Learning and Motivation 60 (2017) 1–9

Contents lists available at ScienceDirect

Learning and Motivation

journal homepage: www.elsevier.com/locate/l&m

Duration of wheel-running reinforcement: Effects on reinforcement value and motivation in free-feeding and food-deprived rats

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ARTICLE INFO

Keywords:
Wheel-running reinforcement duration
Food deprivation
Intrinsic motivation
Food-related motivation
Automatic reinforcement
Lever press
Rat

ABSTRACT

Ten (pair housed) female Long-Evans rats were exposed to 5 s, 30 s, and 90 s wheel-running reinforcement durations on a response-initiated variable interval 20 s schedule as food deprivation was manipulated. On free feeding, never-deprived rats showed low wheel running and lever-pressing rates with long postreinforcement pauses (PRPs) for the 5-s reinforcement duration. Subsequently, when food deprived (Deprived 1), rats showed no effect of reinforcement duration on all measures. Under a second deprived condition (Deprived 2) with the rats maintained in single cages, there was no effect of housing (single vs. paired). When data from both deprivation assessments (Deprived 1 and Deprived 2) were combined, rats showed lower wheel running and overall lever-pressing rates with longer pauses on the 90-s duration compared to 30 s and 5 s bouts of wheel activity. The pattern of results challenges a reinforcement value interpretation, but is consistent with shifts in the motivational basis of wheel running. On free feeding, never-deprived rats were intrinsically motivated to run on wheels and operant lever-pressing was maintained at moderate rates by the automatic reinforcement of wheel running, except at the short reinforcement duration (5 s). When food deprived, motivation became food-related and rats showed high rates of lever pressing even at the shortest duration. The weak effects under initial deprivation (Deprived 1) raise questions about equivalence between wheel-running reinforcement duration and reinforcement magnitude using food reinforcement.

1. Introduction

Prior research on single operant schedules indicates that the reinforcement value of wheel running varies inversely with duration of access to a freely turning wheel (Belke, 1997; Belke & Dunbar, 1998; Belke & Hancock, 2003; Belke, Pierce, Harris, Leblanc, & Clennett, 2017). For example, Belke (1997) showed that lever pressing for 30-s bouts of wheel running were maintained at higher levels than by bouts of 60-s and 120-s durations. In addition to high lever-pressing rates, 30-s opportunities for wheel running generated relatively short postreinforcement pauses (PRPs) and high wheel-running rates. If lever-pressing rates index reinforcement value, short bouts of wheel running are higher in reinforcement value than longer durations—a puzzling finding as duration of access to conventional, food reinforcement is commonly used to manipulate reinforcement magnitude and value varies directly with magnitude, higher magnitude equals greater value (Bonem & Crossman, 1988). More recently, a study of resistance to extinction also reported that shorter periods of wheel running have higher reinforcement value than longer durations (Belke, Pierce, Harris, Leblanc, & Clennett, 2017). That is, lever presses maintained by 5-s opportunities to run were more resistant to extinction than responding maintained by 30-s and 90-s bouts of wheel running.

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http://dx.doi.org/10.1016/j.lmot.2017.10.001
Received 26 July 2017; Received in revised form 4 October 2017; Accepted 4 October 2017

On concurrent schedules, these single operant studies predict that shorter bouts of wheel-running reinforcement would be preferred to longer durations. This prediction, however, was not supported. Belke (2006) showed that rats were indifferent between 10-s and 50-s reinforcement durations on both concurrent VI VI schedules and concurrent VR VR schedules. Preference for one alternative over the other only developed when the opportunity for wheel running on one alternative was decreased to 2.5 s. At 2.5 s and below, rats showed a preference for the longer duration alternative.

Findings from single operant schedules indicate that shorter bouts of wheel running are of greater reinforcement value than are longer durations. But, concurrent schedules of wheel-running reinforcement show that there are no differences in relative reinforcement value between different durations until the duration on one alternative is almost negligible (2.5 s or less). Obviously, more research is required to further our understanding of the relationship between wheel-running duration and the reinforcement value of wheel running.

