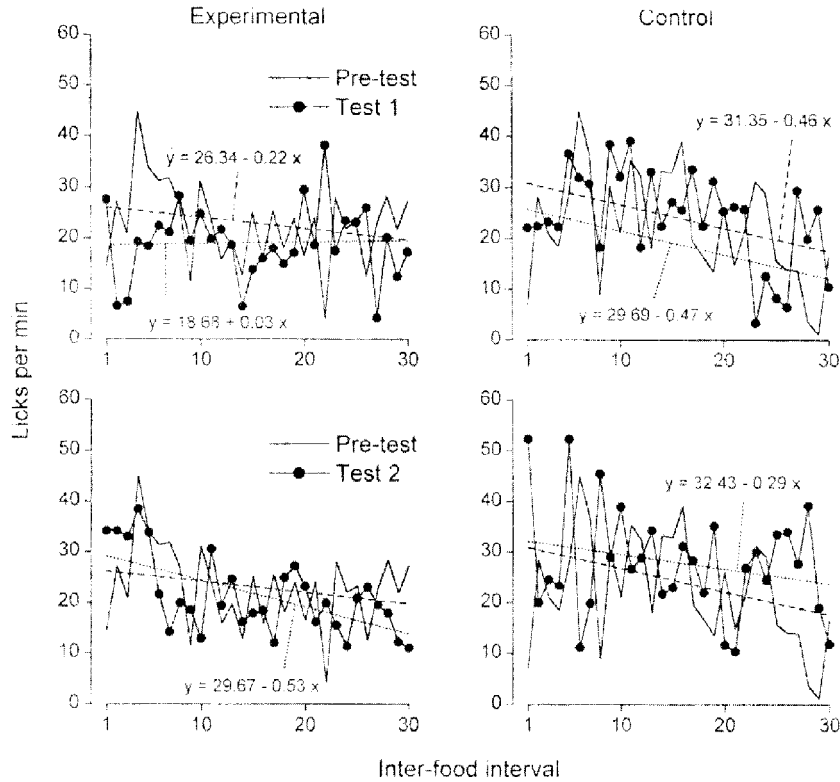


Figure 3. Mean licking rate for each of the successive 30 inter-food intervals for animals in the experimental and control groups. Lines represent the best linear fit with respect to the results yielded by the Pre-test, Test 1 and Test 2 sessions.

respond to the experimental group and those on the right to the control group. A general downward trend in licks per minute can be seen over the course of the sessions, with the sole exception of Test 1 in the experimental group. This result becomes clearer by plotting the regression lines that best fit the response profiles. The regression lines appear in Figure 3 along with the resulting equations. Negative slopes were obtained for each session, except in the case of Test 1 in the experimental group, where the slope was slightly positive (indicating that the behavior remained relatively stable across the session).

A more detailed observation of the performance of the experimental group during Test 1 showed that licks per minute did not remain entirely stable across the session, and thus the fits fail to provide an accurate description of interval-to-interval behavior changes. Licking rate declined during the first in-

tervals (the second and third intervals in particular) and later recovered along the course of the session. This result was not observed during the Pre-test, disappeared in Test 2, and did not appear in the control group.

Figure 4 shows the fit to the data obtained in intervals 2 to 8 in the experimental group during Pre-test and Test 1. (The first interval, corresponding to the time between the start of the session and the release of the first food pellet, was omitted, because behavior could not yet have been affected by the experimental manipulation; see the Discussion section below). A positive trend was clearly observable in licks per minute during Test 1 session, with more licks as time elapsed, whereas in the Pre-test session no systematic changes were seen during the first intervals.

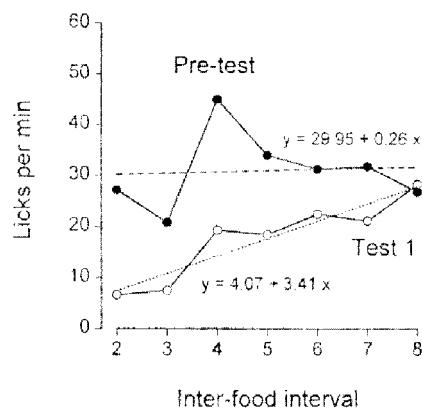


Figure 4. Mean licking rate in intervals 2 to 8 between successive food presentations for animals in the experimental group. Lines represent the best linear fit with respect to the results yielded by the Pre-test and Test 1 sessions.

