Extinction of Consummatory Behavior in Rats*

Alba E. Mustaca, Esteban Freidín
Universidad de Buenos Aires, Argentina
and
Mauricio R. Papini
Texas Christian University, U.S.A.

Two experiments with rats studied the relationship between reinforcer magnitude and frequency, and extinction rate in a consummatory situation with rats. In Experiment 1, groups received access to either a 2% or a 32% sucrose solution during twenty 5-min sessions and were subsequently shifted to extinction (access to an empty sipper tube). Goal tracking time (time spent near the sipper tube) was the dependent measure. Extinction was faster after training with 2% solution than with 32% solution. In Experiment 2, extinction was faster after training with 50% partial reinforcement than with continuous reinforcement. In both experiments, extinction was gradual and rats exhibited spontaneous recovery of goal-tracking behavior. Results are discussed in the context of evidence pointing to a dissociation of consummatory and instrumental behavior.

Experiments with a variety of mammalian species demonstrate that performance maintained by a small reinforcer is lower for animals that experienced a larger reward in the same situation, than it is for animals trained always with the small reward (see Papini, 2002a). Such performance deterioration, referred to as the successive negative contrast (SNC) effect, has been reported in experiments involving instrumental behavior (iSNC; e.g., food-reinforced running in rats: Crespi, 1942), operant behavior (e.g., food-reinforced lever pressing in rats: Weinstein, 1970; sensory-reinforced kicking in human infants: Mast, Fagen, Rovee-Collier, & Sullivan, 1980), Pavlovian training procedures (e.g., food-reinforced autoshaping in rats: Papini, Ludvigson, Huneycutt, & Boughner, 2001), and consummatory behavior (cSNC; e.g., drinking of sucrose solutions in marsupials, Papini, Mustaca, & Bitterman, 1988; eating of solid reinforcers in rats, Pellegrini & Mustaca, 2000; and drinking sucrose solutions in human infants, Kobre & Lipsitt, 1972).

Despite the apparent generality of the SNC effect, restrictions do emerge when some of these conditions of training are interchanged. For reasons that were never fully clarified, the rat's running performance seems impervious to surprising downshifts in reward magnitude when the reinforcers are sucrose solutions (for a review, see Flaherty, 1996). Interestingly, Flaherty, Riley, and Spear (1973) reported a runway experiment in which the same rats that failed to exhibit iSNC,

---

demonstrated simultaneous negative contrast. That is, rats ran slower for a 6% sucrose reward when such trials were intermixed with trials reinforced by a 64% solutionin a different runway, relative to control rats always reinforced with the 6% solution. However, a shift from a 64% to a 6% solution yielded no evidence of SNC. Furthermore, rats running for 32% sucrose solution failed to show the iSNC after a shift to 4% solution in terms of running speed but, once in the goal box, they consumed significantly less 4% solution than control rats always reinforced with 4% solution (Flaherty & Caprio, 1976). Therefore, the surprising reduction in the magnitude of a sucrose solution generated a reliable cSNC, but it failed to induce an iSCN. A similar dissociation between consummatory and instrumental phenomena is apparent in terms of agonistic behavior. In instrumental training situations, the surprising omission of an appetitive reinforcer induces aggressive behavior in several mammalian species (for a review, see Papini & Dudley, 1997). By contrast, rats exposed to such downward shifts in reward magnitude in a consummatory situation exhibit a reduction in aggressive behavior (Mustaca & Martinez, 2000; Mustaca, Martinez, & Papini, 2000). A third source of evidence regarding the dissociability of iSNC and cSNC is provided by studies involving brain lesions. For example, lesions of the hippocampus and nucleus accumbens affect iSNC, but not cSNC (Flaherty, Coppotelli, Hsu, & Otto, 1998; Leszczuk & Flaherty, 2000).

