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Reinforcement of a reinforcing behavior: Effect of sucrose concentration on wheel-running rate

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A B S T R A C T

Wheel running, unlike typical operant behavior, generates its own automatic reinforcement that alters the control exerted by extrinsic reinforcement on wheel running. The current study investigated the implications of the automatic reinforcement of wheel running by arranging different sucrose concentrations as extrinsic reinforcement for operant wheel running in ad-lib fed and food-deprived rats. Eleven female Long Evans rats ran on fixed revolution 30 schedules that delivered a drop of sucrose solution as reinforcement. Sucrose concentration varied across values of 0%, 2.5%, 5%, 10%, and 15% sucrose (w/v). Results showed that under ad-lib feeding, only the highest concentrations increased operant wheel-running rate. By contrast, under deprivation, all concentrations of sucrose increased the rate of wheel running. Despite the differences in sucrose-reinforced operant wheel-running rates by deprivation level (ad lib vs. deprived), wheel-running rates did not differ at the highest concentrations. Prior research on operant lever pressing, a response generating low (or no) automatic reinforcement, has shown considerably higher lever-pressing rates as a function of increasing amounts of sucrose reinforcement when rats are food deprived. Together, these previous observations and the current study suggest that automatic reinforcement generated by an operant decreases the control exerted by extrinsic reinforcement. Additionally, the regulation by extrinsic reinforcement on automatically reinforcing behavior depends on the organism's motivation or deprivation level (ad lib vs. deprived).

1. Introduction

Running in a wheel is behavior that can function as reinforcement for an operant behavior (e.g., Belke, 1997; Belke & Pierce, 2014, 2015; Collier & Hirsch, 1971; Iversen, 1993; Kagan & Berkun, 1954; Premack, 1962; Premack et al., 1964) or as an operant behavior that produces reinforcement (Belke, Mann, & Pierce, 2015; Belke & Pierce, 2014, 2015; Iso, 1996; Skinner & Morse, 1958). Operant wheel running generates its own the automatic reinforcement that maintains this behavior at a higher operant level than more typical responses such as lever pressing or nose poking (Belke et al., 2015). One implication of the high operant level of wheel running is that extrinsic sucrose reinforcement would show weak response-strengthening effects, especially in free-feeding rats. The objective of the current study was to investigate how different concentrations (0% to 15% solutions) of sucrose reinforcement controlled operant wheel-running rate in food deprived and non-deprived rats.

Sucrose, or the opportunity to consume sucrose, functions as reinforcement for operant behavior. Previous research (Bailey, Hsiao, & King, 1986; Belke & Hancock, 2003; Guttman, 1953; Leslie, 1977; Vigorito et al., 1994) with rats has shown that lever-

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pressing rate increases as sucrose concentration increases up to a point and then either levels off or decreases with further increases in concentration, depending on factors such as the schedule, effort, volume, and/or satiation. For example, Bailey et al. (1986) assessed the effect of 0.025 M (.08%) to 1.1 M (37.7%) sucrose solutions on lever-pressing rate by Sprague-Dawley rats on a continuous reinforcement (CRF) schedule. With the lever force set at 30 g, lever-pressing rate increased with molarity up to .5 M (17.1%) and then leveled off. Guttman (1953) assessed the effect of sucrose concentrations of 4%, 8%, 16% and 32% on lever-pressing rates by albino rats on CRF and fixed interval (FI) 1-min reinforcement schedules. On the CRF schedule, lever-pressing rate increased from 4 to 8%, remained unchanged from 8 to 16%, then decreased at 16%. On the FI schedule, lever-pressing rates increased with concentration. Thus, the function relating concentration of sucrose reinforcement to rate of lever pressing depended on the schedule (CRF or FI). In Belke and Hancock (2003), male Wistar rats lever pressed on FI schedules that produced either a drop of sucrose or the opportunity to run for 15 s. With sucrose concentration manipulated across concentrations of 0%, 2.5%, 5%, 10%, and 15%, lever-pressing rates increased from 0% to 10% but remained unchanged at 15%, a finding inconsistent with the increasing function reported by Guttman (1953).