DISCUSSION

In this experiment, the animals developed stable patterns of operant behavior and schedule-induced polydipsia while exposed to an FI 60-s food reinforcement schedule. It seems that adjunctive drinking was temporarily reduced when food presentation was changed to an FT 60-s schedule and subjects were prevented from engaging in operant lever pressing. This result should probably be attributed to the change caused by withholding the lever, inasmuch as a similar change in food schedule without withdrawing the lever failed to produce the same effect. The effect of withholding the lever is best appreciated by examining within-session changes in local response rates. Licks per minute in the experimental rats declined during the first inter-food intervals of

Test 1, recovered as the test session progressed, and were no longer evident in Test 2 session.

The results reported here appear to show that in well-trained animals with stable patterns of adjunctive and operant behavior, it is sufficient to withhold the opportunity to perform the operant response for adjunctive drinking to be transitorily reduced. Pending replication, these data extend the range of procedures that can reduce schedule-induced drinking (e.g., Pellón & Blackman, 1987; Reberg, 1980) and may have important implications for current theories of adjunctive behavior.

Lashley and Rosellini (1980), for example, suggest that food presentation acts as a conditioned inhibitory stimulus, on signaling the occurrence of a period during which the next reinforcer is highly improbable. Adjunctive drinking would thus arise and be limited to periods of low probability of reinforcement. Palya (1993) stresses that adjunctive behavior is an effective vehicle to escape from such periods of non-reinforcement, and can be negatively reinforced by keeping the animal away from its own performance on the intermittent reinforcement schedule.

The present results are not easily explained by these approaches. During Test 1, food was presented at the same regular intervals as under the FI schedule; yet the animals that underwent withdrawal of the lever decreased their drinking more than those exposed to the (ineffective) response lever. For both groups, food presentation retained the same signal value than in the previous sessions; thus, an explanation for the differences between the two treatments must be sought in what happened in the moments immediately following, rather than preceding, drinking behavior.

Although arguably premature, given the tentative nature of the results, a theoretical alternative might be considered. Rather than serving exclusively to strengthen immediately preceding behavior, a reinforcement contingency may affect broad patterns of behavior (cf. Williams, 1983). Food might not merely reinforce lever pressing, but also reorganize the entire behavioral repertoire of the organism in the experimental situation (cf. Segal, 1972). It is thus conceivable that the animal might learn to emit a sequence of behaviors consisting of drinking, then pressing the lever (if required), and finally approaching the food tray. Any impediment to the completion of any of the links in the chain would affect the immediately preceding behavior patterns—transitorily, until the entire pattern reorganized. This is what may have occurred to drinking when the opportunity of lever pressing was withheld.

Rats typically drink after food presentation, but this drinking might be maintained, in part, by the presentation of the next reinforcer. Adjunctive behavior develops over time and does not occur instantaneously on the mere presentation of food (Reynorse & Spanier, 1968). Although the development and maintenance of adjunctive and operant behavior patterns are fairly simi-

lar in the present case (Figure 1), lever pressing nonetheless reached a peak slightly before drinking behavior. Indeed, the within-session frequency of adjunctive behavior (Figure 3) often showed a decelerating pattern akin to that observed for operant lever pressing (e.g., McSweeney, 1992).

Reinforcement schedules generate characteristic patterns and response rates, but these effects may not solely be the result of the schedules *per se*. They also depend on behavioral history. Prior histories with differential reinforcement of low rates of response and with ratio schedules produce differential effects on subsequent performance under fixed-interval schedules (e.g., Bickel, Higgins, Kirby & Johnson, 1988). Development of schedule-induced drinking can also be a function of behavioral history (Johnson, Bickel, Higgins & Morris, 1991) and be critically dependent upon whether or not adjunctive behavior fit in the latter (Tang, Williams & Falk, 1988; Williams, Tang & Falk, 1992).

The present analysis assumes that behavior can be induced and maintained in the absence of explicit reinforcement contingencies (cf. Lattal, 1995). This is consistent with the functional approaches that suggest that unconditioned responses can change with experience (e.g., Domjan, Akins & Vandergriff, 1992) and that the effects of biologically important stimuli can change over time (McSweeney, Hinson & Cannon, 1996). The present approach emphasizes that the natural behavior of organisms may be subject to modification by experience (consequences) and suggests a way in which this might occur in the case of adjunctive behavior. The tenability of this proposal, however, awaits further research.

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