The goal of the present experiments was to describe the extinction of consummatory behavior and determine some of its properties. Consummatory extinction (cE) was characterized in terms of two properties typically observed in responses undergoing instrumental extinction (iE; see Papini, 2002b). Across sessions, iE is typically characterized by the gradual decrement in the strength of the instrumental response. Within sessions, performance also tends to decrease gradually, usually recovering to relatively high levels at the start of each session. This phenomenon, called spontaneous recovery, implies the reemergence of behavior during the early portions of an extinction session, relative to the level exhibited in the later portions of the previous session.

The ultimate goal of the present experiments is to provide initial information on cE that would eventually allow for an assessment of the extent to which consummatory and instrumental responses can be dissociated in the context of extinction. Experiments in which rats receive daily access to sucrose solutions show that animals spend increasingly more time consuming the solution across sessions of training. If these changes in consummatory behavior reflect the presence of an acquisition process related to conditioning, then the complete withdrawal of the solution should lead to cE, that is, a gradual decline of consummatory behavior. In this case, the sucrose solution may be said to reinforce consummatory behavior. In studies involving instrumental behavior, such as running in a runway, rats typically demonstrate slower iE after small, rather than large, reinforcement, and after partial, rather than continuous, reinforcement (e.g., Hulse, 1958; Wagner, 1961). Amsel (1992) refered to such effects as paradoxical in the sense that more behavior is obtained in extinction after administering less reinforcement (in terms of magnitude or frequency) during acquisition. If cE and iE are dissociable, then one would predict that cE should be slower after exposure to a larger (rather than smaller) reinforcer, or to a continuous (rather than a partial) reinforcement during acquisi-

tion sessions. The present experiments provide evidence of such nonparadoxical cE.

Experiment 1

In the present experiment, animals received 20 acquisition sessions followed by 12 extinction sessions. In acquisition, two groups of rats received exposure to 32% or 2% sucrose solutions in 5-min long sessions. In extinction, all rats had access to an empty sipper tube in otherwise similar sessions. There were two questions of interest. First, whether extinction rate is directly or inversely related to the magnitude of the sweet solution used in acquisition. Second, whether extinction of consummatory behavior is characterized by a gradual decline and exhibits spontaneous recovery, as is the case with instrumental behavior.

Two sets of previous observations on cE provide relevant background for the present experiments. First, a previous experiment compared extinction (i.e., access to an empty sipper tube, as used in the present experiments; see below) after access to 32% with the performance of groups that had received the 32% or an empty sipper tube throughout training. Goal tracking scores (see below) in the extinction group were significantly below the scores of the group receiving 32% in all sessions, but above the group given access to the empty sipper tube in all sessions (Mustaca, Freidin, & Martelli, 2001). Extinction performance is thus dependent on prior exposure to the 32% solution and current exposure to the empty sipper tube.

Second, previous results from our lab validate the measure of consummatory behavior used in the present experiments (goal-tracking time) by correlating it with the amount of sucrose solution consumed during the session (Mustaca & Bentosela, 2002). A photocell positioned such that its light beam passed in front of the sipper tube recorded goal-tracking time (0.01 s units) automatically; fluid consumption (ml) was determined after each session. Rats were randomly assigned to either a 32% ($n = 26$) or a 4% ($n = 23$) sucrose solution condition. The strain, age, maintenance conditions, deprivation level, and training protocol were as described below for the present experiment. Pearson's coefficients of correlation were computed for each group in each of 10 sessions, as well as for the overall average across the 10 sessions. The results, shown in Table 1, indicated that the two measures were significantly positively correlated in each case. Therefore, we will consider goal tracking time as a measure of the rat's consummatory activity under the present conditions of training.

Table 1
Pearson's Coefficients of Correlation for Consumption (ml) and Goal Tracking Time (0.01 s).