Skinner and Morse (1958) were the first to investigate wheel running as operant behavior on a FI 5-min schedule with food pellets delivered as reinforcement. Results for two food-deprived brown rats showed higher rates of wheel running with food reinforcement; also, rats developed a break-and-run pattern of responding characterized by a postreinforcement pause (PRP) followed by a high rate of wheel running that decelerated near the end of the reinforcement interval. Subsequently, Iso (1996) compared wheel-running rates in rats receiving food reinforcement for running on fixed ratio (FR) 40 or FI 60-s schedules with yoked rats receiving food independent of wheel running. Running rates did not differ between the yoked and reinforcement groups; however, rats receiving food reinforcement showed response patterns consistent with the reinforcement schedules.

More recently, Belke and Pierce (2015) investigated the effect of sucrose solution as reinforcement for wheel-running rate on a multiple schedule. In this study, wheel running served as reinforcement for lever pressing in one component and as operant behavior producing sucrose solution in the other component. Results showed that wheel-running rates that produced 15% sucrose (operant running component) were higher than wheel-running rates that functioned as reinforcement for lever pressing (reinforcement component) – confirming a reinforcement effect of sucrose. When 15% sucrose solution was replaced with water (0% sucrose), operant wheel-running rates decreased by approximately 26% from 61.25 to 44.62 revolutions/min, on average. Notably, wheel running still occurred at a high rate during extinction.

Using the same multiple-schedule procedure, Belke et al. (2015) showed that operant lever-pressing rate declined by 90% from 229.0 presses/min to 19.3 presses/min when 15% sucrose was replaced with water (0% sucrose). But, operant wheel-running rate only decreased by 24% from 58.8 to 44.1 revolutions/min. The relatively limited decrease in wheel-running rate with the removal of sucrose occurs because wheel running, unlike lever pressing, generates its own automatic reinforcement. As a result, wheel running is maintained at a higher rate in extinction, and at a higher operant level, than lever pressing. With respect to the current study, the automatic reinforcement generated by wheel running limits the range of wheel-running rates controlled by different concentrations of sucrose reinforcement, especially when rats are not food deprived.

In terms of food deprivation, it is notable that the value of sucrose and wheel running as reinforcing consequences increase with deprivation (Belke, 1996, 2004; Belke & Pierce, 2009, 2016). That is, both the opportunity to run and the opportunity to consume sucrose support higher operant rates when rats are food deprived. At 0% sucrose, deprived rats should run in wheels at higher rates than non-deprived animals, and wheel-running rates for deprived rats should increase with concentration of sucrose reinforcement. On the other hand, non-deprived rats would run in wheels for automatic reinforcement and extrinsic sucrose reinforcement would have more limited effects on wheel-running rates–generating a slowly increasing rate of wheel running with variation in sucrose concentration or perhaps even a flat function with no changes in wheel-running rate as sucrose concentration increases. The current study was designed to investigate the functional relationship between wheel-running rate and sucrose reinforcement concentration (0% to 15% solutions) in the same rats when non-deprived and deprived.

2. Methods

2.1. Participants

The experiment was conducted using 12 female Long Evans rats obtained from Charles River Laboratories in Saint-Constant, Quebec. Rats were housed in pairs in polycarbonate cages (48.3 cm × 26.7 cm × 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 distilled water. Water was freely available within home cages. 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

Two Wahmann and two Lafayette activity wheels (350 mm in diameter) were used in the present experiment. 24 VDC lights were mounted on the sides of the wheel frame to illuminate the interior of the wheel chamber. Wheel revolutions were recorded by a microswitch attached to the wheel frame. A solenoid was attached to the base of the wheel and when activated, the solenoid caused a rubber tip attached to a metal shaft to contact the outer edge of the wheel to prevent it from turning. The wheels were located in sound-attenuated cubicles equipped with electric fans to circulate air and diminish background noise.

A metal panel (180 mm × 185 mm × 2 mm) containing a liquid receptacle and two stimulus lights was attached to the