Recently, Belke and Pierce (2016) proposed that motivation for wheel running differs for free-feeding rats with no experience with deprivation (never deprived) and food-deprived rats. This distinction is important because prior research suggests that exposure to food deprivation alters the physiological response to subsequent deprivation (Hampstead, Labounty, & Hurd, 2003). According to Belke and Pierce's (2016) analysis, wheel-running activity is intrinsically motivated in free-feeding (ad libitum) rats, occurring at moderate rates without experimentally arranged contingencies of reinforcement. When wheel running is made contingent on operant lever pressing, lever pressing increases, being maintained by the automatic reinforcement of the activity (Skinner, 1957; Vaughn & Michael, 1982). That is, wheel running provides its own reinforcement. Rats that are food deprived, however, show higher rates of running than at ad libitum (ad lib) level and wheel running is motivated by the food restriction (Baumeister, Hawkins, & Cromwell, 1964; Collier, 1970; Jakubczak, 1967; Moskowitz, 1959; Price, 1976; Sclafani & Rendel, 1978; Treichler & Hall, 1962). Under these conditions, the reinforcement properties of wheel running are food-related and not solely based on the automatic reinforcement of the wheel activity.

The current study was designed to further elucidate the relationship between wheel-running duration and reinforcement value in ad-lib and deprived rats. Previous studies with food-deprived rats show that wheel-running rates and lever-pressing rates vary inversely with body weight while PRP interval varies directly with weight level. Based on these findings, we expected that free-feeding rats would show the same basic relationships, but with lower rates of wheel running and lever pressing and longer PRPs than when food deprived. If the motivational basis for wheel running, however, shifts between ad lib (never deprived) and deprived conditions, the relationship of shorter and longer bouts of wheel-running reinforcement to wheel running, lever pressing, and PRP is difficult to predict. That relationship may be clarified in the present study.

2. Methods

2.1. Participants

The experiment was conducted using 10 female Long Evans rats obtained from Charles River Laboratories in Saint-Constant, Quebec. Rats were experimentally naïve and approximately 3 months old at the start of the study. Rats were housed in pairs in polycarbonate cages (48.3 cm x 26.7 cm x 20.3 cm). Heat-treated beta chips and paper towel were used as bedding. Lighting in the colony room was on a 12-h light/dark cycle (lights on at 0730). Rats were fed Prolab R-M-H 3000 lab chow and provided with distilled water. Water was freely available in home cages throughout the study. This research was conducted in accord with the guidelines of the Canadian Council on Animal Care under a protocol approved by the Mount Allison Animal Care Committee.

2.2. Apparatus

Experimental sessions used four Med Associates (ENV-042) activity wheels (37 cm in diameter). The floors of the wheels had metal bars, 4 mm in diameter, with a 1 cm space between each bar. The length and width of the opening of the wheel was 10 cm by 7 cm. Each wheel was equipped with a retractable lever (Med Associates ENV-12), a solenoid-operated brake, and two 24 VDC lights. A retractable lever was mounted at the opening of each wheel. The lever was 5 cm long and extended 2 cm into the wheel chamber. A solenoid was attached to the base of the wheel and when activated, a rubber tip attached to a metal shaft contacted the outer edge of the wheel to prevent it from turning. 24 VDC lights were mounted on sides of the wheel frame to illuminate the interior of the wheel chamber. Revolutions were recorded by a microswitch attached to the wheel frame. Each wheel was enclosed in a sound-attenuating shell equipped with fans to mask extraneous noise and to provide ventilation. Control of experimental events and recording of data were handled by a Borland Turbo Pascal 4.0 program run on PC computers interfaced to the wheel through the parallel port.

2.3. Procedure

2.3.1. Training

Each rat was placed in a running wheel that was free to turn for 30 min each day over 30 sessions. Subsequently, operant training started with the opportunity to run on a wheel for 60 s made contingent on a single lever press. When the rat pressed the lever, it retracted and the brake disengaged leaving the wheel free to turn for 60 s. After 60 s, the brake engaged and the retractable lever extended. A session terminated when 30 wheel-running reinforcements were completed. This fixed ratio (FR) 1 schedule remained in effect for 10 sessions. Following this, the schedule of reinforcement was changed to a variable ratio (VR) 3 schedule for 5 sessions.

After initial training, the rats were placed on a response-initiated VI 20 s schedule that produced 5-s, 30-s, or 90-s opportunities to