Group (*n*)	Sessions											
	1	2	3	4	5	6	7	8	9	10	Mean	Table (2-tailed)
32% (26)	.71	.63	.68	.70	.65	.61	.56	.55	.55	.55	.66	$r_{(24, .05)} = 0.33$
4% (23)	.82	.90	.76	.77	.82	.86	.80	.76	.72	.81	.81	$r_{(21, .05)} = 0.35$

Note. The column titled "Mean" reports the correlations obtained when the consumption and goal tracking time were averaged over the 10 sessions of training for each animal. All coefficients were significant.

Method

  Subjects. The subjects were 16 male Wistar rats, all experimentally naïve and bred in the vivarium at the Lanari Institute of Medical Research, University of Buenos Aires. Rats were approximately 90 days old at the start of the experiment and weighed between 257 and 378 g. They were housed individually in a room subject to a 12:12 h light:dark cycle (light on from 06:00 to 18:00 h). Temperature was maintained at 23°C. Animals had ad libitum access to water throughout the experiment. Rats were deprived of food until they reached an 85% of the free-food weight; they were maintained at such a level during the course of the experiment by daily access to food not less than 20 min after the end of the training session.

  Apparatus. Rats received training in 4 similar MED Associates conditioning boxes enclosed in a sound-attenuating cubicle that provided masking white noise. Each box measured 24.1 cm in length, 29.2 cm in width, and 21 cm in height. The floor was made of aluminum bars 0.4 cm in diameter and separated by gaps measuring 1.1 cm. In the center of one of the lateral walls there was a squared, 5-cm hole, 3.5 cm deep, and 1 cm above the floor level in which a sipper tube could be introduced from the outside. When fully inserted into the box, the sipper tube protruded 2 cm. Goal tracking was measured by detecting the insertion of the head into the hole by means of a photocell. A diffuse house light was located above the sipper tube, also in the center and 18 cm above the floor. The 32% solution was prepared by mixing 32 g of commercial sugar for every 68 ml of tap water; the 2% solution was prepared by mixing 2 g of sugar for every 98 ml of tap water.

  Procedure. Pairs of rats matched for weight were randomly assigned to one of two groups: 32-0 and 2-0 ($n = 8$). A day before training, all subjects received access to the training solution in their home cage (32% or 2%, depending on group assignment). A drinking bottle with 10 ml of solution was placed in the cage during 20 min. Acquisition started the following day and lasted for 20 sessions, administered at a rate of 2 sessions per day. Within a day, the intersession interval was approximately 1.5 h; between days, the interval was about 22 h long. The rats were placed in their home cages during the intersession interval. Each session (during both acquisition and extinction) started by placing the rat facing the lateral wall opposite to that of the sipper tube and lasted 5 min from the first interruption of the photocell. Squads of four rats were trained simultaneously, but the order of squads was rotated randomly across days. Acquisition was followed by 12 extinction sessions. These sessions were similar to acquisition sessions except that the sipper tube was empty.
 The dependent measure was goal-tracking time (in 0.01 s units). A computer accumulated the amount of time the photocell was activated during the session. Time scores were subject to conventional analysis of variance. The alpha value was set at the 0.05 level.

Results and Discussion

  A rat from Group 2-0 was eliminated from the study because it failed to consume the reinforcer during three consecutive acquisition sessions. The main results are presented in Figure 1. The average goal-tracking time grew more rapidly in Group 32-0 than in Group 2-0, reaching a higher asymptote by the end of acquisition training. A Group x Session analysis indicated a significant interaction effect, $F(19, 247) = 2.70$; moreover, rats exposed to the 32% solution spent more time at the goal than those exposed to the 2% solution, $F(1, 13) = 57.30$, and the increasing goal tracking across sessions was also significant, $F(19, 247) = 11.93$.
  A shift to extinction resulted in a sharp initial decline in both groups, followed by a more gradual decrease in goal-tracking behavior in the subsequent sessions. The average extinction scores from Group 32-0 remained above those from Group 2-0 throughout the 12 extinction sessions. An analysis of extinction performance indicated significant effects for all the factors. There was a significant

group by session interaction, $F(11, 143) = 3.44$; Group 32-0 performed significantly above Group 2-0, $F(1, 13) = 17.71$; and the extinction effect was also significant, $F(11, 143) = 7.31$.
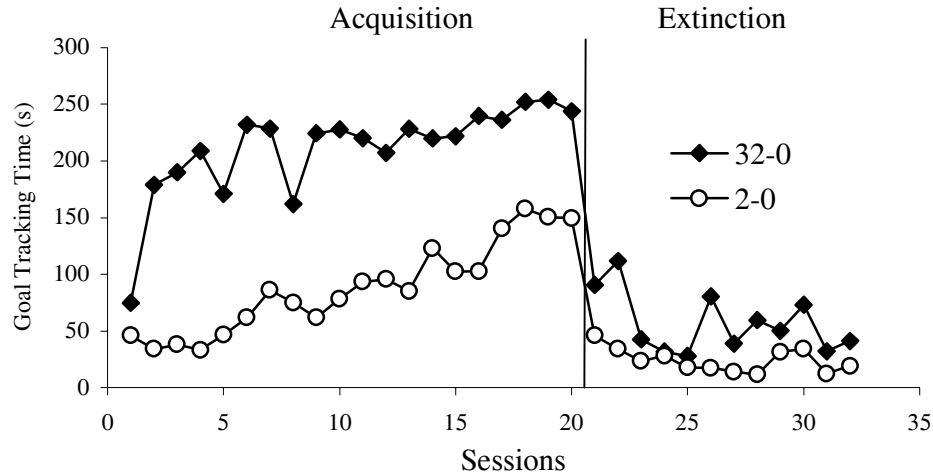
Figure 1. Consummatory performance, measure in terms of goal tracking time, as a function of reinforcer magnitude (32% and 2% sucrose solution), phase of training (acquisition and extinction), and sessions.
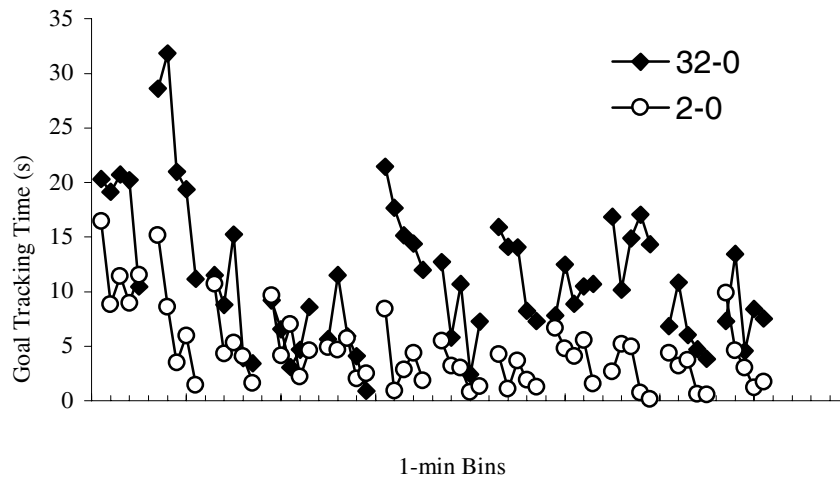
Figure 2. Within-session performance during extinction in groups that had access to either a 32% or a 2% sucrose solution during acquisition.

Figure 2 shows extinction performance in both groups in terms of 1-min bins for each of the 12 sessions. A view of the within-session pattern of behavior allows for an assessment of spontaneous recovery, a common property of behavior during extinction (Pavlov, 1927). Spontaneous recovery is present when the initial performance level in any given session is higher than the terminal level of the preceding session. As shown in Figure 2, not only was spontaneous recovery common in this experiment, but also there was generally a greater recovery level in Group 32-0 than in Group 2-0. A Group x Bin x Session analysis of these data indicated

the presence of greater spontaneous recovery in Group 32-0 than in Group 2-0 in terms of a significant triple interaction, $F(10, 130) = 2.37$. Also significant was the bin by session interaction, $F(10, 130) = 3.66$, which shows the presence of spontaneous recovery, and the main effects of group, $F(1, 13) = 9.35$, and bin, $F(1, 13) = 6.64$. Other effects failed to reach significance.

As far as we know, this experiment provides the first description of the course of extinction in a consummatory response situation. cE, much like iE, was gradual and exhibited spontaneous recovery across sessions. cE was also directly related to the magnitude of the sucrose solution accessible during acquisition sessions. The implications of this finding will be considered in the General Discussion.

Experiment 2

The present experiment was designed with two goals in mind. First, to extend the study of extinction to the case of partial reinforcement. In a consummatory situation, partial reinforcement may be instrumented by intermixing extinction-like sessions (i.e., access to an empty drinking bottle) with regular sessions in a random fashion. The inverse relationship between reinforcement frequency in acquisition and extinction rate in instrumental situations is obtained more reliably when large, rather than small reward are used during training (Gonzalez & Bitterman, 1969). Therefore, we used the 32% sucrose solution in the present experiment. Second, to replicate the properties of cE observed in the previous experiment, namely, the gradual response decrement and spontaneous recovery.

Method

Subjects and Apparatus. The subjects were 16 male Wistar rats, all experimentally naïve, bred and maintained as described in the previous experiment. Rats were approximately 90 days old at the start of the experiment and weighed between 215 and 355 g. The same conditioning boxes described previously were used in the present experiment.

Procedure. Pairs of rats matched for weight were randomly assigned to Groups C and P (*n* = 8). Animals received 42 acquisition sessions followed by 12 extinction sessions. All the acquisition sessions in Group C involved access to the 32% solution, prepared as described previously. In Group P, 21 acquisition sessions were reinforced (R) and 21 nonreinforced (N). R and N sessions were intermixed randomly with the following restrictions: the first and last acquisition sessions were reinforced, and up to two successive sessions with the same outcome were allowed. The actual sequence was the following: RNRRN NRRNN RNNRN RRNNR RNRRN NRRNN RNNRN RRNNR NR. All other aspects of the training procedure and data analysis were as described in Experiment 1.

Results and Discussion

A rat assigned to Group P was discarded because it failed to exhibit goal-tracking behavior during 3 successive acquisition sessions. The main results are presented in Figure 3. Goal-tracking times clearly reflect whether a particular session was reinforced or nonreinforced in Group P. Whereas there was evidence that the amount of time spent at the goal increased in both groups during the reinforced sessions, there was little indication that the rats in Group P modified their behavior toward the goal during nonreinforced sessions. The consummatory performance of

Group P in reinforced trials was above that of Group C in 12 of the 21 reinforced sessions. Such a performance overshooting could reflect positive contrast as rats are shifted from nonreinforced to reinforced sessions during acquisition (e.g., Flaherty, Becker, & Checke, 1983). More importantly, nonreinforced sessions did not retard the increase in consummatory performance across sessions in Group P.
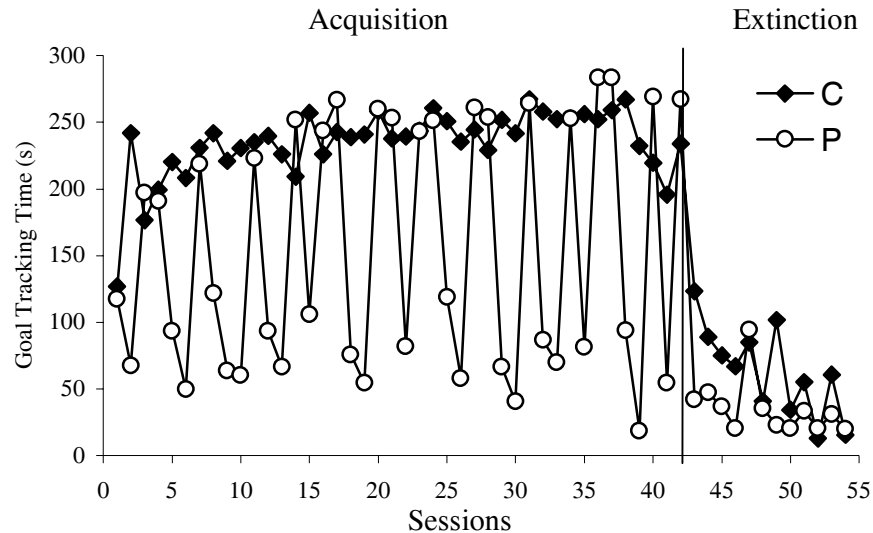

Figure 3. Consummatory performance, measure in terms of goal tracking time, as a function of reinforcer frequency (continuous, C, and 50% partial reinforcement, P), phase of training (acquisition and extinction), and sessions. Rats had access to a 32% sucrose solution during reinforced trials and to an empty sipper tube during nonreinforced trials.

A Group x Session analysis indicated a significant interaction effect, $F(41, 533) = 27.34$, which is at least in part a reflection of the drastic effect of nonreinforcement on goal-tracking time in Group P. The interaction may also, in part, reflect the overshooting observed in most reinforced sessions, especially during the second half of acquisition. The main effects for groups, $F(1, 13) = 76.87$, and sessions, $F(41, 533) = 30.65$, were also significant. An analysis was also computed just on the 21 acquisition sessions in which both groups had access to the solution. This analysis yielded a significant group by session interaction that captures the tendency of Group P to score above Group C toward the end of training, $F(20, 260) = 4.41$. The acquisition effect was also significant, $F(20, 260) = 19.12$, but not the difference between groups.

Figure 3 also shows the consummatory performance of both groups during extinction. As in the previous experiment, the first session is characterized by a sharp decline in goal-tracking times in both groups. This was followed by a gradual decline in performance that was more pronounced in Group P than in Group C. An analysis of these data confirmed this conclusion in terms of a significant group by session interaction, $F(11, 143) = 3.60$. The difference between groups, $F(1, 13) = 4.78$, and the extinction effect, $F(11, 143) = 8.30$, were both significant.

Figure 4 shows the within-session performance of both groups during extinction. There was a clear spontaneous recovery effect that seems larger in Group C than in Group P. A Group x Bin x Session analysis confirmed this conclusion in terms of a significant triple interaction, $F(10, 130) = 2.00$. Also significant were the group by session interaction, $F(10, 130) = 2.96$, and the bin by session interaction, $F(10, 130) = 2.49$. The extinction effect across sessions was reliable, $F(10, 130) = 4.40$, but all other effects failed to reach a significant level.
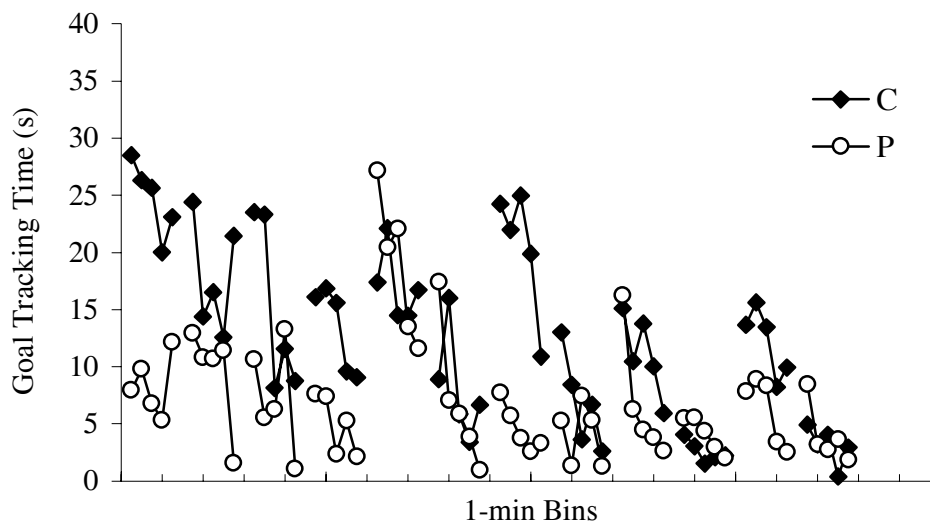
Figure 4. Within-session performance during extinction in groups that had access to either continuous (C) or partial (P) reinforcement during acquisition. In all extinction sessions, rats had access to an empty sipper tube during the session.

As in the previous experiment, cE was characterized by a gradual decline in performance and by the reemergence of the goal-tracking response in the early portions of extinction sessions. A history of continuous reinforcement in which rats have access to the sucrose solution in each acquisition trial promotes a higher extinction performance than a history of partial reinforcement.

General Discussion

The present experiments provide the first evidence that consummatory performance can be extinguished and that its extinction exhibits two properties commonly observed in instrumental and Pavlovian conditioning situations, namely, a gradual decline of performance and the spontaneous recovery of performance after a period of rest. Spontaneous recovery also was greater in the groups that had exhibited slower extinction (Groups 32-0 and C in Experiments 1 and 2, respectively). According to Pavlov (1927, p. 59), the degree of restoration of the conditioned response is a function of the "depth of the preceding extinction" and of "the intensity of the conditioned reflex," among other factors. Both of these properties apply to the present results suggesting a degree of commonality between anticipatory and consummatory behaviors. In the present experiments, the groups that exhibited greater spontaneous recovery also generally showed a higher extinction

performance in the preceding session. Furthermore, Group 32-0, Experiment 1, may be said to have had the strongest consummatory behavior of the two groups given its acquisition performance. Thus, the high level of spontaneous recovery of this group may also reflect a higher strength of the consummatory response established with the larger sucrose solution. These results provide support for the assumption that cE shares some important properties with iE.

The main result of the present experiments is that extinction of consummatory behavior was slower with larger reinforcer magnitudes and more frequent reinforcement. Rats trained to lick for a solution of lower sucrose concentration extinguished faster than rats trained with a larger concentration and, similarly, rats given access to the high sucrose concentration in a random 50% of the trials extinguished faster than rats given access to the solution in every trial. These effects contrast with the indirect relationship between extinction rate and reinforcer magnitude or frequency observed in instrumental training situations (e.g., Hulse, 1958; Wagner, 1961).

The results reported here are consistent with a growing body of evidence suggesting that consummatory and instrumental behaviors occurring in situations involving surprising reward omission or reduction obey different principles. In addition to the present extinction data, there is evidence of dissociation in terms of the emergence of SNC, agonistic behavior, and brain lesion effects (see introduction for references). One limitation of the present results is that they provide no direct evidence of the dissociation between cE and iE. Such evidence would require, for example, the use of a runway procedure that would allow for an assessment of both instrumental (i.e., anticipatory running performance) and consummatory behaviors (i.e., consumption of the reward in the goal box) in the same animals (e.g., Flaherty & Caprio, 1976). The present results suggest that rats trained under such conditions and with the appropriate reinforcer (e.g., solid food; see Pellegrini & Mustaca, 2000), would produce both paradoxical iE and nonparadoxical cE.

References

Amsel, A. (1992). *Frustration theory*. Cambridge, UK: Cambridge University Press.

Crespi, L. P. (1942). Quantitative variation in incentive and performance in the white rat. *American Journal of Psychology*, **55**, 467-517.

Flaherty, C. F. (1996). *Incentive relativity*. Cambridge, UK: Cambridge University Press.

Flaherty, C. F., Becker, H., & Checke, S. (1983). Repeated contrast in consummatory and open field behaviors with repeated reward shifts. *Animal Learning and Behavior*, **11**, 407-414.

Flaherty, C. F., & Caprio, M. (1976). Dissociation between instrumental and consummatory measures of incentive contrast. *American Journal of Psychology*, **89**, 485-498.

Flaherty, C. F., Coppotelli, C., Hsu, D., & Otto, T. (1998). Excitotoxic lesions of the hippocampus disrupt runway but not consummatory contrast. *Behavioural Brain Research*, **93**, 1-9.

Flaherty, C. F., Riley, E. P., & Spear, N. E. (1973). Effect of sucrose concentration and goal units on runway behavior in the rat. *Learning and Motivation*, **4**, 163-175.

Gonzalez, R. C., & Bitterman, M. E. (1969). Spaced-trial partial reinforcement effect as a function of contrast. *Journal of Comparative and Physiological Psychology*, **67**, 94-103.

Hulse, S. H. Jr. (1958). Amount and percentage of reinforcement and duration of goal confinement in conditioning and extinction. *Journal of Experimental Psychology*, **56**, 48-57.

Kobre, K. R., & Lipsitt, L. P. (1972). A negative contrast effect in newborns. *Journal of Experimental Child Psychology*, **14**, 81-91.

Leszczuk, M. H., & Flaherty, C. F. (2000). Lesions of nucleus accumbens reduce instrumental but not consummatory negative contrast in rats. *Behavioural Brain Research*, **116**, 61-79.

Mast, V. K., Fagen, J. W., Rovee-Collier, C. K., & Sullivan, M. W. (1980). Immediate and long-term memory for reinforcement context: the development of learned expectancies in early infancy. *Child Development*, **51**, 700-707.

Mustaca, A. E., & Bentosela, M. (2002). [Goal-tracking time correlates with fluid consumption in the consummatory contrast situation with rats.] Unpublished raw data.

Mustaca, A. E., Freidín, E., & Martelli, M. I. (2001, July). *Extinción consumatoria.* Paper presented at the 28th Interamerican Congress of Psychology, Santiago, Chile.

Mustaca, A. E., & Martínez, C. (2000). Respuestas agonísticas en ratas sometidas a frustración. *Revista Latinoamericana de Psicología*, **32**, 485-504.

Mustaca, A. E., Martínez, C., & Papini, M. R. (2000). Surprising nonreward reduces aggressive behavior in rats. *International Journal of Comparative Psychology*, **13**, 91-100.

Papini, M. R. (2002a). Pattern and process in the evolution of learning. *Psychological Review*, **109**, 186-201.

Papini, M. R. (2002b). *Comparative psychology. Evolution and development of behavior.* Upper Saddle River, NJ: Prentice Hall.

Papini, M. R., & Dudley, R. T. (1997). Consequences of surprising reward omissions. *Review of General Psychology*, **1**, 175-197.

Papini, M. R., Ludvigson, H. W., Huneycutt, D., & Boughner, R. L. (2001). Apparent incentive contrast effects in autoshaping with rats. *Learning and Motivation*, **32**, 434-456.

Papini, M. R., Mustaca, A. E., & Bitterman, M. E. (1988). Successive negative contrast in the consummatory responding of didelphid marsupials. *Animal Learning and Behavior*, **16**, 53-57.

Pavlov, I. P. (1927). *Conditioned reflexes. An investigation of the physiological activity of the cerebral cortex.* Oxford, UK: Oxford University Press.

Pellegrini, S., & Mustaca, A. E. (2000). Consummatory successive negative contrast with solid food. *Learning and Motivation*, **31**, 200-209.

Wagner, A. R. (1961). Effects of amount and percentage of reinforcement and number of acquisition trials on conditioning and extinction. *Journal of Experimental Psychology*, **62**, 234-242.

Weistein, L. (1970). Negative incentive contrast with sucrose. *Psychonomic Science*, **19**, 13-14.